

Appendix B
Genstat Code
Vanessa Cave

Many chapters in this book provided examples using SAS code and output. For readers who prefer Genstat, this Appendix translates much of the SAS code to Genstat and provides the corresponding output. The Appendix identifies each chapter and author(s) to help readers easily find the code they wish to have in Genstat. The chapter authors did not participate in the translation of this code and have no responsibility for the contents of this Appendix.

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Chapter 1. Errors in Statistical Decision-Making by Kimberly Garland-Campbell

Genstat code developed by Vanessa M. Cave and output are provided here for the two examples and the homework exercises presented in Chapter 1.

Minimum Average Error Example

Genstat Commands for the Minimum Average Error Example

```
" ***** "  
"           Hypothetical Experiment: Minimum Average Error           "  
" ***** "  
  
" The first section of code performs a single power analysis for  
  detecting a 10% difference. In the second section, the code is  
  extended to perform power analyses for detecting 10%, 16% and 25%  
  differences. Figures 2 and 3 are also generated."  
  
JOB  
  
" Create the variate ALPHA. This contains Type 1 error rates ranging  
  from 0.001 to 0.99 in approximately 0.01 increments "  
VARIATE ALPHA; VALUES=!(0.001,0.01,0.02...0.99)  
  
" Form a scalar FVALUE containing the F values associated with  
  detecting a 10% difference "  
SCALAR SED; SQRT(2*250000/3)  
SCALAR MEAN; 5000  
SCALAR DIFFPERCENT; 10  
SCALAR FVALUE; (DIFFPERCENT/100*MEAN/SED)**2  
  
" Create scalars containing the numerator and denominator degrees of  
  freedom "  
SCALAR NUMDF; 7  
SCALAR DENDF; 14  
  
" Calculate the noncentrality parameter (lambda) "  
CALC NCP = NUMDF*FVALUE  
  
" Calculate the critical F values "  
CALC PROB = 1-ALPHA  
CALC FCRIT = EDF(PROB;NUMDF;DENDF;0)  
  
" Calculate the power values, Type 2 error rates and the average of  
  the Type 1 and Type 2 error rates "  
CALC POWER = 1-CLF(FCRIT;NUMDF;DENDF;NCP)  
CALC BETA = 1-POWER  
CALC AVEERROR = (ALPHA+BETA)/2  
  
" Print the results in a table"  
CALC min_AVEERROR = MIN(AVEERROR)  
SCALAR ALPHAmIn, BETAmIn, POWERmIn, POWER5%  
SUBSET [CONDITION=AVEERROR==min_AVEERROR] ALPHA; a
```

```

CALC ALPHAmin = a$[1]
SUBSET [CONDITION=AVEERROR==min_AVEERROR] BETA; b
CALC BETAmin = b$[1]
SUBSET [CONDITION=AVEERROR==min_AVEERROR] POWER; p
CALC POWERmin = p$[1]
SUBSET [CONDITION=ALPHA==0.05] POWER; p5%
CALC POWER5% = p5%$[1]
PRINT [SQUASH='yes'] DIFFPERCENT,FVALUE,NCP,min_AVEERROR, \
      ALPHAmin,BETAmin,POWERmin,POWER5%; \
      HEADING='% Diff','F value','~{lambda}','\
      'Min avg ~{alpha} and ~{beta}','~{alpha} at min', \
      '~{beta} at min','Power at min','Power at 0.05'; \
      DECIMALS=0,2(1),5(2); JUSTIFICATION=right; \
      FIELDWIDTH=2(8),5,16,2(8),2(12)

ENDJOB

JOB

" Create the variate ALPHA. This contains Type 1 error rates ranging
  from 0.001 to 0.99 in approximately 0.01 increments "
VARIATE ALPHA; VALUES=!(0.001,0.01,0.02...0.99)

" Create the variate FVALUE. This contains the F values associated
  with the detectable differences of 10%, 16% and 25% "
SCALAR SED; Sqrt(2*250000/3)
SCALAR MEAN; 5000
VARIATE DIFFPERCENT; VALUES=!(10,16,25)
VARIATE FVALUE; VALUES=((MEAN/SED)*DIFFPERCENT/100)**2

" Create scalars containing the numerator and denominator degrees of
  freedom "
SCALAR NUMDF; 7
SCALAR DENDF; 14

" Calculate the noncentrality parameters (lambda) "
CALC NCP = NUMDF*FVALUE

" Calculate the critical F values "
CALC PROB = 1-ALPHA
CALC FCRIT = EDF(PROB;NUMDF;DENDF;0)

" Calculate the power values, Type 2 error rates and the average of
  the error rates (Note: To calculate the results for all three
  detectable differences simultaneously, pointers are used) "
POINTER [NVALUES=3] POWER, BETA, AVEERROR
CALC POWER[] = 1-CLF(FCRIT;NUMDF;DENDF;NCP$[1...3])
CALC BETA[] = 1-POWER[]
CALC AVEERROR[] = (ALPHA+BETA[])/2

" Print the results in a table"
VARIATE [NVALUES=3] min_AVEERROR
CALC min_AVEERROR$[1...3] = MIN(AVEERROR[])
VARIATE [NVALUES=3] ALPHAmin, BETAmin, POWERmin, POWER5%
FOR [NTIMES=3; INDEX=i]
  SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] ALPHA; a
  CALC ALPHAmin$[i] = a$[1]

```

```

SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] BETA[i]; b
CALC BETAmin$[i] = b$[1]
SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] POWER[i]; p
CALC POWERmin$[i] = p$[1]
SUBSET [CONDITION=ALPHA==0.05] POWER[i]; p5%
CALC POWER5%$[i] = p5%$[1]
ENDFOR
PRINT [SQUASH='yes'] DIFFPERCENT,FVALUE,NCP,min_AVEERROR, \
      ALPHAmín,BETAmin,POWERmin,POWER5%; \
      HEADING='% Diff','F value','~{lambda}',' \
      'Min avg ~{alpha} and ~{beta}','~{alpha} at min', \
      '~{beta} at min','Power at min','Power at 0.05'; \
      DECIMALS=0,2(1),5(2); JUSTIFICATION=right; \
      FIELDWIDTH=2(8),5,16,2(8),2(12)

" Generate Figure 2: Plot of the Type 2 error rate against the
  Type 1 error rate "
PEN [RESET=yes] 1...3; METHOD=line; SYMBOL=0; COLOUR='black'; \
  LINSTYLE='solid','dash','dot'
TXCONSTRUCT [TEXT=keydescription; PREFIX='~{lambda} = '] NCP; DEC=1
XAXIS [RESET=yes] WINDOW=1; TITLE='~{alpha}'
YAXIS [RESET=yes] WINDOW=1; TITLE='~{beta}'
DGRAPH [WINDOW=1] Y=BETA[]; X=ALPHA; DESCRIPTION=#keydescription

" Generate Figure 3: Plot of the average of the error rates against
  the Type 1 error rates "
YAXIS [RESET=yes] WINDOW=1; TITLE='Average of ~{alpha} and ~{beta}'
DGRAPH [WINDOW=1] Y=AVEERROR[]; X=ALPHA; DESCRIPTION=#keydescription

ENDJOB

```

Genstat Output from the Minimum Average Error Example

```

4  " Create the variate ALPHA. This contains Type 1 error rates ranging
-5  from 0.001 to 0.99 in approximately 0.01 increments "
6  VARIATE ALPHA; VALUES=!(0.001,0.01,0.02...0.99)
7
8  " Form a scalar FVALUE containing the F values associated with
-9  detecting a 10% difference "
10 SCALAR SED; SQRT(2*250000/3)
11 SCALAR MEAN; 5000
12 SCALAR DIFFPERCENT; 10
13 SCALAR FVALUE; (DIFFPERCENT/100*MEAN/SED)**2
14
15 " Create scalars containing the numerator and denominator degrees of
-16 freedom "
17 SCALAR NUMDF; 7
18 SCALAR DENDF; 14
19
20 " Calculate the noncentrality parameter (lambda) "
21 CALC NCP = NUMDF*FVALUE
22
23 " Calculate the critical F values "
24 CALC PROB = 1-ALPHA
25 CALC FCRT = EDF(PROB;NUMDF;DENDF;0)

```

```

26
27 " Calculate the power values, Type 2 error rates and the average of
-28 the Type 1 and Type 2 error rates "
29 CALC POWER = 1-CLF(FCRIT;NUMDF;DENDF;NCP)
30 CALC BETA = 1-POWER
31 CALC AVEERROR = (ALPHA+BETA)/2
32
33 " Print the results in a table"
34 CALC min_AVEERROR = MIN(AVEERROR)
35 SCALAR ALPHAmin, BETAmin, POWERmin, POWER5%
36 SUBSET [CONDITION=AVEERROR==min_AVEERROR] ALPHA; a
37 CALC ALPHAmin = a$[1]
38 SUBSET [CONDITION=AVEERROR==min_AVEERROR] BETA; b
39 CALC BETAmin = b$[1]
40 SUBSET [CONDITION=AVEERROR==min_AVEERROR] POWER; p
41 CALC POWERmin = p$[1]
42 SUBSET [CONDITION=ALPHA==0.05] POWER; p5%
43 CALC POWER5% = p5%$[1]
44 PRINT [SQUASH='yes'] DIFFPERCENT,FVALUE,NCP,min_AVEERROR, \
45           ALPHAmin,BETAmin,POWERmin,POWER5%; \
46   HEADING='% Diff','F value','~{lambda}','\
47           'Min avg ~{alpha} and ~{beta}','~{alpha} at min',' \
48           '~{beta} at min','Power at min','Power at 0.05'; \
49   DECIMALS=0,2(1),5(2); JUSTIFICATION=right; \
50   FIELDWIDTH=2(8),5,16,2(8),2(12)

```

% Diff	F value	λ	Min avg α and β	α at min	β at min	Power at min	Power at 0.05
10	1.5	10.5	0.22	0.23	0.22	0.78	0.42

```

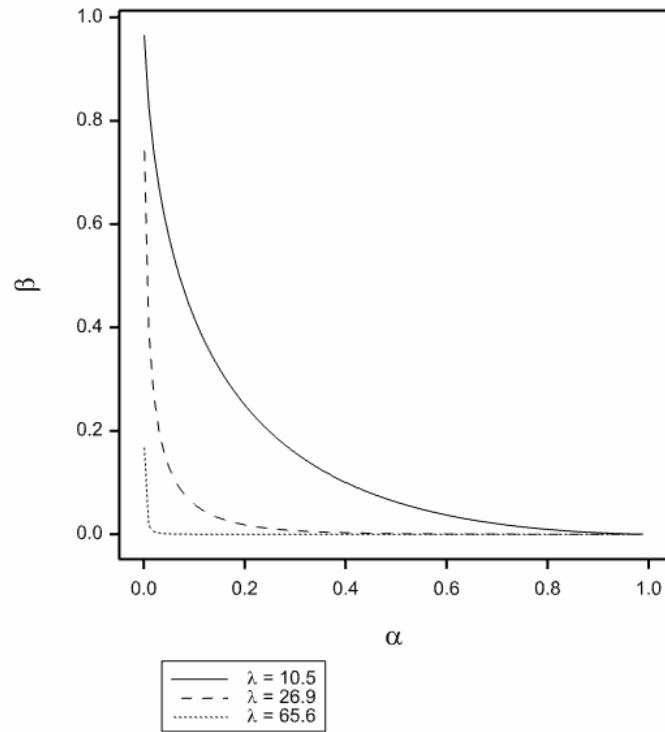
56 " Create the variate ALPHA. This contains Type 1 error rates ranging
-57 from 0.001 to 0.99 in approximately 0.01 increments "
58 VARIATE ALPHA; VALUES=!(0.001,0.01,0.02...0.99)
59
60 " Create the variate FVALUE. This contains the F values associated
-61 with the detectable differences of 10%, 16% and 25% "
62 SCALAR SED; SQRT(2*250000/3)
63 SCALAR MEAN; 5000
64 VARIATE DIFFPERCENT; VALUES=!(10,16,25)
65 VARIATE FVALUE; VALUES=((MEAN/SED)*DIFFPERCENT/100)**2
66
67 " Create scalars containing the numerator and denominator degrees of
-68 freedom "
69 SCALAR NUMDF; 7
70 SCALAR DENDF; 14
71
72 " Calculate the noncentrality parameters (lambda) "
73 CALC NCP = NUMDF*FVALUE
74
75 " Calculate the critical F values "
76 CALC PROB = 1-ALPHA
77 CALC FCRIT = EDF(PROB;NUMDF;DENDF;0)
78
79 " Calculate the power values, Type 2 error rates and the average of
-80 the error rates (Note: To calculate the results for all three
-81 detectable differences simultaneously, pointers are used) "
82 POINTER [NVALUES=3] POWER, BETA, AVEERROR
83 CALC POWER[] = 1-CLF(FCRIT;NUMDF;DENDF;NCP$[1...3])
84 CALC BETA[] = 1-POWER[]

```

```

85  CALC AVEERROR[] = (ALPHA+BETA[])/2
86
87  " Print the results in a table"
88  VARIATE [NVALUES=3] min_AVEERROR
89  CALC min_AVEERROR$[1...3] = MIN(AVEERROR[])
90  VARIATE [NVALUES=3] ALPHAmin, BETAmin, POWERmin, POWER5%
91  FOR [NTIMES=3; INDEX=i]
92      SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] ALPHA; a
93      CALC ALPHAmin$[i] = a$[1]
94      SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] BETA[i]; b
95      CALC BETAmin$[i] = b$[1]
96      SUBSET [CONDITION=AVEERROR[i]==min_AVEERROR$[i]] POWER[i]; p
97      CALC POWERmin$[i] = p$[1]
98      SUBSET [CONDITION=ALPHA==0.05] POWER[i]; p5%
99      CALC POWER5%$[i] = p5%$[1]
100 ENDFOR
101 PRINT [SQUASH='yes'] DIFFPERCENT,FVALUE,NCP,min_AVEERROR, \
102      ALPHAmin,BETAmin,POWERmin,POWER5%; \
103      HEADING='% Diff','F value','~{lambda}','\
104      'Min avg ~{alpha} and ~{beta}','~{alpha} at min', \
105      '~{beta} at min','Power at min','Power at 0.05'; \
106      DECIMALS=0,2(1),5(2); JUSTIFICATION=right; \
107      FIELDWIDTH=2(8),5,16,2(8),2(12)
      % Diff  F value      λ   Min avg α and β  α at min  β at min  Power at min  Power at 0.05
      10      1.5  10.5           0.22    0.23    0.22          0.78          0.42
      16      3.8  26.9           0.08    0.09    0.07          0.93          0.87
      25      9.4  65.6           0.01    0.02    0.01          0.99          1.00
108
109  " Generate Figure 2: Plot of the Type 2 error rate against the
-110  Type 1 error rate "
111  PEN [RESET=yes] 1...3; METHOD=line; SYMBOL=0; COLOUR='black'; \
112      LINESTYLE='solid','dash','dot'
113  TXCONSTRUCT [TEXT=keydescription; PREFIX='~{lambda} = '] NCP; DEC=1
114  XAXIS [RESET=yes] WINDOW=1; TITLE='~{alpha}'
115  YAXIS [RESET=yes] WINDOW=1; TITLE='~{beta}'
116  DGRAPH [WINDOW=1] Y=BETA[]; X=ALPHA; DESCRIPTION=#keydescription

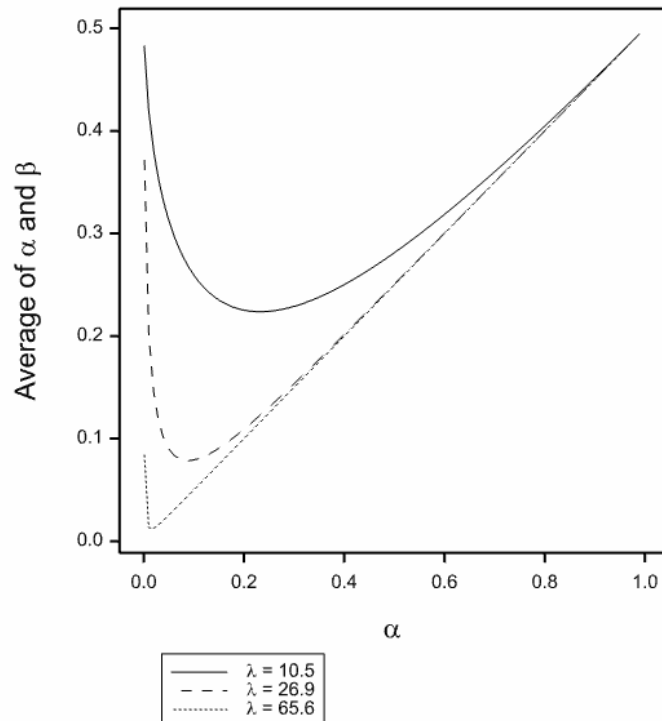
```



```

117
118 " Generate Figure 3: Plot of the average of the error rates against
-119 the Type 1 error rates "
120 YAXIS [RESET=yes] WINDOW=1; TITLE='Average of ~{alpha} and ~{beta}'
121 DGRAPH [WINDOW=1] Y=AVEERROR[]; X=ALPHA; DESCRIPTION=#keydescription

```



Estimates of Error Variance Example

Genstat Commands for the Estimates of Error Variance Example

```
" ***** "  
"           Yates Oat Experiment: Estimates of Error Variance           "  
" ***** "  
  
JOB  
  
" Load the Oats data, supplied by Genstat as an example data set "  
SPLOAD '%GENDIR%/Data/Oats.gsh'  
  
" Create variates x and y containing the columns and rows of the  
  experimental design, respectively "  
VARIATE x; VALUES=!((1,2)18,(3,4)18)  
VARIATE y; VALUES=! (2(18...1)2)  
  
" Generate Figure 4: A heatmap of the yield data "  
" Create a matrix of yield values"  
DELETE [REDEFINE=yes] xfac,xlevs,yfac,ylevs,zvals,exptgrid  
GROUPS [REDEFINE=yes] x; FACTOR=xfac; LEVELS=xlevs  
GROUPS [REDEFINE=yes] y; FACTOR=yfac; LEVELS=ylevs  
TABULATE [CLASS=yfac,xfac] yield; MEANS=zvals  
MATRIX [! (#ylevs);! (#xlevs)] exptgrid; ! (#zvals)  
" Plot a shade plot "  
XAXIS [RESET=yes] WINDOW=1; LPOSITION=*; MPOSITION=*  
YAXIS [RESET=yes] WINDOW=1; LPOSITION=*; MPOSITION=*  
PEN 2; COLOUR='red'  
PEN 3; COLOUR='blue'  
DSHADE [WINDOW=1; YORIENTATION=normal; GRID=*; \  
  TITLE='Heatmap of Yield Data'] exptgrid; PEN=!(2,3)  
  
" Add lines to distinguish the blocks "  
PEN [RESET=yes] 1; COLOUR='black'; THICKNESS=3  
DREFERENCELINE [WINDOW=1; ORIENTATION=vertical] POSITION=2.5; \  
  LABEL=''; PEN=1  
DREFERENCELINE [WINDOW=1; ORIENTATION=horizontal] POSITION=6.5,12.5; \  
  LABEL=''; PEN=1  
" Label by variety (i.e. cultivar) and nitrogen level "  
FACPRODUCT [ISEPARATOR=' ' ] !P(variety,nitrogen); VN  
TXCONSTRUCT [TEXT=VNt] VN  
PEN [RESET=yes] 1; COLOUR='white'; SIZE=0.7; YLPOSITION=centre; \  
  XLPOSITION=centre  
DTEXT [WINDOW=1] Y=y; X=x; TEXT=VNt; PEN = 1  
  
" Conduct a split-plot analysis "  
BLOCK blocks/wplots/subplots  
TREATMENTS nitrogen*variety  
COVARIATE "No Covariate"  
ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \  
  FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield  
APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram  
AGRAPH [METHOD=lines; PSE=differences] X=nitrogen; GROUPS=variety  
  
" Rerun the model with a linear trend across columns "
```



```

BLOCK blocks/wplots/subplots
TREATMENTS nitrogen*variety
COVARIATE x
ANOVA [PRINT=acovtable,information,effects,means,stratumvariance; \
      FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram
AGRAPH [METHOD=lines; PSE=differences] X=nitrogen; GROUPS=variety

ENDJOB

```

Genstat Output from the Estimates of Error Variance Example

```

4  " Load the Oats data, supplied by Genstat as an example data set "
5  SPLOAD '%GENDIR%/Data/Oats.gsh'

```

Loading Spreadsheet File

Catalogue of file D:\GenStatTrunk\installsets\Data\Oats.gsh

Sheet Type: vector

Index	Type	Nval	Name
1	factor	72	blocks
2	factor	72	wplots
3	factor	72	subplots
6	factor	72	variety
9	factor	72	nitrogen
10	variate	72	yield

Note: Missing indices are used by unnamed or system structures. These store ancillary information, for example factor labels.

```

6
7  " Create variates x and y containing the columns and rows of the
-8  experimental design, respectively "
9  VARIATE x; VALUES=!( (1,2)18, (3,4)18)
10 VARIATE y; VALUES=!(2 (18...1)2)
11
12 " Generate Figure 4: A heatmap of the yield data "
13 " Create a matrix of yield values"
14 DELETE [REDEFINE=yes] xfac,xlevs,yfac,ylevs,zvals,exptgrid
15 GROUPS [REDEFINE=yes] x; FACTOR=xfac; LEVELS=xlevs
16 GROUPS [REDEFINE=yes] y; FACTOR=yfac; LEVELS=ylevs
17 TABULATE [CLASS=yfac,xfac] yield; MEANS=zvals
18 MATRIX [!(#ylevs);!(#xlevs)] exptgrid; !(#zvals)
19 " Plot a shade plot "
20 XAXIS [RESET=yes] WINDOW=1; LPOSITION=*; MPOSITION=*
21 YAXIS [RESET=yes] WINDOW=1; LPOSITION=*; MPOSITION=*
22 PEN 2; COLOUR='red'
23 PEN 3; COLOUR='blue'
24 DSHADE [WINDOW=1; YORIENTATION=normal; GRID=*; \
25       TITLE='Heatmap of Yield Data'] exptgrid; PEN=!(2,3)
26 " Add lines to distinguish the blocks "
27 PEN [RESET=yes] 1; COLOUR='black'; THICKNESS=3
28 DREFERENCELINE [WINDOW=1; ORIENTATION=vertical] POSITION=2.5; \

```

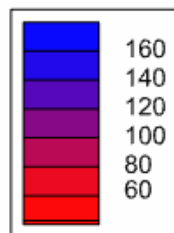
```

29 LABEL=''; PEN=1
30 DREFERENCeline [WINDOW=1; ORIENTATION=horizontal] POSITION=6.5,12.5;\
31 LABEL=''; PEN=1
32 " Label by variety (i.e. cultivar) and nitrogen level "
33 FACPRODUCT [ISEPARATOR=' ' ] !P(variety,nitrogen); VN
34 TXCONSTRUCT [TEXT=VNt] VN
35 PEN [RESET=yes] 1; COLOUR='white'; SIZE=0.7; YLPOSITION=centre; \
36 XLPOSITION=centre
37 DTEXT [WINDOW=1] Y=y; X=x; TEXT=VNt; PEN = 1

```

Heatmap of Yield Data

Marvellous 0.6 cwt	Marvellous 0.4 cwt	Marvellous 0.4 cwt	Marvellous 0.6 cwt
Marvellous 0.2 cwt	Marvellous 0 cwt	Marvellous 0 cwt	Marvellous 0.2 cwt
Victory 0 cwt	Victory 0.2 cwt	Golden rain 0 cwt	Golden rain 0.4 cwt
Victory 0.6 cwt	Victory 0.4 cwt	Golden rain 0.6 cwt	Golden rain 0.2 cwt
Golden rain 0 cwt	Golden rain 0.2 cwt	Victory 0.2 cwt	Victory 0.4 cwt
Golden rain 0.4 cwt	Golden rain 0.6 cwt	Victory 0.6 cwt	Victory 0 cwt
Marvellous 0.4 cwt	Marvellous 0 cwt	Golden rain 0.6 cwt	Golden rain 0 cwt
Marvellous 0.2 cwt	Marvellous 0.6 cwt	Golden rain 0.4 cwt	Golden rain 0.2 cwt
Victory 0.6 cwt	Victory 0 cwt	Victory 0.4 cwt	Victory 0.6 cwt
Victory 0.2 cwt	Victory 0.4 cwt	Victory 0 cwt	Victory 0.2 cwt
Golden rain 0.2 cwt	Golden rain 0 cwt	Marvellous 0.4 cwt	Marvellous 0.6 cwt
Golden rain 0.4 cwt	Golden rain 0.6 cwt	Marvellous 0.2 cwt	Marvellous 0 cwt
Golden rain 0.2 cwt	Golden rain 0.4 cwt	Victory 0.4 cwt	Victory 0 cwt
Golden rain 0.6 cwt	Golden rain 0 cwt	Victory 0.6 cwt	Victory 0.2 cwt
Marvellous 0.6 cwt	Marvellous 0.2 cwt	Golden rain 0.6 cwt	Golden rain 0.4 cwt
Marvellous 0.4 cwt	Marvellous 0 cwt	Golden rain 0 cwt	Golden rain 0.2 cwt
Victory 0 cwt	Victory 0.6 cwt	Marvellous 0 cwt	Marvellous 0.2 cwt
Victory 0.2 cwt	Victory 0.4 cwt	Marvellous 0.4 cwt	Marvellous 0.6 cwt



```

38
39 " Conduct a split-plot analysis "
40 BLOCK blocks/wplots/subplots
41 TREATMENTS nitrogen*variety
42 COVARIATE "No Covariate"
43 ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
44 FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield

```

Variate: yield

Message: the following units have large residuals.

Tables of effects

Variate: yield

variety effects, e.s.e. 5.01, rep. 24

blocks.wplots.subplots stratum

nitrogen effects, e.s.e. 3.14, rep. 18

nitrogen.variety effects, e.s.e. 5.43, rep. 6

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Tables of means

Variate: yield

Grand mean 104.0

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	79.4	98.9	114.2	123.4

variety	Victory	Golden rain	Marvellous
	97.6	104.5	109.8

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		71.5	80.0	86.7
0.2 cwt		89.7	98.5	108.5
0.4 cwt		110.8	114.7	117.2
0.6 cwt		118.5	124.8	126.8

Standard errors of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
e.s.e.	3.14	5.01	6.87
d.f.	45	10	30.23
Except when comparing means with the same level(s) of variety			5.43
d.f.			45

Standard errors of differences of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
s.e.d.	4.44	7.08	9.72
d.f.	45	10	30.23
Except when comparing means with the same level(s) of variety			7.68
d.f.			45

Least significant differences of means (5% level)

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
l.s.d.	8.93	15.77	19.83
d.f.	45	10	30.23
Except when comparing means with the same level(s) of variety			15.47

d.f.

45

Estimated stratum variances

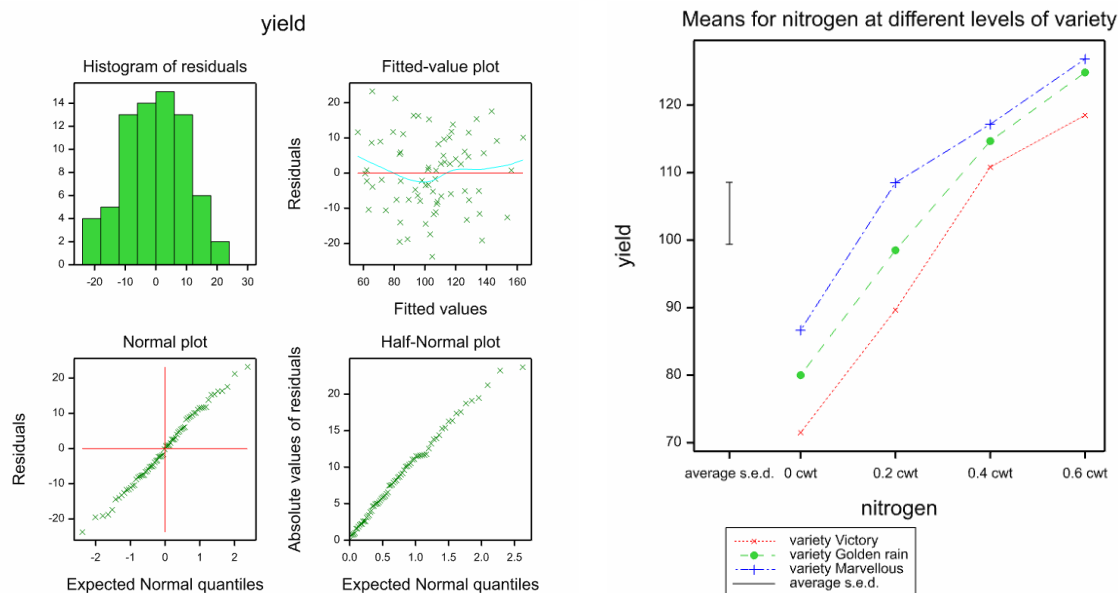
Variate: yield

Stratum	variance	effective d.f.	variance component
blocks	3175.06	5.000	214.48
blocks.wplots	601.33	10.000	106.06
blocks.wplots.subplots	177.08	45.000	177.08

```

45  APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram
46  AGRAPH [METHOD=lines; PSE=differences] X=nitrogen; GROUPS=variety

```



```

47
48  " Rerun the model with a linear trend across columns "
49  BLOCK blocks/wplots/subplots
50  TREATMENTS nitrogen*variety
51  COVARIATE x
52  ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
53  FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield

```

Analysis of variance (adjusted for covariate)

Variate: yield

Covariate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
blocks stratum						
Covariate	1	6650.9	6650.9	2.88		0.165
Residual	4	9224.4	2306.1	3.83	1.38	

blocks.wplots stratum						
variety	2	1786.4	893.2	1.49	1.00	0.272
Residual	10	6013.3	601.3	5.41	1.00	
blocks.wplots.subplots stratum						
nitrogen	3	18410.3	6136.8	55.19	1.00	<.001
nitrogen.variety	6	684.1	114.0	1.03	0.99	0.422
Covariate	1	3076.6	3076.6	27.67		<.001
Residual	44	4892.2	111.2		1.59	
Total	71	51985.9				

Message: the following units have large residuals.

blocks 2 wplots 2 subplots 4	-19.1	s.e. 8.2
blocks 5 wplots 1 subplots 4	25.8	s.e. 8.2

Tables of effects (adjusted for covariate)

Variate: yield

Covariate: x

blocks.wplots stratum

variety effects, e.s.e. 5.01, rep. 24

variety	Victory	Golden rain	Marvellous
	-6.3	0.5	5.8

blocks.wplots.subplots stratum

nitrogen effects, e.s.e. 2.49, rep. 18

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	-23.8	-4.3	9.5	18.7

nitrogen.variety effects, e.s.e. 4.34, rep. 6

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		-2.3	-0.7	3.0
0.2 cwt		-3.6	0.6	3.0
0.4 cwt		6.0	0.7	-6.7
0.6 cwt		-0.1	-0.6	0.7

Tables of means (adjusted for covariate)

Variate: yield

Covariate: x

Grand mean 104.0

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	80.2	99.7	113.5	122.6

variety	Victory	Golden rain	Marvellous
	97.6	104.5	109.8

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		71.5	80.0	89.0
0.2 cwt		89.7	100.8	108.5
0.4 cwt		113.1	114.7	112.6
0.6 cwt		116.2	122.5	129.1

Standard errors of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
e.s.e.	2.49	5.01	6.27
d.f.	44	10	22.59
Except when comparing means with the same level(s) of variety			4.32
d.f.			44

Standard errors of differences of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
s.e.d.	3.52	7.08	8.87
d.f.	44	10	22.59
Except when comparing means with the same level(s) of variety			6.12
d.f.			44

Least significant differences of means (5% level)

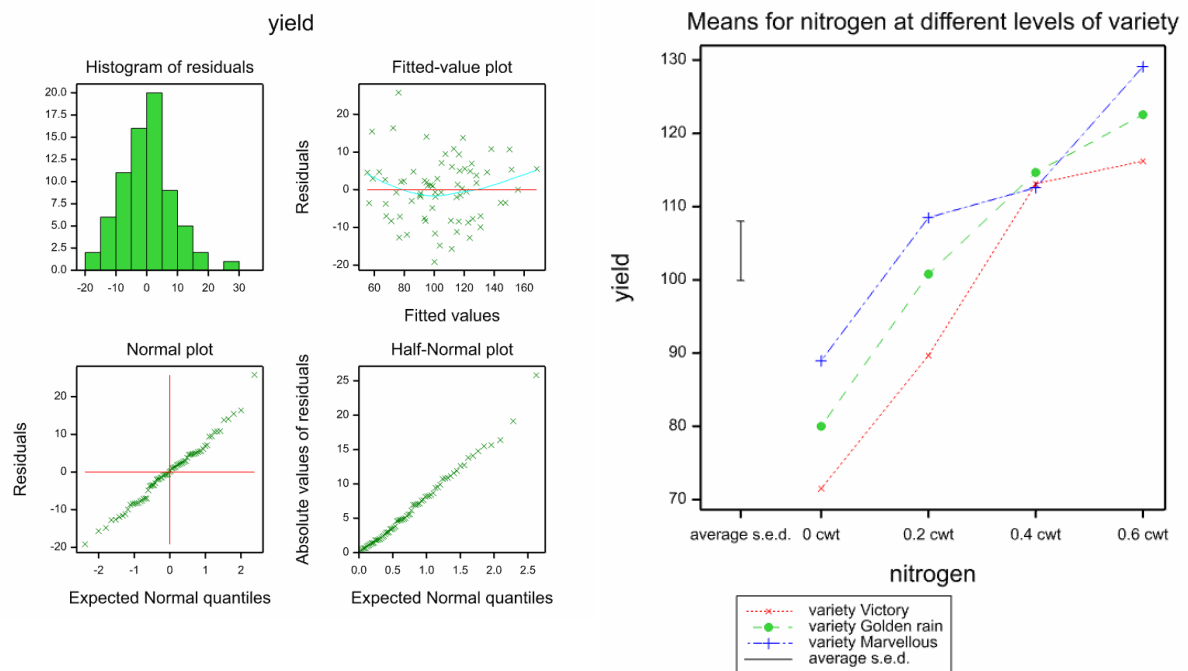
Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
l.s.d.	7.10	15.77	18.36
d.f.	44	10	22.59
Except when comparing means with the same level(s) of variety			12.33
d.f.			44

Estimated stratum variances (adjusted for covariate)

Variate: yield
Covariate: x

Stratum	variance	effective d.f.	variance component
blocks	2083.92	4.810	123.55
blocks.wplots	601.33	10.000	122.60
blocks.wplots.subplots	110.93	44.190	110.93

```
54  APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram
55  AGRAPH [METHOD=lines; PSE=differences] X=nitrogen; GROUPS=variety
```



Homework Exercises

Genstat Commands for the Homework Exercises

```
" ***** "
"                               HOMEWORK EXERCISES                               "
" ***** "
```

JOB

```
" Load the Oats data, supplied by Genstat as an example data set "
SPLOAD '%GENDIR%/Data/Oats.gsh'
```

```
" Create variates x and y containing the columns and rows of the
  experimental design, respectively "
```

```
VARIATE x; VALUES=! ((1,2)18, (3,4)18)
```

```
VARIATE y; VALUES=! (2 (18...1) 2)
```



```

" Question 1 "
BLOCK blocks
TREATMENTS nitrogen*variety
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
      FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram

" Question 2 "
BLOCK blocks
TREATMENTS nitrogen*variety
COVARIATE x
ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
      FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram

" Question 3 "
BLOCK blocks
TREATMENTS nitrogen*variety
COVARIATE y
ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
      FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram

" Question 4 "
" Note: code illustrates the calculations for cultivar (i.e. the
  variety term) for a 25% difference based on the RCB design"
SCALAR MSE; 254.2 "MSE set here"
SCALAR N; 24 "Replication set here"
SCALAR MEAN; 104 "Grand mean set here"
SCALAR DIFFPERCENT; 25 "Percent difference set here"
SCALAR ALPHA; 0.05 "Type 1 error set here"
SCALAR NUMDF; 2 "Numerator degrees of freedom set here"
SCALAR DENDF; 55 "Denominator degrees of freedom set here"
SCALAR SED; SQRT(2*MSE/N)
SCALAR FVALUE; (DIFFPERCENT/100*MEAN/SED)**2
CALC NCP = NUMDF*FVALUE
CALC PROB = 1-ALPHA
CALC FCRIT = EDF(PROB;NUMDF;DENDF;0)
CALC POWER = 1-CLF(FCRIT;NUMDF;DENDF;NCP)
CALC BETA = 1-POWER
CALC AVEERROR = (ALPHA+BETA)/2
PRINT [SQUASH='yes'; ORIENTATION='across'] DIFFPERCENT,FVALUE,ALPHA,\
      BETA,AVEERROR,POWER; DECIMALS=0,1,4(2)

ENDJOB

```

Genstat Output from the Homework Exercises

```

4 " Load the Oats data, supplied by Genstat as an example data set "
5 SLOAD '%GENDIR%/Data/Oats.gsh'

```

Loading Spreadsheet File

Catalogue of file D:\GenStatTrunk\installsets\Data\Oats.gsh

Sheet Type: vector

Index	Type	Nval	Name
1	factor	72	blocks
2	factor	72	wplots
3	factor	72	subplots
6	factor	72	variety
9	factor	72	nitrogen
10	variate	72	yield

Note: Missing indices are used by unnamed or system structures. These store ancillary information, for example factor labels.

```
6
7 " Create variates x and y containing the columns and rows of the
-8 experimental design, respectively "
9 VARIATE x; VALUES=!((1,2)18,(3,4)18)
10 VARIATE y; VALUES=! (2(18...1)2)
11
12 " Question 1 "
13 BLOCK blocks
14 TREATMENTS nitrogen*variety
15 COVARIATE "No Covariate"
16 ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
17 FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
blocks stratum	5	15875.3	3175.1	12.49	
blocks.*Units* stratum					
nitrogen	3	20020.5	6673.5	26.25	<.001
variety	2	1786.4	893.2	3.51	0.037
nitrogen.variety	6	321.8	53.6	0.21	0.972
Residual	55	13982.1	254.2		
Total	71	51985.9			

Message: the following units have large residuals.

blocks 1	31.4	s.e. 14.8

Tables of effects

Variate: yield

blocks.*Units* stratum

nitrogen effects, e.s.e. 3.76, rep. 18

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	-24.6	-5.1	10.2	19.4

variety effects, e.s.e. 3.25, rep. 24

variety	Victory	Golden rain	Marvellous
	-6.3	0.5	5.8

nitrogen.variety effects, e.s.e. 6.51, rep. 6

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		-1.5	0.1	1.5
0.2 cwt		-2.9	-0.9	3.8
0.4 cwt		3.0	-0.1	-2.9
0.6 cwt		1.5	0.9	-2.4

Tables of means

Variate: yield

Grand mean 104.0

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	79.4	98.9	114.2	123.4

variety	Victory	Golden rain	Marvellous
	97.6	104.5	109.8

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		71.5	80.0	86.7
0.2 cwt		89.7	98.5	108.5
0.4 cwt		110.8	114.7	117.2
0.6 cwt		118.5	124.8	126.8

Standard errors of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	55	55	55
e.s.e.	3.76	3.25	6.51

Standard errors of differences of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6

d.f.	55	55	55
s.e.d.	5.31	4.60	9.21

Least significant differences of means (5% level)

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	55	55	55
l.s.d.	10.65	9.22	18.45

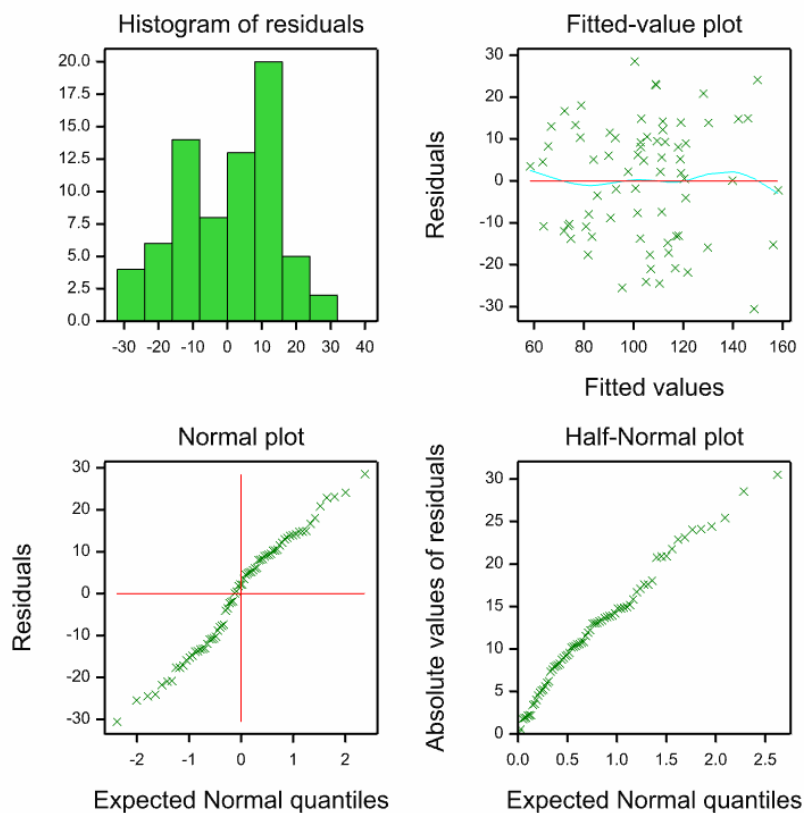
Estimated stratum variances

Variate: yield

Stratum	variance	effective d.f.	variance component
blocks	3175.06	5.000	243.40
blocks.*Units*	254.22	55.000	254.22

```
18  APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram
```

yield



```

19
20 " Question 2 "
21 BLOCK blocks
22 TREATMENTS nitrogen*variety
23 COVARIATE x
24 ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
25       FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield

```

Analysis of variance (adjusted for covariate)

Variate: yield

Covariate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
blocks stratum						
Covariate	1	6650.9	6650.9	2.88		0.165
Residual	4	9224.4	2306.1	11.42	1.38	
blocks.*Units* stratum						
nitrogen	3	18410.3	6136.8	30.39	1.00	<.001
variety	2	1786.4	893.2	4.42	1.00	0.017
nitrogen.variety	6	684.1	114.0	0.56	0.99	0.757
Covariate	1	3076.6	3076.6	15.23		<.001
Residual	54	10905.5	202.0		1.26	
Total	71	51985.9				

Tables of effects (adjusted for covariate)

Variate: yield

Covariate: x

blocks.*Units* stratum

nitrogen effects, e.s.e. 3.36, rep. 18

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	-23.8	-4.3	9.5	18.7

variety effects, e.s.e. 2.90, rep. 24

variety	Victory	Golden rain	Marvellous
	-6.3	0.5	5.8

nitrogen.variety effects, e.s.e. 5.84, rep. 6

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		-2.3	-0.7	3.0
0.2 cwt		-3.6	0.6	3.0
0.4 cwt		6.0	0.7	-6.7
0.6 cwt		-0.1	-0.6	0.7

Tables of means (adjusted for covariate)

Variate: yield

Covariate: x

Grand mean 104.0

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	80.2	99.7	113.5	122.6

variety	Victory	Golden rain	Marvellous
	97.6	104.5	109.8

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		71.5	80.0	89.0
0.2 cwt		89.7	100.8	108.5
0.4 cwt		113.1	114.7	112.6
0.6 cwt		116.2	122.5	129.1

Standard errors of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
e.s.e.	3.36	2.90	5.83

Standard errors of differences of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
s.e.d.	4.75	4.10	8.24

Least significant differences of means (5% level)

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
l.s.d.	9.52	8.22	16.53

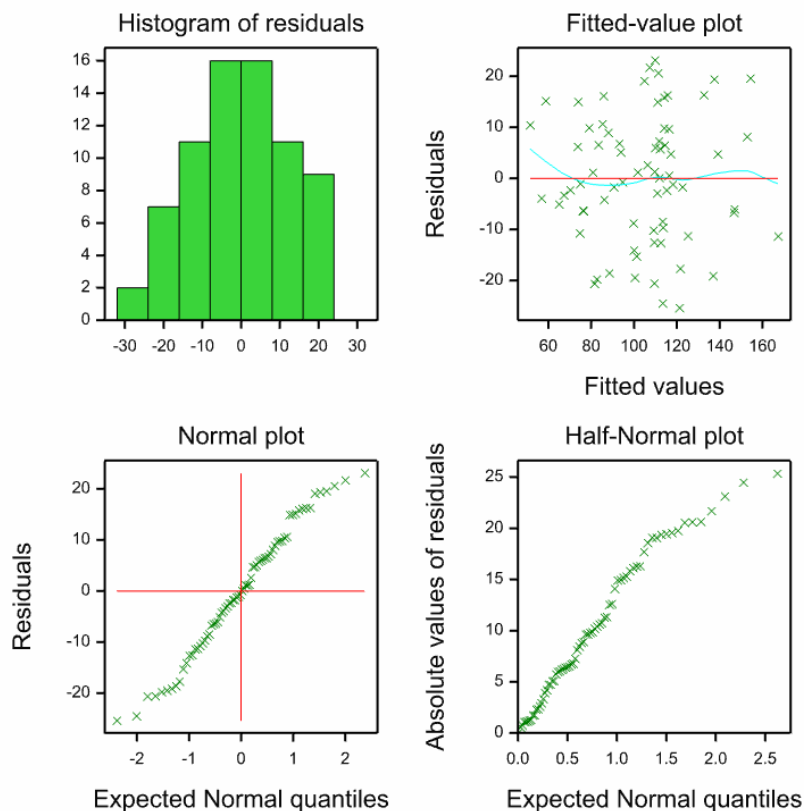
Estimated stratum variances (adjusted for covariate)

Variate: yield
Covariate: x

Stratum	variance	effective d.f.	variance component
blocks	2089.49	4.702	157.35
blocks.*Units*	201.30	54.298	201.30

```
26  APLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram
```

yield



```
27
28  " Question 3 "
29  BLOCK blocks
30  TREATMENTS nitrogen*variety
31  COVARIATE y
32  ANOVA [PRINT=aovtable,information,effects,means,stratumvariance; \
33        FPROB=yes; PSE=means,diff,lsd; LSDLEVEL=5] yield
```

Analysis of variance (adjusted for covariate)

Variate: yield
Covariate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
blocks stratum						

Covariate	1	1552.7	1552.7	0.43		0.546
Residual	4	14322.6	3580.6	15.34	0.89	
blocks.*Units* stratum						
nitrogen	3	20004.4	6668.1	28.57	1.00	<.001
variety	2	2278.0	1139.0	4.88	0.99	0.011
nitrogen.variety	6	276.2	46.0	0.20	1.00	0.976
Covariate	1	1377.1	1377.1	5.90		0.019
Residual	54	12604.9	233.4		1.09	
Total	71	51985.9				

Tables of effects (adjusted for covariate)

Variate: yield

Covariate: y

blocks.*Units* stratum

nitrogen effects, e.s.e. 3.60, rep. 18

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	-24.4	-5.4	10.4	19.4

variety effects, e.s.e. 3.14, rep. 24

variety	Victory	Golden rain	Marvellous
	-7.2	0.5	6.7

nitrogen.variety effects, e.s.e. 6.24, rep. 6

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		-1.3	0.4	0.9
0.2 cwt		-3.0	-0.6	3.6
0.4 cwt		2.8	-0.2	-2.6
0.6 cwt		1.5	0.5	-1.9

Tables of means (adjusted for covariate)

Variate: yield

Covariate: y

Grand mean 104.0

nitrogen	0 cwt	0.2 cwt	0.4 cwt	0.6 cwt
	79.5	98.6	114.4	123.4

variety	Victory	Golden rain	Marvellous
	96.8	104.5	110.7

nitrogen	variety	Victory	Golden rain	Marvellous
0 cwt		71.1	80.4	87.1

0.2 cwt	88.4	98.5	108.9
0.4 cwt	110.0	114.7	118.5
0.6 cwt	117.6	124.4	128.1

Standard errors of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
e.s.e.	3.60	3.14	6.25

Standard errors of differences of means

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
s.e.d.	5.09	4.44	8.83

Least significant differences of means (5% level)

Table	nitrogen	variety	nitrogen variety
rep.	18	24	6
d.f.	54	54	54
l.s.d.	10.21	8.90	17.71

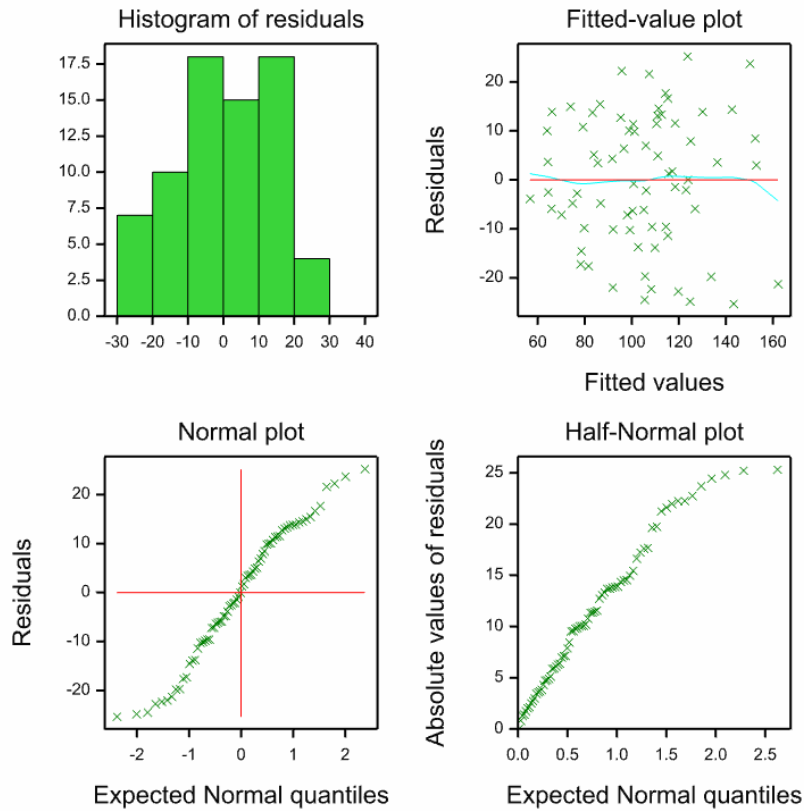
Estimated stratum variances (adjusted for covariate)

Variate: yield
Covariate: y

Stratum	variance	effective d.f.	variance component
blocks	5499.02	4.733	438.62
blocks.*Units*	235.64	54.267	235.64

34 A PLOT [RMETHOD=simple] fitted,normal,halfnormal,histogram

yield



```

35
36 " Question 4 "
37 " Note: code illustrates the calculations for cultivar (i.e. the
-38   variety term) for a 25% difference based on the RCB design"
39 SCALAR MSE; 254.2 "MSE set here"
40 SCALAR N; 24 "Replication set here"
41 SCALAR MEAN; 104 "Grand mean set here"
42 SCALAR DIFFPERCENT; 25 "Percent difference set here"
43 SCALAR ALPHA; 0.05 "Type 1 error set here"
44 SCALAR NUMDF; 2 "Numerator degrees of freedom set here"
45 SCALAR DENDF; 55 "Denominator degrees of freedom set here"
46 SCALAR SED; SQRT(2*MSE/N)
47 SCALAR FVALUE; (DIFFPERCENT/100*MEAN/SED)**2
48 CALC NCP = NUMDF*FVALUE
49 CALC PROB = 1-ALPHA
50 CALC FCRIT = EDF(PROB;NUMDF;DENDF;0)
51 CALC POWER = 1-CLF(FCRIT;NUMDF;DENDF;NCP)
52 CALC BETA = 1-POWER
53 CALC AVEERROR = (ALPHA+BETA)/2
54 PRINT [SQUASH='yes'; ORIENTATION='across'] DIFFPERCENT,FVALUE,ALPHA,\
55       BETA,AVEERROR,POWER; DECIMALS=0,1,4(2)
DIFFPERCENT      25
FVALUE           31.9
ALPHA             0.05
BETA              0.00
AVEERROR         0.03
POWER            1

```

Chapter 2. Analysis of Variance and Hypothesis Testing by Marla McIntosh

Genstat code developed by Vanessa M. Cave and output are provided here for the case study presented in Chapter 2.

Case Study: The Story of Statbean Example

Genstat Commands

```
" ***** "
"           Case Study: The Story of Statbean           "
" ***** "

" Note: Here, Genstat's ANOVA facilities are used to analyse the
      statbean data. Alternatively, Genstat's REML facilities can
      be used. However, unlike ANOVA, REML is unable to produce
      an analysis-of-variance table that partitions the variation
      into strata with an appropriate random error term
      (or residual) for each treatment term. Hence, it is better
      to use ANOVA whenever possible. "

JOB

" Import the data "
IMPORT 'Supplement 1. Statbean Data.xlsx'; CELLRANGE='A2:H92'

" Convert Ca_Trtr and Loc from text structures to factors, and convert
  N, P, Blk, Mulch and Trtr_No from variates to factors "
GROUP [REDEFINE=yes] Ca_Trtr,Loc,Blk,Mulch,Trtr_No; \
      Ca_Trtr,Loc,Blk,Mulch,Trtr_No

" *** Descriptive Summary of the pH data *** "
DESCRIBE [SELECTION=nobs,nmv,mean,median,min,max,q1,q3,sd] pH
TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Loc] pH
BOXPLOT [TITLE='pH by Location'] pH; GROUPS=Loc
TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Mulch] pH
BOXPLOT [TITLE='pH by Mulch treatment'] pH; GROUPS=Mulch
TRELLIS [TITLE='pH by Mulch within Location'; GROUPS=Loc; \
      PENGROUP=Mulch] Y=pH; METHOD=boxplot
TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Ca_Trtr] pH
BOXPLOT [TITLE='pH by Ca treatment'] pH; GROUPS=Ca_Trtr
TRELLIS [TITLE='pH by Ca treatment within Location'; GROUPS=Loc; \
      PENGROUP=Ca_Trtr] Y=pH; METHOD=boxplot
TABULATE [PRINT=means,minima,maxima,sd; CLASS=Mulch,Ca_Trtr,Loc] pH

" *** Supplements 2 and 3 *** "

" pH ANOVA by location "
FOR location = 'Central','East','West'
  RESTRICT pH; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  BLOCK Blk
  TREATMENTS Mulch*Ca_Trtr
```

```

ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
      PSE=means,diff] pH
APLOT [TITLE=location]
" Plot of Ca_trt means with sems "
AGRAPH [METHOD=barchart; PSE=allmeans] X=Ca_Trt
RESTRICT pH
ENDFOR

" Code for using the REML facilities "
" FOR location = 'Central','East','West'
  RESTRICT pH; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  VCOMPONENTS [FIXED=Mulch*Ca_Trt] RANDOM=Blk
  REML [PRINT=model,components,waldTests,means; PSE=allest] pH
  VPLOT [Title=location]
  RESTRICT pH
ENDFOR "

" pH ANOVA by location with contrasts "
GETATTRIBUTE [ATTRIBUTE=labels] Ca_Trt; SAVE=Ca_Trtlab
MATRIX [ROWS=!T('Gypsum Linear','Gypsum Quadratic','Lime Linear', \
                  'Lime Quadratic','Gypsum vrs Lime'); \
        COLUMNS=#Ca_Trtlab] Contrasts; VALUES=!( -1, 0, 1, 0, 0, \
                                                    1,-2, 1, 0, 0, \
                                                    1, 0, 0, 0,-1, \
                                                    1, 0, 0,-2, 1, \
                                                    0, 1, 1,-1,-1)

PRINT Contrasts; DECIMALS=0
FOR location = 'Central','East','West'
  RESTRICT pH; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  BLOCK Blk
  TREATMENTS Mulch*COMP(Ca_Trt;5;Contrasts)
  ANOVA [PRINT=aovtable; FPROB=yes; CONTRASTS=10] pH
  RESTRICT pH
ENDFOR

" Calcium ANOVA by location with contrasts "
FOR location = 'Central','East','West'
  RESTRICT Ca; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  BLOCK Blk
  TREATMENTS Mulch*COMP(Ca_Trt;5;Contrasts)
  ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
        PSE=means,diff; CONTRASTS=10] Ca
  APLOT [TITLE=location]
  " Plot of Ca_trt means with sems "
  AGRAPH [METHOD=barchart; PSE=allmeans] X=Ca_Trt
  RESTRICT Ca
ENDFOR

" pH ANOVA combined over locations "
BLOCK Loc.Blk
TREATMENTS Loc*Mulch*Ca_Trt
ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
      PSE=means,diff] pH
APLOT
" Code for using the REML facilities "

```

```

" VCOMPONENTS [FIXED=Loc*Mulch*Ca_Trt] RANDOM=Loc.Blk
REML [PRINT=model,components,waldTests,means; PSE=allest] pH
VPLOT "

" *** Supplements 4 and 5 *** "

" Calcium ANOVA by location "
FOR location = 'Central','East','West'
  RESTRICT Ca; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  BLOCK Blk
  TREATMENTS Mulch*Ca_Trt
  ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
    PSE=means,diff] Ca
  APLOT [TITLE=location]
  RESTRICT Ca
ENDFOR

" Calcium ANOVA combined over locations "
BLOCK Loc.Blk
TREATMENTS Loc*Mulch*Ca_Trt
ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
  PSE=means,diff] Ca
APLOT

" Mixed percent total ANOVA by location "
FOR location = 'Central','East','West'
  RESTRICT Pct_Total; CONDITION=Loc .IN. location
  CAPTION location; STYLE=meta
  BLOCK Blk
  TREATMENTS Mulch*Ca_Trt
  ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
    PSE=means,diff] Pct_Total
  APLOT [TITLE=location]
  RESTRICT Pct_Total
ENDFOR

" Mixed percent total combined over locations "
BLOCK Loc.Blk
TREATMENTS Loc*Mulch*Ca_Trt
ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
  PSE=means,diff] Pct_Total
APLOT

ENDJOB

```

Genstat Output

```

2  " ***** "
3  "           Case Study: The Story of Statbean           "
4  " ***** "
5
6  " Note: Here, Genstat's ANOVA facilities are used to analyse the
-7      statbean data. Alternatively, Genstat's REML facilities can
-8      be used. However, unlike ANOVA, REML is unable to produce
-9      an analysis-of-variance table that partitions the variation

```

```

-10         into strata with an appropriate random error term
-11         (or residual) for each treatment term. Hence, it is better
-12         to use ANOVA whenever possible. "
13
14 JOB

```

End of job.

```

15
16 " Import the data "
17 IMPORT 'Supplement 1. Statbean Data.xlsx'; CELLRANGE='A2:H92'

```

Loading Spreadsheet File

Catalogue of file Supplement 1. Statbean Data.xlsx

Sheet Title: statbean1

Description: Data read from Supplement 1. Statbean Data.xlsx [statbean1]A3:H92

Sheet Type: vector

Index	Type	Nval	Name
1	text	90	Loc
2	variate	90	Blk
3	variate	90	Mulch
4	text	90	Ca_Trt
5	variate	90	pH
6	variate	90	Ca
7	variate	90	Pct_Total
8	variate	90	Trt_No

```

18
19 " Convert Ca_Trt and Loc from text structures to factors, and convert
-20 N, P, Blk, Mulch and Trt_No from variates to factors "
21 GROUP [REDEFINE=yes] Ca_Trt,Loc,Blk,Mulch,Trt_No; \
22 Ca_Trt,Loc,Blk,Mulch,Trt_No
23
24 " *** Descriptive Summary of the pH data *** "
25 DESCRIBE [SELECTION=nobs,nmv,mean,median,min,max,q1,q3,sd] pH

```

Summary statistics for pH

```

Number of observations = 90
Number of missing values = 0
Mean = 5.557
Median = 5.73
Minimum = 3.75
Maximum = 7.31
Lower quartile = 4.21
Upper quartile = 6.58
Standard deviation = 1.139

```

```

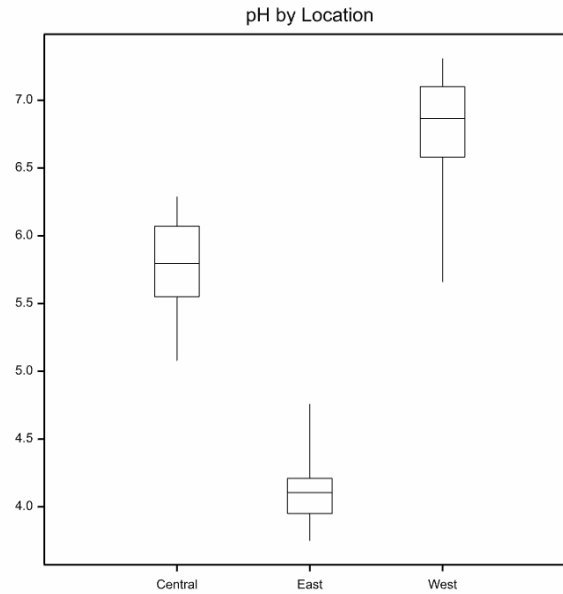
26 TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Loc] pH

```

	Nobs	Mean	Minimum	Maximum	s.d.
Loc					

Central	30	5.775	5.080	6.290	0.3225
East	30	4.138	3.750	4.760	0.2568
West	30	6.757	5.660	7.310	0.4363

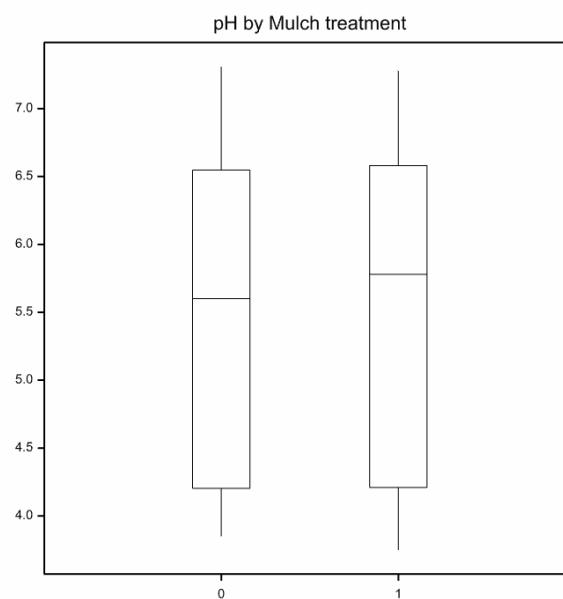
27 BOXPLOT [TITLE='pH by Location'] pH; GROUPS=Loc



28 TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Mulch] pH

	Nobs	Mean	Minimum	Maximum	s.d.
Mulch					
0	45	5.527	3.850	7.310	1.134
1	45	5.586	3.750	7.280	1.156

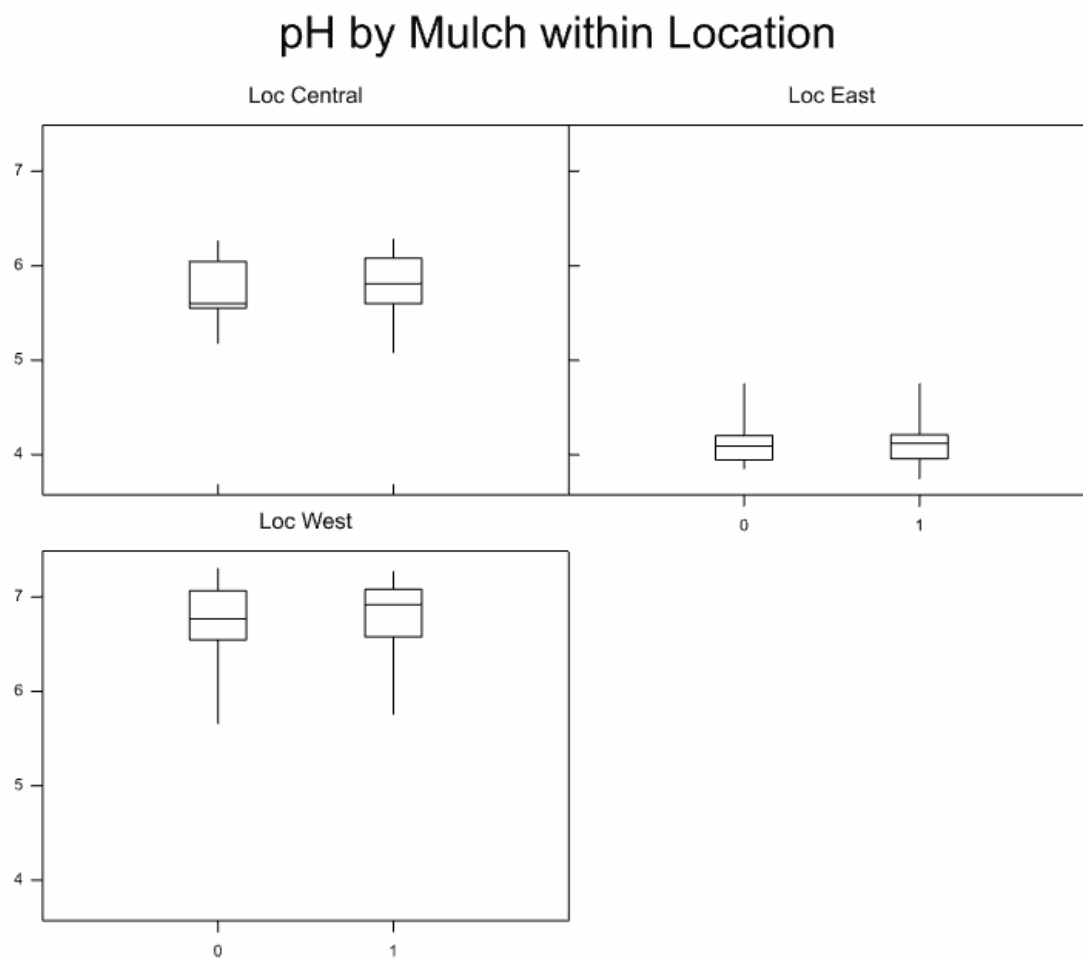
29 BOXPLOT [TITLE='pH by Mulch treatment'] pH; GROUPS=Mulch



```

30 TRELLIS [TITLE='pH by Mulch within Location'; GROUPS=Loc; \
31   PENGROUP=Mulch] Y=pH; METHOD=boxplot

```



```

32 TABULATE [PRINT=nobs,means,minima,maxima,sd; CLASS=Ca_Trt] pH

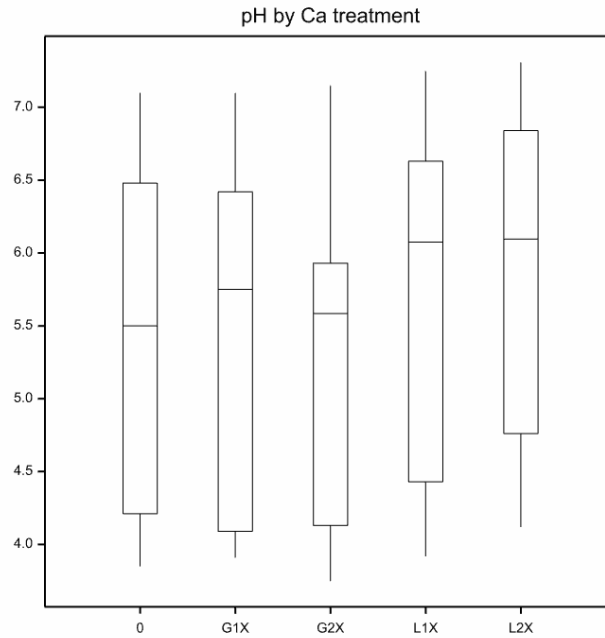
```

Ca_Trt	Nobsrvd	Mean	Minimum	Maximum	s.d.
0	18	5.436	3.850	7.100	1.150
G1X	18	5.467	3.910	7.100	1.148
G2X	18	5.361	3.750	7.150	1.150
L1X	18	5.707	3.920	7.250	1.175
L2X	18	5.814	4.120	7.310	1.135

```

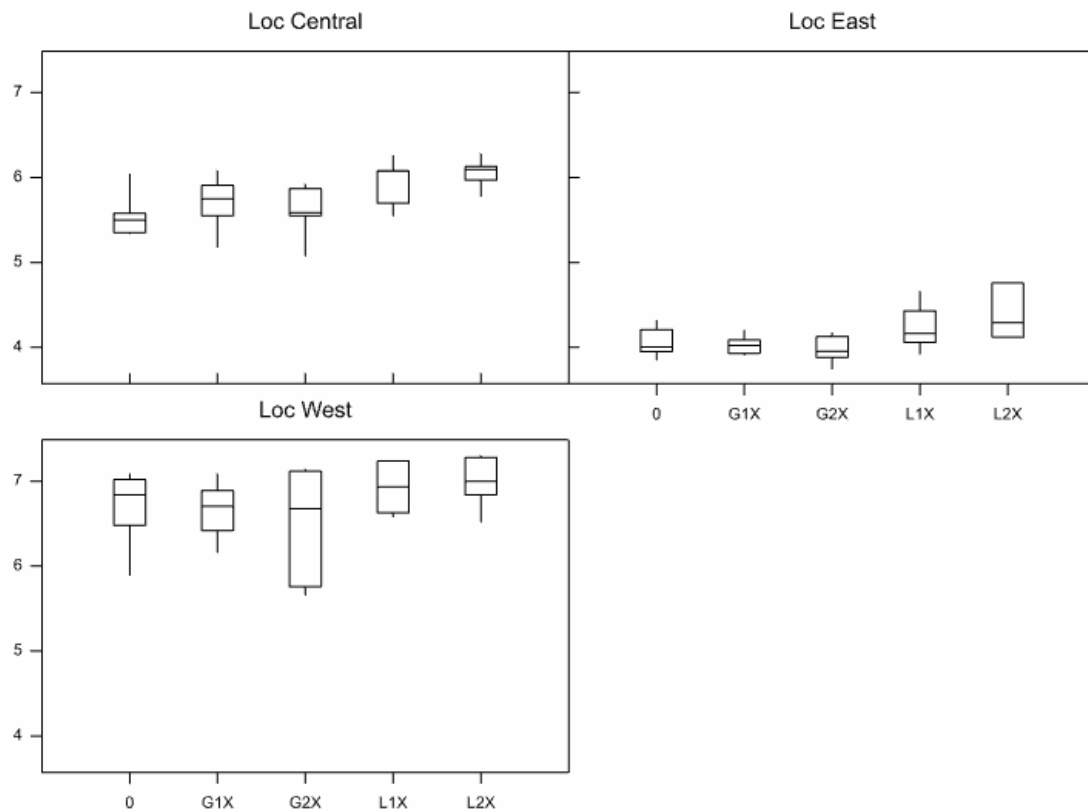
33 BOXPLOT [TITLE='pH by Ca treatment'] pH; GROUPS=Ca_Trt

```

```
34 TRELLIS [TITLE='pH by Ca treatment within Location'; GROUPS=Loc; \
35     PENGROUP=Ca_Trt] Y=pH; METHOD=boxplot
```

pH by Ca treatment within Location



36 TABULATE [PRINT=means,minima,maxima,sd; CLASS=Mulch,Ca_Trt,Loc] pH

	Loc	Central Mean	Minimum	Maximum	s.d.
Mulch	Ca_Trt				
	0	5.423	5.340	5.580	0.1358
	G1X	5.547	5.180	5.910	0.3650
	G2X	5.693	5.550	5.930	0.2065
	L1X	5.963	5.550	6.270	0.3717
	L2X	6.057	5.970	6.130	0.0808
	1	5.683	5.470	6.050	0.3190
	G1X	5.863	5.690	6.090	0.2053
	G2X	5.507	5.080	5.870	0.3988
	L1X	5.953	5.700	6.080	0.2194
	L2X	6.063	5.780	6.290	0.2597

	Loc	East Mean	Minimum	Maximum	s.d.
Mulch	Ca_Trt				
	0	4.013	3.850	4.210	0.1823
	G1X	4.033	3.930	4.090	0.0896
	G2X	4.017	3.880	4.180	0.1518
	L1X	4.157	3.920	4.430	0.2570
	L2X	4.440	4.120	4.760	0.3200
	1	4.103	3.950	4.330	0.2003
	G1X	4.030	3.910	4.210	0.1587
	G2X	3.933	3.750	4.130	0.1904
	L1X	4.313	4.060	4.670	0.3179
	L2X	4.340	4.120	4.760	0.3639

	Loc	West Mean	Minimum	Maximum	s.d.
Mulch	Ca_Trt				
	0	6.583	5.890	7.100	0.6240
	G1X	6.597	6.160	6.890	0.3855
	G2X	6.517	5.660	7.120	0.7623
	L1X	6.937	6.630	7.240	0.3050
	L2X	6.933	6.520	7.310	0.3963
	1	6.807	6.480	7.020	0.2873
	G1X	6.730	6.420	7.100	0.3439
	G2X	6.497	5.760	7.150	0.6987
	L1X	6.920	6.580	7.250	0.3351
	L2X	7.050	6.840	7.280	0.2207

```

37
38 " *** Supplements 2 and 3 *** "
39
40 " pH ANOVA by location "
41 FOR location = 'Central','East','West'
42   RESTRICT pH; CONDITION=Loc .IN. location
43   CAPTION location; STYLE=meta
44   BLOCK Blk
45   TREATMENTS Mulch*Ca_Trt
46   ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
47     PSE=means,diff] pH
48   APLOT [TITLE=location]
49   " Plot of Ca_trt means with sems "
50   AGRAPH [METHOD=barchart; PSE=allmeans] X=Ca_Trt
51   RESTRICT pH
52 ENDFOR

```

Central

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	0.27693	0.13846	2.01	
Blk.*Units* stratum					
Mulch	1	0.04485	0.04485	0.65	0.430
Ca_Trt	4	1.19698	0.29925	4.35	0.012
Mulch.Ca_Trt	4	0.25945	0.06486	0.94	0.462
Residual	18	1.23794	0.06877		
Total	29	3.01615			

Tables of means

Variate: pH

Grand mean 5.775

Mulch		0	1			
		5.737	5.814			
Ca_Trt		0	G1X	G2X	L1X	L2X
		5.553	5.705	5.600	5.958	6.060
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		5.423	5.547	5.693	5.963	6.057
1		5.683	5.863	5.507	5.953	6.063

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	0.0677	0.1071	0.1514

Standard errors of differences of means

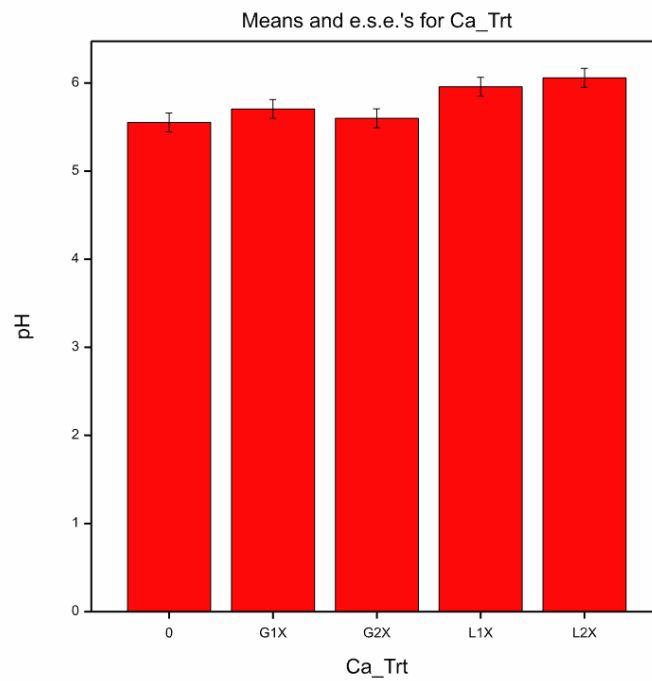
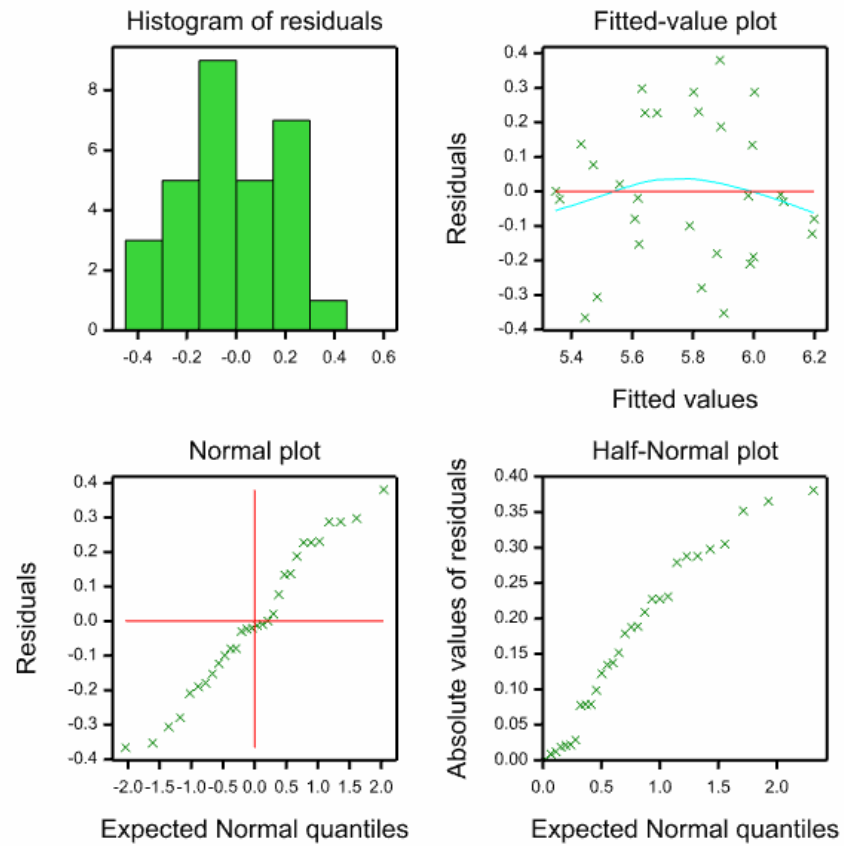
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	0.0958	0.1514	0.2141

Estimated stratum variances

Variate: pH

Stratum	variance	effective d.f.	variance component
Blk	0.1385	2.000	0.0070
Blk.*Units*	0.0688	18.000	0.0688

Central



East

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	0.85304	0.42652	27.18	
Blk.*Units* stratum					
Mulch	1	0.00108	0.00108	0.07	0.796
Ca_Trt	4	0.70281	0.17570	11.20	<.001
Mulch.Ca_Trt	4	0.07332	0.01833	1.17	0.358
Residual	18	0.28243	0.01569		
Total	29	1.91268			

Tables of means

Variate: pH

Grand mean 4.138

Mulch	0	1				
	4.132	4.144				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	4.058	4.032	3.975	4.235	4.390	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		4.013	4.033	4.017	4.157	4.440
1		4.103	4.030	3.933	4.313	4.340

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	0.0323	0.0511	0.0723

Standard errors of differences of means

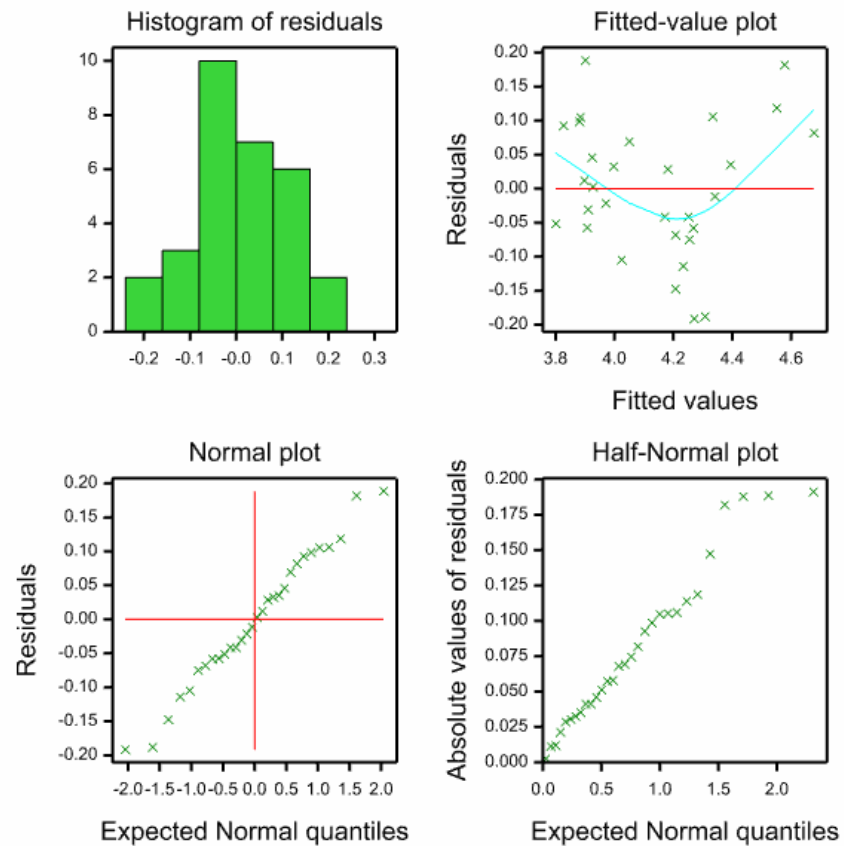
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	0.0457	0.0723	0.1023

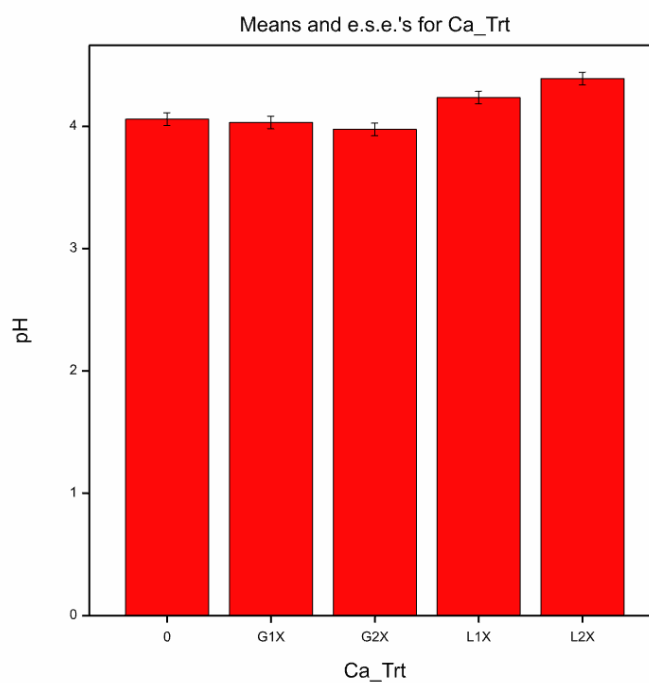
Estimated stratum variances

Variate: pH

Stratum	variance	effective d.f.	variance component
Blk	0.4265	2.000	0.0411
Blk.*Units*	0.0157	18.000	0.0157

East





West

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	3.71166	1.85583	45.96	
Blk.*Units* stratum					
Mulch	1	0.05720	0.05720	1.42	0.249
Ca_Trt	4	0.95825	0.23956	5.93	0.003
Mulch.Ca_Trt	4	0.06571	0.01643	0.41	0.801
Residual	18	0.72681	0.04038		
Total	29	5.51963			

Tables of means

Variate: pH

Grand mean 6.757

Mulch	0	1				
	6.713	6.801				
Ca_Trt	0	G1X	G2X	L1X	L2X	

		6.695	6.663	6.507	6.928	6.992	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X	
0		6.583	6.597	6.517	6.937	6.933	
1		6.807	6.730	6.497	6.920	7.050	

Standard errors of means

Table	Mulch	Ca_Trt	Mulch
			Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	0.0519	0.0820	0.1160

Standard errors of differences of means

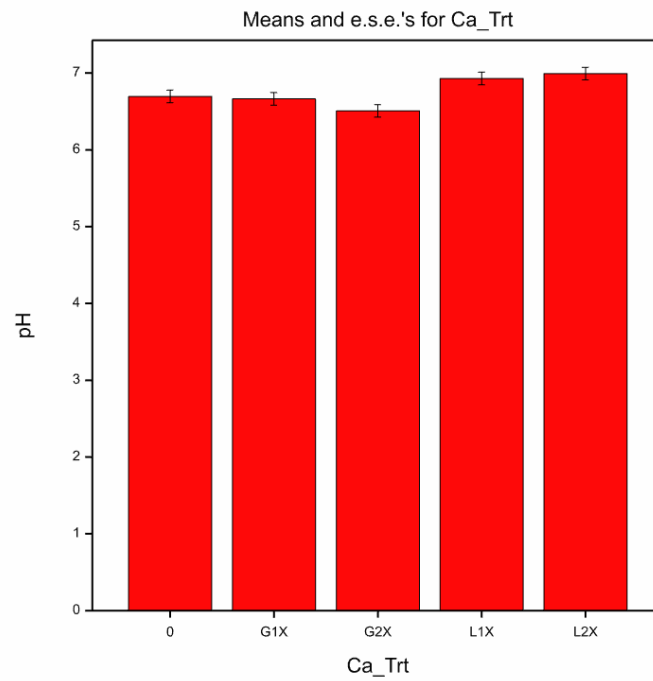
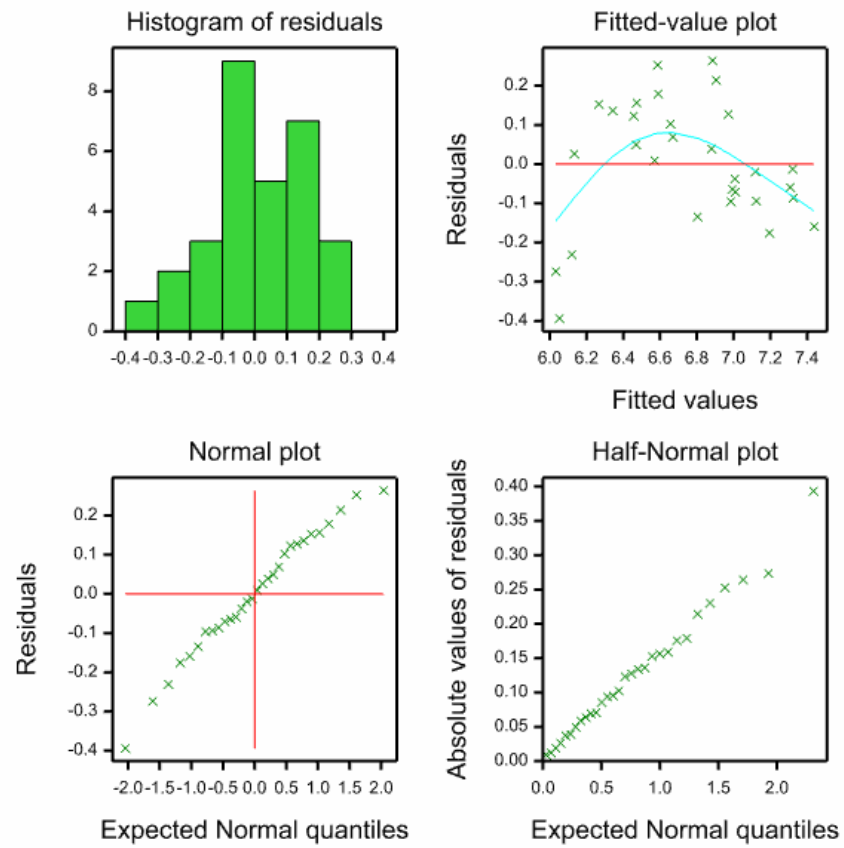
Table	Mulch	Ca_Trt	Mulch
			Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	0.0734	0.1160	0.1641

Estimated stratum variances

Variate: pH

Stratum	variance	effective d.f.	variance component
Blk	1.8558	2.000	0.1815
Blk.*Units*	0.0404	18.000	0.0404

West



```

53 " Code for using the REML facilities "
54 " FOR location = 'Central','East','West'
-55 RESTRICT pH; CONDITION=Loc .IN. location
-56 CAPTION location; STYLE=meta
-57 VCOMPONENTS [FIXED=Mulch*Ca_Trt] RANDOM=Blk
-58 REML [PRINT=model,components,waldTests,means; PSE=allest] pH
-59 VPLOT [Title=location]
-60 RESTRICT pH
-61 ENDFOR "
62
63 " pH ANOVA by location with contrasts "
64 GETATTRIBUTE [ATTRIBUTE=labels] Ca_Trt; SAVE=Ca_Trtlab
65 MATRIX [ROWS=!T('Gypsum Linear','Gypsum Quadratic','Lime Linear', \
66               'Lime Quadratic','Gypsum vrs Lime'); \
67         COLUMNS=#Ca_Trtlab] Contrasts; VALUES=!(-1, 0, 1, 0, 0,\
68                                                     1,-2, 1, 0, 0,\
69                                                     1, 0, 0, 0,-1,\
70                                                     1, 0, 0,-2, 1,\
71                                                     0, 1, 1,-1,-1)
72 PRINT Contrasts; DECIMALS=0

```

	Contrasts				
	0	G1X	G2X	L1X	L2X
Gypsum Linear	-1	0	1	0	0
Gypsum Quadratic	1	-2	1	0	0
Lime Linear	1	0	0	0	-1
Lime Quadratic	1	0	0	-2	1
Gypsum vrs Lime	0	1	1	-1	-1

```

73 FOR location = 'Central','East','West'
74 RESTRICT pH; CONDITION=Loc .IN. location
75 CAPTION location; STYLE=meta
76 BLOCK Blk
77 TREATMENTS Mulch*COMP(Ca_Trt;5;Contrasts)
78 ANOVA [PRINT=aovtable; FPROB=yes; CONTRASTS=10] pH
79 RESTRICT pH
80 ENDFOR

```

Central

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	0.27693	0.13846	2.01	
Blk.*Units* stratum					
Mulch	1	0.04485	0.04485	0.65	0.430
Ca_Trt	4	1.19698	0.29925	4.35	0.012
Gypsum Linear	1	0.00653	0.00653	0.09	0.761
Gypsum Quadratic	1	0.06588	0.06588	0.96	0.341
Lime Linear	1	0.77013	0.77013	11.20	0.004

Lime Quadratic	1	0.09201	0.09201	1.34	0.263
Gypsum vrs Lime	1	0.76327	0.76327	11.10	0.004
Mulch.Ca_Tr	4	0.25945	0.06486	0.94	0.462
Mulch.Gypsum Linear	1	0.14963	0.14963	2.18	0.157
Mulch.Gypsum Quadratic	1	0.07840	0.07840	1.14	0.300
Mulch.Lime Linear	1	0.04813	0.04813	0.70	0.414
Mulch.Lime Quadratic	1	0.02054	0.02054	0.30	0.591
Mulch.Gypsum vrs Lime	1	0.00667	0.00667	0.10	0.759
Residual	18	1.23794	0.06877		
Total	29	3.01615			

East

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	0.85304	0.42652	27.18	
Blk.*Units* stratum					
Mulch	1	0.00108	0.00108	0.07	0.796
Ca_Tr	4	0.70281	0.17570	11.20	<.001
Gypsum Linear	1	0.02083	0.02083	1.33	0.264
Gypsum Quadratic	1	0.00090	0.00090	0.06	0.813
Lime Linear	1	0.33001	0.33001	21.03	<.001
Lime Quadratic	1	0.00047	0.00047	0.03	0.865
Gypsum vrs Lime	1	0.57350	0.57350	36.55	<.001
Mulch.Ca_Tr	4	0.07332	0.01833	1.17	0.358
Mulch.Gypsum Linear	1	0.02253	0.02253	1.44	0.246
Mulch.Gypsum Quadratic	1	0.00004	0.00004	0.00	0.958
Mulch.Lime Linear	1	0.02708	0.02708	1.73	0.205
Mulch.Lime Quadratic	1	0.02614	0.02614	1.67	0.213
Mulch.Gypsum vrs Lime	1	0.00770	0.00770	0.49	0.492
Residual	18	0.28243	0.01569		
Total	29	1.91268			

West

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	3.71166	1.85583	45.96	

Blk.*Units* stratum					
Mulch	1	0.05720	0.05720	1.42	0.249
Ca_Trtr	4	0.95825	0.23956	5.93	0.003
Gypsum Linear	1	0.10641	0.10641	2.64	0.122
Gypsum Quadratic	1	0.01562	0.01562	0.39	0.542
Lime Linear	1	0.26403	0.26403	6.54	0.020
Lime Quadratic	1	0.02890	0.02890	0.72	0.409
Gypsum vrs Lime	1	0.84375	0.84375	20.90	<.001
Mulch.Ca_Trtr	4	0.06571	0.01643	0.41	0.801
Mulch.Gypsum Linear	1	0.04441	0.04441	1.10	0.308
Mulch.Gypsum Quadratic					
	1	0.00100	0.00100	0.02	0.877
Mulch.Lime Linear	1	0.00853	0.00853	0.21	0.651
Mulch.Lime Quadratic	1	0.03484	0.03484	0.86	0.365
Mulch.Gypsum vrs Lime	1	0.00007	0.00007	0.00	0.968
Residual	18	0.72681	0.04038		
Total	29	5.51963			

```

81
82 " Calcium ANOVA by location with contrasts "
83 FOR location = 'Central','East','West'
84   RESTRICT Ca; CONDITION=Loc .IN. location
85   CAPTION location; STYLE=meta
86   BLOCK Blk
87   TREATMENTS Mulch*COMP(Ca_Trtr;5;Contrasts)
88   ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
89     PSE=means,diff; CONTRASTS=10] Ca
90   APLOT [TITLE=location]
91   " Plot of Ca_trtr means with sems "
92   AGRAPH [METHOD=barchart; PSE=allmeans] X=Ca_Trtr
93   RESTRICT Ca
94 ENDFOR

```

Central

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	97983.	48992.	0.43	
Blk.*Units* stratum					
Mulch	1	129418.	129418.	1.12	0.303
Ca_Trtr	4	1301933.	325483.	2.83	0.056
Gypsum Linear	1	255751.	255751.	2.22	0.154
Gypsum Quadratic	1	69801.	69801.	0.61	0.446
Lime Linear	1	1093016.	1093016.	9.49	0.006
Lime Quadratic	1	158571.	158571.	1.38	0.256
Gypsum vrs Lime	1	428452.	428452.	3.72	0.070
Mulch.Ca_Trtr	4	177643.	44411.	0.39	0.816
Mulch.Gypsum Linear	1	51280.	51280.	0.45	0.513

Mulch.Gypsum Quadratic	1	115255.	115255.	1.00	0.330
Mulch.Lime Linear	1	10177.	10177.	0.09	0.770
Mulch.Lime Quadratic	1	46.	46.	0.00	0.984
Mulch.Gypsum vrs Lime	1	4981.	4981.	0.04	0.838
Residual	18	2073468.	115193.		
Total	29	3780446.			

Tables of means

Variate: Ca

Grand mean 957.

Mulch	0	1				
	891.	1022.				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	622.	900.	914.	1123.	1225.	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		534.	708.	957.	1061.	1196.
1		710.	1092.	871.	1185.	1255.

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	87.6	138.6	196.0

Standard errors of differences of means

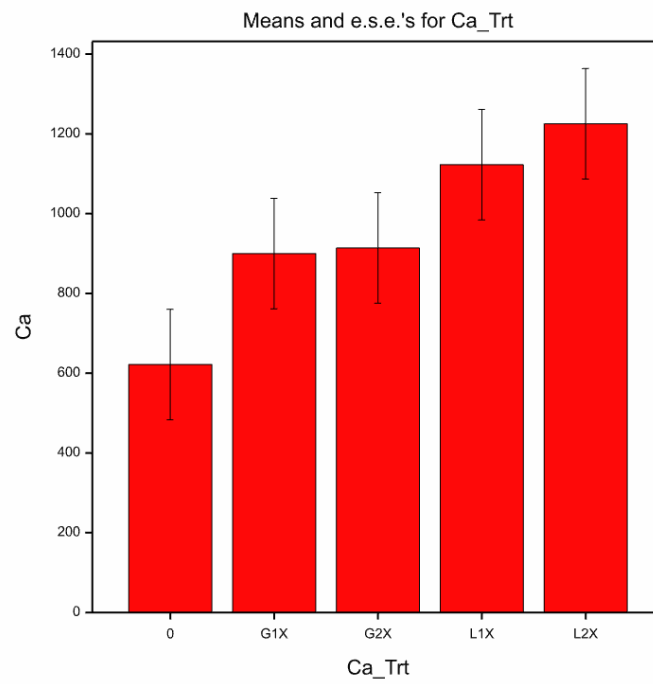
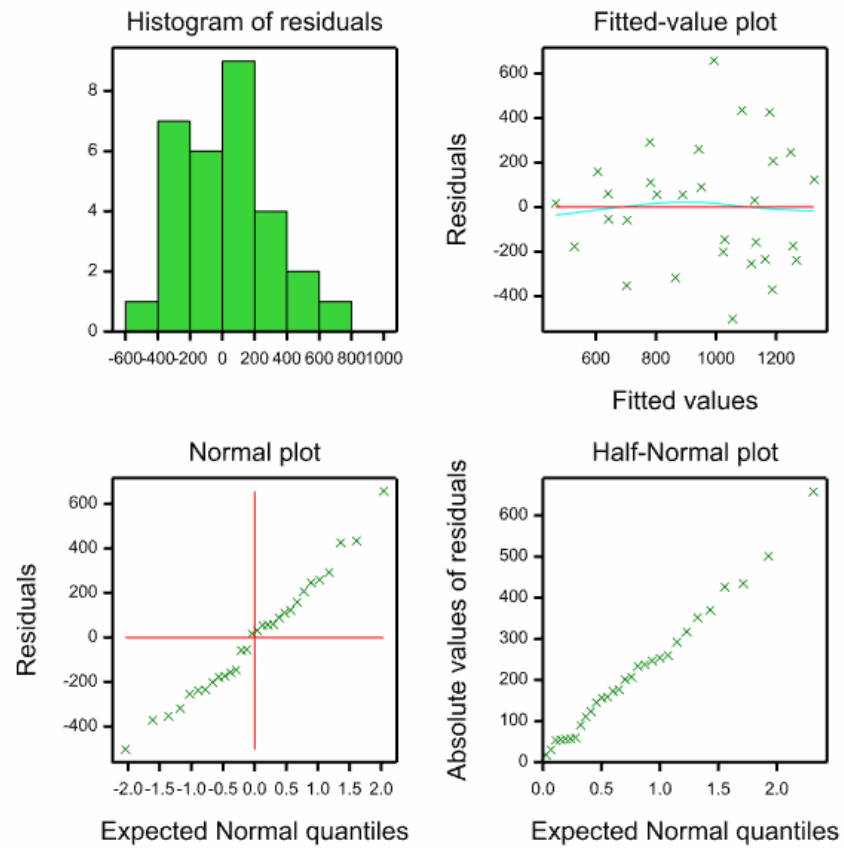
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	123.9	196.0	277.1

Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	48991.7	2.000	-6620.1
Blk.*Units*	115192.7	18.000	115192.7

Central



East

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	312811.	156406.	21.02	
Blk.*Units* stratum					
Mulch	1	9673.	9673.	1.30	0.269
Ca_Trtr	4	111028.	27757.	3.73	0.022
Gypsum Linear	1	53742.	53742.	7.22	0.015
Gypsum Quadratic	1	232.	232.	0.03	0.862
Lime Linear	1	99435.	99435.	13.36	0.002
Lime Quadratic	1	171.	171.	0.02	0.881
Gypsum vrs Lime	1	7613.	7613.	1.02	0.325
Mulch.Ca_Trtr	4	36216.	9054.	1.22	0.338
Mulch.Gypsum Linear	1	23177.	23177.	3.11	0.095
Mulch.Gypsum Quadratic	1	712.	712.	0.10	0.761
Mulch.Lime Linear	1	491.	491.	0.07	0.800
Mulch.Lime Quadratic	1	3796.	3796.	0.51	0.484
Mulch.Gypsum vrs Lime	1	17140.	17140.	2.30	0.146
Residual	18	133944.	7441.		
Total	29	603672.			

Tables of means

Variate: Ca

Grand mean 176.

Mulch	0	1				
	158.	194.				
Ca_Trtr	0	G1X	G2X	L1X	L2X	
	78.	152.	212.	176.	260.	
Mulch	Ca_Trtr	0	G1X	G2X	L1X	L2X
0		86.	130.	132.	159.	281.
1		70.	175.	292.	192.	239.

Standard errors of means

Table	Mulch	Ca_Trtr	Mulch Ca_Trtr
rep.	15	6	3
d.f.	18	18	18
e.s.e.	22.3	35.2	49.8

Standard errors of differences of means

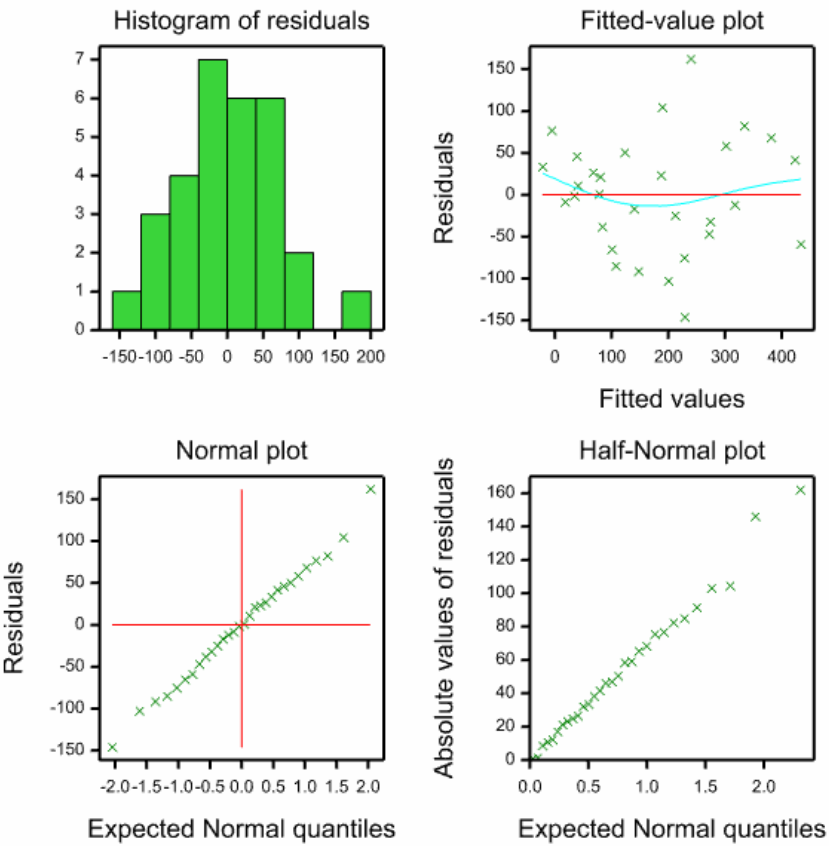
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	31.5	49.8	70.4

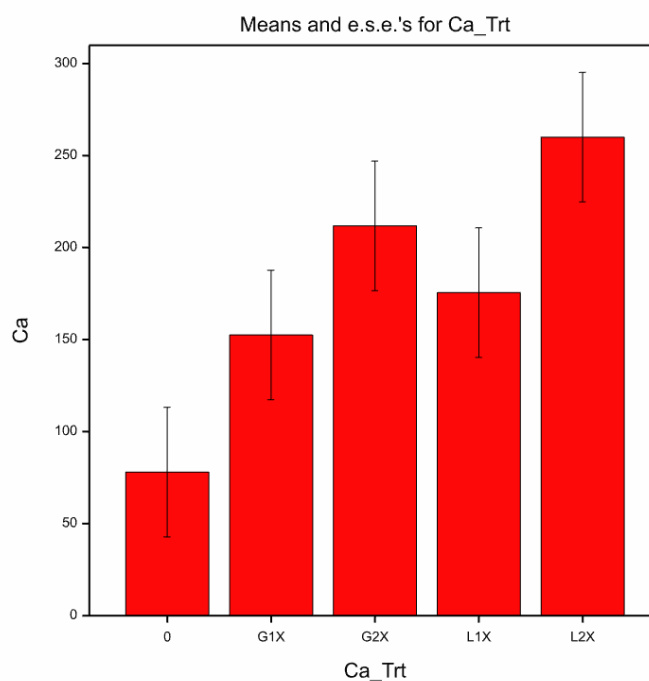
Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	156405.6	2.000	14896.4
Blk.*Units*	7441.4	18.000	7441.4

East





West

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	3211081.	1605541.	11.64	
Blk.*Units* stratum					
Mulch	1	13325.	13325.	0.10	0.760
Ca_Trt	4	1654968.	413742.	3.00	0.046
Gypsum Linear	1	1663.	1663.	0.01	0.914
Gypsum Quadratic	1	2344.	2344.	0.02	0.898
Lime Linear	1	914547.	914547.	6.63	0.019
Lime Quadratic	1	34031.	34031.	0.25	0.625
Gypsum vrs Lime	1	1301640.	1301640.	9.44	0.007
Mulch.Ca_Trt	4	147545.	36886.	0.27	0.895
Mulch.Gypsum Linear	1	1793.	1793.	0.01	0.910
Mulch.Gypsum Quadratic	1	59479.	59479.	0.43	0.520
Mulch.Lime Linear	1	18276.	18276.	0.13	0.720
Mulch.Lime Quadratic	1	42275.	42275.	0.31	0.587
Mulch.Gypsum vrs Lime	1	44833.	44833.	0.33	0.576
Residual	18	2482894.	137939.		
Total	29	7509814.			

Tables of means

Variate: Ca

Grand mean 2170.

Mulch	0	1				
	2191.	2149.				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	1988.	2001.	1965.	2357.	2540.	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		1980.	2127.	1981.	2413.	2455.
1		1996.	1874.	1948.	2301.	2626.

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	95.9	151.6	214.4

Standard errors of differences of means

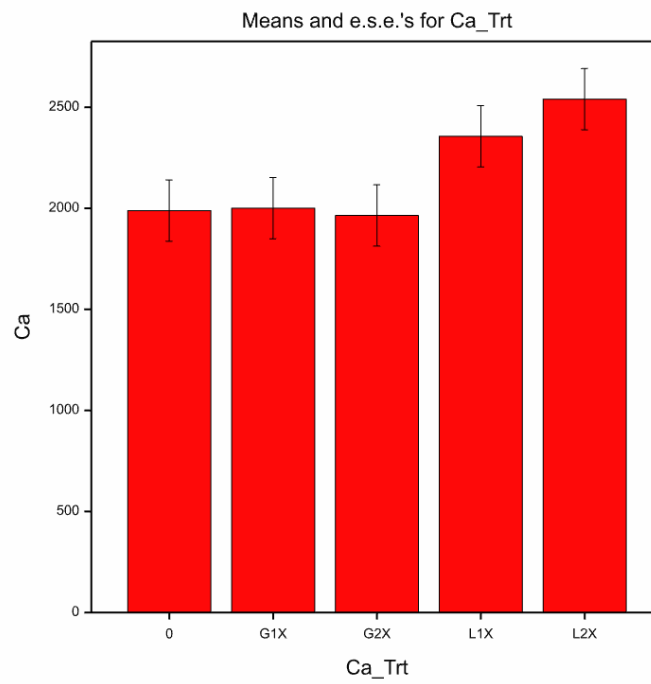
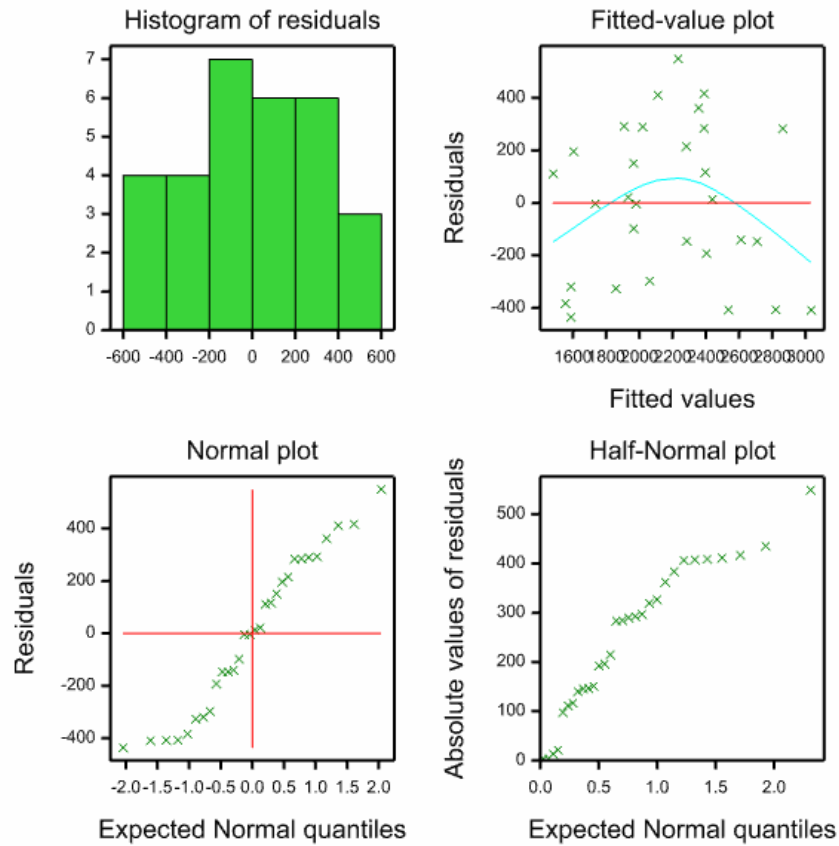
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	135.6	214.4	303.2

Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	1605540.5	2.000	146760.2
Blk.*Units*	137938.6	18.000	137938.6

West



```

95
96 " pH ANOVA combined over locations "
97 BLOCK Loc.Blk
98 TREATMENTS Loc*Mulch*Ca_Trt
99 ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
100     PSE=means,diff] pH

```

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Loc.Blk stratum					
Loc	2	105.03691	52.51845	65.08	<.001
Residual	6	4.84163	0.80694	19.39	
Loc.Blk.*Units* stratum					
Mulch	1	0.07803	0.07803	1.88	0.177
Ca_Trt	4	2.70104	0.67526	16.23	<.001
Loc.Mulch	2	0.02511	0.01255	0.30	0.741
Loc.Ca_Trt	8	0.15700	0.01963	0.47	0.871
Mulch.Ca_Trt	4	0.23686	0.05921	1.42	0.239
Loc.Mulch.Ca_Trt	8	0.16162	0.02020	0.49	0.861
Residual	54	2.24717	0.04161		
Total	89	115.48537			

Tables of means

Variate: pH

Grand mean 5.557

Loc	Central	East	West			
	5.775	4.138	6.757			
Mulch	0	1				
	5.527	5.586				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	5.436	5.467	5.361	5.707	5.814	
Loc	Mulch	0	1			
Central		5.737	5.814			
East		4.132	4.144			
West		6.713	6.801			
Loc	Ca_Trt	0	G1X	G2X	L1X	L2X
Central		5.553	5.705	5.600	5.958	6.060
East		4.058	4.032	3.975	4.235	4.390
West		6.695	6.663	6.507	6.928	6.992
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X

		0	5.340	5.392	5.409	5.686	5.810
		1	5.531	5.541	5.312	5.729	5.818
Loc	Mulch	Ca_Tr	0	G1X	G2X	L1X	L2X
Central	0		5.423	5.547	5.693	5.963	6.057
	1		5.683	5.863	5.507	5.953	6.063
East	0		4.013	4.033	4.017	4.157	4.440
	1		4.103	4.030	3.933	4.313	4.340
West	0		6.583	6.597	6.517	6.937	6.933
	1		6.807	6.730	6.497	6.920	7.050

Standard errors of means

Table	Loc	Mulch	Ca_Tr	Loc Mulch
rep.	30	45	18	15
e.s.e.	0.1640	0.0304	0.0481	0.1682
d.f.	6	54	54	6.63
Except when comparing means with the same level(s) of				
Loc				0.0527
d.f.				54

Table	Loc Ca_Tr	Mulch Ca_Tr	Loc Mulch Ca_Tr
rep.	6	9	3
e.s.e.	0.1801	0.0680	0.1984
d.f.	8.69	54	12.56
Except when comparing means with the same level(s) of			
Loc	0.0833		0.1178
d.f.	54		54
Loc.Mulch			0.1178
d.f.			54
Loc.Ca_Tr			0.1178
d.f.			54

Standard errors of differences of means

Table	Loc	Mulch	Ca_Tr	Loc Mulch
rep.	30	45	18	15
s.e.d.	0.2319	0.0430	0.0680	0.2378
d.f.	6	54	54	6.63
Except when comparing means with the same level(s) of				
Loc				0.0745
d.f.				54

Table	Loc Ca_Tr	Mulch Ca_Tr	Loc Mulch Ca_Tr
rep.	6	9	3
s.e.d.	0.2547	0.0962	0.2807

d.f.	8.69	54	12.56
Except when comparing means with the same level(s) of			
Loc	0.1178		0.1666
d.f.	54		54
Loc.Mulch			0.1666
d.f.			54
Loc.Ca_Trt			0.1666
d.f.			54

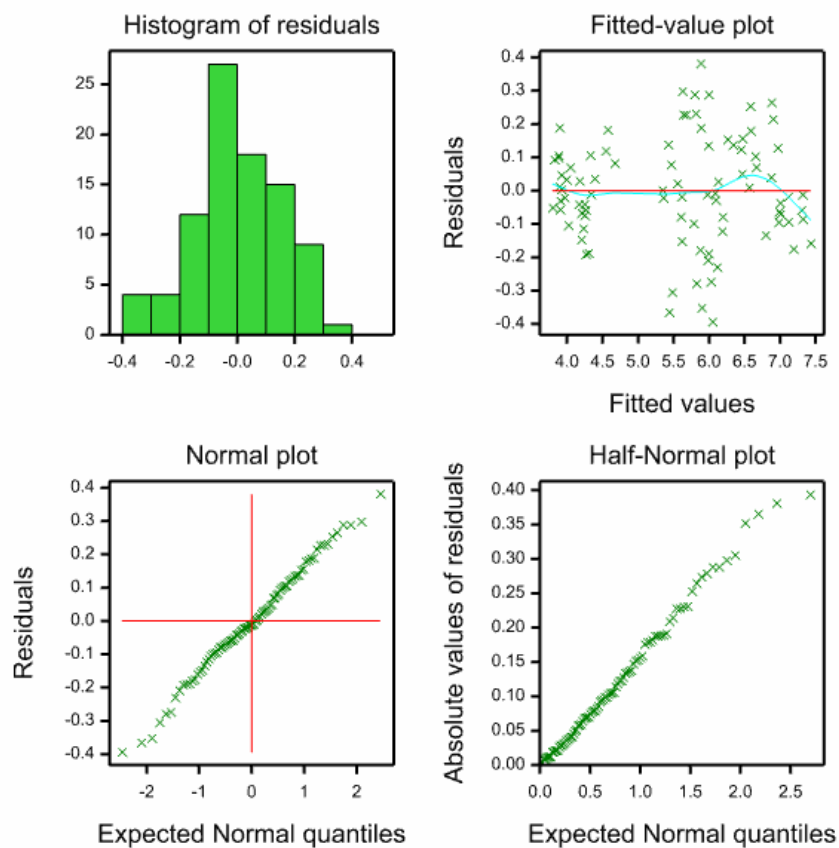
Estimated stratum variances

Variate: pH

Stratum	variance	effective d.f.	variance component
Loc.Blk	0.8069	6.000	0.0765
Loc.Blk.*Units*	0.0416	54.000	0.0416

101 APLLOT

pH



```

102 " Code for using the REML facilities "
103 " VCOMPONENTS [FIXED=Loc*Mulch*Ca_Trt] RANDOM=Loc.Blk
-104 REML [PRINT=model,components,waldTests,means; PSE=alltest] pH

```

```

-105  VPLOT "
106
107  " *** Supplements 4 and 5 *** "
108
109  " Calcium ANOVA by location "
110  FOR location = 'Central','East','West'
111    RESTRICT Ca; CONDITION=Loc .IN. location
112    CAPTION location; STYLE=meta
113    BLOCK Blk
114    TREATMENTS Mulch*Ca_Trt
115    ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
116      PSE=means,diff] Ca
117    APLOT [TITLE=location]
118    RESTRICT Ca
119  ENDFOR

```

Central

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	97983.	48992.	0.43	
Blk.*Units* stratum					
Mulch	1	129418.	129418.	1.12	0.303
Ca_Trt	4	1301933.	325483.	2.83	0.056
Mulch.Ca_Trt	4	177643.	44411.	0.39	0.816
Residual	18	2073468.	115193.		
Total	29	3780446.			

Tables of means

Variate: Ca

Grand mean 957.

Mulch		0	1			
		891.	1022.			
Ca_Trt		0	G1X	G2X	L1X	L2X
		622.	900.	914.	1123.	1225.
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		534.	708.	957.	1061.	1196.
1		710.	1092.	871.	1185.	1255.

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	87.6	138.6	196.0

Standard errors of differences of means

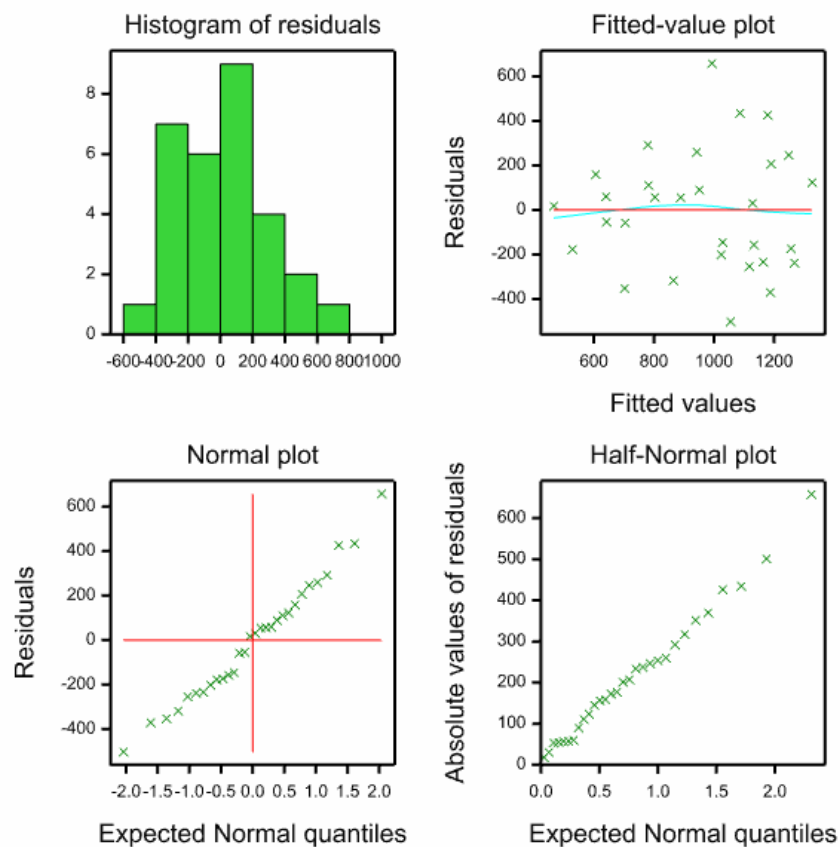
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	123.9	196.0	277.1

Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	48991.7	2.000	-6620.1
Blk.*Units*	115192.7	18.000	115192.7

Central



East

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	312811.	156406.	21.02	
Blk.*Units* stratum					
Mulch	1	9673.	9673.	1.30	0.269
Ca_Trtr	4	111028.	27757.	3.73	0.022
Mulch.Ca_Trtr	4	36216.	9054.	1.22	0.338
Residual	18	133944.	7441.		
Total	29	603672.			

Tables of means

Variate: Ca

Grand mean 176.

Mulch		0	1			
		158.	194.			
Ca_Trtr		0	G1X	G2X	L1X	L2X
		78.	152.	212.	176.	260.
Mulch	Ca_Trtr	0	G1X	G2X	L1X	L2X
0		86.	130.	132.	159.	281.
1		70.	175.	292.	192.	239.

Standard errors of means

Table	Mulch	Ca_Trtr	Mulch Ca_Trtr
rep.	15	6	3
d.f.	18	18	18
e.s.e.	22.3	35.2	49.8

Standard errors of differences of means

Table	Mulch	Ca_Trtr	Mulch Ca_Trtr
rep.	15	6	3
d.f.	18	18	18

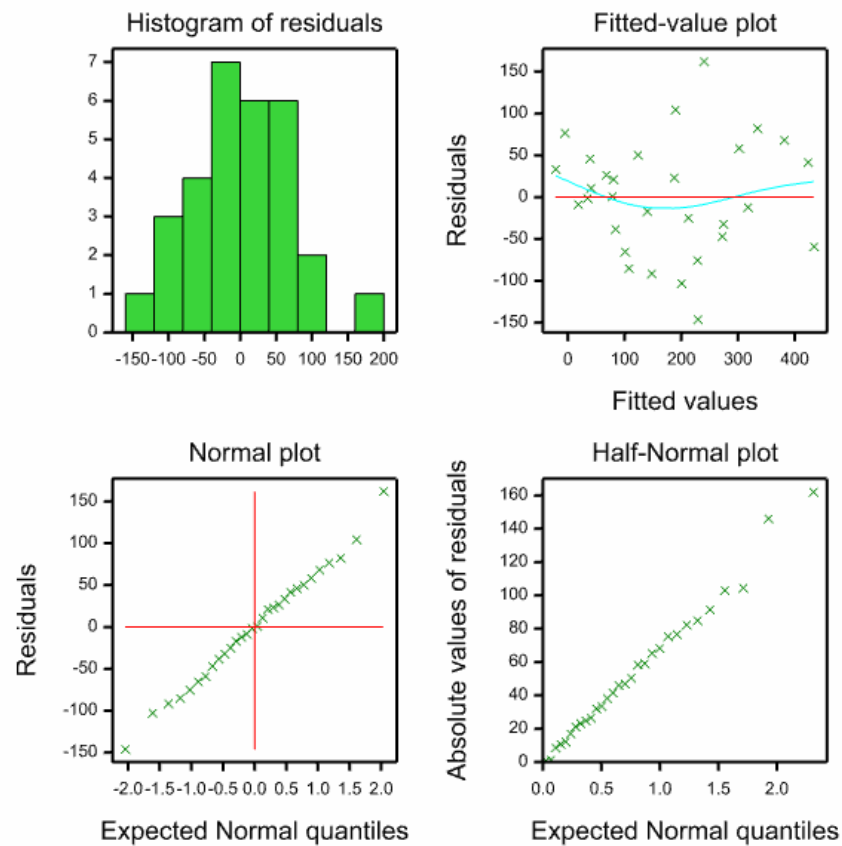
s.e.d. 31.5 49.8 70.4

Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	156405.6	2.000	14896.4
Blk.*Units*	7441.4	18.000	7441.4

East



West

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	3211081.	1605541.	11.64	
Blk.*Units* stratum					
Mulch	1	13325.	13325.	0.10	0.760

Ca_Trt	4	1654968.	413742.	3.00	0.046
Mulch.Ca_Trt	4	147545.	36886.	0.27	0.895
Residual	18	2482894.	137939.		
Total	29	7509814.			

Tables of means

Variate: Ca

Grand mean 2170.

Mulch	0	1				
	2191.	2149.				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	1988.	2001.	1965.	2357.	2540.	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		1980.	2127.	1981.	2413.	2455.
1		1996.	1874.	1948.	2301.	2626.

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	95.9	151.6	214.4

Standard errors of differences of means

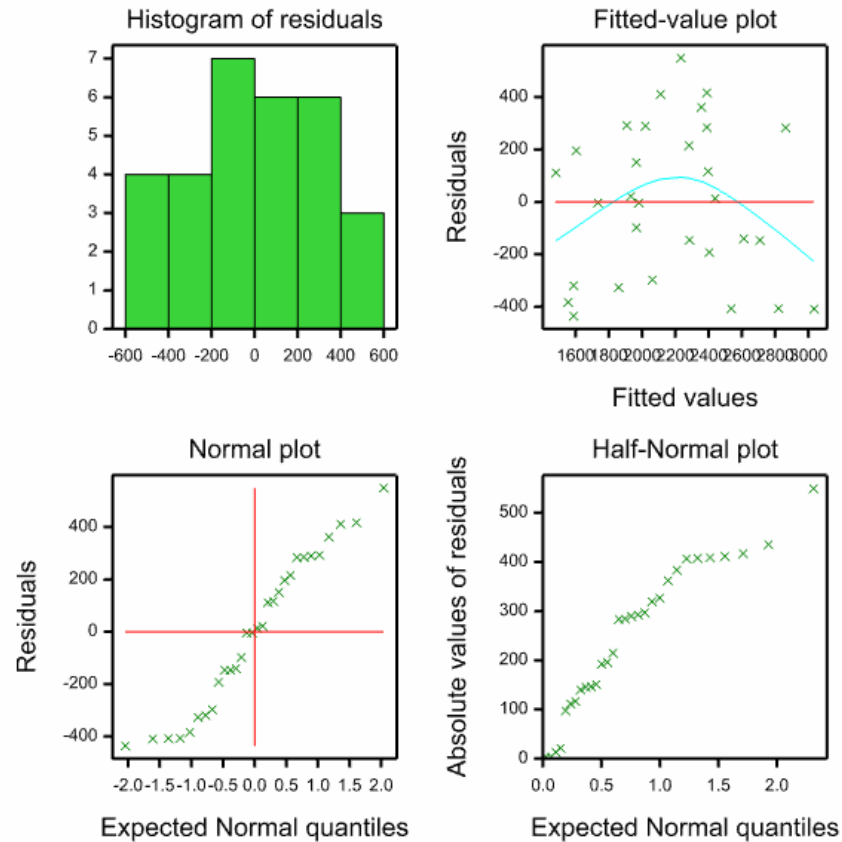
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	135.6	214.4	303.2

Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Blk	1605540.5	2.000	146760.2
Blk.*Units*	137938.6	18.000	137938.6

West



```

120
121 " Calcium ANOVA combined over locations "
122 BLOCK Loc.Blk
123 TREATMENTS Loc*Mulch*Ca_Trtr
124 ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
125       PSE=means,diff] Ca

```

Analysis of variance

Variate: Ca

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Loc.Blk stratum					
Loc	2	60607326.	30303663.	50.20	<.001
Residual	6	3621876.	603646.	6.95	
Loc.Blk.*Units* stratum					
Mulch	1	39140.	39140.	0.45	0.505
Ca_Trtr	4	2264234.	566059.	6.52	<.001
Loc.Mulch	2	113276.	56638.	0.65	0.525
Loc.Ca_Trtr	8	803694.	100462.	1.16	0.342
Mulch.Ca_Trtr	4	11429.	2857.	0.03	0.998
Loc.Mulch.Ca_Trtr	8	349975.	43747.	0.50	0.848
Residual	54	4690307.	86858.		

Total 89 72501258.

Tables of means

Variate: Ca

Grand mean 1101.

Loc	Central	East	West				
	957.	176.	2170.				
Mulch	0	1					
	1080.	1122.					
Ca_Tr	0	G1X	G2X	L1X	L2X		
	896.	1018.	1030.	1218.	1342.		
Loc	Mulch	0	1				
Central		891.	1022.				
East		158.	194.				
West		2191.	2149.				
Loc	Ca_Tr	0	G1X	G2X	L1X	L2X	
Central		622.	900.	914.	1123.	1225.	
East		78.	152.	212.	176.	260.	
West		1988.	2001.	1965.	2357.	2540.	
Mulch	Ca_Tr	0	G1X	G2X	L1X	L2X	
0		867.	988.	1023.	1211.	1310.	
1		925.	1047.	1037.	1226.	1373.	
Loc	Mulch	Ca_Tr	0	G1X	G2X	L1X	L2X
Central	0		534.	708.	957.	1061.	1196.
	1		710.	1092.	871.	1185.	1255.
East	0		86.	130.	132.	159.	281.
	1		70.	175.	292.	192.	239.
West	0		1980.	2127.	1981.	2413.	2455.
	1		1996.	1874.	1948.	2301.	2626.

Standard errors of means

Table	Loc	Mulch	Ca_Tr	Loc Mulch
rep.	30	45	18	15
e.s.e.	141.9	43.9	69.5	151.7
d.f.	6	54	54	7.83
Except when comparing means with the same level(s) of				
Loc				76.1
d.f.				54

Table	Loc Ca_Tr	Mulch Ca_Tr	Loc Mulch

rep.	6	9	Ca_Trt	3
e.s.e.	178.1	98.2		214.9
d.f.	14.37	54		26.64
Except when comparing means with the same level(s) of				
Loc	120.3			170.2
d.f.	54			54
Loc.Mulch				170.2
d.f.				54
Loc.Ca_Trt				170.2
d.f.				54

Standard errors of differences of means

Table	Loc	Mulch	Ca_Trt	Loc Mulch
rep.	30	45	18	15
s.e.d.	200.6	62.1	98.2	214.6
d.f.	6	54	54	7.83
Except when comparing means with the same level(s) of				
Loc				107.6
d.f.				54

Table	Loc Ca_Trt	Mulch Ca_Trt	Loc Mulch Ca_Trt
rep.	6	9	3
s.e.d.	251.8	138.9	303.9
d.f.	14.37	54	26.64
Except when comparing means with the same level(s) of			
Loc	170.2		240.6
d.f.	54		54
Loc.Mulch			240.6
d.f.			54
Loc.Ca_Trt			240.6
d.f.			54

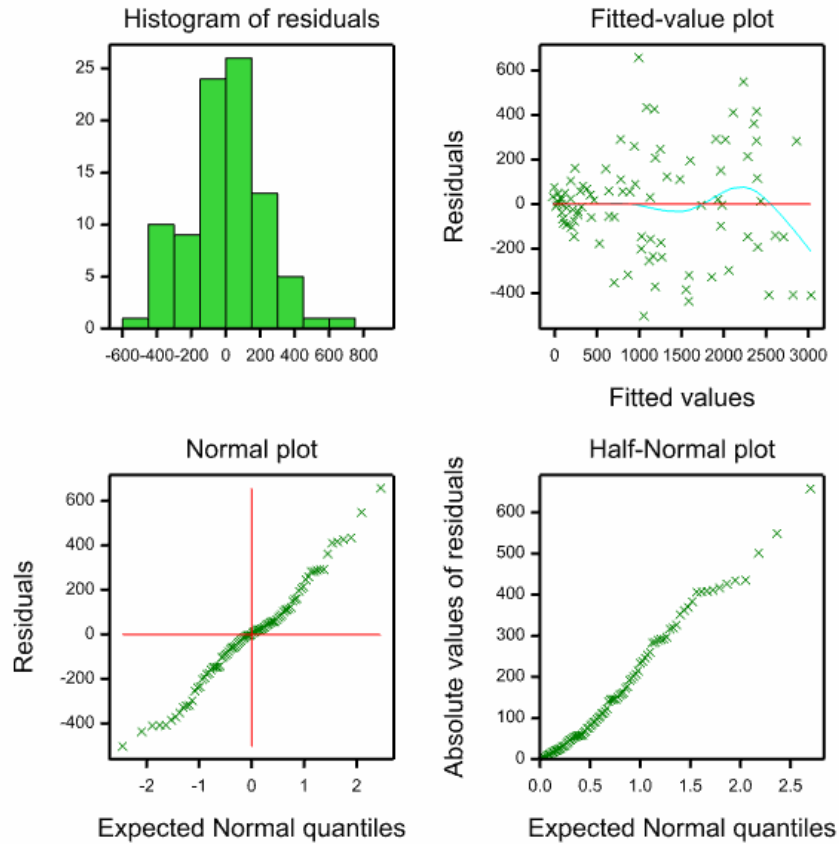
Estimated stratum variances

Variate: Ca

Stratum	variance	effective d.f.	variance component
Loc.Blk	603646.0	6.000	51678.8
Loc.Blk.*Units*	86857.5	54.000	86857.5

126 APLOT

Ca



```

127
128 " Mixed percent total ANOVA by location "
129 FOR location = 'Central','East','West'
130   RESTRICT Pct_Total; CONDITION=Loc .IN. location
131   CAPTION location; STYLE=meta
132   BLOCK Blk
133   TREATMENTS Mulch*Ca_Trt
134   ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
135     PSE=means,diff] Pct_Total
136   APLOT [TITLE=location]
137   RESTRICT Pct_Total
138 ENDFOR

```

Central

Analysis of variance

Variate: Pct_Total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	425.66	212.83	5.11	
Blk.*Units* stratum					
Mulch	1	1336.27	1336.27	32.11	<.001

Ca_Trt	4	75.61	18.90	0.45	0.768
Mulch.Ca_Trt	4	74.63	18.66	0.45	0.772
Residual	18	749.08	41.62		
Total	29	2661.25			

Tables of means

Variate: Pct_Total

Grand mean 12.7

Mulch	0	1				
	19.4	6.0				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	12.3	12.5	15.5	10.5	12.7	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		21.0	21.0	21.2	15.3	18.5
1		3.7	4.1	9.8	5.8	6.9

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	1.67	2.63	3.72

Standard errors of differences of means

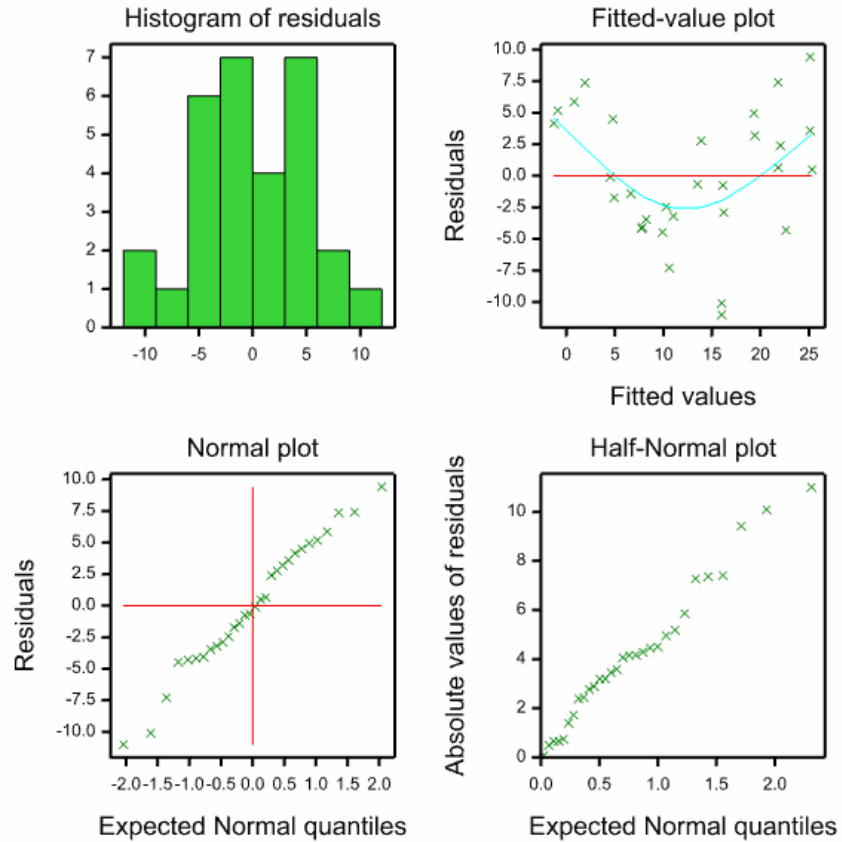
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	2.36	3.72	5.27

Estimated stratum variances

Variate: Pct_Total

Stratum	variance	effective d.f.	variance component
Blk	212.83	2.000	17.12
Blk.*Units*	41.62	18.000	41.62

Central



East

Analysis of variance

Variate: Pct_Total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	3458.53	1729.26	32.28	
Blk.*Units* stratum					
Mulch	1	108.76	108.76	2.03	0.171
Ca_Trt	4	370.33	92.58	1.73	0.188
Mulch.Ca_Trt	4	146.13	36.53	0.68	0.614
Residual	18	964.42	53.58		
Total	29	5048.17			

Tables of means

Variate: Pct_Total

Grand mean 8.5

Mulch	0	1				
	10.4	6.6				
Ca_Trt	0	G1X	G2X	L1X	L2X	
	8.6	5.0	4.2	11.1	13.4	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		12.2	6.2	2.1	13.8	17.5
1		5.0	3.8	6.2	8.3	9.4

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	1.89	2.99	4.23

Standard errors of differences of means

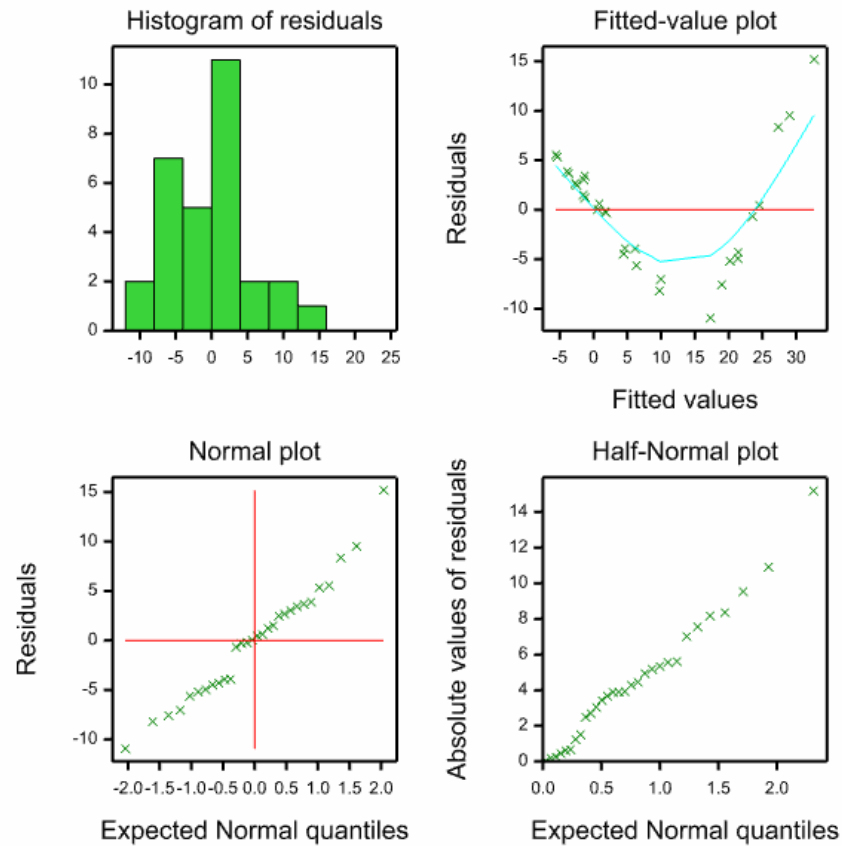
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	2.67	4.23	5.98

Estimated stratum variances

Variate: Pct_Total

Stratum	variance	effective d.f.	variance component
Blk	1729.26	2.000	167.57
Blk.*Units*	53.58	18.000	53.58

East



West

Analysis of variance

Variate: Pct_Total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blk stratum	2	2676.5	1338.2	13.21	
Blk.*Units* stratum					
Mulch	1	387.8	387.8	3.83	0.066
Ca_Trt	4	489.6	122.4	1.21	0.341
Mulch.Ca_Trt	4	56.2	14.0	0.14	0.966
Residual	18	1822.9	101.3		
Total	29	5433.0			

Tables of means

Variate: Pct_Total

Grand mean 30.9

Mulch		0	1			
		27.3	34.5			
Ca_Trt		0	G1X	G2X	L1X	L2X
		27.3	31.0	28.9	38.6	28.7
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
0		24.7	27.7	27.1	33.9	23.1
1		29.8	34.4	30.7	43.3	34.2

Standard errors of means

Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
e.s.e.	2.60	4.11	5.81

Standard errors of differences of means

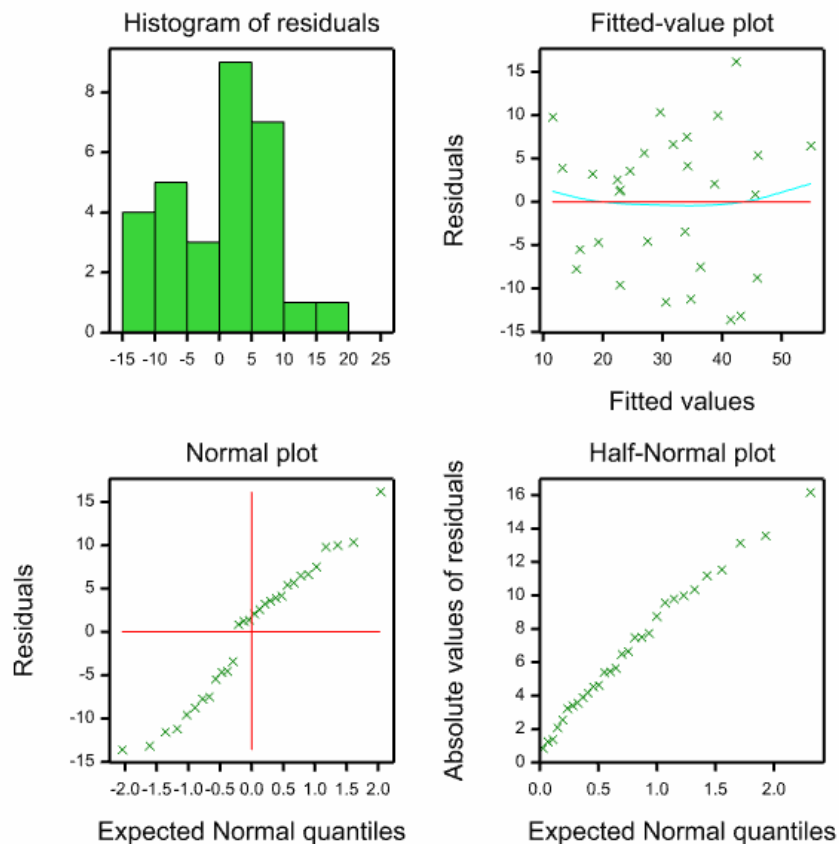
Table	Mulch	Ca_Trt	Mulch Ca_Trt
rep.	15	6	3
d.f.	18	18	18
s.e.d.	3.67	5.81	8.22

Estimated stratum variances

Variate: Pct_Total

Stratum	variance	effective d.f.	variance component
Blk	1338.25	2.000	123.70
Blk.*Units*	101.27	18.000	101.27

West



```

139
140 " Mixed percent total combined over locations "
141 BLOCK Loc.Blk
142 TREATMENTS Loc*Mulch*Ca_Trt
143 ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
144       PSE=means,diff] Pct_Total

```

Analysis of variance

Variate: Pct_Total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Loc.Blk stratum					
Loc	2	8525.57	4262.79	3.90	0.082
Residual	6	6560.68	1093.45	16.70	
Loc.Blk.*Units* stratum					
Mulch	1	248.27	248.27	3.79	0.057
Ca_Trt	4	227.56	56.89	0.87	0.489
Loc.Mulch	2	1584.55	792.27	12.10	<.001
Loc.Ca_Trt	8	707.99	88.50	1.35	0.239
Mulch.Ca_Trt	4	77.80	19.45	0.30	0.879
Loc.Mulch.Ca_Trt	8	199.13	24.89	0.38	0.927
Residual	54	3536.40	65.49		

Total 89 21667.95

Tables of means

Variate: Pct_Total

Grand mean 17.36

Loc	Central	East	West				
	12.72	8.46	30.90				
Mulch	0	1					
	19.02	15.70					
Ca_Trt	0	G1X	G2X	L1X	L2X		
	16.06	16.19	16.20	20.08	18.26		
Loc	Mulch	0	1				
Central		19.39	6.04				
East		10.36	6.55				
West		27.30	34.50				
Loc	Ca_Trt	0	G1X	G2X	L1X	L2X	
Central		12.33	12.54	15.48	10.53	12.69	
East		8.58	5.00	4.19	11.09	13.42	
West		27.26	31.02	28.92	38.62	28.68	
Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X	
0		19.29	18.28	16.81	21.02	19.69	
1		12.83	14.09	15.59	19.14	16.83	
Loc	Mulch	Ca_Trt	0	G1X	G2X	L1X	L2X
Central	0		20.98	20.99	21.20	15.28	18.49
	1		3.68	4.08	9.76	5.78	6.90
East	0		12.16	6.19	2.13	13.84	17.47
	1		5.00	3.81	6.25	8.34	9.36
West	0		24.73	27.65	27.09	33.93	23.12
	1		29.80	34.39	30.75	43.30	34.25

Standard errors of means

Table	Loc	Mulch	Ca_Trt	Loc Mulch
rep.	30	45	18	15
e.s.e.	6.037	1.206	1.907	6.215
d.f.	6	54	54	6.74
Except when comparing means with the same level(s) of				
Loc				2.089
d.f.				54

Table	Loc Ca_Trt	Mulch Ca_Trt	Loc Mulch

rep.	6	9	Ca_Trt	3
e.s.e.	6.722	2.698		7.490
d.f.	9.16	54		13.77
Except when comparing means with the same level(s) of				
Loc	3.304			4.672
d.f.	54			54
Loc.Mulch				4.672
d.f.				54
Loc.Ca_Trt				4.672
d.f.				54

Standard errors of differences of means

Table	Loc	Mulch	Ca_Trt	Loc Mulch
rep.	30	45	18	15
s.e.d.	8.538	1.706	2.698	8.790
d.f.	6	54	54	6.74
Except when comparing means with the same level(s) of				
Loc				2.955
d.f.				54

Table	Loc Ca_Trt	Mulch Ca_Trt	Loc Mulch Ca_Trt
rep.	6	9	3
s.e.d.	9.506	3.815	10.592
d.f.	9.16	54	13.77
Except when comparing means with the same level(s) of			
Loc	4.672		6.608
d.f.	54		54
Loc.Mulch			6.608
d.f.			54
Loc.Ca_Trt			6.608
d.f.			54

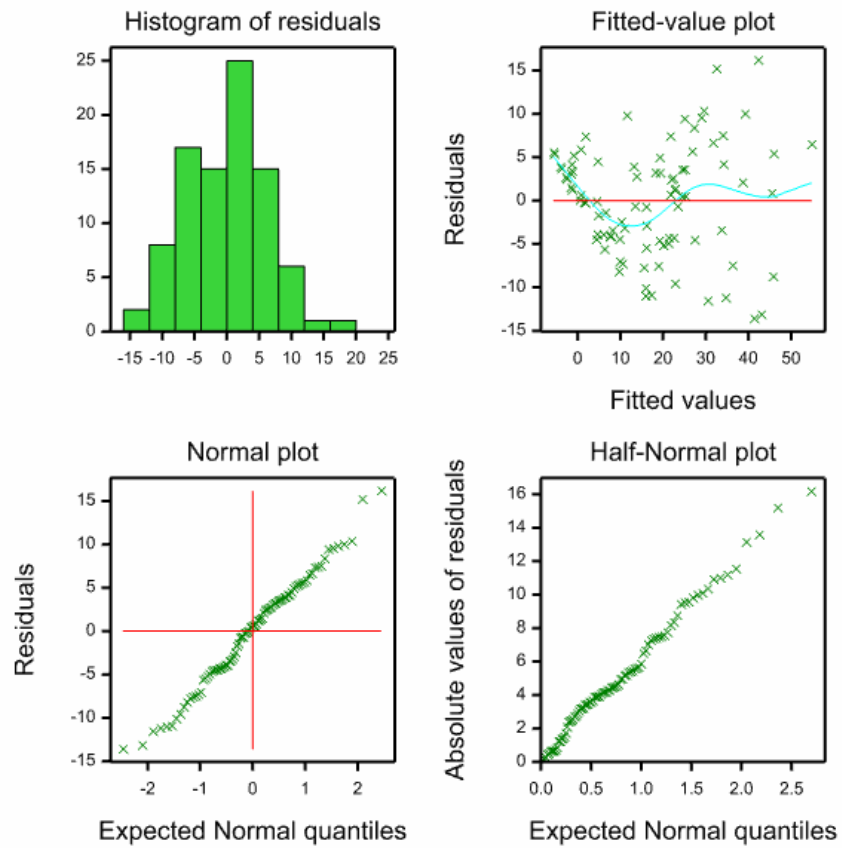
Estimated stratum variances

Variate: Pct_Total

Stratum	variance	effective d.f.	variance component
Loc.Blk	1093.447	6.000	102.796
Loc.Blk.*Units*	65.489	54.000	65.489

145 APL0T

Pct_Total



146

147 ENDJOB

Chapter 3. Blocking Principles for Biological Experiments by Michael Casler

Genstat code developed by Vanessa M. Cave and output are provided here for the three exercises presented in Chapter 3.

Exercise 1: Conduct a linear mixed model ANOVA from an augmented design

Genstat Commands for Exercise 1

```
" ***** "  
" EXERCISE #1 "  
" Conduct a linear mixed model ANOVA from an augmented design. "  
" ***** "
```

JOB

```
" Load the data, where entry is a factor "  
FACTOR entry  
READ [MISSING='.'; SETLEVELS=yes] entryno,entry,y1,y2,y3; \  
FREPRESENTATION=labels  
1 Sibley 4098 4060 4283  
1 Sibley . . 3952  
2 Hardin 4020 4414 3571  
3 Weber 4440 3835 4154  
4 Kato 3860 3865 3674  
5 TEgg 2169 . .  
6 Harlon 3250 . .  
7 Rampage 3807 . .  
8 Steele 4068 . .  
9 Vinton 3871 . .  
10 Vinton81 3838 . .  
11 BSR101 . 4244 .  
12 Norsoy . 3290 .  
13 WBlack . 3019 .  
14 Mandarin . 3506 .  
15 Hark . 4384 .  
16 Coles . 4148 .  
17 Hodgson78 . . 4167  
18 Lakota . . 4023  
19 Mandan507 . . 2435  
20 Bert . . 4595  
21 Leslie . . 3957 :  
  
" Stack y1, y2 & y3 to form the Yield variate (and remove old data  
Structures) "  
APPEND [NEWVECTOR=Yield] y1,y2,y3  
DELETE [REDEFINE=yes] y1,y2,y3  
  
" Form the block factor "  
CALC n = NVALUES(entryno)  
FACTOR [LEVELS=3; VALUES=#n(1,2,3)] block
```

```

" Recode the cultivar entry number into 2 factors (check and test)
  check = entryno for all check cultivars, and 0 otherwise
  test = entryno for all test cultivars, 0 otherwise "
APPEND [NEWVECTOR=entrynostacked] 3(entryno)
CALC cv = (entrynostacked < 5) * entrynostacked
GROUP cv; check
CALC xv = (entrynostacked > 4) * entrynostacked
GROUP xv; test

" Use REML to estimate the cultivar means and standard errors "
VCOMPONENTS [FIXED=check/test] RANDOM=block; CONSTRAINTS=pos
REML [PRINT=model,components,waldTests,means; PSE=allest] Yield
" Note: the denominator degrees of freedom (ddf) are different to
  those in the SAS output as, by default, SAS uses the containment
  method for computing ddf, whereas Genstat uses the Kenward-Roger
  method. The containment method is not available in Genstat. "

ENDJOB

```

Genstat Output from Exercise 1

```

4  " Load the data, where entry is a factor "
5  FACTOR entry
6  READ [MISSING='.'; SETLEVELS=yes] entryno,entry,y1,y2,y3; \
7    FREPRESENTATION=labels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
entryno	1.000	10.55	21.00	22	0
y1	2169	3742	4440	22	12
y2	3019	3876	4414	22	12
y3	2435	3881	4595	22	12

Identifier	Values	Missing	Levels
entry	22	0	21

```

30
31  " Stack y1, y2 & y3 to form the Yield variate (and remove old data
-32    structures) "
33  APPEND [NEWVECTOR=Yield] y1,y2,y3
34  DELETE [REDEFINE=yes] y1,y2,y3
35
36  " Form the block factor "
37  CALC n = NVALUES(entryno)
38  FACTOR [LEVELS=3; VALUES=#n(1,2,3)] block
39
40  " Recode the cultivar entry number into 2 factors (check and test)
-41    check = entryno for all check cultivars, and 0 otherwise
-42    test = entryno for all test cultivars, 0 otherwise "
43  APPEND [NEWVECTOR=entrynostacked] 3(entryno)
44  CALC cv = (entrynostacked < 5) * entrynostacked
45  GROUP cv; check
46  CALC xv = (entrynostacked > 4) * entrynostacked

```

```

47  GROUP xv; test
48
49  " Use REML to estimate the cultivar means and standard errors "
50  VCOMPONENTS [FIXED=check/test] RANDOM=block; CONSTRAINTS=pos
51  REML [PRINT=model,components,waldTests,means; PSE=allest] Yield

```

REML variance components analysis

Response variate: Yield
 Fixed model: Constant + check + check.test
 Random model: block
 Number of units: 30 (36 units excluded due to zero weights or missing values)

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
block	0.	bound

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	68856.	32459.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
check	14.44	4	3.61	9.0	0.051
check.test	104.05	16	6.50	9.0	0.004

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
check.test	104.05	16	6.50	9.0	0.004

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

4876. Standard error: 166.4

Table of predicted means for check

check	0	1	2	3	4
	*	*	*	*	*

All values in table missing: due to missing factor combinations in higher order interactions.

Table of predicted means for check.test

test	0	5	6	7	8	9	10
check							
0	*	2169	3250	3807	4068	3871	3838
1	4098	*	*	*	*	*	*
2	4002	*	*	*	*	*	*
3	4143	*	*	*	*	*	*
4	3800	*	*	*	*	*	*

test	11	12	13	14	15	16	17
check							
0	4244	3290	3019	3506	4384	4148	4167
1	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*

test	18	19	20	21
check				
0	4023	2435	4595	3957
1	*	*	*	*
2	*	*	*	*
3	*	*	*	*
4	*	*	*	*

Standard errors

test	0	5	6	7	8	9	10
check							
0	*	262.4	262.4	262.4	262.4	262.4	262.4
1	131.2	*	*	*	*	*	*
2	151.5	*	*	*	*	*	*
3	151.5	*	*	*	*	*	*
4	151.5	*	*	*	*	*	*

test	11	12	13	14	15	16	17
check							
0	262.4	262.4	262.4	262.4	262.4	262.4	262.4
1	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*

3	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*

test	18	19	20	21
check				
0	262.4	262.4	262.4	262.4
1	*	*	*	*
2	*	*	*	*
3	*	*	*	*
4	*	*	*	*

Standard errors

Average: 240.3
Maximum: 262.4
Minimum: 131.2

```

52  " Note: the denominator degrees of freedom (ddf) are different to
-53  those in the SAS output as, by default, SAS uses the containment
-54  method for computing ddf, whereas Genstat uses the Kenward-Roger
-55  method. The containment method is not available in Genstat. "

```

Exercise 2: Make a logical and objective decision regarding whether or not random design effects should be retained in the final model for publication purposes

Genstat Commands for Exercise 2

```

" ***** "
" EXERCISE #2 "
" Make a logical and objective decision regarding whether or not "
" random design effects should be retained in the final model for "
" publication purposes. "
" ***** "

```

JOB

```

" Load the first block of data, all of which are factors "
FACTOR IDENTIFIER=row,rep,rate,x1,x2,x3,x4,x5,x6,x7
READ [SETLEVELS=yes] row,rep,rate,x1,x2,x3,x4,x5,x6,x7; \
FREPRESENTATION=levels
1  4  40  1  11  13  9  4  7  10
2  4  40  5  8  2  6  3  12  14
3  4  80  3  11  6  1  10  7  8
4  4  80  14  9  4  12  5  2  13
5  4  20  4  8  2  11  1  10  12
6  4  20  3  9  14  7  6  13  5
7  3  80  4  5  2  3  10  6  1
8  3  80  8  12  7  14  9  11  13
9  3  40  5  7  9  8  4  14  11
10 3  40  1  2  3  10  13  12  6
11 3  20  11  5  4  3  13  7  1
12 3  20  6  14  9  8  2  10  12

```

13	2	40	13	9	2	12	6	8	5
14	2	40	11	14	10	3	4	1	7
15	2	20	12	13	7	1	11	10	4
16	2	20	6	14	5	9	3	8	2
17	2	80	14	1	9	12	2	3	6
18	2	80	4	11	8	5	7	10	13
19	1	80	5	2	8	9	3	14	11
20	1	80	12	1	13	10	7	4	6
21	1	20	11	1	8	13	14	7	10
22	1	20	5	3	6	4	9	2	12
23	1	40	10	1	12	11	4	8	2
24	1	40	6	5	14	13	3	7	9 :

" Stack the data (and remove old data structures) "

```

APPEND [NEWVECTOR=Cultivar] x1,x2,x3,x4,x5,x6,x7
APPEND [NEWVECTOR=Row] 7(row)
APPEND [NEWVECTOR=Rep] 7(rep)
APPEND [NEWVECTOR=Rate] 7(rate)
DELETE [REDEFINE=yes] row,rep,rate,x1,x2,x3,x4,x5,x6,x7

```

" Load the second block of data, in which row is a factor "

```

FACTOR row
READ [SETLEVELS=yes] row,x1,x2,x3,x4,x5,x6,x7; \
  FREPRESENTATION=levels

```

1	50	5	5	5	5	5	5
2	5	50	40	5	5	5	10
3	5	5	5	40	5	10	25
4	50	5	60	5	20	45	5
5	5	20	5	5	20	5	5
6	5	5	10	5	5	5	5
7	20	5	70	5	5	10	50
8	40	5	5	60	10	15	5
9	5	10	5	80	50	50	5
10	30	80	5	5	10	5	5
11	5	5	20	5	5	10	40
12	5	5	5	40	30	5	5
13	5	5	40	5	5	30	5
14	5	15	5	5	50	30	20
15	5	5	5	15	5	5	35
16	5	15	5	5	5	25	50
17	20	75	10	5	60	5	5
18	30	5	60	10	30	5	5
19	5	80	75	5	5	30	15
20	5	60	15	5	40	55	10
21	5	10	20	5	5	5	5
22	5	5	5	10	5	40	5
23	5	25	5	5	40	30	65
24	5	5	40	5	5	5	5 :

" Stack percentage survival data (and remove old data structures) "

```

APPEND [NEWVECTOR=gc95] x1,x2,x3,x4,x5,x6,x7
DELETE [REDEFINE=yes] row,x1,x2,x3,x4,x5,x6,x7

```

" Fit the full model that includes the random effects of the
split-plot randomization: whole plot - Rep, subplot - Rep.Rate "

```

VCOMPONENTS [FIXED=Rate*Cultivar] RANDOM=Rep/Rate
REML [PRINT=model,components,waldTests,dev,means; PSE=est] gc95

```

```

" Save the deviance of model 1 "
VKEEP [DEVIANC=DevM1]

" Fit the reduced model that excludes the variance component
  associated with the subplot (Rep.Rate), i.e. treating this
  analysis as a simple randomized complete block design"
VCOMPONENTS [FIXED=Rate*Cultivar] RANDOM=Rep
REML [PRINT=model,components,waldTests,dev,means; PSE=est] gc95
" Save the deviance of model 2 "
VKEEP [DEVIANC=DevM2]

" Perform the likelihood ratio test "
CALC diff = DevM2 - DevM1
CALC p = CUCHISQUARE(diff;1)
PRINT diff,p

ENDJOB

```

Genstat Output from Exercise 2

```

4  " Load the first block of data, all of which are factors "
5  FACTOR IDENTIFIER=row,rep,rate,x1,x2,x3,x4,x5,x6,x7
6  READ [SETLEVELS=yes] row,rep,rate,x1,x2,x3,x4,x5,x6,x7; \
7    FREPRESENTATION=levels

```

Identifier	Values	Missing	Levels
row	24	0	24
rep	24	0	4
rate	24	0	3
x1	24	0	11
x2	24	0	11
x3	24	0	12
x4	24	0	13
x5	24	0	12
x6	24	0	12
x7	24	0	13

```

32
33 " Stack the data (and remove old data structures) "
34 APPEND [NEWVECTOR=Cultivar] x1,x2,x3,x4,x5,x6,x7
35 APPEND [NEWVECTOR=Row] 7(row)
36 APPEND [NEWVECTOR=Rep] 7(rep)
37 APPEND [NEWVECTOR=Rate] 7(rate)
38 DELETE [REDEFINE=yes] row,rep,rate,x1,x2,x3,x4,x5,x6,x7
39
40 " Load the second block of data, in which row is a factor "
41 FACTOR row
42 READ [SETLEVELS=yes] row,x1,x2,x3,x4,x5,x6,x7; \
43   FREPRESENTATION=levels

```

Identifier	Minimum	Mean	Maximum	Values	Missing	
x1	5.000	13.54	50.00	24	0	Skew
x2	5.000	21.04	80.00	24	0	Skew
x3	5.000	21.67	75.00	24	0	Skew
x4	5.000	14.17	80.00	24	0	Skew

x5	5.000	17.71	60.00	24	0	Skew
x6	5.000	18.12	55.00	24	0	
x7	5.000	16.25	65.00	24	0	Skew
Identifier row	Values 24	Missing 0	Levels 24			

```

68
69 " Stack percentage survival data (and remove old data structures) "
70 APPEND [NEWVECTOR=gc95] x1,x2,x3,x4,x5,x6,x7
71 DELETE [REDEFINE=yes] row,x1,x2,x3,x4,x5,x6,x7
72
73 " Fit the full model that includes the random effects of the
-74 split-plot randomization: whole plot - Rep, subplot - Rep.Rate "
75 VCOMPONENTS [FIXED=Rate*Cultivar] RANDOM=Rep/Rate
76 REML [PRINT=model,components,waldTests,dev,means; PSE=est] gc95

```

REML variance components analysis

Response variate: gc95
 Fixed model: Constant + Rate + Cultivar + Rate.Cultivar
 Random model: Rep + Rep.Rate
 Number of units: 168

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Rep	2.2	5.6
Rep.Rate	4.4	7.1

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	108.4	14.2

Deviance: -2*Log-Likelihood

Deviance	d.f.
779.97	123

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Rate	27.06	2	13.53	6.0	0.006
Cultivar	379.58	13	29.20	117.0	<0.001
Rate.Cultivar	50.96	26	1.96	117.0	0.008

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Rate.Cultivar	50.96	26	1.96	117.0	0.008

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

17.50 Standard error: 1.250

Table of predicted means for Rate

Rate	20	40	80
	10.80	18.12	23.57

Standard error: 1.893

Table of predicted means for Cultivar

Cultivar	1	2	3	4	5	6	7	8
	37.08	50.42	5.00	31.67	6.67	5.83	12.50	41.25
Cultivar	9	10	11	12	13	14		
	5.83	5.00	6.67	5.00	6.25	25.83		

Standard error: 3.154

Table of predicted means for Rate.Cultivar

Cultivar	1	2	3	4	5	6	7
Rate							
20	21.25	31.25	5.00	17.50	5.00	5.00	6.25
40	33.75	56.25	5.00	36.25	5.00	5.00	10.00
80	56.25	63.75	5.00	41.25	10.00	7.50	21.25

Cultivar Rate	8	9	10	11	12	13	14
20	26.25	5.00	5.00	5.00	5.00	5.00	8.75
40	47.50	5.00	5.00	5.00	5.00	6.25	28.75
80	50.00	7.50	5.00	10.00	5.00	7.50	40.00

Standard error: 5.361

```

77 " Save the deviance of model 1 "
78 VKEEP [DEVIANC=DevM1]
79
80 " Fit the reduced model that excludes the variance component
-81 associated with the subplot (Rep.Rate), i.e. treating this
-82 analysis as a simple randomized complete block design"
83 VCOMPONENTS [FIXED=Rate*Cultivar] RANDOM=Rep
84 REML [PRINT=model,components,waldTests,dev,means; PSE=est] gc95

```

REML variance components analysis

Response variate: gc95
Fixed model: Constant + Rate + Cultivar + Rate.Cultivar
Random model: Rep
Number of units: 168

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Rep	3.6	5.1

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	111.4	14.2

Deviance: -2*Log-Likelihood

Deviance	d.f.
780.63	124

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Rate	41.27	2	20.64	123.0	<0.001
Cultivar	369.36	13	28.41	123.0	<0.001
Rate.Cultivar	49.59	26	1.91	123.0	0.010

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Rate.Cultivar	49.59	26	1.91	123.0	0.010

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

17.50 Standard error: 1.250

Table of predicted means for Rate

Rate	20	40	80
	10.80	18.12	23.57

Standard error: 1.699

Table of predicted means for Cultivar

Cultivar	1	2	3	4	5	6	7	8
	37.08	50.42	5.00	31.67	6.67	5.83	12.50	41.25

Cultivar	9	10	11	12	13	14
	5.83	5.00	6.67	5.00	6.25	25.83

Standard error: 3.191

Table of predicted means for Rate.Cultivar

Cultivar	1	2	3	4	5	6	7
Rate							
20	21.25	31.25	5.00	17.50	5.00	5.00	6.25
40	33.75	56.25	5.00	36.25	5.00	5.00	10.00

	80	56.25	63.75	5.00	41.25	10.00	7.50	21.25
Cultivar								
Rate	8	9	10	11	12	13	14	
20	26.25	5.00	5.00	5.00	5.00	5.00	8.75	
40	47.50	5.00	5.00	5.00	5.00	6.25	28.75	
80	50.00	7.50	5.00	10.00	5.00	7.50	40.00	

Standard error: 5.361

```

85 " Save the deviance of model 2 "
86 VKEEP [DEVIANC=DevM2]
87
88 " Perform the likelihood ratio test "
89 CALC diff = DevM2 - DevM1
90 CALC p = CUCHISQUARE(diff;1)
91 PRINT diff,p

```

diff	p
0.6617	0.4159

Exercise 3: Arranging blocks and blocking patterns for future experiments

Genstat Commands for Exercise 3

```

" ***** "
" EXERCISE #3 "
" Arranging blocks and blocking patterns for future experiments. "
" ***** "

```

JOB

```

" Load the data, in which row is a factor "
FACTOR row
READ [SETLEVELS=yes] row,y1,y2,y3,y4,y5,y6; \
  FREPRESENTATION=levels
1      7.85      7.86      9.13      9.63      10.52      10.24
2      10.08     10.78     15.18     11.66     12.57     13.60
3      14.41     10.19     16.11     13.53     12.66     14.37
4      14.18      9.77     13.85     12.99     13.09     13.38
5       9.87      6.24      7.27      9.68     13.91      9.62
6      11.63     14.00     15.34     10.99     13.04     13.21
7      11.39     12.33     18.57     18.65     12.79     12.10
8      19.20     13.75     11.47      9.43     17.94      9.26
9      19.03     13.59     11.52     14.09     16.19     12.21
10     11.31      5.52     11.40      9.71     13.51     10.65
11      8.23     13.27     14.51     13.16     17.15     16.81
12     12.59     11.27     11.44     13.58     15.69     13.87 :

```

```

" Stack y1...y6 to form the yield variate (and remove old data
  structures) "
APPEND [NEWVECTOR=yield] y1,y2,y3,y4,y5,y6

```

```

DELETE [REDEFINE=yes] y1,y2,y3,y4,y5,y6

" Form the stacked column factor "
CALC n = NVALUES(row)
FACTOR [LEVELS=6; VALUES=#n(1,2,3,4,5,6)] c1

" Form the stacked row factor (and remove old data structure) "
APPEND [NEWVECTOR=r1] 6(row)
DELETE [REDEFINE=yes] row

" Set up new experimental layouts. Note, the integer in the name
  indicates the number of rows/columns forming the blocks "
CALC r2v=INT((r1+1)/2)
CALC r3v=INT((r1+2)/3)
CALC r4v=INT((r1+3)/4)
CALC r6v=INT((r1+5)/6)
CALC c2v=INT((c1+1)/2)
CALC c3v=INT((c1+2)/3)
GROUP r2v; r2
GROUP r3v; r3
GROUP r4v; r4
GROUP r6v; r6
GROUP c2v; c2
GROUP c3v; c3

" Fit ANOVA to provide an estimate of the residual variance expected
  from the use of a completely randomized design at the site "
BLOCK "No Blocking"
TREATMENTS r1.c1
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,information] yield

" ANOVA table saved using AKEEP, then residual variance stored in
  variate resvar "
AKEEP [aovtable=aov]
VARIATE [NVALUES=23] resvar
CALC resvar$[2]=aov['m.s.'][$[1]]

" Fit models to provide estimates of the residual variances expected
  for a range of different blocking designs. ANOVA tables saved using
  AKEEP, then residual variances stored in variate resvar "
BLOCK "No Blocking"
COVARIATE "No Covariate"
SCALAR i; 1
FOR C = c1,c2,c3
  TREATMENTS C
  ANOVA [PRINT=aovtable,information; FPROB=yes] yield
  AKEEP [aovtable=aov]
  CALC resvar$[i]=aov['m.s.'][$[2]]
  CALC i = i + 1
FOR R = r1,r2,r3,r4,r6
  TREATMENTS C.R
  ANOVA [PRINT=aovtable,information; FPROB=yes] yield
  AKEEP [aovtable=aov]
  IF i <> 2 "Residual from r1c1 stored above"
    CALC resvar$[i]=aov['m.s.'][$[2]]
  ENDIF

```

```

        CALC i = i + 1
    ENDFOR
ENDFOR
FOR R = r1,r2,r3,r4,r6
    TREATMENTS R
    ANOVA [PRINT=aovtable,information; FPROB=yes] yield
    AKEEP [aovtable=aov]
    CALC resvar[i]=aov['m.s.'][$[2]]
    CALC i = i + 1
ENDFOR

" Print all residual variances "
VARIATE [VALUES=12,12,2,3,4,6,(12,1,2,3,4,6)2,1,2,3,4,6] \
    RowsWithinBlock
VARIATE [VALUES=1,6,4(1),6(2,3),5(6)] ColsWithinBlock
PRINT !T((( 'r12', 'r1', 'r2', 'r3', 'r4', 'r6') 3), \
    'r1', 'r2', 'r3', 'r4', 'r6'), !T(6('c1', 'c2', 'c3'), 5('c6')), \
    RowsWithinBlock, ColsWithinBlock, resvar; \
    DEC=2(*), 2(0), 3

" Visualize the residual variances according to the number of rows
  within the blocks and the number of columns within the blocks "
FRAME [RESET=yes] WINDOW=1; BOX=include
XAXIS [RESET=yes] WINDOW=1; TITLE='Number of rows within a block'
YAXIS [RESET=yes] WINDOW=1; TITLE='Expected residual variance'; \
    UPPER=10
PEN [RESET=yes] 1...3,6; SYMBOL=13,2,7,5; SIZE=4(2); COLOUR=4(1); \
    CFILL=1,*,*,*; METHOD=4('spline'); DFSPLINE=1.5; LINESTYLE=2,7,6,1
DGRAPH [KEYDESCRIPTION=!t('Columns within block')]\
    Y=resvar; X=RowsWithinBlock; PEN=ColsWithinBlock; \
    DESCRIPTION=!t('1','2','3','6')

ENDJOB

```

Genstat Output from Exercise 3

```

4 " Load the data, in which row is a factor "
5 FACTOR row
6 READ [SETLEVELS=yes] row,y1,y2,y3,y4,y5,y6; \
7     FREPRESENTATION=levels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
y1	7.850	12.48	19.20	12	0
y2	5.520	10.71	14.00	12	0
y3	7.270	12.98	18.57	12	0
y4	9.430	12.26	18.65	12	0
y5	10.52	14.09	17.94	12	0
y6	9.260	12.44	16.81	12	0

Identifier	Values	Missing	Levels
row	12	0	12

```

20
21 " Stack y1...y6 to form the yield variate (and remove old data
-22     structures) "

```

```

23  APPEND [NEWVECTOR=yield] y1,y2,y3,y4,y5,y6
24  DELETE [REDEFINE=yes] y1,y2,y3,y4,y5,y6
25
26  " Form the stacked column factor "
27  CALC n = NVALUES(row)
28  FACTOR [LEVELS=6; VALUES=#n(1,2,3,4,5,6)] c1
29
30  " Form the stacked row factor (and remove old data structure) "
31  APPEND [NEWVECTOR=r1] 6(row)
32  DELETE [REDEFINE=yes] row
33
34  " Set up new experimental layouts. Note, the integer in the name
-35  indicates the number of rows/columns forming the blocks "
36  CALC r2v=INT((r1+1)/2)
37  CALC r3v=INT((r1+2)/3)
38  CALC r4v=INT((r1+3)/4)
39  CALC r6v=INT((r1+5)/6)
40  CALC c2v=INT((c1+1)/2)
41  CALC c3v=INT((c1+2)/3)
42  GROUP r2v; r2
43  GROUP r3v; r3
44  GROUP r4v; r4
45  GROUP r6v; r6
46  GROUP c2v; c2
47  GROUP c3v; c3
48
49  " Fit ANOVA to provide an estimate of the residual variance expected
-50  from the use of a completely randomized design at the site "
51  BLOCK "No Blocking"
52  TREATMENTS r1.c1
53  COVARIATE "No Covariate"
54  ANOVA [PRINT=aovtable,information] yield

```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.
r1.c1	71	612.7472	8.6302	
Total	71	612.7472		

```

55
56  " ANOVA table saved using AKEEP, then residual variance stored in
-57  variate resvar "
58  AKEEP [aovtable=aov]
59  VARIATE [NVALUES=23] resvar
60  CALC resvar$[2]=aov['m.s.'][$[1]]
61
62  " Fit models to provide estimates of the residual variances expected
-63  for a range of different blocking designs. ANOVA tables saved using
-64  AKEEP, then residual variances stored in variate resvar "
65  BLOCK "No Blocking"
66  COVARIATE "No Covariate"
67  SCALAR i; 1

```


Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c1.r3	23	225.601	9.809	1.22	0.278
Residual	48	387.146	8.066		
Total	71	612.747			

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c1.r4	17	125.305	7.371	0.82	0.668
Residual	54	487.443	9.027		
Total	71	612.747			

Message: the following units have large residuals.

units 8	6.18	s.e. 2.60
units 9	6.24	s.e. 2.60
units 43	6.46	s.e. 2.60

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c1.r6	11	132.065	12.006	1.50	0.156
Residual	60	480.682	8.011		
Total	71	612.747			

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2	2	33.970	16.985	2.02	0.140
Residual	69	578.777	8.388		
Total	71	612.747			

Message: the following units have large residuals.

units 8	7.60	s.e. 2.84
units 9	7.43	s.e. 2.84

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2.r1	35	428.731	12.249	2.40	0.005
Residual	36	184.017	5.112		
Total	71	612.747			

Message: the following units have large residuals.

units 56	4.34	s.e.	1.60
units 68	-4.34	s.e.	1.60

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2.r2	17	180.720	10.631	1.33	0.211
Residual	54	432.027	8.001		
Total	71	612.747			

Message: the following units have large residuals.

units 9	6.67	s.e.	2.45
units 22	-6.84	s.e.	2.45

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2.r3	11	156.887	14.262	1.88	0.061
Residual	60	455.860	7.598		
Total	71	612.747			

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2.r4	8	64.968	8.121	0.93	0.495
Residual	63	547.779	8.695		
Total	71	612.747			

Message: the following units have large residuals.

units 8	6.90	s.e.	2.76
units 9	7.18	s.e.	2.76

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c2.r6	5	78.837	15.767	1.95	0.098
Residual	66	533.910	8.090		
Total	71	612.747			

Message: the following units have large residuals.

units 22	-7.10	s.e. 2.72

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3	1	13.650	13.650	1.59	0.211
Residual	70	599.097	8.559		
Total	71	612.747			

Message: the following units have large residuals.

units 8	7.14	s.e. 2.88

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3.r1	23	291.377	12.669	1.89	0.031
Residual	48	321.370	6.695		
Total	71	612.747			

Message: the following units have large residuals.

units 56	5.73	s.e. 2.11

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3.r2	11	139.346	12.668	1.61	0.120
Residual	60	473.401	7.890		
Total	71	612.747			

Message: the following units have large residuals.

units 9	6.97	s.e. 2.56
units 22	-6.54	s.e. 2.56

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3.r3	7	109.983	15.712	2.00	0.069
Residual	64	502.764	7.856		
Total	71	612.747			

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3.r4	5	36.110	7.222	0.83	0.535
Residual	66	576.637	8.737		
Total	71	612.747			

Message: the following units have large residuals.

units 9	7.06	s.e. 2.83

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
c3.r6	3	55.312	18.437	2.25	0.090
Residual	68	557.435	8.198		
Total	71	612.747			

Message: the following units have large residuals.

units 22	-7.28	s.e. 2.78

```
84  FOR R = r1,r2,r3,r4,r6
85    TREATMENTS R
86    ANOVA [PRINT=aovtable,information; FPROB=yes] yield
87    AKEEP [aovtable=aov]
88    CALC resvar$(i)=aov['m.s.'][$[2]
89    CALC i = i + 1
90  ENDFOR
```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
r1	11	219.876	19.989	3.05	0.003
Residual	60	392.871	6.548		
Total	71	612.747			

Message: the following units have large residuals.

units 8	5.69	s.e.	2.34
units 11	-5.62	s.e.	2.34

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
r2	5	96.750	19.350	2.48	0.041
Residual	66	515.997	7.818		
Total	71	612.747			

Message: the following units have large residuals.

units 9	6.64	s.e.	2.68
units 22	-6.87	s.e.	2.68

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
r3	3	66.446	22.149	2.76	0.049
Residual	68	546.301	8.034		
Total	71	612.747			

Message: the following units have large residuals.

units 22	-6.91	s.e.	2.75

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
r4	2	10.912	5.456	0.63	0.538
Residual	69	601.836	8.722		
Total	71	612.747			

Message: the following units have large residuals.

units 22 -7.41 s.e. 2.89

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
r6	1	41.633	41.633	5.10	0.027
Residual	70	571.114	8.159		
Total	71	612.747			

Message: the following units have large residuals.

units 22 -7.74 s.e. 2.82

```

91
92 " Print all residual variances "
93 VARIATE [VALUES=12,12,2,3,4,6,(12,1,2,3,4,6)2,1,2,3,4,6] \
94   RowsWithinBlock
95 VARIATE [VALUES=1,6,4(1),6(2,3),5(6)] ColsWithinBlock
96 PRINT !T((('r12','r1','r2','r3','r4','r6')3),\
97   'r1','r2','r3','r4','r6'),!T(6('c1','c2','c3'),5('c6')),\
98   RowsWithinBlock,ColsWithinBlock,resvar; \
99   DEC=2(*),2(0),3

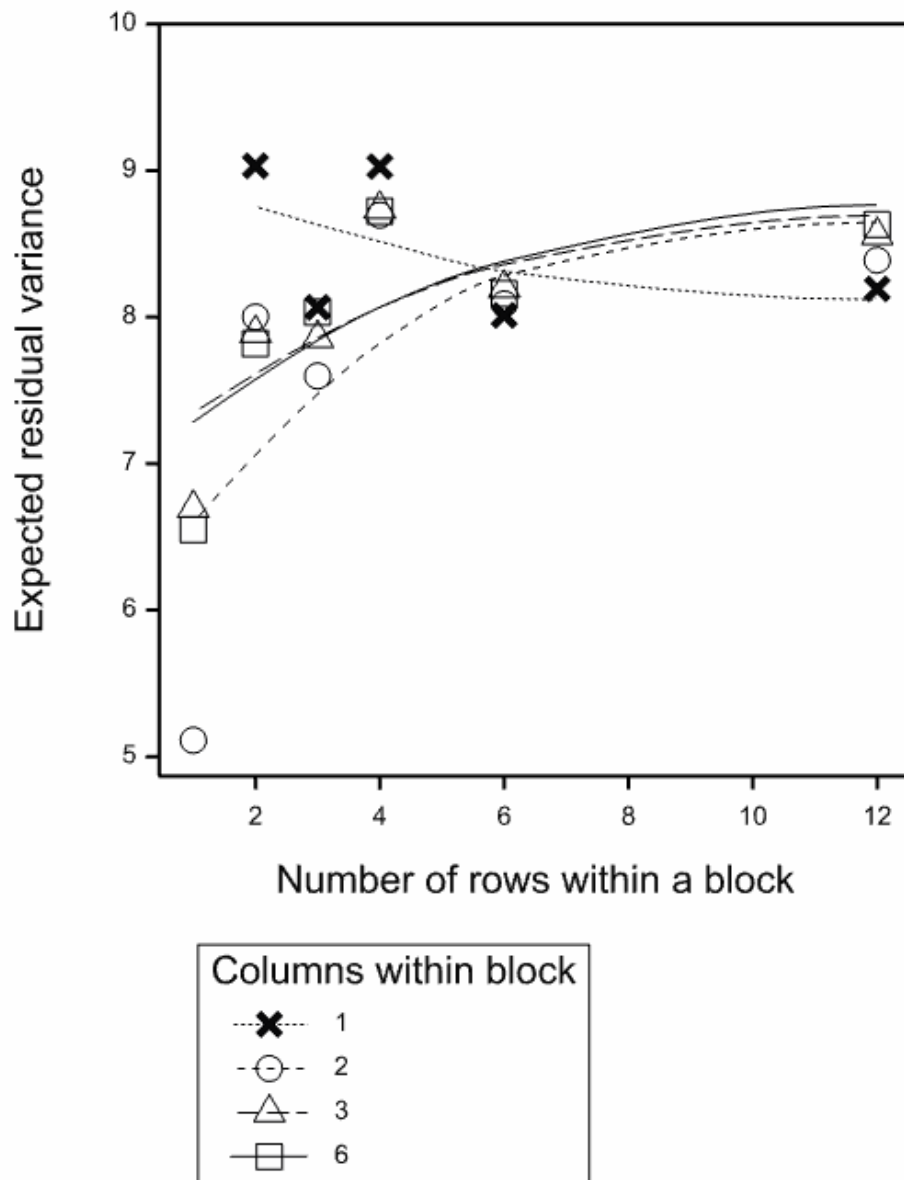
```

	RowsWithinBlock	ColsWithinBlock	resvar
r12 c1	12	1	8.192
r1 c1	12	6	8.630
r2 c1	2	1	9.031
r3 c1	3	1	8.066
r4 c1	4	1	9.027
r6 c1	6	1	8.011
r12 c2	12	2	8.388
r1 c2	1	2	5.112
r2 c2	2	2	8.001
r3 c2	3	2	7.598
r4 c2	4	2	8.695
r6 c2	6	2	8.090
r12 c3	12	3	8.559
r1 c3	1	3	6.695
r2 c3	2	3	7.890
r3 c3	3	3	7.856
r4 c3	4	3	8.737
r6 c3	6	3	8.198
r1 c6	1	6	6.548
r2 c6	2	6	7.818
r3 c6	3	6	8.034
r4 c6	4	6	8.722
r6 c6	6	6	8.159

```

100
101 " Visualize the residual variances according to the number of rows
-102 within the blocks and the number of columns within the blocks "
103 FRAME [RESET=yes] WINDOW=1; BOX=include
104 XAXIS [RESET=yes] WINDOW=1; TITLE='Number of rows within a block'
105 YAXIS [RESET=yes] WINDOW=1; TITLE='Expected residual variance'; \
106 UPPER=10
107 PEN [RESET=yes] 1...3,6; SYMBOL=13,2,7,5; SIZE=4(2); COLOUR=4(1);\
108 CFILL=1,*,*,*; METHOD=4('spline'); DFSPLINE=1.5; LINESTYLE=2,7,6,1
109 DGRAPH [KEYDESCRIPTION=!t('Columns within block')]\
110 Y=resvar; X=RowsWithinBlock; PEN=ColsWithinBlock; \
111 DESCRIPTION=!t('1','2','3','6')

```



Chapter 4. Power and Replication – Designing Powerful Experiments by Michael Casler

Genstat code developed by Vanessa M. Cave and output are provided here for the three exercises presented in Chapter 4.

Exercise 1: Predict the power of a future hypothetical experiment using the probability distribution method

Genstat Commands for Exercise 1

```
" ***** "  
" EXERCISE #1 "  
" Predict the power of a future hypothetical experiment using the "  
" probability distribution method. "  
" ***** "  
  
JOB  
  
" Create a representative data set with 4 replicates per treatment  
  (rep), 2 samples per experimental unit (samples) and with  
  treatment means at the desired detection value "  
FACTOR [LEVELS=4; VALUES=2(1...4)2] rep  
FACTOR [LEVELS=2; VALUES=(1,2)8] samples  
FACTOR [LEVELS=2; VALUES=8(1,2)] trt  
VARIATE [VALUES=8(95,100)] y  
  
" Power predicted using the APOWER procedure "  
SCALAR expterror; 5  
SCALAR samplingerror; 10  
GETATTRIBUTE [ATTRIBUTE=nlevels] samples; SAVE=N  
CALC rms = samplingerror + #N*expterror  
APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.rep; \  
  TMETHOD=fratio] y; RMS=rms  
  
ENDJOB
```

Genstat Output from Exercise 1

```
4 " Create a representative data set with 4 replicates per treatment  
-5 (rep), 2 samples per experimental unit (samples) and with  
-6 treatment means at the desired detection value "  
7 FACTOR [LEVELS=4; VALUES=2(1...4)2] rep  
8 FACTOR [LEVELS=2; VALUES=(1,2)8] samples  
9 FACTOR [LEVELS=2; VALUES=8(1,2)] trt  
10 VARIATE [VALUES=8(95,100)] y  
11  
12 " Power predicted using the APOWER procedure "  
13 SCALAR expterror; 5  
14 SCALAR samplingerror; 10  
15 GETATTRIBUTE [ATTRIBUTE=nlevels] samples; SAVE=N
```

```

16  CALC rms = samplingerror + #N*expterror
17  APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.rep; \
18      TMETHOD=fratio] y; RMS=rms

```

Power of analysis of variance

For an F-ratio of 5.00 at a significance level of 0.050, the power is 0.467.

```

19
20  ENDJOB

```

Exercise 2: Simultaneously predict the power of several future hypothetical experiments using the probability distribution method

Genstat Commands for Exercise 2

```

" ***** "
" EXERCISE #2 "
" Simultaneously predict the power of several future hypothetical "
" experiments using the probability distribution method. "
" ***** "

```

JOB

```

" Create a representative data set with 'numreps' replicates per
  treatment, 'numsamples' samples per experimental unit and with
  treatment means at the desired detection value "

```

```

FOR numsamples = 2,3
  FOR numreps = 4...6
    CALC units = numreps*numsamples
    FACTOR [LEVELS=numreps; VALUES=#numsamples(1...#numreps)2] rep
    FACTOR [LEVELS=numsamples; VALUES=((1...#numsamples)#numreps)2] \
      samples
    FACTOR [LEVELS=2; VALUES=#units(1,2)] trt
    VARIATE [VALUES=#units(95,100)] y

    " Power predicted using the APOWER procedure "
    SCALAR expterror; 5
    SCALAR samplingerror; 10
    CALC rms = samplingerror + numsamples*expterror
    APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.rep; \
      TMETHOD=fratio] y; RMS=rms; POWER=p
    PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
      'Number of sampling units: ', numsamples; FIELDWIDTH=*,2
    PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
      'Number of replicates: ', numreps; FIELDWIDTH=*,2
  ENDFOR
ENDFOR

ENDJOB

```

Genstat Output from Exercise 2

```
4  " Create a representative data set with 'numreps' replicates per
-5  treatment, 'numsamples' samples per experimental unit and with
-6  treatment means at the desired detection value "
7
8  FOR numsamples = 2,3
9    FOR numreps = 4...6
10     CALC units = numreps*numsamples
11     FACTOR [LEVELS=numreps; VALUES=#numsamples(1...#numreps)2] rep
12     FACTOR [LEVELS=numsamples; VALUES=((1...#numsamples)#numreps)2] \
13     samples
14     FACTOR [LEVELS=2; VALUES=#units(1,2)] trt
15     VARIATE [VALUES=#units(95,100)] y
16
17     " Power predicted using the APOWER procedure "
18     SCALAR expterror; 5
19     SCALAR samplingerror; 10
20     CALC rms = samplingerror + numsamples*expterror
21     APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.rep; \
22     TMETHOD=fratio] y; RMS=rms; POWER=p
23     PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
24     'Number of sampling units: ', numsamples; FIELDWIDTH=*,2
25     PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
26     'Number of replicates: ', numreps; FIELDWIDTH=*,2
27   ENDFOR
28 ENDFOR
```

Power of analysis of variance

For an F-ratio of 5.00 at a significance level of 0.050, the power is 0.467.

Number of sampling units: 2.000

Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 6.25 at a significance level of 0.050, the power is 0.593.

Number of sampling units: 2.000

Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 7.50 at a significance level of 0.050, the power is 0.695.

Number of sampling units: 2.000

Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 6.00 at a significance level of 0.050, the power is 0.537.

Number of sampling units: 3.000
Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 7.50 at a significance level of 0.050, the power is 0.671.

Number of sampling units: 3.000
Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 9.00 at a significance level of 0.050, the power is 0.771.

Number of sampling units: 3.000
Number of replicates: 6.000

```
29  
30  ENDJOB
```

Exercise 3: Design a new experiment to evaluate treatments that are expected to have very small mean differences, but for which it critically important to be able to detect differences

Genstat Commands for Exercise 3

```
" ***** "  
" EXERCISE #3 "  
" Design a new experiment to evaluate treatments that are expected "  
" to have very small mean differences, but for which it is "  
" critically important to be able to detect differences. "  
" ***** "  
  
JOB  
  
" Create a representative data set with 'numreps' replicates,  
'numlocs' locations samples per experimental unit and with  
treatment means at the desired detection value "  
  
FOR numlocs = 2...6  
  FOR numreps = 4...8  
    CALC units = numreps*numlocs  
    FACTOR [LEVELS=numreps; VALUES=#numlocs(1...#numreps)2] rep  
    FACTOR [LEVELS=numlocs; VALUES=((1...#numlocs)#numreps)2] \\  
      location  
    FACTOR [LEVELS=2; VALUES=#units(1,2)] trt  
    VARIATE [VALUES=#units(9.5,10)] y  
  
    " Power predicted using the APOWER procedure "  
    SCALAR resvar; 0.2  
    SCALAR trtlocerror; 0.02  
    CALC rms = resvar+trtlocerror*numreps  
    APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.location; \
```

```

        TMETHOD=fratio] y; RMS=rms; POWER=p
PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
      'Number of locations: ', numlocs; FIELDWIDTH=*,2
PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
      'Number of replicates: ', numreps; FIELDWIDTH=*,2
ENDFOR
ENDFOR

ENDJOB

```

Genstat Output from Exercise 3

```

4  " Create a representative data set with 'numreps' replicates,
-5  'numlocs' locations samples per experimental unit and with
-6  treatment means at the desired detection value "
7
8  FOR numlocs = 2...6
9    FOR numreps = 4...8
10     CALC units = numreps*numlocs
11     FACTOR [LEVELS=numreps; VALUES=#numlocs(1...#numreps)2] rep
12     FACTOR [LEVELS=numlocs; VALUES=((1...#numlocs)#numreps)2] \
13       location
14     FACTOR [LEVELS=2; VALUES=#units(1,2)] trt
15     VARIATE [VALUES=#units(9.5,10)] y
16
17     " Power predicted using the APOWER procedure "
18     SCALAR resvar; 0.2
19     SCALAR trtlocerror; 0.02
20     CALC rms = resvar+trtlocerror*numreps
21     APOWER [PRINT=power; TERM=trt; TREATMENT=trt; BLOCK=trt.location;
\
22       TMETHOD=fratio] y; RMS=rms; POWER=p
23     PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
24       'Number of locations: ', numlocs; FIELDWIDTH=*,2
25     PRINT [IPRINT=*; SQUASH=yes; STYLE=plain] \
26       'Number of replicates: ', numreps; FIELDWIDTH=*,2
27   ENDFOR
28 ENDFOR

```

Power of analysis of variance

For an F-ratio of 3.57 at a significance level of 0.050, the power is 0.202.

Number of locations: 2.000
Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 4.17 at a significance level of 0.050, the power is 0.225.

Number of locations: 2.000
Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 4.69 at a significance level of 0.050, the power is 0.244.

Number of locations: 2.000
Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 5.15 at a significance level of 0.050, the power is 0.261.

Number of locations: 2.000
Number of replicates: 7.000

Power of analysis of variance

For an F-ratio of 5.56 at a significance level of 0.050, the power is 0.275.

Number of locations: 2.000
Number of replicates: 8.000

Power of analysis of variance

For an F-ratio of 5.36 at a significance level of 0.050, the power is 0.424.

Number of locations: 3.000
Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 6.25 at a significance level of 0.050, the power is 0.477.

Number of locations: 3.000
Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 7.03 at a significance level of 0.050, the power is 0.521.

Number of locations: 3.000
Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 7.72 at a significance level of 0.050, the power is 0.557.

Number of locations: 3.000
Number of replicates: 7.000

Power of analysis of variance

For an F-ratio of 8.33 at a significance level of 0.050, the power is 0.588.

Number of locations: 3.000
Number of replicates: 8.000

Power of analysis of variance

For an F-ratio of 7.14 at a significance level of 0.050, the power is 0.609.

Number of locations: 4.000
Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 8.33 at a significance level of 0.050, the power is 0.674.

Number of locations: 4.000
Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 9.38 at a significance level of 0.050, the power is 0.724.

Number of locations: 4.000
Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 10.29 at a significance level of 0.050, the power is 0.762.

Number of locations: 4.000
Number of replicates: 7.000

Power of analysis of variance

For an F-ratio of 11.11 at a significance level of 0.050, the power is 0.792.

Number of locations: 4.000
Number of replicates: 8.000

Power of analysis of variance

For an F-ratio of 8.93 at a significance level of 0.050, the power is 0.745.

Number of locations: 5.000
Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 10.42 at a significance level of 0.050, the power is 0.806.

Number of locations: 5.000
Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 11.72 at a significance level of 0.050, the power is 0.849.

Number of locations: 5.000

Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 12.87 at a significance level of 0.050, the power is 0.880.

Number of locations: 5.000

Number of replicates: 7.000

Power of analysis of variance

For an F-ratio of 13.89 at a significance level of 0.050, the power is 0.902.

Number of locations: 5.000

Number of replicates: 8.000

Power of analysis of variance

For an F-ratio of 10.71 at a significance level of 0.050, the power is 0.838.

Number of locations: 6.000

Number of replicates: 4.000

Power of analysis of variance

For an F-ratio of 12.50 at a significance level of 0.050, the power is 0.889.

Number of locations: 6.000

Number of replicates: 5.000

Power of analysis of variance

For an F-ratio of 14.06 at a significance level of 0.050, the power is 0.921.

Number of locations: 6.000

Number of replicates: 6.000

Power of analysis of variance

For an F-ratio of 15.44 at a significance level of 0.050, the power is 0.942.

Number of locations: 6.000

Number of replicates: 7.000

Power of analysis of variance

For an F-ratio of 16.67 at a significance level of 0.050, the power is 0.956.

Number of locations: 6.000

Number of replicates: 8.000

29

30 ENDJOB

Chapter 5. Multiple Comparison Procedures: The Ins and Outs by David J. Saville

Genstat code, developed by Vanessa M. Cave and David J. Saville, and output are provided here for the Garlic and Alfalfa examples presented in Chapter 5.

Garlic Example

Genstat Commands for the Garlic Example

```
" ***** "
```

```
"                               Garlic Example                               "
```

```
" ***** "
```



```
JOB
```



```
" Load the data, where Spacing, No_rows, Block and Trt are factors "
```

```
FACTOR Spacing, No_rows, Block, Trt
```

```
READ [SETLEVELS=yes] Spacing, No_rows, Block, Trt, Yield; \
```

```
  FREPRESENTATION=labels
```

5cm	3	1	1	5110
5cm	4	1	2	6675
5cm	5	1	3	7265
10cm	3	1	4	3710
10cm	4	1	5	4095
10cm	5	1	6	6415
5cm	3	2	1	4040
5cm	4	2	2	7000
5cm	5	2	3	7230
10cm	3	2	4	3785
10cm	4	2	5	3730
10cm	5	2	6	5355
5cm	3	3	1	8405
5cm	4	3	2	8150
5cm	5	3	3	6660
10cm	3	3	4	4637
10cm	4	3	5	4985
10cm	5	3	6	5070
5cm	3	4	1	7045
5cm	4	4	2	8145
5cm	5	4	3	9259
10cm	3	4	4	4635
10cm	4	4	5	6540
10cm	5	4	6	5875

```
  :
```



```
" Naive analysis: ANOVA with 6 treatments and 4 blocks "
```

```
BLOCK Block
```

```
TREATMENTS Trt
```

```
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
```

```
  LSDLEVEL=5] Yield
```

```
AMCOMPARISON [PRINT=letter; METHOD=fulsd; DIRECTION=descending; \
```

```
  PROB=0.05] Trt
```



```
" Analysis that recognizes treatment structure: ANOVA with a 2
```

```

    Spacing by 3 No_rows factorial design, linear and quadratic
    polynomial contrasts for the No_rows factor, and 4 blocks "
BLOCK Block
TREATMENTS Spacing*POL(No_rows;2)
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
    LSDLEVEL=5] Yield
APLOT

" Plotting the means "
AGRAPH [PSE=lsd] TITLE=''; YTITLE='Garlic yield (kg ha-1)';\
    XTITLE='Number of rows per bed'

" Adding independently fitted parallel regression lines "
AKEEP TERMS=Spacing*No_rows; MEANS=mean
VTABLE TABLE=mean; VARIATE=meanV; \
    CLASSIFICATION=!P(meanSpacingF,meanNo_rowsF)
CALC meanNo_rowsV = meanNo_rowsF
MODEL meanV
TERMS meanNo_rowsV+meanSpacingF
FIT [PRINT=*] meanNo_rowsV+meanSpacingF
DELETE [REDEFINE=yes] fit
PREDICT [PRINT=*; PREDICTIONS=fit] meanNo_rowsV,meanSpacingF; \
    LEVELS=!(1,2,3),*
VTABLE TABLE=fit; VARIATE=fitV; \
    CLASSIFICATION=!P(fitNo_rowsF,fitSpacingF)
CALC fitNo_rowsV = fitNo_rowsF
PEN 1,2; COLOUR='red','green'; METHOD='line'; SYMBOL=0
DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=fitNo_rowsV; \
    PEN=fitSpacingF
PEN [RESET=yes] 1,2

ENDJOB

```

Genstat Output from the Garlic Example

```

4  " Load the data, where Spacing, No_rows, Block and Trt are factors "
5  FACTOR Spacing, No_rows, Block, Trt
6  READ [SETLEVELS=yes] Spacing, No_rows, Block, Trt, Yield; \
7      FREPRESENTATION=labels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
Yield	3710	5992	9259	24	0

Identifier	Values	Missing	Levels
Spacing	24	0	2
No_rows	24	0	3
Block	24	0	4
Trt	24	0	6

```

32
33  " Naive analysis: ANOVA with 6 treatments and 4 blocks "
34  BLOCK Block
35  TREATMENTS Trt
36  ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
37      LSDLEVEL=5] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	10823281.	3607760.	4.23	
Block.*Units* stratum					
Trt	5	38181167.	7636233.	8.95	<.001
Residual	15	12796692.	853113.		
Total	23	61801139.			

Message: the following units have large residuals.

Block 3 *units* 1 1930. s.e. 730.

Tables of means

Variate: Yield

Grand mean 5992.

Trt	1	2	3	4	5	6
	6150.	7492.	7604.	4192.	4838.	5679.

Least significant differences of means (5% level)

Table	Trt
rep.	4
d.f.	15
l.s.d.	1392.1

```
38  AMCOMPARISON [PRINT=letter; METHOD=fulsd; DIRECTION=descending; \  
39  PROB=0.05] Trt
```

Fisher's unprotected least significant difference test

Trt

	Mean	
3	7604	a
2	7492	ab
1	6150	bc
6	5679	c

```

5      4838  cd
4      4192  d

40
41  " Analysis that recognizes treatment structure: ANOVA with a 2
-42  Spacing by 3 No_rows factorial design, linear and quadratic
-43  polynomial contrasts for the No_rows factor, and 4 blocks "
44  BLOCK Block
45  TREATMENTS Spacing*POL(No_rows;2)
46  ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
47  LSDLEVEL=5] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	10823281.	3607760.	4.23	
Block.*Units* stratum					
Spacing	1	28496963.	28496963.	33.40	<.001
No_rows	2	9004306.	4502153.	5.28	0.018
Lin	1	8646540.	8646540.	10.14	0.006
Quad	1	357765.	357765.	0.42	0.527
Spacing.No_rows	2	679899.	339949.	0.40	0.678
Spacing.Lin	1	1122.	1122.	0.00	0.972
Spacing.Quad	1	678776.	678776.	0.80	0.386
Residual	15	12796692.	853113.		
Total	23	61801139.			

Message: the following units have large residuals.

Block 3 *units* 1	1929.	s.e. 730.

Tables of means

Variate: Yield

Grand mean 5992.

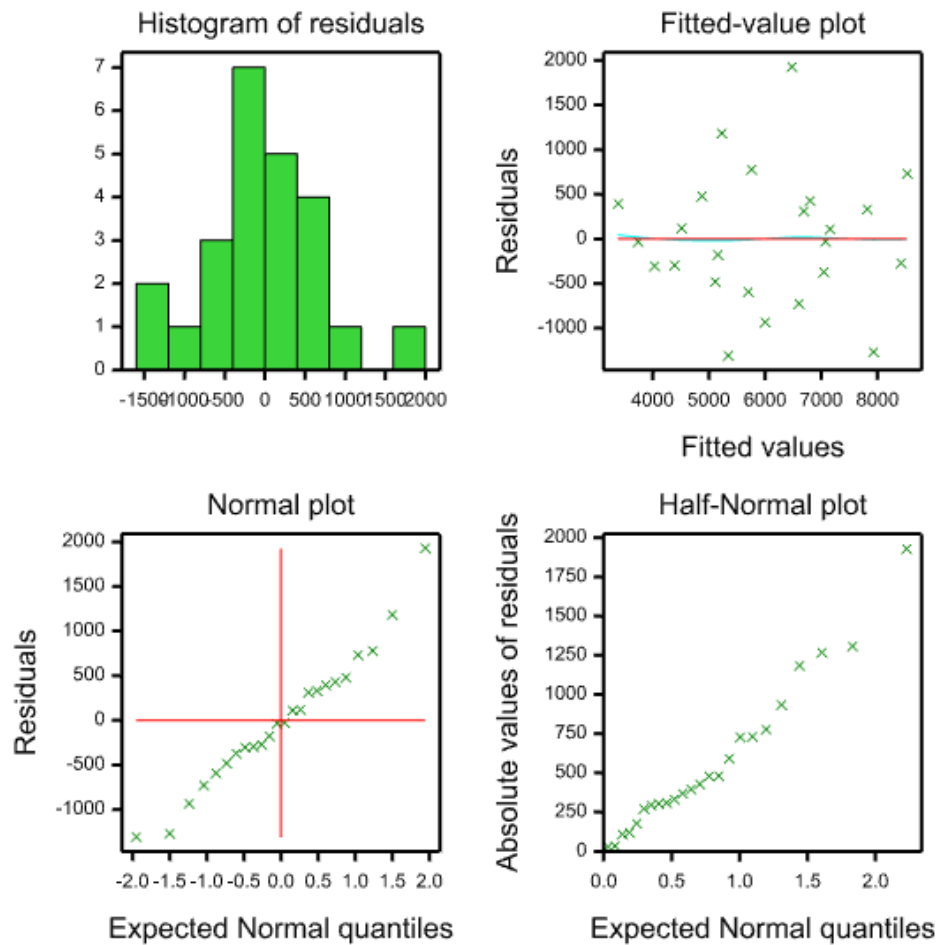
Spacing	10cm	5cm		
	4903.	7082.		
No_rows	3	4	5	
	5171.	6165.	6641.	
SpacingNo_rows	3	4	5	
10cm	4192.	4838.	5679.	
5cm	6150.	7492.	7604.	

Least significant differences of means (5% level)

Table	Spacing	No_rows	Spacing No_rows
rep.	12	8	4
d.f.	15	15	15
l.s.d.	803.7	984.3	1392.1

48 A PLOT

Yield



```

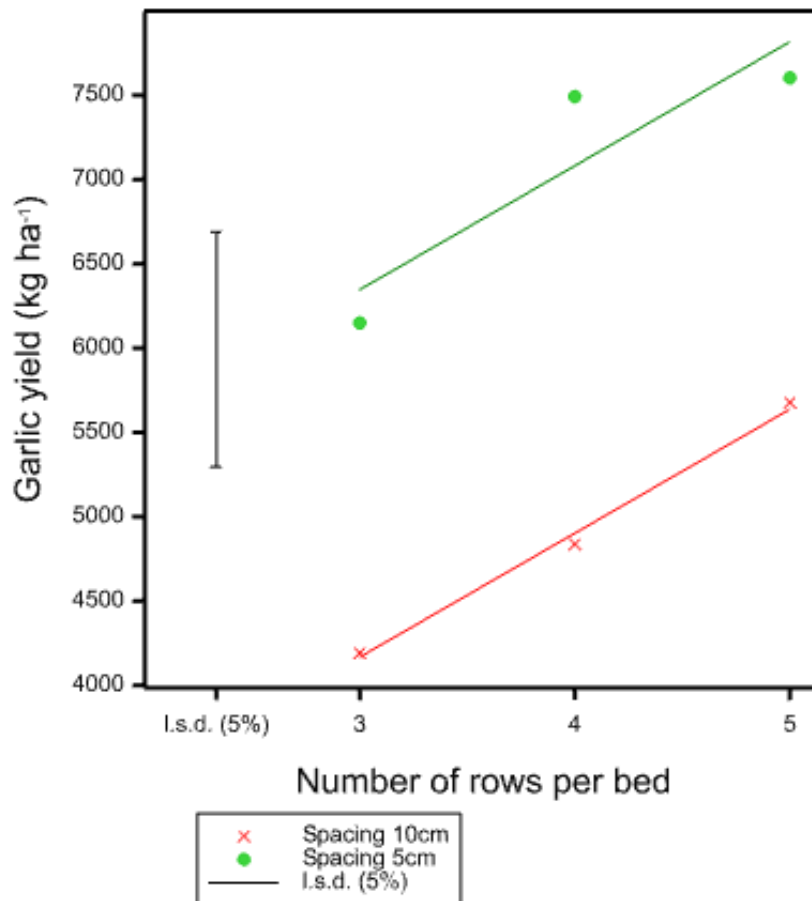
49
50 " Plotting the means "
51 AGRAPH [PSE=lsd] TITLE=''; YTITLE='Garlic yield (kg ha-1)';\
52   XTITLE='Number of rows per bed'
53
54 " Adding independently fitted parallel regression lines "
55 AKEEP TERMS=Spacing*No_rows; MEANS=mean
56 VTABLE TABLE=mean; VARIATE=meanV; \
57   CLASSIFICATION=!P(meanSpacingF,meanNo_rowsF)
58 CALC meanNo_rowsV = meanNo_rowsF
59 MODEL meanV

```

```

60 TERMS meanNo_rowsV+meanSpacingF
61 FIT [PRINT=*] meanNo_rowsV+meanSpacingF
62 DELETE [REDEFINE=yes] fit
63 PREDICT [PRINT=*; PREDICTIONS=fit] meanNo_rowsV,meanSpacingF; \
64     LEVELS=!(1,2,3),*
65 VTABLE TABLE=fit; VARIATE=fitV; \
66     CLASSIFICATION=!P(fitNo_rowsF,fitSpacingF)
67 CALC fitNo_rowsV = fitNo_rowsF
68 PEN 1,2; COLOUR='red','green'; METHOD='line'; SYMBOL=0
69 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=fitNo_rowsV; \
70     PEN=fitSpacingF
71 PEN [RESET=yes] 1,2

```



Alfalfa Example

Genstat Commands for the Alfalfa Example

```

" ***** "
"               Alfalfa Example               "
" ***** "

```

JOB

```

" Load the data, where trt, cultivar, fertilizer and block are
  factors "
FACTOR trt, cultivar, fertilizer, block
READ [SETLEVELS=yes] trt, cultivar, fertilizer, block, yield; \
  FREPRESENTATION=labels
1    NZ_1    '10kg K/ha'    1    2.17
1    NZ_1    '10kg K/ha'    2    1.88
1    NZ_1    '10kg K/ha'    3    1.62
1    NZ_1    '10kg K/ha'    4    2.34
2    NZ_1    '20kg K/ha'    1    2.98
2    NZ_1    '20kg K/ha'    2    1.66
2    NZ_1    '20kg K/ha'    3    1.62
2    NZ_1    '20kg K/ha'    4    1.99
3    NZ_1    '30kg K/ha'    1    2.69
3    NZ_1    '30kg K/ha'    2    2.00
3    NZ_1    '30kg K/ha'    3    2.07
3    NZ_1    '30kg K/ha'    4    2.31
4    NZ_2    '10kg K/ha'    1    2.33
4    NZ_2    '10kg K/ha'    2    2.01
4    NZ_2    '10kg K/ha'    3    1.70
4    NZ_2    '10kg K/ha'    4    1.78
5    NZ_2    '20kg K/ha'    1    2.26
5    NZ_2    '20kg K/ha'    2    1.70
5    NZ_2    '20kg K/ha'    3    2.25
5    NZ_2    '20kg K/ha'    4    1.49
6    NZ_2    '30kg K/ha'    1    2.36
6    NZ_2    '30kg K/ha'    2    2.10
6    NZ_2    '30kg K/ha'    3    2.21
6    NZ_2    '30kg K/ha'    4    1.94
7    UScv    '10kg K/ha'    1    1.69
7    UScv    '10kg K/ha'    2    1.65
7    UScv    '10kg K/ha'    3    1.83
7    UScv    '10kg K/ha'    4    1.48
8    UScv    '20kg K/ha'    1    2.18
8    UScv    '20kg K/ha'    2    1.87
8    UScv    '20kg K/ha'    3    2.20
8    UScv    '20kg K/ha'    4    1.77
9    UScv    '30kg K/ha'    1    2.75
9    UScv    '30kg K/ha'    2    2.41
9    UScv    '30kg K/ha'    3    2.62
9    UScv    '30kg K/ha'    4    2.36 :

" Naive analysis: ANOVA with 9 treatments and 4 blocks "
BLOCK block
TREATMENTS trt
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
  LSDLEVEL=5] yield
AMCOMPARISON [PRINT=letter; METHOD=fulsd; DIRECTION=descending; \
  PROB=0.05] trt

" Analysis that recognizes treatment structure: ANOVA with a 3
  cultivar by 3 fertilizer factorial design, and 4 blocks "
BLOCK block
TREATMENTS cultivar*fertilizer
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
  LSDLEVEL=5] yield

```



```

" Analysis that recognizes treatment structure and the comparisons
of most interest: ANOVA with a 3 cultivar by 3 fertilizer factorial
design, 4 blocks, and contrasts for both cultivar, fertilizer and
their interactions "
MATRIX [rows=!t(' (NZ vs US)', '(NZ_1 vs NZ_2)'); columns=3; \
        values=-1,-1, 2, \
              -1, 1, 0] contrasts
BLOCK block
TREATMENTS COMP(cultivar;2;contrasts) * POL(fertilizer;2)
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
      LSDLEVEL=5] yield
APLOT

" Plotting the means "
AGRAPH [PSE=lsd] XFACTOR=fertilizer; GROUP=cultivar; TITLE=''; \
      YTITLE='Alfalfa yield (kg plot~^{-1})'; \
      XTITLE='Rate of potassium (K) fertilizer (kg K ha~^{-1})'

" Adding independently fitted regression lines "
AKEEP TERMS=cultivar*fertilizer; MEANS=mean
VTABLE TABLE=mean; VARIATE=meanV; \
      CLASSIFICATION=!P(meancultivarF,meanfertilizerF)
CALC meanfertilizerV = meanfertilizerF
MODEL meanV
TERMS meanfertilizerV*meancultivarF
FIT [PRINT=*] meanfertilizerV*meancultivarF
DELETE [REDEFINE=yes] fit
PREDICT [PRINT=*; PREDICTIONS=fit] meanfertilizerV,meancultivarF; \
      LEVELS=!(1,2,3),*
VTABLE TABLE=fit; VARIATE=fitV; \
      CLASSIFICATION=!P(fitfertilizerF,fitcultivarF)
CALC fitfertilizerV = fitfertilizerF
PEN 1,2,3; COLOUR='red','green','blue'; METHOD='line'; SYMBOL=0
DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=fitfertilizerV; \
      PEN=fitcultivarF
PEN [RESET=yes] 1,2,3

ENDJOB

```

Genstat Output from the Alfalfa Example

```

4  " Load the data, where trt, cultivar, fertilizer and block are
-5  factors "
6  FACTOR trt, cultivar, fertilizer, block
7  READ [SETLEVELS=yes] trt, cultivar, fertilizer, block, yield; \
8  FREPRESENTATION=labels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
yield	1.480	2.063	2.980	36	0

Identifier	Values	Missing	Levels
trt	36	0	9
cultivar	36	0	3
fertilizer	36	0	3
block	36	0	4

```

45
46 " Naive analysis: ANOVA with 9 treatments and 4 blocks "
47 BLOCK block
48 TREATMENTS trt
49 ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
50     LSDLEVEL=5] yield

```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	1.24047	0.41349	6.00	
block.*Units* stratum					
trt	8	1.88299	0.23537	3.42	0.009
Residual	24	1.65390	0.06891		
Total	35	4.77736			

Message: the following units have large residuals.

block 1 *units* 2	0.602	s.e.	0.214
block 4 *units* 1	0.461	s.e.	0.214

Tables of means

Variate: yield

Grand mean 2.063

trt	1	2	3	4	5	6	7	8	9
	2.002	2.062	2.267	1.955	1.925	2.152	1.662	2.005	2.535

Least significant differences of means (5% level)

Table	trt
rep.	4
d.f.	24
l.s.d.	0.3831

```

51 AMCOMPARISON [PRINT=letter; METHOD=fulsd; DIRECTION=descending; \
52     PROB=0.05] trt

```

Fisher's unprotected least significant difference test

trt

	Mean	
9	2.535	a
3	2.267	ab
6	2.152	ab
2	2.062	b
8	2.005	bc
1	2.002	bc
4	1.955	bc
5	1.925	bc
7	1.662	c

```

53
54  " Analysis that recognizes treatment structure: ANOVA with a 3
-55  cultivar by 3 fertilizer factorial design, and 4 blocks "
56  BLOCK block
57  TREATMENTS cultivar*fertilizer
58  ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
59  LSDLEVEL=5] yield

```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	1.24047	0.41349	6.00	
block.*Units* stratum					
cultivar	2	0.06036	0.03018	0.44	0.650
fertilizer	2	1.26551	0.63275	9.18	0.001
cultivar.fertilizer	4	0.55713	0.13928	2.02	0.123
Residual	24	1.65390	0.06891		
Total	35	4.77736			

Message: the following units have large residuals.

block 1 *units* 2	0.602	s.e.	0.214
block 4 *units* 1	0.461	s.e.	0.214

Tables of means

Variate: yield

Grand mean 2.063

cultivar	NZ_1	NZ_2	UScv
	2.111	2.011	2.067

fertilizer	10kg K/ha	20kg K/ha	30kg K/ha
	1.873	1.997	2.318

cultivar	fertilizer	10kg K/ha	20kg K/ha	30kg K/ha
NZ_1		2.002	2.062	2.267
NZ_2		1.955	1.925	2.152
UScv		1.662	2.005	2.535

Least significant differences of means (5% level)

Table	cultivar	fertilizer	cultivar fertilizer
rep.	12	12	4
d.f.	24	24	24
l.s.d.	0.2212	0.2212	0.3831

```

60
61 " Analysis that recognizes treatment structure and the comparisons
-62 of most interest: ANOVA with a 3 cultivar by 3 fertilizer factorial
-63 design, 4 blocks, and contrasts for both cultivar, fertilizer and
-64 their interactions "
65 MATRIX [rows=!t('(NZ vs US)', '(NZ_1 vs NZ_2)'); columns=3; \
66     values=-1,-1, 2, \
67     -1, 1, 0] contrasts
68 BLOCK block
69 TREATMENTS COMP(cultivar;2;contrasts) * POL(fertilizer;2)
70 ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
71     LSDLEVEL=5] yield

```

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	1.24047	0.41349	6.00	
block.*Units* stratum					
cultivar	2	0.06036	0.03018	0.44	0.650
(NZ vs US)	1	0.00036	0.00036	0.01	0.943
(NZ_1 vs NZ_2)	1	0.06000	0.06000	0.87	0.360
fertilizer	2	1.26551	0.63275	9.18	0.001
Lin	1	1.18815	1.18815	17.24	<.001
Quad	1	0.07736	0.07736	1.12	0.300
cultivar.fertilizer	4	0.55713	0.13928	2.02	0.123
(NZ vs US).Lin	1	0.54827	0.54827	7.96	0.009
(NZ_1 vs NZ_2).Lin	1	0.00456	0.00456	0.07	0.799
(NZ vs US).Quad	1	0.00008	0.00008	0.00	0.972
(NZ_1 vs NZ_2).Quad	1	0.00422	0.00422	0.06	0.807
Residual	24	1.65390	0.06891		
Total	35	4.77736			

Message: the following units have large residuals.

block 1 *units* 2	0.602	s.e.	0.214
block 4 *units* 1	0.461	s.e.	0.214

Tables of means

Variate: yield

Grand mean 2.063

cultivar	NZ_1	NZ_2	UScv
	2.111	2.011	2.067

fertilizer	10kg K/ha	20kg K/ha	30kg K/ha
	1.873	1.997	2.318

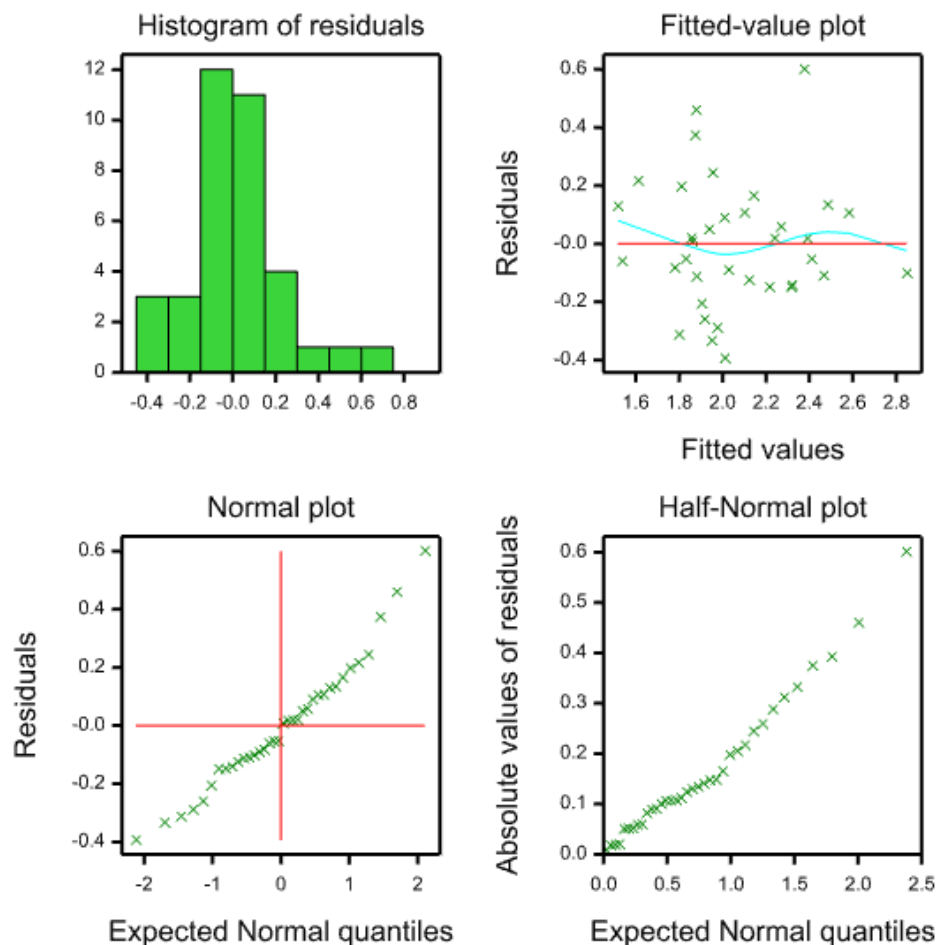
cultivar	fertilizer	10kg K/ha	20kg K/ha	30kg K/ha
NZ_1		2.002	2.062	2.267
NZ_2		1.955	1.925	2.152
UScv		1.662	2.005	2.535

Least significant differences of means (5% level)

Table	cultivar	fertilizer	cultivar fertilizer
rep.	12	12	4
d.f.	24	24	24
l.s.d.	0.2212	0.2212	0.3831

72 APLLOT

yield



```

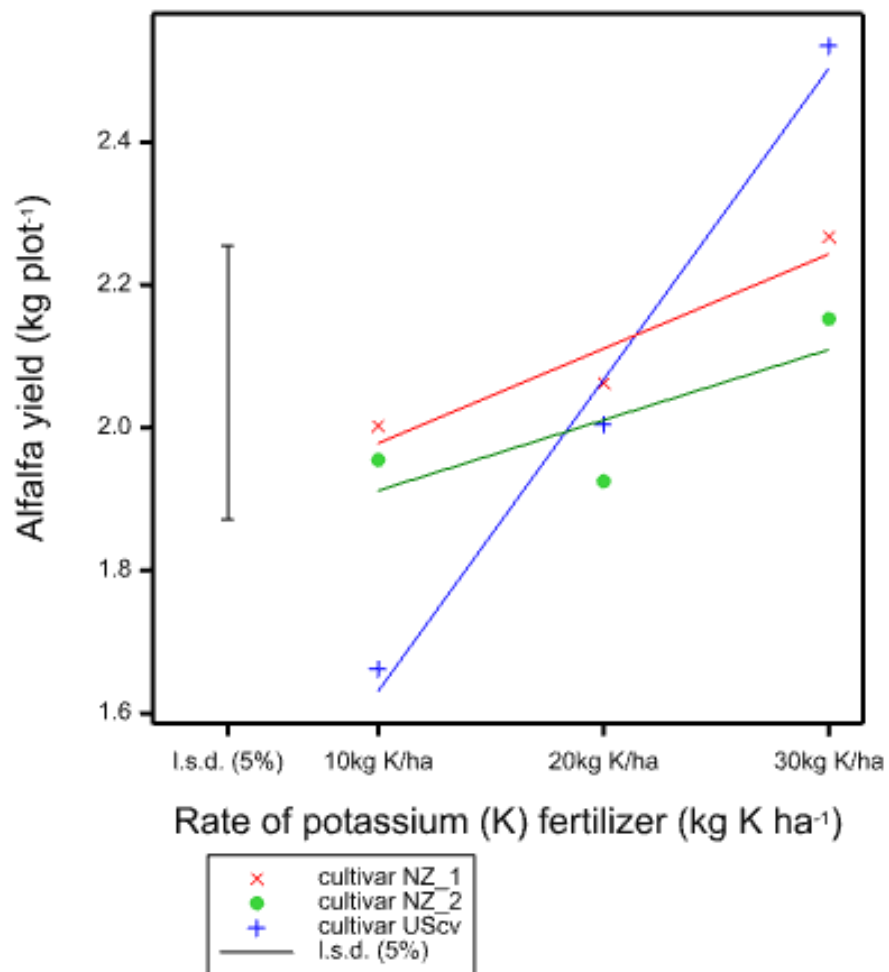
73
74 " Plotting the means "
75 AGRAPH [PSE=lsd] XFACTOR=fertilizer; GROUP=cultivar; TITLE=''; \
76     YTITLE='Alfalfa yield (kg plot-1)'; \
77     XTITLE='Rate of potassium (K) fertilizer (kg K ha-1)'
78
79 " Adding independently fitted regression lines "
80 AKEEP TERMS=cultivar*fertilizer; MEANS=mean
81 VTABLE TABLE=mean; VARIATE=meanV; \
82     CLASSIFICATION=!P(meancultivarF,meanfertilizerF)
83 CALC meanfertilizerV = meanfertilizerF
84 MODEL meanV
85 TERMS meanfertilizerV*meancultivarF
86 FIT [PRINT=*] meanfertilizerV*meancultivarF
87 DELETE [REDEFINE=yes] fit
88 PREDICT [PRINT=*; PREDICTIONS=fit] meanfertilizerV,meancultivarF; \
89     LEVELS=!(1,2,3),*
90 VTABLE TABLE=fit; VARIATE=fitV; \
91     CLASSIFICATION=!P(fitfertilizerF,fitcultivarF)

```

```

92 CALC fitfertilizerV = fitfertilizerF
93 PEN 1,2,3; COLOUR='red','green','blue'; METHOD='line'; SYMBOL=0
94 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=fitfertilizerV; \
95     PEN=fitcultivarF
96 PEN [RESET=yes] 1,2,3

```



Chapter 6. Linear Regression Techniques by Christel Richter and Hans-Peter Piepho

Genstat code developed by Vanessa M. Cave and output are provided here for the eight examples presented in Chapter 6.

Example 1

Genstat Commands for Example 1

```
" ***** "
"                               Example One                               "
" ***** "

JOB

" Load the data, where Eel_no is a text structure "
TEXT Eel_no
READ Eel_no, length, weight
  1  33  108.6   2  34  114.1
  3  36  120.4   4  36  128.6
  5  37  137.5   6  39  144.2
  7  39  148.3   8  40  152.4
  9  41  160.5  10  42  166.4
 11  42  165.9  12  42  162.8
 13  43  179.0  14  43  172.1
 15  44  178.0  16  45  189.7
 17  46  194.9  18  46  184.8
 19  46  191.8  20  46  189.7
 21  47  202.6  22  47  198.9
 23  47  198.2  24  48  209.6
 25  49  212.1  26  51  224.5
 27  51  224.7  28  51  228.3
 29  51  221.6  30  52  231.7
 31  53  246.2  32  54  247.5
 33  55  254.8  34  58  275.0 :

" Figure 1: A scatter plot of weight against length with boxplots in
  the margins "
XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
DXYGRAPH [XMETHOD=boxplot; YMETHOD=boxplot] Y=weight; X=length; \
  WINDOW=3; KEY=0; TITLE='Weight and length of eels'
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1

" Simple linear regression "
MODEL [SAVE=Example1] weight
TERMS length
```



```

FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
    TPROB=yes; SELECTION=adjustedr2,r2] length
" Fitted model with 95% confidence intervals "
RGRAPH [SAVE=Example1; CILOT=yes]
" Figure 3: 95% confidence and prediction intervals "
VARIATE xlevels; !(33...58)
PREDICT [SAVE=Example1; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
    SE=_predSE] CLASSIFY=length; LEVELS=xlevels
PREDICT [SAVE=Example1; PRINT=*; SCOPE=data; SE=_confSE] \
    CLASSIFY=length; LEVELS=xlevels
RKEEP [SAVE=Example1] DF=df
VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Length and weight of eels'] \
    Y=weight; X=length
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
    LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
    Y=pred,predU,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Correlation analysis "
FCORRELATION [PRINT=correlations,test; METHOD=twosided] weight,length

" Figure 6: Residual diagnostic plots "
RCHECK [SAVE=Example1] residual

" Table 4: Evaluation of each data point "
" Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
  by Genstat, but they are easily calculated "
" Internally Studentized residual "
RKEEP [SAVE=Example1] RESIDUALS=standardized_residual
" Raw residual,leverage "
RKEEP [SAVE=Example1; RMETHOD=simple] RESIDUAL=raw_residual; \
    LEVERAGES=leverage
" Externally Studentized residual "
RCHECK [SAVE=Example1; RMETHOD=deletion; \
    RESIDUAL=ex_standardized_residual] XMETHOD=*
" PRESS "
CALC Press=raw_residual/(1-leverage)
" Modified Cook's statistic "
RCHECK [SAVE=Example1; COOK=Modified_Cooks] XMETHOD=*
" Cook's D "
RKEEP [SAVE=Example1] MEANDEVIANCE=rmse
CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
" DDFITS "

```

```

CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
" DFBETA and COVRATIO "
RKEEP [SAVE=Example1] ESTIMATES=beta; VCOVARIANCE=vcov
" Note: the variance-covariance matrix of the estimates (vcov) is
      scaled by the residual mean square error (rmse) "
CALC n = NVALUES(weight)
VARIATE [VALUES=1...n] ObsNum
VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
FOR [NTIMES=n; INDEX=i]
  RESTRICT weight,length; CONDITION=ObsNum .NE. i
  MODEL weight
  TERMS length
  FIT [PRINT=*] length
  RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
  CALC DFBETAS_intercept[i] = (beta[1]-beta_i[1]) / \
                                Sqrt(rmse_i * #vcov[1;1]/rmse)
  CALC DFBETAS_slope[i] = (beta[2]-beta_i[2]) / \
                            Sqrt(rmse_i * #vcov[2;2]/rmse)
  CALC covratio[i] = DET(vcov_i) / DET(vcov)
  RESTRICT weight,length
ENDFOR
PRINT Eel_no,raw_residual,standardized_residual,\
      ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
      DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

" Tests for normality "
WSTATISTIC standardized_residual
EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
        standardized_residual

" Figure 7: A scatter plot of standardized residual against length "
XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized Residual'
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=length
PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESSTYLE=2
DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
PEN=2
RESTRICT standardized_residual; \
  CONDITION=ABS(standardized_residual) > 2;
TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Eel_no
PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
DGRAPH [WINDOW=3; SCREEN=keep] Y=standardized_residual; X=length
RESTRICT standardized_residual
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1,2

" Table 5 "
CALC PRESS=SUM(Press**2)
RKEEP [SAVE=Example1] SUMMARY=anova
PRINT PRESS,anova['s.s.'][$2]; HEADING='PRESS','RSS'

" Note: As of Genstat 19, procedures for calculating confidence
      and prediction ellipses are not available "

ENDJOB

```

Genstat Output from Example 1

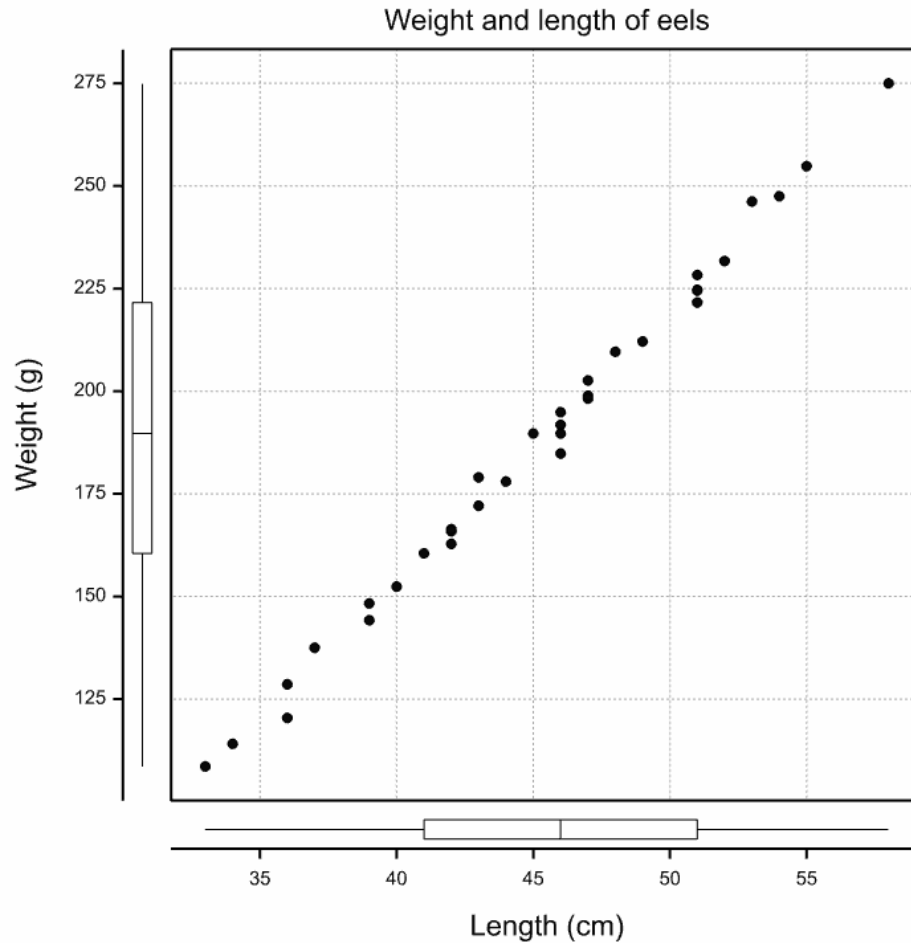
```
2  " ***** "
3  "                               Example One                               "
4  " ***** "
5
6  JOB
```

End of job.

```
7
8  " Load the data, where Eel_no is a text structure "
9  TEXT Eel_no
10 READ Eel_no, length, weight
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Eel_no				34	0
length	33.00	45.12	58.00	34	0
weight	108.6	187.2	275.0	34	0

```
28
29  " Figure 1: A scatter plot of weight against length with boxplots in
-30  the margins "
31  XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm)'
32  YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
33  FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
34  PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
35  DXYGRAPH [XMETHOD=boxplot; YMETHOD=boxplot] Y=weight; X=length; \
36  WINDOW=3; KEY=0; TITLE='Weight and length of eels'
37  XAXIS [RESET=yes] WINDOW=3
38  YAXIS [RESET=yes] WINDOW=3
39  FRAME [RESET=yes] WINDOW=3
40  PEN [RESET=yes] 1
```



```

41
42 " Simple linear regression "
43 MODEL [SAVE=Example1] weight
44 TERMS length
45 FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
46     TPROB=yes; SELECTION=adjustedr2,r2] length

```

Regression analysis

Response variate: weight
Fitted terms: Constant, length

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	57466.5	57466.45	5560.78	<.001
Residual	32	330.7	10.33		
Total	33	57797.1	1751.43		

Adjusted r-squared statistic 0.994
R-squared statistic 0.994

Message: the following units have large standardized residuals.

Unit	Response	Residual
18	184.80	-2.63

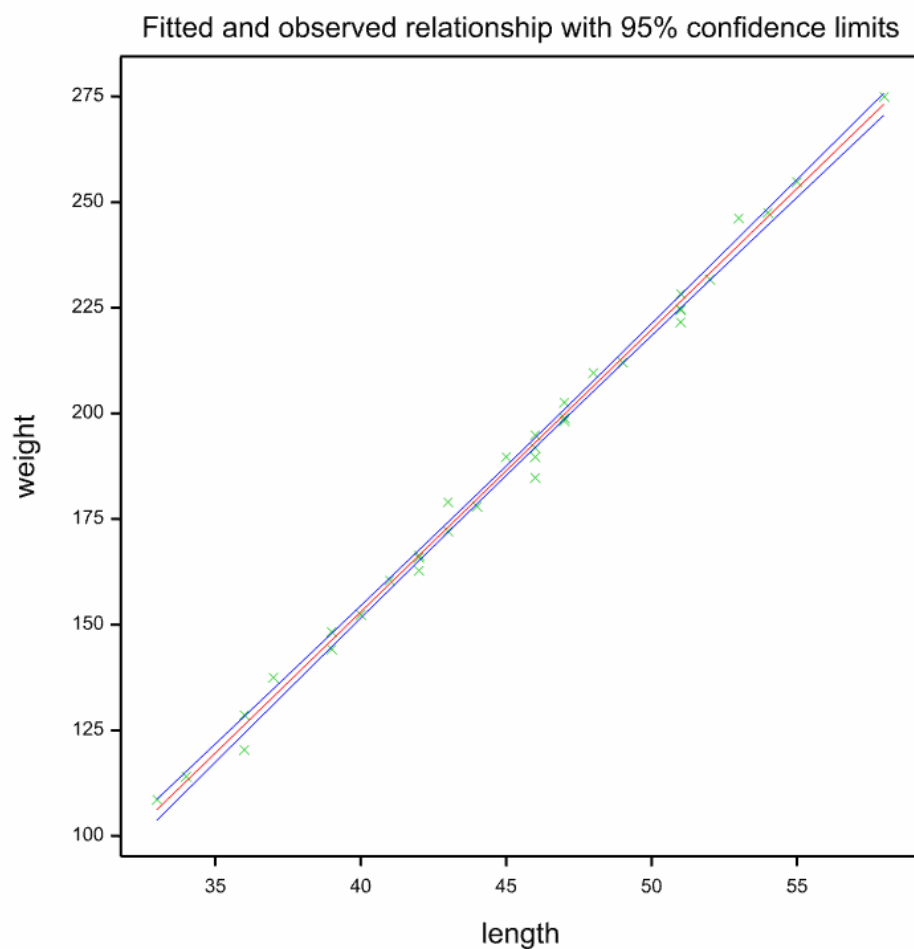
Message: the following units have high leverage.

Unit	Response	Leverage
1	108.60	0.143
34	275.00	0.158

Estimates of parameters

Parameter	estimate	s.e.	t(32)	t pr.
Constant	-114.20	4.08	-27.99	<.001
length	6.6808	0.0896	74.57	<.001

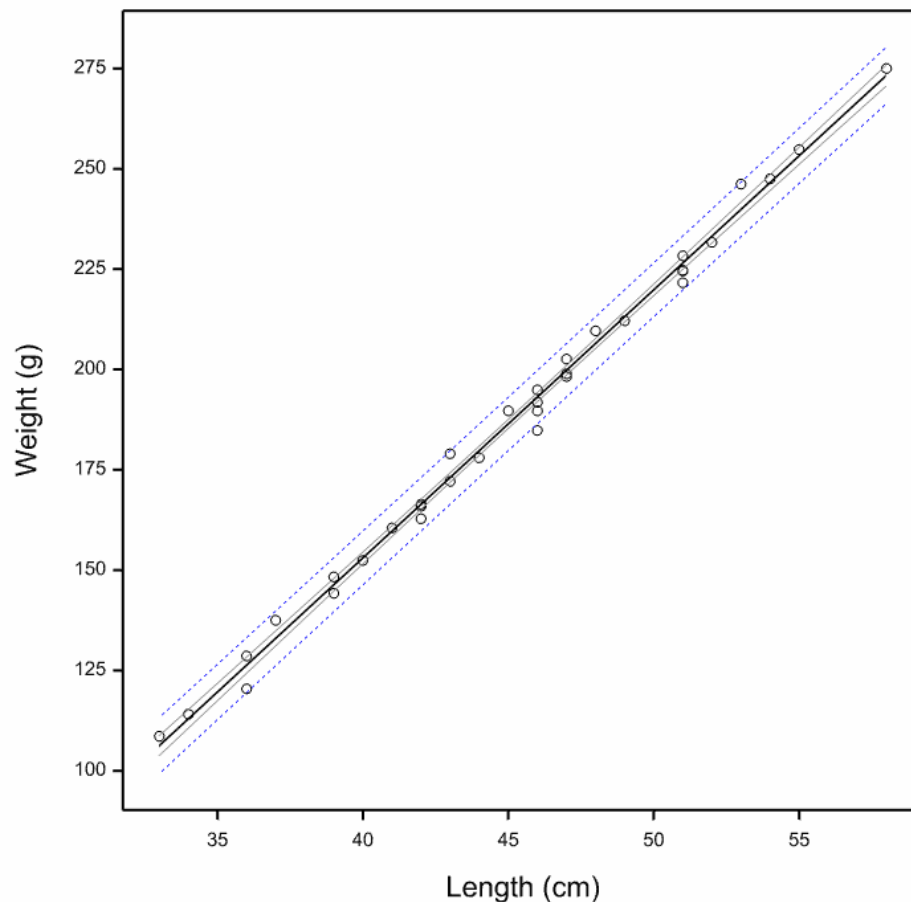
```
47 " Fitted model with 95% confidence intervals "  
48 RGRAPH [SAVE=Example1; CIPLLOT=yes]
```



```

49 " Figure 3: 95% confidence and prediction intervals "
50 VARIATE xlevels; !(33...58)
51 PREDICT [SAVE=Example1; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
52   SE=_predSE] CLASSIFY=length; LEVELS=xlevels
53 PREDICT [SAVE=Example1; PRINT=*; SCOPE=data; SE=_confSE] \
54   CLASSIFY=length; LEVELS=xlevels
55 RKEEP [SAVE=Example1] DF=df
56 VTABLE _pred, _predSE, _confSE; VARIATE=pred,predSE,confSE
57 CALC predL = pred - EDT(0.975;df)*predSE
58 CALC predU = pred + EDT(0.975;df)*predSE
59 CALC confL = pred - EDT(0.975;df)*confSE
60 CALC confU = pred + EDT(0.975;df)*confSE
61 XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm)'
62 YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
63 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
64 DGRAPH [WINDOW=3; KEY=0; TITLE='Length and weight of eels'] \
65   Y=weight; X=length
66 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
67 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
68   LINESTYLE='dot'
69 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
70 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
71   Y=pred,predU,predL,confU,confL; X=xlevels
72 XAXIS [RESET=yes] WINDOW=3
73 YAXIS [RESET=yes] WINDOW=3
74 FRAME [RESET=yes] WINDOW=3
75 PEN [RESET=yes] 1...5

```



```

76
77 " Correlation analysis "
78 FCORRELATION [PRINT=correlations,test; METHOD=twosided] weight,length

```

Correlations

weight	1	-	
length	2	0.9971	-
		1	2

Number of observations: 34

Two-sided test of correlations different from zero

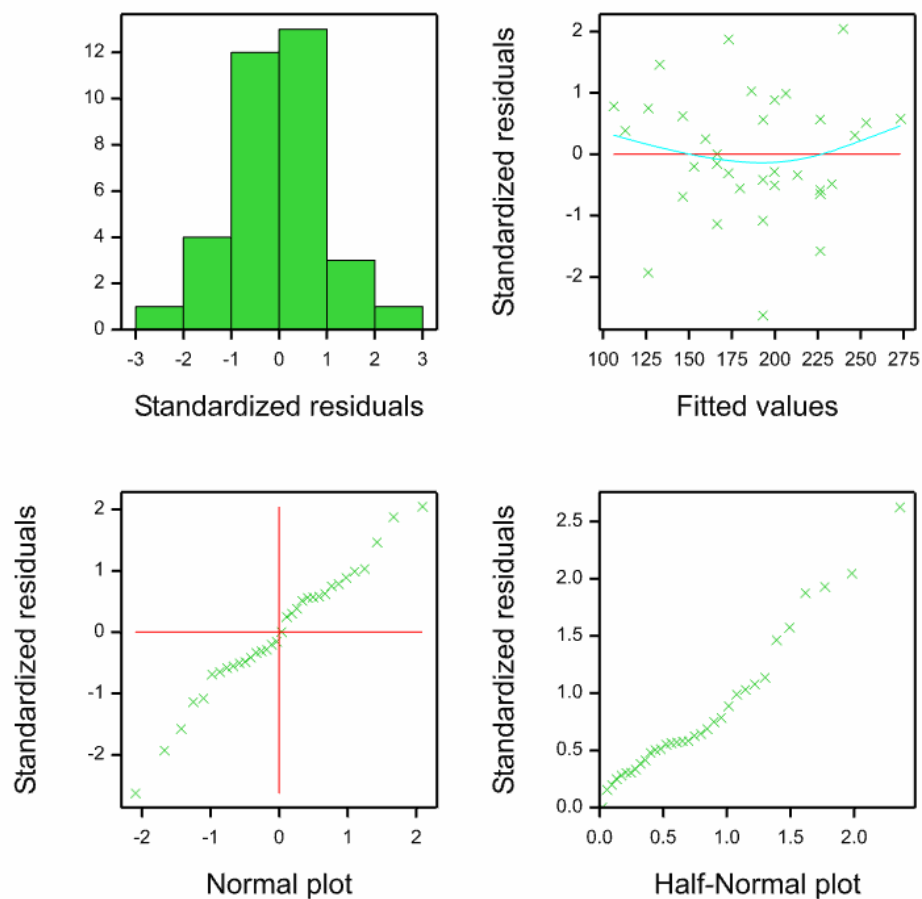
weight	1	-	
length	2	<0.001	-
		1	2

```

79
80 " Figure 6: Residual diagnostic plots "
81 RCHECK [SAVE=Example1] residual

```

weight



```

82
83 " Table 4: Evaluation of each data point "
84 " Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
-85   by Genstat, but they are easily calculated "
86 " Internally Studentized residual "
87 RKEEP [SAVE=Example1] RESIDUALS=standardized_residual
88 " Raw residual,leverage "
89 RKEEP [SAVE=Example1; RMETHOD=simple] RESIDUAL=raw_residual; \
90   LEVERAGES=leverage
91 " Externally Studentized residual "
92 RCHECK [SAVE=Example1; RMETHOD=deletion; \
93   RESIDUAL=ex_standardized_residual] XMETHOD=*
94 " PRESS "
95 CALC Press=raw_residual/(1-leverage)
96 " Modified Cook's statistic "
97 RCHECK [SAVE=Example1; COOK=Modified_Cooks] XMETHOD=*
98 " Cook's D "
99 RKEEP [SAVE=Example1] MEANDEVIANCE=rmse
100 CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
101 " DDFITS "
102 CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
103 " DFBETA and COVRATIO "
104 RKEEP [SAVE=Example1] ESTIMATES=beta; VCOVARIANCE=vcov
105 " Note: the variance-covariance matrix of the estimates (vcov) is
-106   scaled by the residual mean square error (rmse) "
107 CALC n = NVALUES(weight)
108 VARIATE [VALUES=1...n] ObsNum
109 VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
110 FOR [NTIMES=n; INDEX=i]
111   RESTRICT weight,length; CONDITION=ObsNum .NE. i
112   MODEL weight
113   TERMS length
114   FIT [PRINT=*] length
115   RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
116   CALC DFBETAS_intercept$[i] = (beta$[1]-beta_i$[1]) / \
117     Sqrt(rmse_i * #vcov$[1;1]/rmse)
118   CALC DFBETAS_slope$[i] = (beta$[2]-beta_i$[2]) / \
119     Sqrt(rmse_i * #vcov$[2;2]/rmse)
120   CALC covratio$[i] = DET(vcov_i) / DET(vcov)
121   RESTRICT weight,length
122 ENDFOR
123 PRINT Eel_no,raw_residual,standardized_residual,\
124   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
125   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

```

Eel_no	raw_residual	standardized_residual	ex_standardized_residual	leverage
1	2.34	0.79	0.78	0.14
2	1.16	0.38	0.38	0.13
3	-5.90	-1.93	-2.02	0.09
4	2.30	0.75	0.74	0.09
5	4.51	1.46	1.49	0.08
6	-2.15	-0.69	-0.68	0.06
7	1.95	0.63	0.62	0.06
8	-0.63	-0.20	-0.20	0.05
9	0.79	0.25	0.25	0.04
10	0.01	0.00	0.00	0.04

11	-0.49	-0.16	-0.15	0.04
12	-3.59	-1.14	-1.14	0.04
13	5.93	1.88	1.96	0.03
14	-0.97	-0.31	-0.30	0.03
15	-1.75	-0.55	-0.55	0.03
16	3.27	1.03	1.03	0.03
17	1.79	0.56	0.56	0.03
18	-8.31	-2.63	-2.92	0.03
19	-1.31	-0.41	-0.41	0.03
20	-3.41	-1.08	-1.08	0.03
21	2.81	0.89	0.88	0.03
22	-0.89	-0.28	-0.28	0.03
23	-1.59	-0.50	-0.50	0.03
24	3.13	0.99	0.99	0.04
25	-1.05	-0.34	-0.33	0.04
26	-2.02	-0.65	-0.64	0.06
27	-1.82	-0.58	-0.58	0.06
28	1.78	0.57	0.56	0.06
29	-4.92	-1.57	-1.61	0.06
30	-1.50	-0.48	-0.48	0.07
31	6.32	2.05	2.16	0.08
32	0.94	0.31	0.30	0.09
33	1.56	0.51	0.51	0.11
34	1.72	0.58	0.58	0.16

Press	Modified_Cooks	Cooks	DFFITS	DFBETAS_intercept
2.73	1.28	0.05	0.32	0.30
1.32	0.58	0.01	0.14	0.13
-6.52	2.60	0.19	-0.65	-0.58
2.53	0.96	0.03	0.24	0.22
4.91	1.77	0.09	0.44	0.38
-2.28	0.68	0.01	-0.17	-0.14
2.07	0.62	0.01	0.15	0.12
-0.66	0.18	0.00	-0.05	-0.03
0.83	0.21	0.00	0.05	0.03
0.01	0.00	0.00	0.00	0.00
-0.51	0.12	0.00	-0.03	-0.02
-3.73	0.90	0.02	-0.22	-0.13
6.13	1.44	0.06	0.36	0.16
-1.00	0.22	0.00	-0.06	-0.03
-1.81	0.39	0.00	-0.10	-0.03
3.37	0.72	0.02	0.18	0.03
1.84	0.39	0.00	0.10	0.00
-8.57	2.05	0.11	-0.51	0.00
-1.35	0.29	0.00	-0.07	0.00
-3.52	0.76	0.02	-0.19	0.00
2.90	0.64	0.01	0.16	-0.03
-0.92	0.20	0.00	-0.05	0.01
-1.65	0.36	0.00	-0.09	0.01
3.24	0.76	0.02	0.19	-0.06
-1.10	0.27	0.00	-0.07	0.03
-2.14	0.62	0.01	-0.16	0.09
-1.92	0.56	0.01	-0.14	0.08
1.89	0.55	0.01	0.14	-0.08
-5.21	1.58	0.07	-0.39	0.23
-1.60	0.51	0.01	-0.13	0.08

6.85	2.51	0.18	0.63	-0.44
1.03	0.38	0.00	0.10	-0.07
1.74	0.70	0.02	0.17	-0.13
2.04	1.00	0.03	0.25	-0.21

DFBETAS_slope	covratio
-0.28	1.20
-0.13	1.21
0.54	0.92
-0.20	1.14
-0.35	1.01
0.12	1.10
-0.11	1.10
0.03	1.12
-0.03	1.11
0.00	1.11
0.01	1.10
0.10	1.02
-0.12	0.87
0.02	1.10
0.02	1.08
0.00	1.03
0.01	1.08
-0.07	0.68
-0.01	1.09
-0.03	1.02
0.05	1.05
-0.01	1.10
-0.03	1.08
0.08	1.04
-0.04	1.10
-0.11	1.10
-0.10	1.11
0.10	1.11
-0.27	0.96
-0.09	1.12
0.49	0.87
0.08	1.16
0.15	1.17
0.23	1.24

```

126
127 " Tests for normality "
128 WSTATISTIC standardized_residual

```

Shapiro-Wilk test for Normality

Data variate: standardized_residual
 Test statistic W: 0.9794
 Probability: 0.754

```

129 EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
130 standardized_residual

```

Likelihood-ratio based empirical-distribution-function goodness-of-fit tests

Distribution: Standard Normal

mean = 0

sd = 1

Message: Default seed for random number generator used with value 114158

Variate: standardized_residual

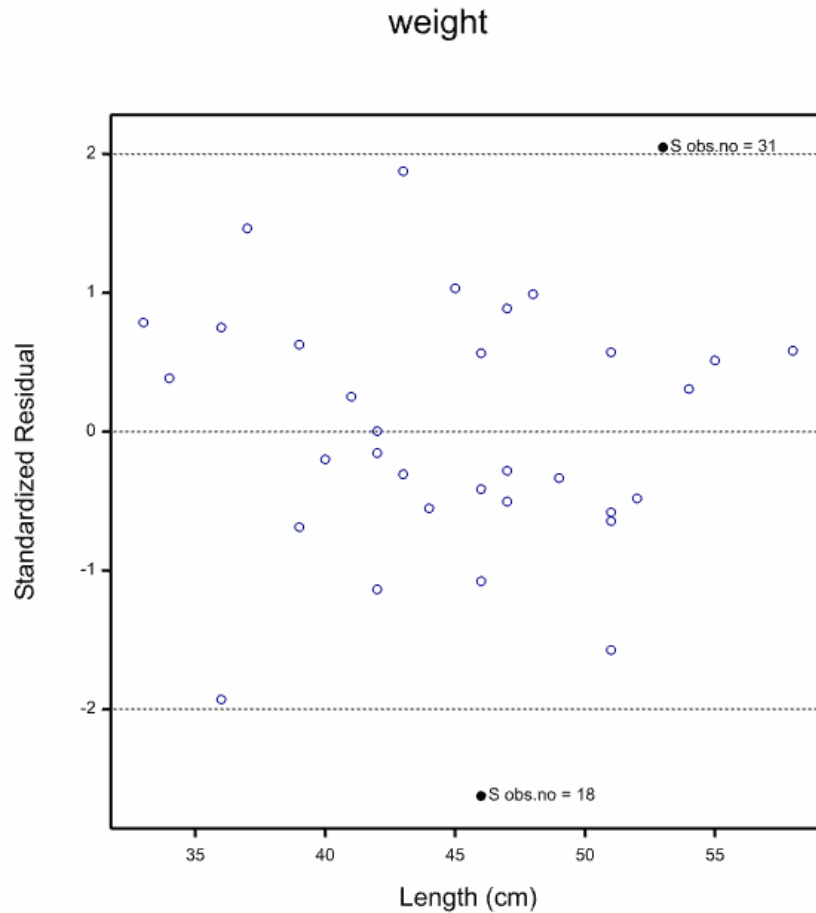
Observations: 34

Monte-Carlo simulations: 999

Seed: 0

	Statistic	Probability
LR-based Kolmogorov-Smirnov	0.707	0.930

```
131
132 " Figure 7: A scatter plot of standardized residual against length "
133 XAXIS [RESET=yes] WINDOW=3; TITLE='Length (cm) '
134 YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized Residual'
135 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
136 DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=length
137 PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESTYLE=2
138 DREFERENCeline [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
139     PEN=2
140 RESTRICT standardized_residual; \
141     CONDITION=ABS(standardized_residual) > 2;
142 TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Eel_no
143 PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
144 DGRAPH [WINDOW=3; SCREEN=keep] Y=standardized_residual; X=length
145 RESTRICT standardized_residual
146 XAXIS [RESET=yes] WINDOW=3
147 YAXIS [RESET=yes] WINDOW=3
148 PEN [RESET=yes] 1,2
```



```

149
150 " Table 5 "
151 CALC PRESS=SUM(Press**2)
152 RKEEP [SAVE=Example1] SUMMARY=anova
153 PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

```

PRESS	RSS
371.7	330.7

```

154
155 " Note: As of Genstat 19, procedures for calculating confidence
-156     and prediction ellipses are not available "
157
158 ENDJOB

```

End of job.

Example 2

Genstat Commands for Example 2

```
" ***** "
"                               Example Two                               "
" ***** "

JOB

" Load the data, where Obs_no is a text structure "
TEXT Obs_no
READ Obs_no, concentration, extinction
  1 0.5  55.5
  2 1.0  77.0
  3 1.5 100.7
  4 3.0 165.5
  5 5.0 253.4 ;

" Figure 2: A scatter plot of extinction against concentration with
  boxplot in the y margin "
XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'
FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
DXYGRAPH [XMETHOD=*; YMETHOD=boxplot] Y=extinction; X=concentration;\
  WINDOW=3; KEY=0; \
  TITLE='Extinction in dependency of 5 concentrations'
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1

" Simple linear regression "
MODEL [SAVE=Example2] extinction
TERMS concentration
FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
  TPROB=yes; SELECTION=adjustedr2,r2] concentration
" Figure 3: 95% confidence and prediction intervals "
VARIATE xlevels; !(0.5,0.6...5.0)
PREDICT [SAVE=Example2; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
  SE=_predSE] CLASSIFY=concentration; LEVELS=xlevels
PREDICT [SAVE=Example2; PRINT=*; SCOPE=data; SE=_confSE] \
  CLASSIFY=concentration; LEVELS=xlevels
RKEEP [SAVE=Example2] DF=df
VTABLE _pred, _predSE, _confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; \
  TITLE='Extinction in dependency of 5 concentrations'] \
  Y=extinction; X=concentration
```

```

PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predU,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Solution for CL and CU "
" Note: The IFUNCTION procedure is used. IFUNCTION solves implicit
  equations of functions of parameters using Newton-Raphson. "
CALC ext = 230 "extinction level to infer concentration at"
RKEEP [SAVE=Example2] MEANDEVIANCE=MSE; NOBSERVATIONS=N; \
  ESTIMATES=estimates
CALC rootMSE = SQRT(MSE)
CALC Cmean = MEAN(concentration)
CALC SSC = SUM((concentration-Cmean)**2)
CALC constant = estimates$['Constant']
CALC slope = estimates$['concentration']
" To calculate CL using IFUNCTION, set up expressions to calculate
  1) the implicit function CL (fCL), and
  2) the 1 by 1 matrix of the derivative of the implicit function
    with respect to CL (dfCL) "
EXPRESSION [VALUE=fCL=constant + slope*CL + rootMSE * \
  sqrt(1 + 1/N + ((CL-Cmean)**2)/SSC) * \
  EDT(0.975;df) - ext] CalcfCL[1]
EXPRESSION [VALUE=dfCL$[1;1]=slope + rootMSE * EDT(0.975;df)/SSC * \
  (CL-Cmean) * \
  (1 + 1/N + ((CL-Cmean)**2)/SSC)**-0.5] \
  CalcfCL[2]
IFUNCTION [ZCALCULATION=CalcfCL[]; MAXCYCLE=100] IMPLICIT=!P(CL); \
  ZERO=fCL; DZBIMPLICIT=dfCL
" To calculate CU using IFUNCTION, set up expressions to calculate
  1) the implicit function CU (fCU), and
  2) the 1 by 1 matrix of the derivative of the implicit function
    with respect to CU (dfCU) "
EXPRESSION [VALUE=fCU=constant + slope*CU - rootMSE * \
  sqrt(1 + 1/N + ((CU-Cmean)**2)/SSC) * \
  EDT(0.975;df) - ext] CalcfCU[1]
EXPRESSION [VALUE=dfCU$[1;1]=slope - rootMSE * EDT(0.975;df)/SSC * \
  (CU-Cmean) * \
  (1 + 1/N + ((CU-Cmean)**2)/SSC)**-0.5] \
  CalcfCU[2]
IFUNCTION [ZCALCULATION=CalcfCU[]; MAXCYCLE=100] IMPLICIT=!P(CU); \
  ZERO=fCU; DZBIMPLICIT=dfCU
" Figure 5: Inference of the concentration from the extinction = 230,
  including Fieller's confidence interval. "
XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'; \
  LOWER=4.3; UPPER=4.6
YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'; \
  LOWER=220; UPPER=240; DECIMALS=0
PEN 1; SYMBOL=0; COLOUR='black'; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
DGRAPH [WINDOW=3; KEY=0] Y=pred,predU,predL; X=xlevels

```

```

PEN 4; COLOUR='red'; METHOD=line; THICKNESS=2
DREFERENCeline [WINDOW=3; ORIENTATION=horizontal] POSITION=230; \
  LABEL='Extinction=230'; YLPOSITION=below; XLPOSITION=left; PEN=4; \
  PENLABEL=4
PEN 5; SYMBOL=0; COLOUR='darkgreen'; METHOD=line; THICKNESS=3
TXCONSTRUCT [TEXT=CLabel] 'Upper limit = ',CU
DREFERENCeline [WINDOW=3; ORIENTATION=vertical] POSITION=CU; \
  LABEL=CLabel; YLPOSITION=below; XLPOSITION=right; PEN=5; \
  PENLABEL=5
TXCONSTRUCT [TEXT=CLlabel] 'Lower limit = ',CL
DREFERENCeline [WINDOW=3; ORIENTATION=vertical] POSITION=CL; \
  LABEL=CLlabel; YLPOSITION=below; XLPOSITION=left; PEN=5; \
  PENLABEL=5
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Table 4: Evaluation of each data point "
" Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
  by Genstat, but they are easily calculated "
" Internally Studentized residual "
RKEEP [SAVE=Example2] RESIDUALS=standardized_residual
" Raw residual,leverage "
RKEEP [SAVE=Example2; RMETHOD=simple] RESIDUAL=raw_residual; \
  LEVERAGES=leverage
" Externally Studentized residual "
RCHECK [SAVE=Example2; RMETHOD=deletion; \
  RESIDUAL=ex_standardized_residual] XMETHOD=*
" PRESS "
CALC Press=raw_residual/(1-leverage)
" Modified Cook's statistic "
RCHECK [SAVE=Example2; COOK=Modified_Cooks] XMETHOD=*
" Cook's D "
RKEEP [SAVE=Example2] MEANDEVIANCE=rmse
CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
" DDFITS "
CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
" DFBETA and COVRATIO "
RKEEP [SAVE=Example2] ESTIMATES=beta; VCOVARIANCE=vcov
" Note: the variance-covariance matrix of the estimates (vcov) is
  scaled by the residual mean square error (rmse) "
CALC n = NVALUES(extinction)
VARIATE [VALUES=1...n] ObsNum
VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
FOR [NTIMES=n; INDEX=i]
  RESTRICT extinction,concentration; CONDITION=ObsNum .NE. i
  MODEL extinction
  TERMS concentration
  FIT [PRINT=*] concentration
  RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
  CALC DFBETAS_intercept[i] = (beta[1]-beta_i[1]) / \
    Sqrt(rmse_i * #vcov$[1;1]/rmse)
  CALC DFBETAS_slope[i] = (beta[2]-beta_i[2]) / \
    Sqrt(rmse_i * #vcov$[2;2]/rmse)
  CALC covratio[i] = DET(vcov_i) / DET(vcov)
  RESTRICT extinction,concentration
ENDFOR

```

```

PRINT Obs_no,raw_residual,standardized_residual,\
      ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
      DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

" Table 5 "
CALC PRESS=SUM(Press**2)
RKEEP [SAVE=Example2] SUMMARY=anova
PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

ENDJOB

```

Genstat Output from Example 2

```

2  " ***** "
3  "                               Example Two                               "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the data, where Obs_no is a text structure "
9  TEXT Obs_no
10 READ Obs_no, concentration, extinction

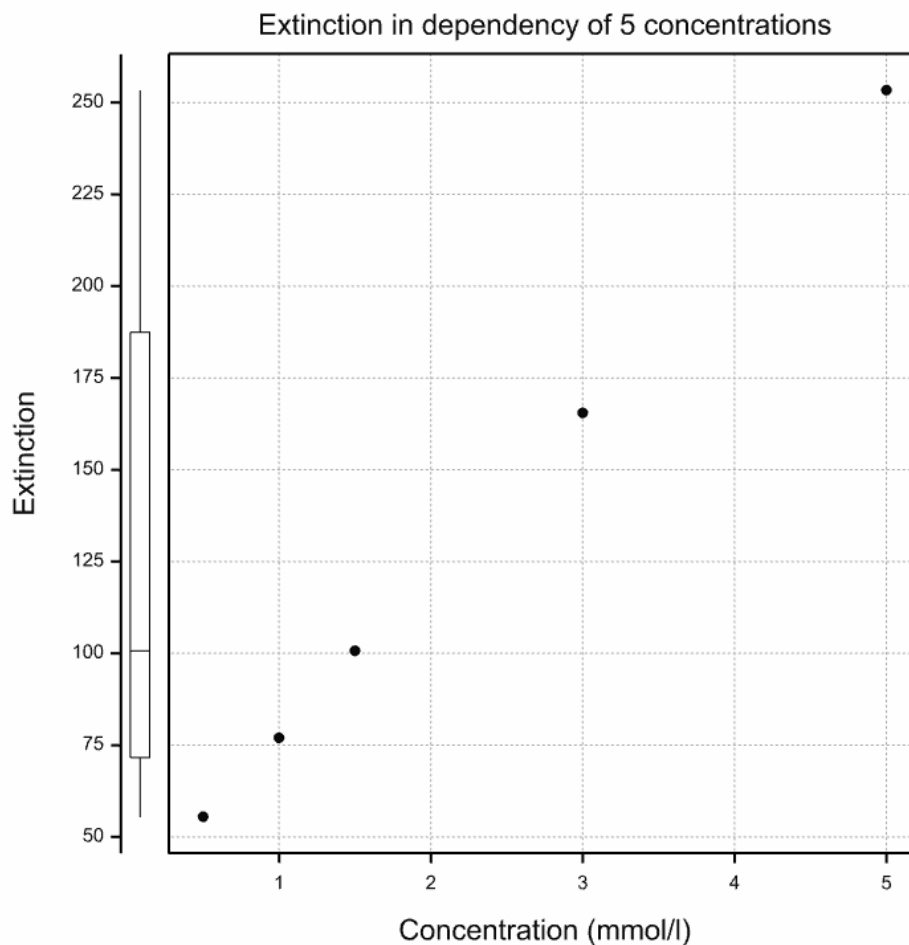
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Obs_no				5	0
concentration	0.5000	2.200	5.000	5	0
extinction	55.50	130.4	253.4	5	0

```

16
17  " Figure 2: A scatter plot of extinction against concentration with
-18  boxplot in the y margin "
19  XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'
20  YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'
21  FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
22  PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
23  DXYGRAPH [XMETHOD=*; YMETHOD=boxplot] Y=extinction; X=concentration;\
24  WINDOW=3; KEY=0; \
25  TITLE='Extinction in dependency of 5 concentrations'
26  XAXIS [RESET=yes] WINDOW=3
27  YAXIS [RESET=yes] WINDOW=3
28  FRAME [RESET=yes] WINDOW=3
29  PEN [RESET=yes] 1

```

```

30
31 " Simple linear regression "
32 MODEL [SAVE=Example2] extinction
33 TERMS concentration
34 FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
35     TPROB=yes; SELECTION=adjustedr2,r2] concentration

```

Regression analysis

Response variate: extinction
Fitted terms: Constant, concentration

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	25703.060	25703.0603	47963.34	<.001
Residual	3	1.608	0.5359		
Total	4	25704.668	6426.1670		

Adjusted r-squared statistic 1.000
R-squared statistic 1.000

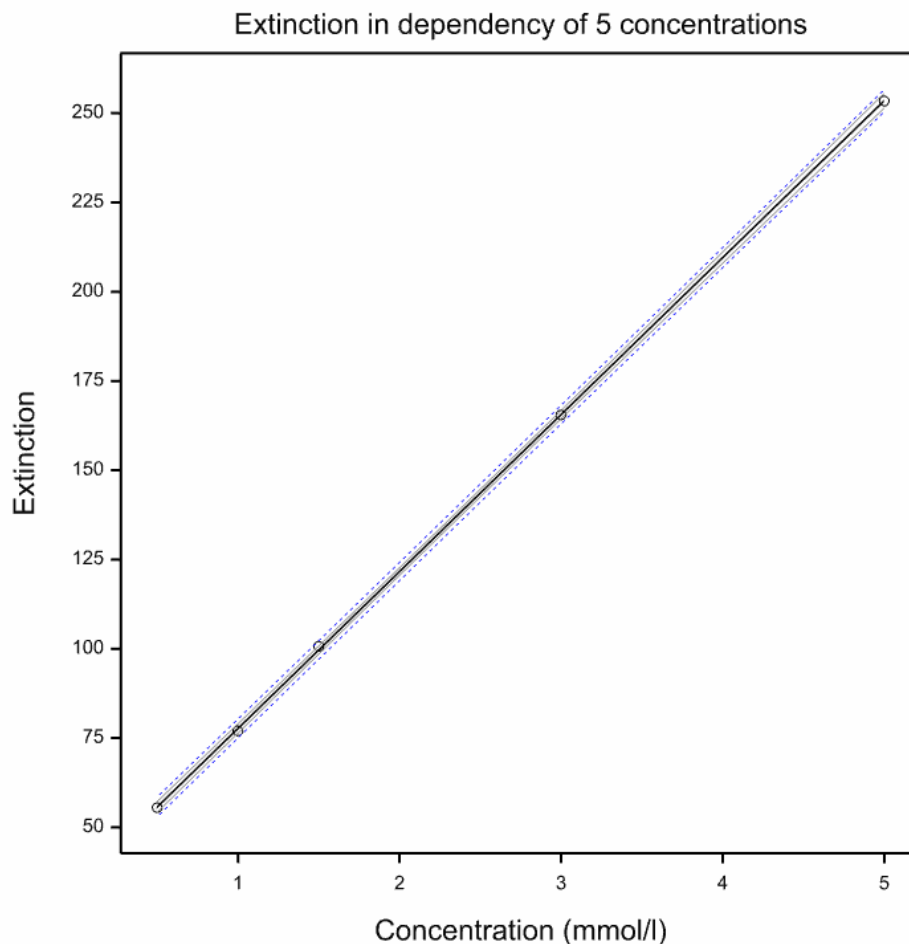
Estimates of parameters

Parameter	estimate	s.e.	t(3)	t pr.
Constant	33.706	0.550	61.31	<.001
concentration	43.961	0.201	219.01	<.001

```

36 " Figure 3: 95% confidence and prediction intervals "
37 VARIATE xlevels; !(0.5,0.6...5.0)
38 PREDICT [SAVE=Example2; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
39   SE=_predSE] CLASSIFY=concentration; LEVELS=xlevels
40 PREDICT [SAVE=Example2; PRINT=*; SCOPE=data; SE=_confSE] \
41   CLASSIFY=concentration; LEVELS=xlevels
42 RKEEP [SAVE=Example2] DF=df
43 VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
44 CALC predL = pred - EDT(0.975;df)*predSE
45 CALC predU = pred + EDT(0.975;df)*predSE
46 CALC confL = pred - EDT(0.975;df)*confSE
47 CALC confU = pred + EDT(0.975;df)*confSE
48 XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'
49 YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'
50 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
51 DGRAPH [WINDOW=3; KEY=0; \
52   TITLE='Extinction in dependency of 5 concentrations'] \
53   Y=extinction; X=concentration
54 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
55 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
56   LINESTYLE='dot'
57 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
58 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
59   Y=pred,predU,predL,confU,confL; X=xlevels
60 XAXIS [RESET=yes] WINDOW=3
61 YAXIS [RESET=yes] WINDOW=3
62 PEN [RESET=yes] 1...5

```



```

63
64 " Solution for CL and CU "
65 " Note: The IFUNCTION procedure is used. IFUNCTION solves implicit
-66 equations of functions of parameters using Newton-Raphson. "
67 CALC ext = 230 "extinction level to infer concentration at"
68 RKEEP [SAVE=Example2] MEANDEVIANCE=MSE; NOBSERVATIONS=N; \
69 ESTIMATES=estimates
70 CALC rootMSE = SQRT(MSE)
71 CALC Cmean = MEAN(concentration)
72 CALC SSC = SUM((concentration-Cmean)**2)
73 CALC constant = estimates$['Constant']
74 CALC slope = estimates$['concentration']
75 " To calculate CL using IFUNCTION, set up expressions to calculate
-76 1) the implicit function CL (fCL), and
-77 2) the 1 by 1 matrix of the derivative of the implicit function
-78 with respect to CL (dfCL) "
79 EXPRESSION [VALUE=fCL=constant + slope*CL + rootMSE * \
80 sqrt(1 + 1/N + ((CL-Cmean)**2)/SSC) * \
81 EDT(0.975;df) - ext] CalcfcCL[1]
82 EXPRESSION [VALUE=dfCL$[1;1]=slope + rootMSE * EDT(0.975;df)/SSC * \
83 (CL-Cmean) * \
84 (1 + 1/N + ((CL-Cmean)**2)/SSC)**-0.5] \
85 CalcfcCL[2]

```

```

86 IFUNCTION [ZCALCULATION=CalcfCL[]; MAXCYCLE=100] IMPLICIT=!P(CL); \
87     ZERO=fCL; DZBIMPLICIT=dfCL

```

Estimates of implicit and/or explicit functions of parameters

	Estimate	fCL
CL	4.399	2.842171E-14

```

88 " To calculate CU using IFUNCTION, set up expressions to calculate
-89     1) the implicit function CU (fCU), and
-90     2) the 1 by 1 matrix of the derivative of the implicit function
-91         with respect to CU (dfCU) "
92 EXPRESSION [VALUE=fCU=constant + slope*CU - rootMSE * \
93             sqrt(1 +1/N + ((CU-Cmean)**2)/SSC) * \
94             EDT(0.975;df) - ext] CalcfCU[1]
95 EXPRESSION [VALUE=dfCU$[1;1]=slope - rootMSE * EDT(0.975;df)/SSC * \
96             (CU-Cmean) * \
97             (1 + 1/N +((CU-Cmean)**2)/SSC)**-0.5] \
98     CalcfCU[2]
99 IFUNCTION [ZCALCULATION=CalcfCU[]; MAXCYCLE=100] IMPLICIT=!P(CU); \
100     ZERO=fCU; DZBIMPLICIT=dfCU

```

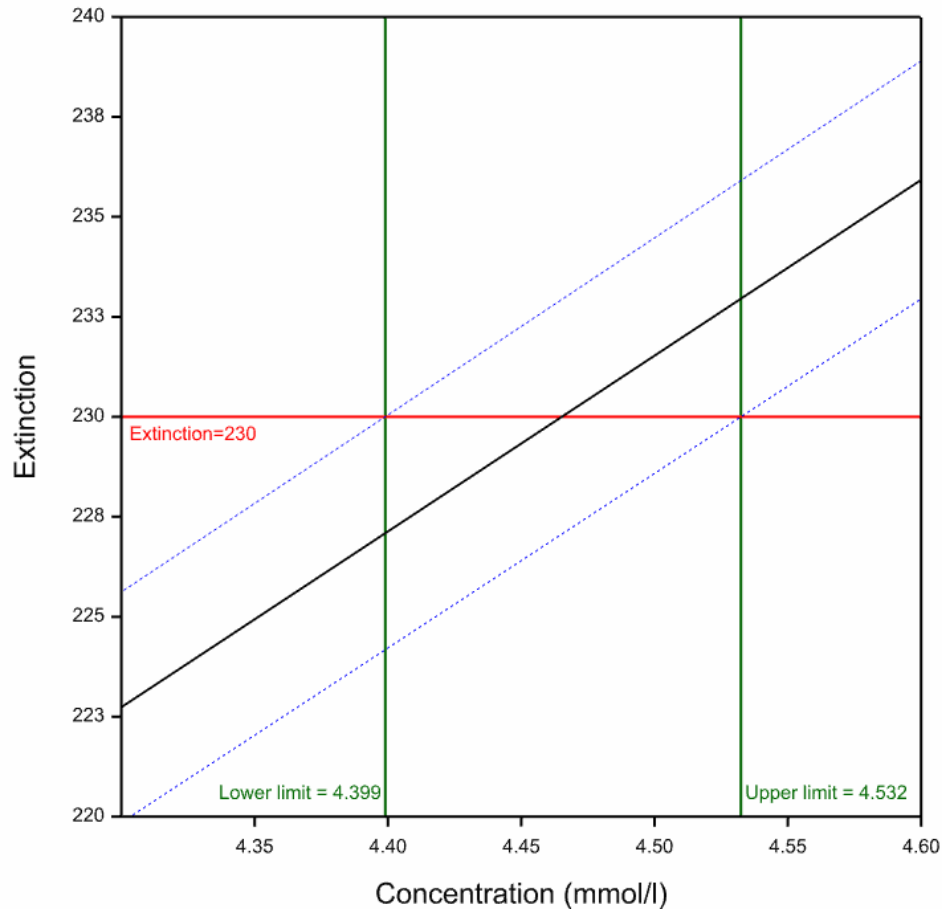
Estimates of implicit and/or explicit functions of parameters

	Estimate	fCU
CU	4.532	0.000000E+00

```

101 " Figure 5: Inference of the concentration from the extinction = 230,
-102     including Fieller's confidence interval. "
103 XAXIS [RESET=yes] WINDOW=3; TITLE='Concentration (mmol/l)'; \
104     LOWER=4.3; UPPER=4.6
105 YAXIS [RESET=yes] WINDOW=3; TITLE='Extinction'; \
106     LOWER=220; UPPER=240; DECIMALS=0
107 PEN 1; SYMBOL=0; COLOUR='black'; METHOD=line; THICKNESS=2
108 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
109     LINESTYLE='dot'
110 DGRAPH [WINDOW=3; KEY=0] Y=pred,predU,predL; X=xlevels
111 PEN 4; COLOUR='red'; METHOD=line; THICKNESS=2
112 DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=230; \
113     LABEL='Extinction=230';YLPOSITION=below; XLPOSITION=left; PEN=4; \
114     PENLABEL=4
115 PEN 5; SYMBOL=0; COLOUR='darkgreen'; METHOD=line; THICKNESS=3
116 TXCONSTRUCT [TEXT=CUlabel] 'Upper limit = ',CU
117 DREFERENCELINE [WINDOW=3; ORIENTATION=vertical] POSITION=CU; \
118     LABEL=CUlabel; YLPOSITION=below; XLPOSITION=right; PEN=5; \
119     PENLABEL=5
120 TXCONSTRUCT [TEXT=CLlabel] 'Lower limit = ',CL
121 DREFERENCELINE [WINDOW=3; ORIENTATION=vertical] POSITION=CL; \
122     LABEL=CLlabel; YLPOSITION=below; XLPOSITION=left; PEN=5; \
123     PENLABEL=5
124 XAXIS [RESET=yes] WINDOW=3
125 YAXIS [RESET=yes] WINDOW=3
126 PEN [RESET=yes] 1...5

```



```

127
128 " Table 4: Evaluation of each data point "
129 " Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
-130   by Genstat, but they are easily calculated "
131 " Internally Studentized residual "
132 RKEEP [SAVE=Example2] RESIDUALS=standardized_residual
133 " Raw residual,leverage "
134 RKEEP [SAVE=Example2; RMETHOD=simple] RESIDUAL=raw_residual; \
135   LEVERAGES=leverage
136 " Externally Studentized residual "
137 RCHECK [SAVE=Example2; RMETHOD=deletion; \
138   RESIDUAL=ex_standardized_residual] XMETHOD=*
139 " PRESS "
140 CALC Press=raw_residual/(1-leverage)
141 " Modified Cook's statistic "
142 RCHECK [SAVE=Example2; COOK=Modified_Cooks] XMETHOD=*
143 " Cook's D "
144 RKEEP [SAVE=Example2] MEANDEVIANCE=rmse
145 CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
146 " DDFITS "
147 CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
148 " DFBETA and COVRATIO "
149 RKEEP [SAVE=Example2] ESTIMATES=beta; VCOVARIANCE=vcov
150 " Note: the variance-covariance matrix of the estimates (vcov) is
-151   scaled by the residual mean square error (rmse) "

```

```

152 CALC n = NVALUES(extinction)
153 VARIATE [VALUES=1...n] ObsNum
154 VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
155 FOR [NTIMES=n; INDEX=i]
156   RESTRICT extinction,concentration; CONDITION=ObsNum .NE. i
157   MODEL extinction
158   TERMS concentration
159   FIT [PRINT=*] concentration
160   RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
161   CALC DFBETAS_intercept$[i] = (beta$[1]-beta_i$[1]) / \
162     Sqrt(rmse_i * #vcov$[1;1]/rmse)
163   CALC DFBETAS_slope$[i] = (beta$[2]-beta_i$[2]) / \
164     Sqrt(rmse_i * #vcov$[2;2]/rmse)
165   CALC covratio$[i] = DET(vcov_i) / DET(vcov)
166   RESTRICT extinction,concentration
167 ENDFOR
168 PRINT Obs_no,raw_residual,standardized_residual,\
169   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
170   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

```

Obs_no	raw_residual	standardized_residual	ex_standardized_residual	leverage
1	-0.19	-0.33	-0.28	0.42
2	-0.67	-1.10	-1.15	0.31
3	1.05	1.65	4.32	0.24
4	-0.09	-0.14	-0.11	0.25
5	-0.11	-0.33	-0.27	0.79

Press	Modified_Cooks	Cooks	DFFITS	DFBETAS_intercept
-0.32	0.29	0.04	-0.23	-0.23
-0.96	0.94	0.27	-0.77	-0.74
1.38	2.95	0.42	2.41	2.08
-0.12	0.08	0.00	-0.07	-0.01
-0.53	0.65	0.20	-0.53	0.21

DFBETAS_slope	covratio
0.17	3.58
0.46	1.17
-0.95	0.03
-0.03	2.95
-0.46	9.93

```

171
172 " Table 5 "
173 CALC PRESS=SUM(Press**2)
174 RKEEP [SAVE=Example2] SUMMARY=anova
175 PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

```

PRESS	RSS
3.224	1.608

```

176
177 ENDJOB

```

End of job.

Example 3

Genstat Commands for Example 3

```
" ***** "
"                               Example Three                               "
" ***** "

JOB

" Load the data, where Obs_no is a text structure and Block is a
  factor "
TEXT Obs_no
FACTOR Block
READ Obs_no, Day, Fibre, Block
1  0  218  1  2  0  225  2
3  0  229  3  4  0  239  4
5  5  246  1  6  5  258  2
7  5  254  3  8  5  269  4
9  10 257  1  10 10 275  2
11 10 289  3  12 10 297  4
13 15 297  1  14 15 307  2
15 15 317  3  16 15 343  4
17 20 316  1  18 20 336  2
19 20 354  3  20 20 351  4 :

" Figure 2: A scatter plot of fibre content against days after the
  first cut with boxplots in the margins "
XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
YAXIS [RESET=yes] WINDOW=3; TITLE='Fibre content (g/100g)'
FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
DXYGRAPH [XMETHOD=*; YMETHOD=boxplot] Y=Fibre; X=Day;\
  WINDOW=3; KEY=0; \
  TITLE='Fibre content against cutting date'
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1

" Simple linear regression (Tables 2A and 2D)"
MODEL [SAVE=Example3] Fibre
TERMS Day
FIT [PRINT=model,summary,estimates,confidence; CONSTANT=estimate; \
  FPROB=yes; TPROB=yes; SELECTION=adjustedr2,r2; PROBABILITY=0.95] \
  Day
" Figure 3: 95% confidence and prediction intervals "
VARIATE xlevels; !(0...20)
RKEEP [SAVE=Example3] DF=df
PREDICT [SAVE=Example3; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
  SE=_predSE] CLASSIFY=Day; LEVELS=xlevels
PREDICT [SAVE=Example3; PRINT=*; SCOPE=data; SE=_confSE] \
  CLASSIFY=Day; LEVELS=xlevels
VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
```

```

CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
YAXIS [RESET=yes] WINDOW=3; TITLE='Fibre content (g/100g)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WIN=3; KEY=0; TITLE='Fibre content against cutting date'] \
  Y=Fibre; X=Day
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Figure 6: Residual diagnostic plots "
RCHECK [SAVE=Example3] residual

" Tests for normality "
RKEEP [SAVE=Example3] RESIDUALS=standardized_residual
WSTATISTIC standardized_residual
EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
  standardized_residual

" Figure 7: A scatter plot of standardized residual against day "
XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized residual'
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=Day
PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESTYLE=2
DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
  PEN=2
RESTRICT standardized_residual; \
  CONDITION=ABS(standardized_residual) > 2;
TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Obs_no
PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
DGRAPH [WINDOW=3; SCREEN=keep] Y=standardized_residual; X=Day
RESTRICT standardized_residual
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1,2

" Table 4: Evaluation of each data point "
" Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
  by Genstat, but they are easily calculated "
" Internally Studentized residual "
RKEEP [SAVE=Example3] RESIDUALS=standardized_residual
" Raw residual,leverage "
RKEEP [SAVE=Example3; RMETHOD=simple] RESIDUAL=raw_residual; \
  LEVERAGES=leverage
" Externally Studentized residual "
RCHECK [SAVE=Example3; RMETHOD=deletion; \
  RESIDUAL=ex_standardized_residual] XMETHOD=*
" PRESS "
CALC Press=raw_residual/(1-leverage)

```



```

" Modified Cook's statistic "
RCHECK [SAVE=Example3; COOK=Modified_Cooks] XMETHOD=*
" Cook's D "
RKEEP [SAVE=Example3] MEANDEVIANCE=rmse
CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
" DDFITS "
CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
" DFBETA and COVRATIO "
RKEEP [SAVE=Example3] ESTIMATES=beta; VCOVARIANCE=vcov
" Note: the variance-covariance matrix of the estimates (vcov) is
      scaled by the residual mean square error (rmse) "
CALC n = NVALUES(Fibre)
VARIATE [VALUES=1...n] ObsNum
VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
FOR [NTIMES=n; INDEX=i]
  RESTRICT Fibre,Day; CONDITION=ObsNum .NE. i
  MODEL Fibre
  TERMS Day
  FIT [PRINT=*] Day
  RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
  CALC DFBETAS_intercept$[i] = (beta$[1]-beta_i$[1]) / \
                                SQRT(rmse_i * #vcov$[1;1]/rmse)
  CALC DFBETAS_slope$[i] = (beta$[2]-beta_i$[2]) / \
                            SQRT(rmse_i * #vcov$[2;2]/rmse)
  CALC covratio$[i] = DET(vcov_i) / DET(vcov)
  RESTRICT Fibre,Day
ENDFOR
RESTRICT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; \
CONDITION=Obs_no .IN. !T('9','16','17')
PRINT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2
RESTRICT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio

" Table 5 "
CALC PRESS=SUM(Press**2)
RKEEP [SAVE=Example3] SUMMARY=anova
PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

" Table 2B: Lack of fit "
MODEL Fibre
TERMS Day
FITINDIVIDUALLY [PRINT=accumulated; FPROB=yes; LACKOFFIT=estimate] \
Day

" Table 2C: Day is a qualitative treatment factor "
GROUP Day; DayF
MODEL Fibre
TERMS DayF
FIT [PRINT=summary; FPROB=yes] DayF

" Table 3: Based on the mean values per day "
TABULATE [PRINT=*; CLASSIFICATION=DayF] Fibre; MEANS=means

```

```

VTABLE means; content_mean; CLASSIFICATION=levels_day
VARIATE [VALUES=#levels_day] day
MODEL content_mean;
TERMS day
FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
    TPROB=yes; SELECTION=adjustedr2,r2] day
" 95% confidence intervals for the parameters "
RKEEP ESTIMATES=estimates; SE=se; DF=df
CALC upper = estimates + EDT(0.975;df)*se
CALC lower = estimates - EDT(0.975;df)*se
PRINT estimates,se,lower,upper; DECIMALS=2

" Table 18A: Example 3 (modified) with fixed block effects "
MODEL Fibre
TERMS Day+Block
FIT [PRINT=model,summary,estimates,accumulated; \
    FPROB=yes; TPROB=yes; SELECTION=adjustedr2] Day+Block
" To get the individual equations, omit the constant "
MODEL Fibre
TERMS [FULL=yes] Day+Block
FIT [PRINT=model,estimates; CONSTANT=omit; SELECTION=*] Day+Block

" Table 18B: Example 3 (modified) with fixed block effects "
" Note: By default the reference level is the first level of the
Block factor "
MODEL [SAVE=Example3_f] Fibre
TERMS Day+Block
FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
    CONSTANT=estimate; \
    FPROB=yes; TPROB=yes; SELECTION=adjustedr2] Day+Block

" Table 19: Example 3 (modified) with random block effects "
VCOMPONENTS [FIXED=Day; CADJUST=none] RANDOM=Block
REML [PRINT=model,components,effects; PTERMS='Constant'+Day+Block; \
    PSE=estimates] Fibre; SAVE=Example3_r

" Table 20: Comparison of the 95% intervals for three models "
DELETE [REDEFINE=yes] xlevels, df, _pred, _predL, _predU, _confL, _confU, \
    pred, predL, predU, confL, confU, _predSE, _confSE, predSE, confSE
VARIATE xlevels; !(0,5,10,15,20)
" Model 1: CRD (saved in Example3) "
PREDICT [SAVE=Example3; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
    SE=_predSE] CLASSIFY=Day; LEVELS=xlevels
PREDICT [SAVE=Example3; PRINT=*; SCOPE=data; SE=_confSE] \
    CLASSIFY=Day; LEVELS=xlevels
RKEEP [SAVE=Example3] DF=df
VTABLE _pred, _predSE, _confSE; VARIATE=pred, predSE, confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
PRINT xlevels, pred, df, predL, predU, confL, confU; DEC=0,1,0,4(1); \
    HEADING='Day', 'Expected Mean', 'df', 'PI L', 'PI U', 'CI L', 'CI U'; \
    FIELDWIDTH = 4,16,5,4(8)
" Model 2: RCBD fixed blocks (saved in Example3_f) "
PREDICT [SAVE=Example3_f; PRINT=*; SCOPE=data; PREDICTIONS=_pred; \
    SE=_confSE] CLASSIFY=Day; LEVELS=xlevels

```

```

RKEEP [SAVE=Example3_f] DF=df
VTABLE _pred,_confSE; VARIATE=pred,confSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
PRINT xlevels,pred,df,confL,confU; DEC=0,1,0,2(1); \
  HEADING='Day','Expected Mean','df','CI L','CI U'; \
  FIELDWIDTH = 4,16,5,2(8)
" Model 3: RCBD random blocks (saved in Example3_r) "
VPREDICT [SAVE=Example3_r; PRINT=*; PREDICTIONS=_pred; SE=_confSE] \
  CLASSIFY=Day; LEVELS=xlevels
VKEEP [SAVE=Example3_r] DDF=df
VTABLE _pred,_confSE; VARIATE=pred,confSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
PRINT xlevels,pred,df,confL,confU; DEC=0,1,0,2(1); \
  HEADING='Day','Expected Mean','df','CI L','CI U'; \
  FIELDWIDTH = 4,16,5,2(8)

ENDJOB

```

Genstat Output from Example 3

```

2  " ***** "
3  "                               Example Three "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the data, where Obs_no is a text structure and Block is a
-9  factor "
10 TEXT Obs_no
11 FACTOR Block
12 READ Obs_no, Day, Fibre, Block

```

Identifier	Minimum	Mean	Maximum	Values	Missing
Obs_no				20	0
Day	0.0000	10.00	20.00	20	0
Fibre	218.0	283.8	354.0	20	0

Identifier	Values	Missing	Levels
Block	20	0	4

```

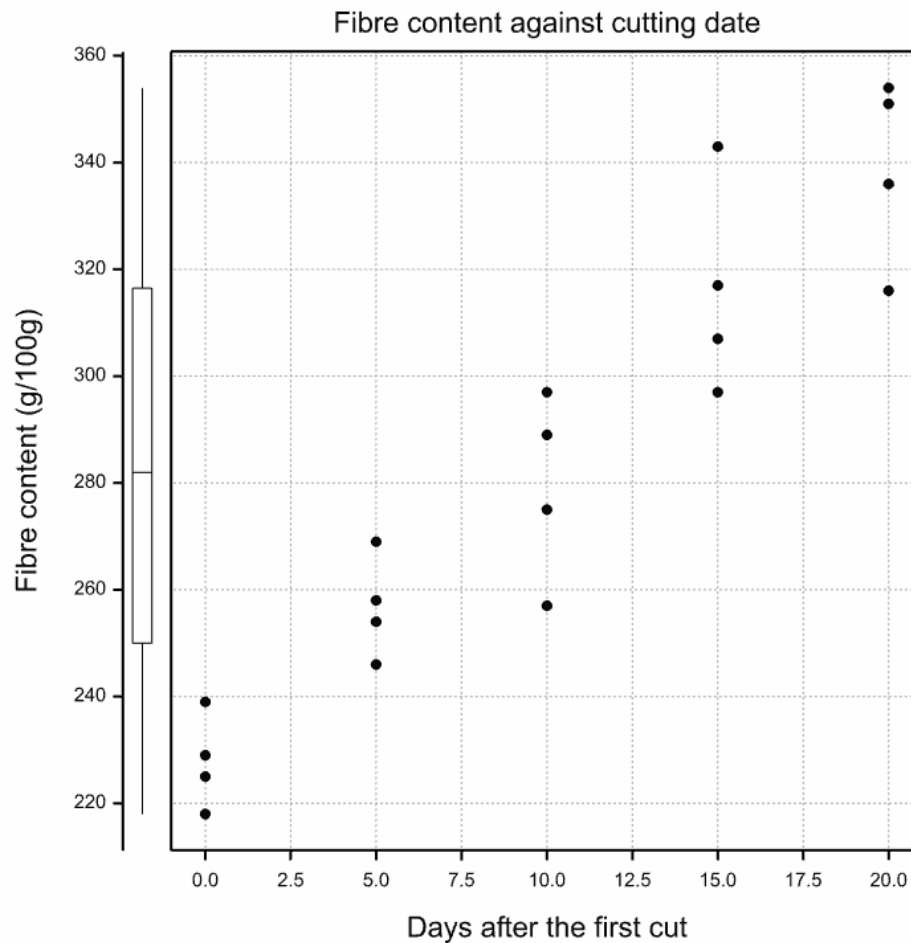
23
24 " Figure 2: A scatter plot of fibre content against days after the
-25 first cut with boxplots in the margins "
26 XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
27 YAXIS [RESET=yes] WINDOW=3; TITLE='Fibre content (g/100g)'
28 FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
29 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
30 DXYGRAPH [XMETHOD=*; YMETHODO=boxplot] Y=Fibre; X=Day;\
31 WINDOW=3; KEY=0; \

```

```

32  TITLE='Fibre content against cutting date'
33  XAXIS [RESET=yes] WINDOW=3
34  YAXIS [RESET=yes] WINDOW=3
35  FRAME [RESET=yes] WINDOW=3
36  PEN [RESET=yes] 1

```



```

37
38  " Simple linear regression (Tables 2A and 2D)"
39  MODEL [SAVE=Example3] Fibre
40  TERMS Day
41  FIT [PRINT=model,summary,estimates,confidence; CONSTANT=estimate; \
42  FPROB=yes; TPROB=yes; SELECTION=adjustedr2,r2; PROBABILITY=0.95] \
43  Day

```

Regression analysis

Response variate: Fibre
Fitted terms: Constant, Day

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	31866.	31866.0	156.95	<.001

Residual	18	3655.	203.0
Total	19	35521.	1869.5

Adjusted r-squared statistic 0.891

R-squared statistic 0.897

Message: the following units have large standardized residuals.

Unit	Response	Residual
16	343.0	2.26

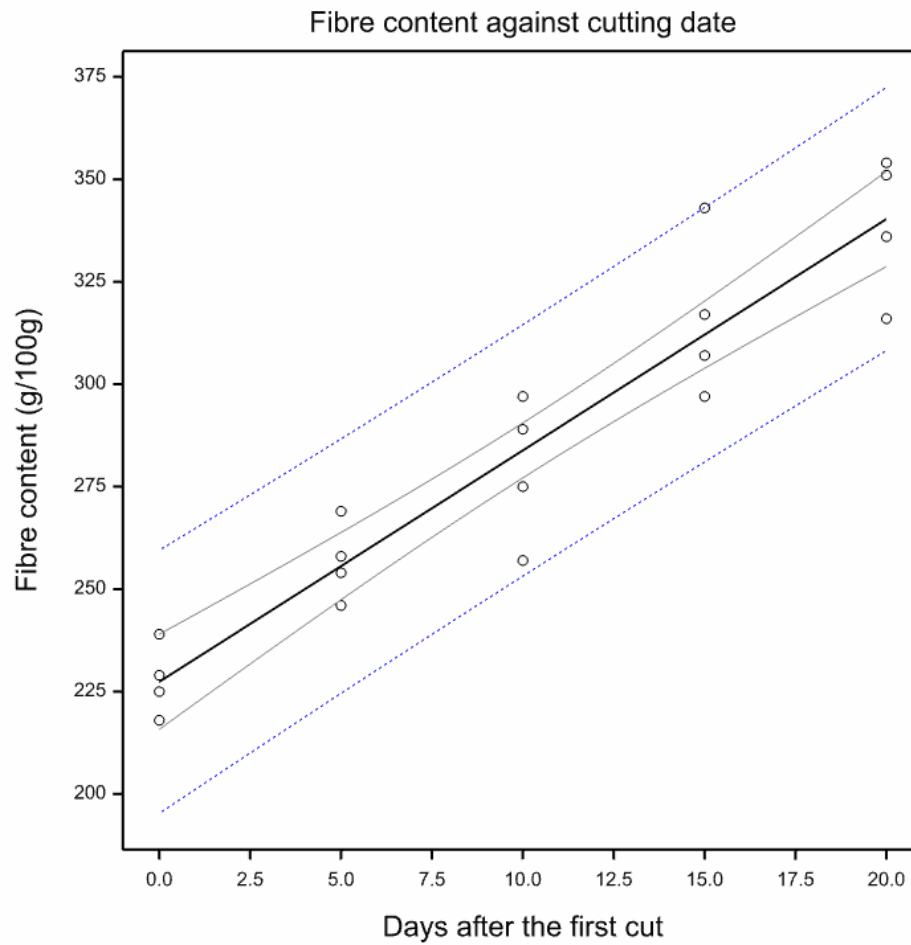
Estimates of parameters

Parameter	estimate	s.e.	t(18)	t pr.	lower 95%	upper 95%
Constant	227.40	5.52	41.21	<.001	215.8	239.0
Day	5.645	0.451	12.53	<.001	4.698	6.592

```

44 " Figure 3: 95% confidence and prediction intervals "
45 VARIATE xlevels; !(0...20)
46 RKEEP [SAVE=Example3] DF=df
47 PREDICT [SAVE=Example3; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
48   SE=_predSE] CLASSIFY=Day; LEVELS=xlevels
49 PREDICT [SAVE=Example3; PRINT=*; SCOPE=data; SE=_confSE] \
50   CLASSIFY=Day; LEVELS=xlevels
51 VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
52 CALC predL = pred - EDT(0.975;df)*predSE
53 CALC predU = pred + EDT(0.975;df)*predSE
54 CALC confL = pred - EDT(0.975;df)*confSE
55 CALC confU = pred + EDT(0.975;df)*confSE
56 XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
57 YAXIS [RESET=yes] WINDOW=3; TITLE='Fibre content (g/100g)'
58 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
59 DGRAPH [WIN=3; KEY=0; TITLE='Fibre content against cutting date'] \
60   Y=Fibre; X=Day
61 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
62 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
63   LINESTYLE='dot'
64 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
65 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
66   Y=pred,predU,predL,confU,confL; X=xlevels
67 XAXIS [RESET=yes] WINDOW=3
68 YAXIS [RESET=yes] WINDOW=3
69 PEN [RESET=yes] 1...5

```

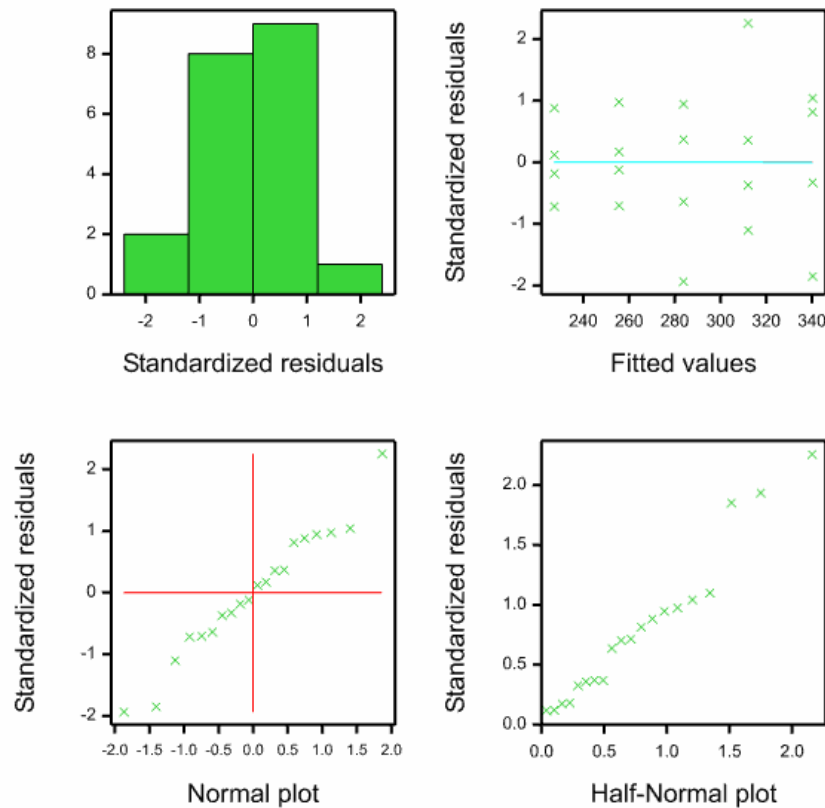


```

70
71 " Figure 6: Residual diagnostic plots "
72 RCHECK [SAVE=Example3] residual

```

Fibre



```

73
74 " Tests for normality "
75 RKEEP [SAVE=Example3] RESIDUALS=standardized_residual
76 WSTATISTIC standardized_residual

```

Shapiro-Wilk test for Normality

Data variate: standardized_residual
 Test statistic W: 0.9728
 Probability: 0.812

```

77 EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
78 standardized_residual

```

Likelihood-ratio based empirical-distribution-function goodness-of-fit tests

Distribution: Standard Normal
 mean = 0
 sd = 1

Message: Default seed for random number generator used with value 734329

Variate: standardized_residual

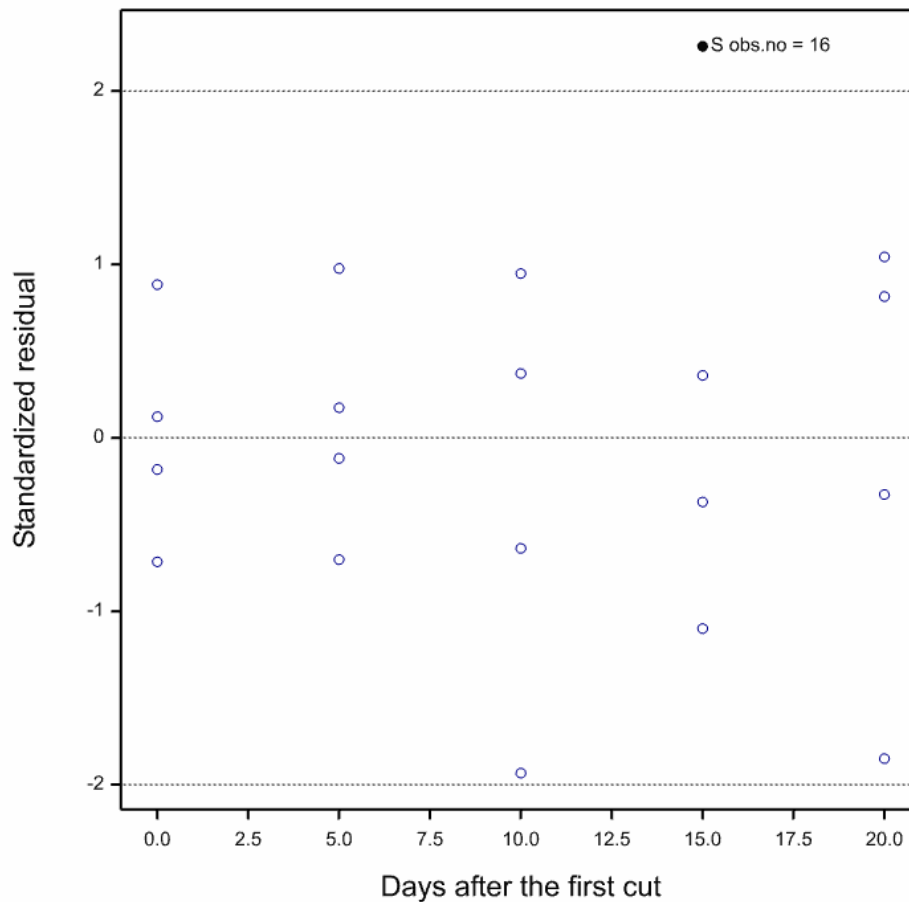
Observations: 20
Monte-Carlo simulations: 999
Seed: 0

	Statistic	Probability
LR-based Kolmogorov-Smirnov	0.507	0.957

```

79
80 " Figure 7: A scatter plot of standardized residual against day "
81 XAXIS [RESET=yes] WINDOW=3; TITLE='Days after the first cut'
82 YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized residual'
83 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
84 DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=Day
85 PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESTYLE=2
86 DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
87   PEN=2
88 RESTRICT standardized_residual; \
89   CONDITION=ABS(standardized_residual) > 2;
90 TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Obs_no
91 PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
92 DGRAPH [WINDOW=3; SCREEN=keep] Y=standardized_residual; X=Day
93 RESTRICT standardized_residual
94 XAXIS [RESET=yes] WINDOW=3
95 YAXIS [RESET=yes] WINDOW=3
96 PEN [RESET=yes] 1,2

```




```

97
98 " Table 4: Evaluation of each data point "
99 " Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
-100   by Genstat, but they are easily calculated "
101 " Internally Studentized residual "
102 RKEEP [SAVE=Example3] RESIDUALS=standardized_residual
103 " Raw residual,leverage "
104 RKEEP [SAVE=Example3; RMETHOD=simple] RESIDUAL=raw_residual; \
105   LEVERAGES=leverage
106 " Externally Studentized residual "
107 RCHECK [SAVE=Example3; RMETHOD=deletion; \
108   RESIDUAL=ex_standardized_residual] XMETHOD=*
109 " PRESS "
110 CALC Press=raw_residual/(1-leverage)
111 " Modified Cook's statistic "
112 RCHECK [SAVE=Example3; COOK=Modified_Cooks] XMETHOD=*
113 " Cook's D "
114 RKEEP [SAVE=Example3] MEANDEVIANCE=rmse
115 CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
116 " DDFITS "
117 CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
118 " DFBETA and COVRATIO "
119 RKEEP [SAVE=Example3] ESTIMATES=beta; VCOVARIANCE=vcov
120 " Note: the variance-covariance matrix of the estimates (vcov) is
-121   scaled by the residual mean square error (rmse) "
122 CALC n = NVALUES(Fibre)
123 VARIATE [VALUES=1...n] ObsNum
124 VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
125 FOR [NTIMES=n; INDEX=i]
126   RESTRICT Fibre,Day; CONDITION=ObsNum .NE. i
127   MODEL Fibre
128   TERMS Day
129   FIT [PRINT=*] Day
130   RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
131   CALC DFBETAS_intercept[i] = (beta[1]-beta_i[1]) / \
132     SQRT(rmse_i * #vcov[1;1]/rmse)
133   CALC DFBETAS_slope[i] = (beta[2]-beta_i[2]) / \
134     SQRT(rmse_i * #vcov[2;2]/rmse)
135   CALC covratio[i] = DET(vcov_i) / DET(vcov)
136   RESTRICT Fibre,Day
137 ENDFOR
138 RESTRICT Obs_no,raw_residual,standardized_residual,\
139   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
140   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; \
141   CONDITION=Obs_no .IN. !T('9','16','17')
142 PRINT Obs_no,raw_residual,standardized_residual,\
143   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
144   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

```

Obs_no	raw_residual	standardized_residual	ex_standardized_residual	leverage
9	-26.85	-1.93	-2.11	0.05
16	30.93	2.26	2.59	0.08
17	-24.30	-1.85	-2.00	0.15

Press	Modified_Cooks	Cooks	DFFITS	DFBETAS_intercept
-28.26	1.45	0.10	-0.48	-0.28
33.43	2.21	0.21	0.74	0.00

	-28.59	2.52	0.30	-0.84	0.28
DFBETAS_slope		covratio			
	0.00	0.74			
	0.43	0.62			
	-0.69	0.87			

```

145 RESTRICT Obs_no,raw_residual,standardized_residual,\
146     ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
147     DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio
148
149 " Table 5 "
150 CALC PRESS=SUM(Press**2)
151 RKEEP [SAVE=Example3] SUMMARY=anova
152 PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

      PRESS      RSS
      4457      3655

153
154 " Table 2B: Lack of fit "
155 MODEL Fibre
156 TERMS Day
157 FITINDIVIDUALLY [PRINT=accumulated; FPROB=yes; LACKOFFIT=estimate] \
158     Day

```

Message: TERMS has been redefined to include a replicate factor to estimate lack of fit; any non-default settings of the FULL, MVINCLUDE or RIDGE options will be lost.

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Day	1	31866.0	31866.0	136.29	<.001
Lack of fit	3	147.3	49.1	0.21	0.888
Residual	15	3507.3	233.8		
Total	19	35520.6	1869.5		

Message: ratios are based on dispersion parameter with value 234, and F probabilities on its specified d.f. of 15.

```

159
160 " Table 2C: Day is a qualitative treatment factor "
161 GROUP Day; DayF
162 MODEL Fibre
163 TERMS DayF
164 FIT [PRINT=summary; FPROB=yes] DayF

```

Regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	4	32013.	8003.3	34.23	<.001
Residual	15	3507.	233.8		
Total	19	35521.	1869.5		

Percentage variance accounted for 87.5

Standard error of observations is estimated to be 15.3.

Message: the following units have large standardized residuals.

Unit	Response	Residual
16	343.0	2.04

```

165
166 " Table 3: Based on the mean values per day "
167 TABULATE [PRINT=*; CLASSIFICATION=DayF] Fibre; MEANS=means
168 VTABLE means; content_mean; CLASSIFICATION=levels_day
169 VARIATE [VALUES=#levels_day] day
170 MODEL content_mean;
171 TERMS day
172 FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
173     TPROB=yes; SELECTION=adjustedr2,r2] day

```

Regression analysis

Response variate: content_mean
Fitted terms: Constant, day

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	7966.51	7966.51	649.11	<.001
Residual	3	36.82	12.27		
Total	4	8003.33	2000.83		

Adjusted r-squared statistic 0.994

R-squared statistic 0.995

Estimates of parameters

Parameter	estimate	s.e.	t(3)	t pr.
Constant	227.40	2.71	83.80	<.001
day	5.645	0.222	25.48	<.001

```

174 " 95% confidence intervals for the parameters "
175 RKEEP ESTIMATES=estimates; SE=se; DF=df
176 CALC upper = estimates + EDT(0.975;df)*se
177 CALC lower = estimates - EDT(0.975;df)*se
178 PRINT estimates,se,lower,upper; DECIMALS=2

```

	estimates	se	lower	upper
Constant	227.40	2.71	218.76	236.04
day	5.64	0.22	4.94	6.35

```

179
180 " Table 18A: Example 3 (modified) with fixed block effects "
181 MODEL Fibre
182 TERMS Day+Block
183 FIT [PRINT=model,summary,estimates,accumulated; \
184     FPROB=yes; TPROB=yes; SELECTION=adjustedr2] Day+Block

```

Regression analysis

Response variate: Fibre
 Fitted terms: Constant + Day + Block

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	4	34771.0	8692.74	173.95	<.001
Residual	15	749.6	49.97		
Total	19	35520.6	1869.50		

Adjusted r-squared statistic 0.973

Message: the following units have large standardized residuals.

Unit	Response	Residual
16	343.00	2.41

Estimates of parameters

Parameter	estimate	s.e.	t(15)	t pr.
Constant	210.35	3.87	54.33	<.001
Day	5.645	0.224	25.25	<.001
Block 2	13.40	4.47	3.00	0.009
Block 3	21.80	4.47	4.88	<.001
Block 4	33.00	4.47	7.38	<.001

Parameters for factors are differences compared with the reference level:

Factor	Reference level
Block	1

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Day	1	31866.03	31866.03	637.68	<.001
+ Block	3	2904.95	968.32	19.38	<.001
Residual	15	749.57	49.97		
Total	19	35520.55	1869.50		

```

185 " To get the individual equations, omit the constant "
186 MODEL Fibre
187 TERMS [FULL=yes] Day+Block
188 FIT [PRINT=model,estimates; CONSTANT=omit; SELECTION=*] Day+Block

```

Regression analysis

Response variate: Fibre
Fitted terms: Day + Block

Estimates of parameters

Parameter	estimate	s.e.	t(15)
Day	5.645	0.224	25.25
Block 1	210.35	3.87	54.33
Block 2	223.75	3.87	57.79
Block 3	232.15	3.87	59.96
Block 4	243.35	3.87	62.85

```

189
190 " Table 18B: Example 3 (modified) with fixed block effects "
191 " Note: By default the reference level is the first level of the
-192   Block factor "
193 MODEL [SAVE=Example3_f] Fibre
194 TERMS Day+Block
195 FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
196   CONSTANT=estimate; \
197   FPROB=yes; TPROB=yes; SELECTION=adjustedr2] Day+Block

```

Regression analysis

Response variate: Fibre
Fitted terms: Constant + Day + Block

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	4	34771.0	8692.74	173.95	<.001
Residual	15	749.6	49.97		
Total	19	35520.6	1869.50		

Adjusted r-squared statistic 0.973

Message: the following units have large standardized residuals.

Unit	Response	Residual
16	343.00	2.41

Estimates of parameters

Parameter	estimate	s.e.	t(15)	t pr.	lower 95%	upper 95%

Constant	210.35	3.87	54.33	<.001	202.1	218.6
Day	5.645	0.224	25.25	<.001	5.169	6.121
Block 2	13.40	4.47	3.00	0.009	3.871	22.93
Block 3	21.80	4.47	4.88	<.001	12.27	31.33
Block 4	33.00	4.47	7.38	<.001	23.47	42.53

Parameters for factors are differences compared with the reference level:

Factor Reference level
Block 1

```

198
199 " Table 19: Example 3 (modified) with random block effects "
200 VCOMPONENTS [FIXED=Day; CADJUST=none] RANDOM=Block
201 REML [PRINT=model,components,effects; PTERMS='Constant'+Day+Block; \
202     PSE=estimates] Fibre; SAVE=Example3_r

```

REML variance components analysis

Response variate: Fibre
Fixed model: Constant + Day
Random model: Block
Number of units: 20

Residual term has been added to model

Sparse algorithm with AI optimisation
Covariates not centred

Estimated variance components

Random term	component	s.e.
Block	183.67	158.17

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	49.97	18.25

Table of effects for Constant

227.4 Standard error: 7.31

Table of effects for Day

5.645 Standard error: 0.2235

Table of effects for Block

Block	1	2	3	4
	-16.170	-3.462	4.505	15.127

Standard error: 7.282

```

203
204 " Table 20: Comparison of the 95% intervals for three models "
205 DELETE [REDEFINE=yes] xlevels, df, _pred, _predL, _predU, _confL, _confU, \
206   _pred, _predL, _predU, _confL, _confU, _predSE, _confSE, _predSE, _confSE
207 VARIATE xlevels; !(0,5,10,15,20)
208 " Model 1: CRD (saved in Example3) "
209 PREDICT [SAVE=Example3; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
210   SE=_predSE] CLASSIFY=Day; LEVELS=xlevels
211 PREDICT [SAVE=Example3; PRINT=*; SCOPE=data; SE=_confSE] \
212   CLASSIFY=Day; LEVELS=xlevels
213 RKEEP [SAVE=Example3] DF=df
214 VTABLE _pred, _predSE, _confSE; VARIATE=pred, predSE, confSE
215 CALC predL = pred - EDT(0.975;df)*predSE
216 CALC predU = pred + EDT(0.975;df)*predSE
217 CALC confL = pred - EDT(0.975;df)*confSE
218 CALC confU = pred + EDT(0.975;df)*confSE
219 PRINT xlevels, pred, df, predL, predU, confL, confU; DEC=0,1,0,4(1); \
220   HEADING='Day', 'Expected Mean', 'df', 'PI L', 'PI U', 'CI L', 'CI U'; \
221   FIELDWIDTH = 4,16,5,4(8)

```

Day	Expected Mean	df	PI L	PI U	CI L	CI U
0	227.4	18	195.3	259.5	215.8	239.0
5	255.6		224.6	286.7	247.4	263.8
10	283.8		253.2	314.5	277.2	290.5
15	312.1		281.0	343.1	303.9	320.3
20	340.3		308.2	372.4	328.7	351.9

```

222 " Model 2: RCBD fixed blocks (saved in Example3_f) "
223 PREDICT [SAVE=Example3_f; PRINT=*; SCOPE=data; PREDICTIONS=_pred; \
224   SE=_confSE] CLASSIFY=Day; LEVELS=xlevels
225 RKEEP [SAVE=Example3_f] DF=df
226 VTABLE _pred, _confSE; VARIATE=pred, confSE
227 CALC confL = pred - EDT(0.975;df)*confSE
228 CALC confU = pred + EDT(0.975;df)*confSE
229 PRINT xlevels, pred, df, confL, confU; DEC=0,1,0,2(1); \
230   HEADING='Day', 'Expected Mean', 'df', 'CI L', 'CI U'; \
231   FIELDWIDTH = 4,16,5,2(8)

```

Day	Expected Mean	df	CI L	CI U
0	227.4	15	221.6	233.2
5	255.6		251.5	259.8
10	283.8		280.5	287.2
15	312.1		307.9	316.2
20	340.3		334.5	346.1

```

232 " Model 3: RCBD random blocks (saved in Example3_r) "
233 VPREDICT [SAVE=Example3_r; PRINT=*; PREDICTIONS=_pred; SE=_confSE] \
234 CLASSIFY=Day; LEVELS=xlevels
235 VKEEP [SAVE=Example3_r] DDF=df
236 VTABLE _pred,_confSE; VARIATE=pred,confSE
237 CALC confL = pred - EDT(0.975;df)*confSE
238 CALC confU = pred + EDT(0.975;df)*confSE
239 PRINT xlevels,pred,df,confL,confU; DEC=0,1,0,2(1); \
240 HEADING='Day','Expected Mean','df','CI L','CI U'; \
241 FIELDWIDTH = 4,16,5,2(8)

Day      Expected Mean    df      CI L      CI U
  0             227.4     15      211.8     243.0
  5             255.6             240.6     270.6
 10             283.8             269.0     298.7
 15             312.1             297.1     327.1
 20             340.3             324.7     355.9

242
243 ENDJOB

```

End of job.

Example 4

Genstat Commands for Example 4

```

" ***** "
"                               Example Four                               "
" ***** "

JOB

" Load the data, where Obs_no is a text structure "
TEXT Obs_no
READ Obs_no, Rx, wgrass, yield, Ry
1  1.5  0  9310  48      27  27.5  99      6410  23
2  1.5  0  8460  43      28  27.5  99      6640  25.5
3  4    1  9770  52      29  29    100     6010  19
4  4    1  9320  49      30  30    101     6940  28
5  4    1  8620  44      31  31.5  102     4930  14
6  6    2  7850  36.5    32  31.5  102     7620  33
7  7.5  3  9520  51      33  33.5  132     5680  17
8  7.5  3  9080  46      34  33.5  132     7570  32
9  9    4  6340  22      35  35    145     5240  16
10 10   5  9340  50      36  36    152     6320  21
11 11   17 7940  39      37  37    161     3970  9
12 12   21 8730  45      38  38    167     4790  13
13 13   22 7870  38      39  39    197     5230  15
14 14   24 8160  41      40  40    243     5980  18
15 15   31 7700  35      41  41    250     7240  29
16 16   37 8120  40      42  42    251     2340  5
17 17   46 7850  36.5    43  43    258     4320  12
18 18   51 7530  31      44  44    268     2830  6

```


19	19.5	56	7630	34	45	45	288	3810	8
20	19.5	56	9120	47	46	46	305	4260	11
21	21.5	57	6640	25.5	47	47	311	4130	10
22	21.5	57	7490	30	48	48	337	3050	7
23	23	61	6280	20	49	49	901	1740	2
24	24	81	8450	42	50	50	927	1750	3
25	25	84	6920	27	51	51	1102	1980	4
26	26	88	6550	24	52	52	1204	540	1 :

```

" Calculate transformed values "
CALC sqrt_wgrass = SQRT(wgrass)
CALC log_yield = LOG(yield)

" Figure 2: A scatter plot of yield against wind grass with boxplots
in the margins "
XAXIS [RESET=yes] WINDOW=3; TITLE='wind grass (number/plot)'
YAXIS [RESET=yes] WINDOW=3; TITLE='yield (g/plot)'
FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=yield; \
  X=wgrass; WINDOW=3; KEY=0; TITLE='Yield against weed infestation'
" Figure 2: A scatter plot of yied against square-root transformed
wind grass with boxplots in the margins "
XAXIS WINDOW=3; TITLE='sqrt(wind grass)'
DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=yield; \
  X=sqrt_wgrass; WINDOW=3; KEY=0; \
  TITLE='After transformation of weed infestation'
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1

" Simple linear regression (Figure 3) "
MODEL [SAVE=Example4] yield
TERMS sqrt_wgrass
FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
  TPROB=yes; SELECTION=adjustedr2,r2] sqrt_wgrass
" Figure 3: 95% confidence and prediction intervals "
VARIATE xlevels; !(0...35)
RKEEP [SAVE=Example4] DF=df
PREDICT [SAVE=Example4; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
  SE=_predSE] CLASSIFY=sqrt_wgrass; LEVELS=xlevels
PREDICT [SAVE=Example4; PRINT=*; SCOPE=data; SE=_confSE] \
  CLASSIFY=sqrt_wgrass; LEVELS=xlevels
VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='sqrt(wind grass)'
YAXIS [RESET=yes] WINDOW=3; TITLE='yield (g/plot)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Yield against weed infestation'] \
  Y=yield; X=sqrt_wgrass
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'

```

```

PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predU,predL,confU,confL; X=xlevels
" Figure 3 with back-transformed x-axis "
XAXIS WINDOW=3; TRANSFORM=square
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Yield against weed infestation'] \
  Y=yield; X=sqrt_wgrass
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predU,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Figure 6: Residual diagnostic plots "
RCHECK [SAVE=Example4] residual

" Tests for normality "
RKEEP [SAVE=Example4] RESIDUALS=standardized_residual
WSTATISTIC standardized_residual
EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
  standardized_residual

" Figure 7: A scatter plot of standardized residual against
  Sqrt(wind grass)"
XAXIS [RESET=yes] WINDOW=3; TITLE='sqrt(wind grass)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized residual'
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=sqrt_wgrass
PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESTYLE=2
DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
  PEN=2
RESTRICT standardized_residual; \
  CONDITION=ABS(standardized_residual) > 2;
TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Obs_no
PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
DGRAPH [WIN=3; SCREEN=keep] Y=standardized_residual; X=sqrt_wgrass
RESTRICT standardized_residual
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1,2

" Table 4: Evaluation of each data point "
" Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
  by Genstat, but they are easily calculated "
" Internally Studentized residual "
RKEEP [SAVE=Example4] RESIDUALS=standardized_residual
" Raw residual,leverage "
RKEEP [SAVE=Example4; RMETHOD=simple] RESIDUAL=raw_residual; \
  LEVERAGES=leverage
" Externally Studentized residual "
RCHECK [SAVE=Example4; RMETHOD=deletion; \
  RESIDUAL=ex_standardized_residual] XMETHOD=*

```

```

" PRESS "
CALC Press=raw_residual/(1-leverage)
" Modified Cook's statistic "
RCHECK [SAVE=Example4; COOK=Modified_Cooks] XMETHOD=*
" Cook's D "
RKEEP [SAVE=Example4] MEANDEVIANCE=rmse
CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
" DDFITS "
CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
" DFBETA and COVRATIO "
RKEEP [SAVE=Example4] ESTIMATES=beta; VCOVARIANCE=vcov
" Note: the variance-covariance matrix of the estimates (vcov) is
      scaled by the residual mean square error (rmse) "
CALC n = NVALUES(yield)
VARIATE [VALUES=1...n] ObsNum
VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
FOR [NTIMES=n; INDEX=i]
  RESTRICT yield,sqrt_wgrass; CONDITION=ObsNum .NE. i
  MODEL yield
  TERMS sqrt_wgrass
  FIT [PRINT=*] sqrt_wgrass
  RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
  CALC DFBETAS_intercept[i] = (beta[1]-beta_i[1]) / \
                                Sqrt(rmse_i * #vcov[1;1]/rmse)
  CALC DFBETAS_slope[i] = (beta[2]-beta_i[2]) / \
                            Sqrt(rmse_i * #vcov[2;2]/rmse)
  CALC covratio[i] = DET(vcov_i) / DET(vcov)
  RESTRICT yield,sqrt_wgrass
ENDFOR
RESTRICT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; \
CONDITION=Obs_no .IN. !T('9','41','42','44','49','50','51','52')
PRINT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2
RESTRICT Obs_no,raw_residual,standardized_residual,\
ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio

" Table 5 "
CALC PRESS=SUM(Press**2)
RKEEP [SAVE=Example4] SUMMARY=anova
PRINT PRESS,anova['s.s.'][$2]; HEADING='PRESS','RSS'

" Spearman's correlation coefficient "
SPEARMAN [PRINT=test,correlations] wgrass,yield

" Regression with logarithm of yield "
MODEL log_yield
TERMS wgrass
FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
TPROB=yes; SELECTION=adjustedr2,r2] wgrass

" Non-linear regression yield=B*exp(k*wgrass) "
MODEL yield
TERMS wgrass

```

```

FITCURVE [PRINT=model,summary,estimates; CURVE=exponential; \
SENSE=right; CONSTANT=omit; FPROB=yes; SELECTION=adjustedr2,r2] \
wgrass
" Note: The exponential regression,  $Y = B * R^{**}X + A$ , is the same
as another common form of the equation:  $Y = B * \exp(k * X) + A$ ,
where  $k = \ln(R)$  "
EXPRESSION [VALUE=k = LOG('R')] Calc_k
RFUNCTION [PRINT=estimate,se; CALC=Calc_k] k

" Non-linear regression  $yield = B * \exp(k * wgrass) + A$  "
MODEL yield
TERMS wgrass
FITCURVE [PRINT=model,summary,estimates; CURVE=exponential; \
SENSE=right; CONSTANT=estimate; FPROB=yes; SELECTION=adjustedr2,r2] \
wgrass
RFUNCTION [PRINT=estimate,se; CALC=Calc_k] k
" Figure 8 "
RGRAPH [TITLE='Non-linear model with 95% C.I.'; CIPLLOT=yes]

ENDJOB

```

Genstat Output from Example 4

```

2 " ***** "
3 "                               Example Four                               "
4 " ***** "
5
6 JOB

```

End of job.

```

7
8 " Load the data, where Obs_no is a text structure "
9 TEXT Obs_no
10 READ Obs_no, Rx, wgrass, yield, Ry

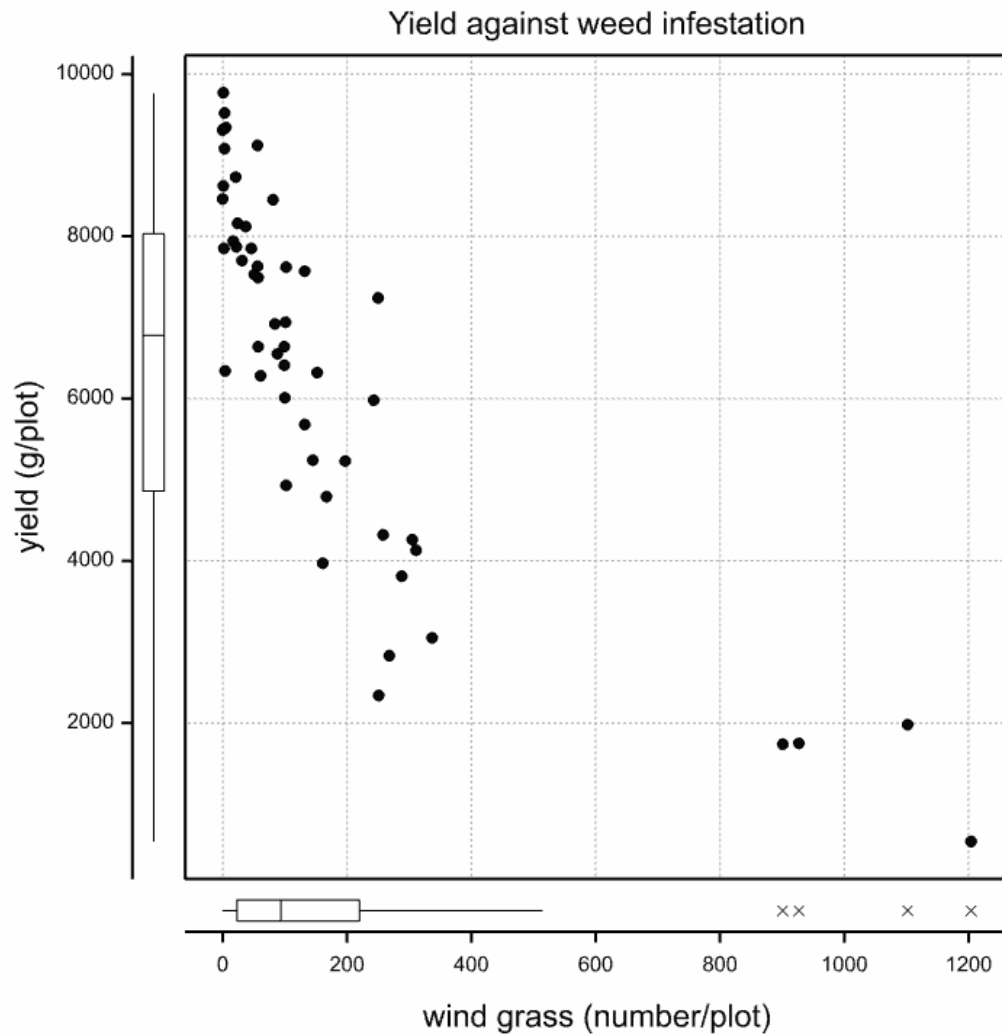
```

Identifier	Minimum	Mean	Maximum	Values	Missing	
Obs_no				52	0	
Rx	1.500	26.50	52.00	52	0	
wgrass	0.0000	175.8	1204	52	0	Skew
yield	540.0	6383	9770	52	0	
Ry	1.000	26.50	52.00	52	0	

```

37
38 " Calculate transformed values "
39 CALC sqrt_wgrass = SQRT(wgrass)
40 CALC log_yield = LOG(yield)
41
42 " Figure 2: A scatter plot of yield against wind grass with boxplots
-43   in the margins "
44 XAXIS [RESET=yes] WINDOW=3; TITLE='wind grass (number/plot)'
45 YAXIS [RESET=yes] WINDOW=3; TITLE='yield (g/plot)'
46 FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
47 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
48 DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=yield; \
49   X=wgrass; WINDOW=3; KEY=0; TITLE='Yield against weed infestation'

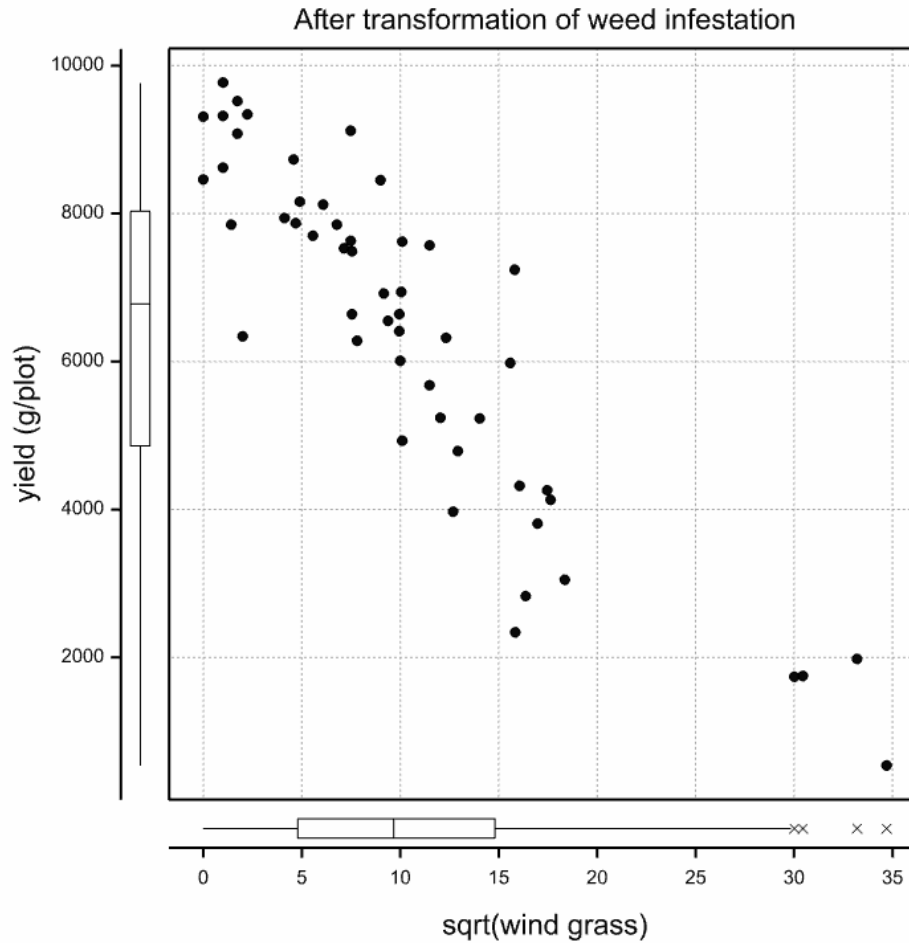
```



```

50 " Figure 2: A scatter plot of yied against square-root transformed
-51 wind grass with boxplots in the margins "
52 XAXIS WINDOW=3; TITLE='sqrt(wind grass)'
53 DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=yield; \
54 X=sqrt_wgrass; WINDOW=3; KEY=0; \
55 TITLE='After transformation of weed infestation'
56 XAXIS [RESET=yes] WINDOW=3
57 YAXIS [RESET=yes] WINDOW=3
58 FRAME [RESET=yes] WINDOW=3
59 PEN [RESET=yes] 1

```



```

60
61 " Simple linear regression (Figure 3) "
62 MODEL [SAVE=Example4] yield
63 TERMS sqrt_wgrass
64 FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
65     TPROB=yes; SELECTION=adjustedr2,r2] sqrt_wgrass

```

Regression analysis

Response variate: yield
Fitted terms: Constant, sqrt_wgrass

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	224548281.	224548281.	212.04	<.001
Residual	50	52949986.	1059000.		
Total	51	277498267.	5441142.		

Adjusted r-squared statistic 0.805
R-squared statistic 0.809

Message: the following units have large standardized residuals.

Unit	Response	Residual
32	2340.	-2.63

Message: the following units have high leverage.

Unit	Response	Leverage
46	1740.	0.131
48	1750.	0.136
50	1980.	0.171
52	540.	0.192

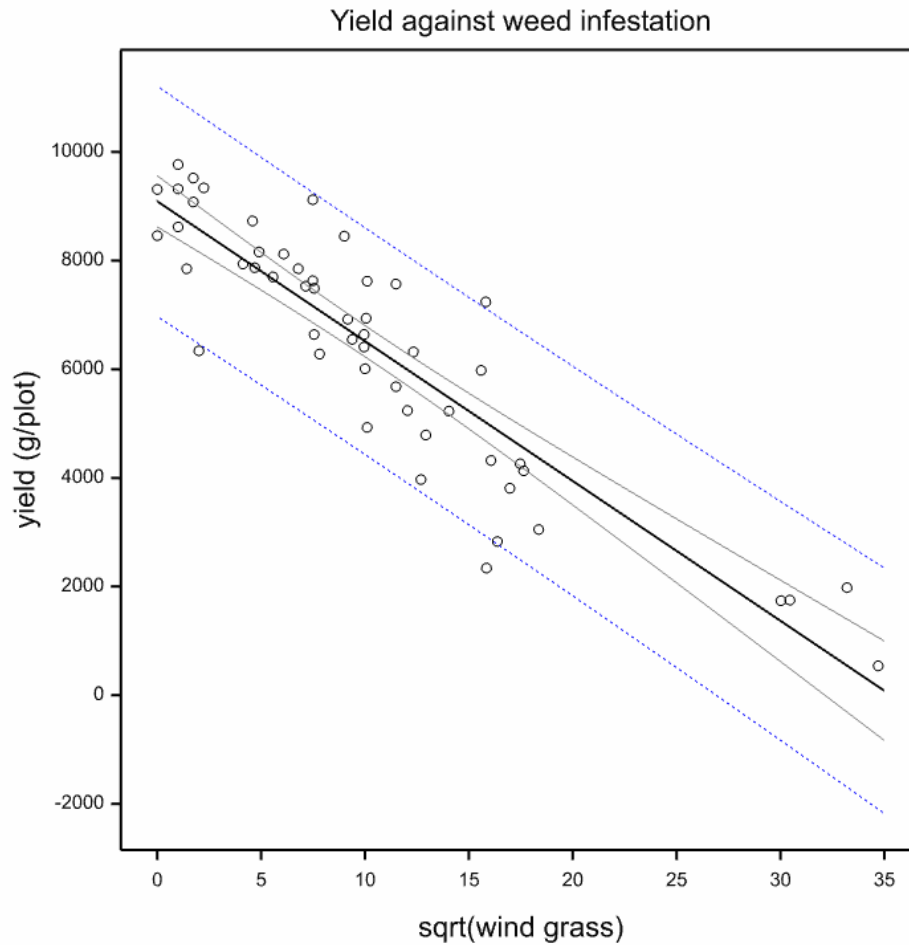
Estimates of parameters

Parameter	estimate	s.e.	t(50)	t pr.
Constant	9091.	234.	38.78	<.001
sqrt_wgrass	-257.4	17.7	-14.56	<.001

```

66 " Figure 3: 95% confidence and prediction intervals "
67 VARIATE xlevels; !(0...35)
68 RKEEP [SAVE=Example4] DF=df
69 PREDICT [SAVE=Example4; PRINT=*; SCOPE=new; PREDICTIONS=_pred; \
70   SE=_predSE] CLASSIFY=sqrt_wgrass; LEVELS=xlevels
71 PREDICT [SAVE=Example4; PRINT=*; SCOPE=data; SE=_confSE] \
72   CLASSIFY=sqrt_wgrass; LEVELS=xlevels
73 VTABLE _pred, _predSE, _confSE; VARIATE=pred,predSE,confSE
74 CALC predL = _pred - EDT(0.975;df)*_predSE
75 CALC predU = _pred + EDT(0.975;df)*_predSE
76 CALC confL = _pred - EDT(0.975;df)*_confSE
77 CALC confU = _pred + EDT(0.975;df)*_confSE
78 XAXIS [RESET=yes] WINDOW=3; TITLE='sqrt(wind grass)'
79 YAXIS [RESET=yes] WINDOW=3; TITLE='yield (g/plot)'
80 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
81 DGRAPH [WINDOW=3; KEY=0; TITLE='Yield against weed infestation'] \
82   Y=yield; X=sqrt_wgrass
83 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
84 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
85   LINESTYLE='dot'
86 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
87 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
88   Y=pred,predU,predL,confU,confL; X=xlevels

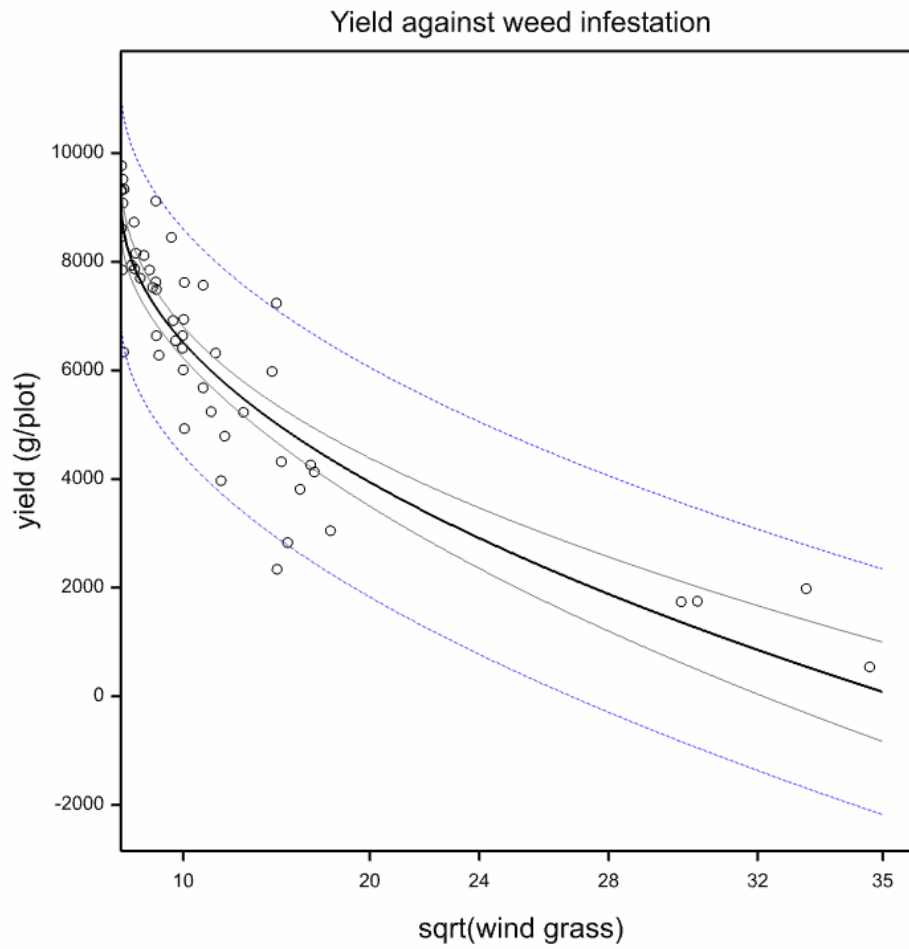
```



```

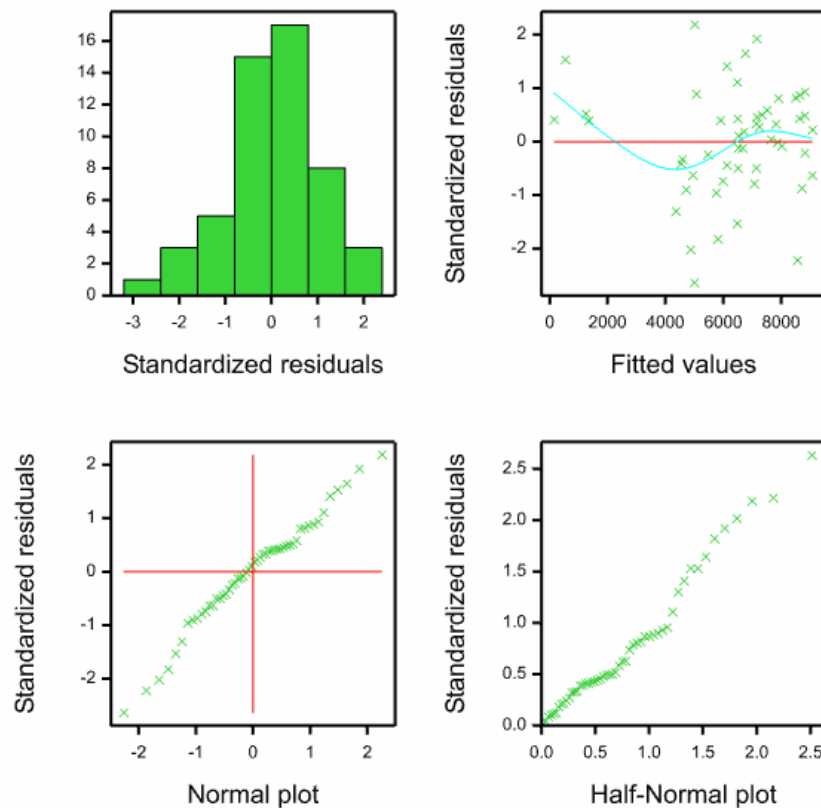
89 " Figure 3 with back-transformed x-axis "
90 XAXIS WINDOW=3; TRANSFORM=square
91 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
92 DGRAPH [WINDOW=3; KEY=0; TITLE='Yield against weed infestation'] \
93   Y=yield; X=sqrt_wgrass
94 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
95 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
96   LINESTYLE='dot'
97 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
98 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
99   Y=pred,predU,predL,confU,confL; X=xlevels
100 XAXIS [RESET=yes] WINDOW=3
101 YAXIS [RESET=yes] WINDOW=3
102 PEN [RESET=yes] 1...5

```

```
103  
104 " Figure 6: Residual diagnostic plots "  
105 RCHECK [SAVE=Example4] residual
```

yield



```

106
107 " Tests for normality "
108 RKEEP [SAVE=Example4] RESIDUALS=standardized_residual
109 WSTATISTIC standardized_residual

```

Shapiro-Wilk test for Normality

Data variate: standardized_residual
 Test statistic W: 0.9784
 Probability: 0.459

```

110 EDFTEST [TEST=kolmogorovsmirnov; DISTRIBUTION=stdnorm] \
111   standardized_residual

```

Likelihood-ratio based empirical-distribution-function goodness-of-fit tests

Distribution: Standard Normal
 mean = 0
 sd = 1

Message: Default seed for random number generator used with value 79739

Variate: standardized_residual

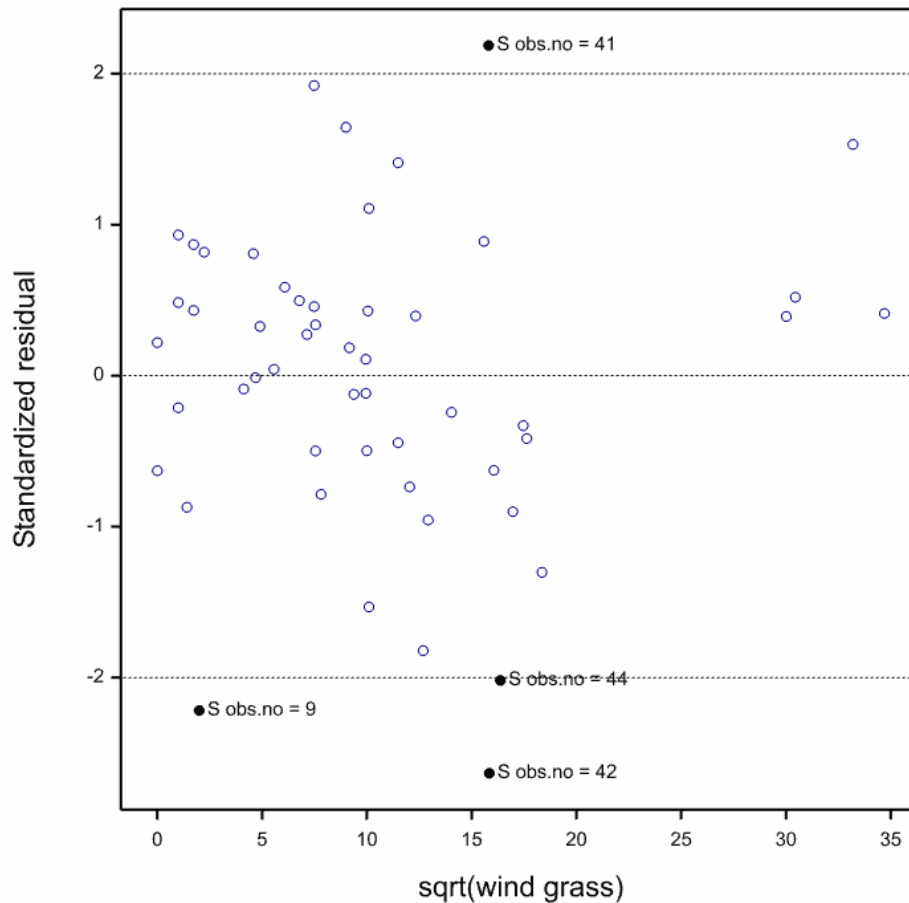
Observations: 52
Monte-Carlo simulations: 999
Seed: 0

	Statistic	Probability
LR-based Kolmogorov-Smirnov	0.673	0.966

```

112
113 " Figure 7: A scatter plot of standardized residual against
-114   Sqrt(wind grass)"
115 XAXIS [RESET=yes] WINDOW=3; TITLE='sqrt(wind grass)'
116 YAXIS [RESET=yes] WINDOW=3; TITLE='Standardized residual'
117 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; COLOUR='darkblue'
118 DGRAPH [WINDOW=3; KEY=0] Y=standardized_residual; X=sqrt_wgrass
119 PEN [RESET=yes] 2; COLOUR='black'; THICKNESS=1.2; LINESSTYLE=2
120 DREFERENCeline [WINDOW=3; ORIENTATION=horizontal] POSITION=2,0,-2; \
121   PEN=2
122 RESTRICT standardized_residual; \
123   CONDITION=ABS(standardized_residual) > 2;
124 TXCONSTRUCT [TEXT=labels] 'S obs.no = ',Obs_no
125 PEN 1; COLOUR='black'; CFILL='black'; LABELS=labels
126 DGRAPH [WIN=3; SCREEN=keep] Y=standardized_residual; X=sqrt_wgrass
127 RESTRICT standardized_residual
128 XAXIS [RESET=yes] WINDOW=3
129 YAXIS [RESET=yes] WINDOW=3
130 PEN [RESET=yes] 1,2

```



```

131
132 " Table 4: Evaluation of each data point "
133 " Note: Cook's DFFITS, DFBETAS and COVRATIO aren't directly provided
-134   by Genstat, but they are easily calculated "
135 " Internally Studentized residual "
136 RKEEP [SAVE=Example4] RESIDUALS=standardized_residual
137 " Raw residual,leverage "
138 RKEEP [SAVE=Example4; RMETHOD=simple] RESIDUAL=raw_residual; \
139   LEVERAGES=leverage
140 " Externally Studentized residual "
141 RCHECK [SAVE=Example4; RMETHOD=deletion; \
142   RESIDUAL=ex_standardized_residual] XMETHOD=*
143 " PRESS "
144 CALC Press=raw_residual/(1-leverage)
145 " Modified Cook's statistic "
146 RCHECK [SAVE=Example4; COOK=Modified_Cooks] XMETHOD=*
147 " Cook's D "
148 RKEEP [SAVE=Example4] MEANDEVIANCE=rmse
149 CALC Cooks = (raw_residual**2)/(2*rmse) * leverage/((1-leverage)**2)
150 " DDFITS "
151 CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
152 " DFBETA and COVRATIO "
153 RKEEP [SAVE=Example4] ESTIMATES=beta; VCOVARIANCE=vcov
154 " Note: the variance-covariance matrix of the estimates (vcov) is
-155   scaled by the residual mean square error (rmse) "
156 CALC n = NVALUES(yield)
157 VARIATE [VALUES=1...n] ObsNum
158 VARIATE [NVALUES=n] DFBETAS_intercept,DFBETAS_slope,covratio
159 FOR [NTIMES=n; INDEX=i]
160   RESTRICT yield,sqrt_wgrass; CONDITION=ObsNum .NE. i
161   MODEL yield
162   TERMS sqrt_wgrass
163   FIT [PRINT=*] sqrt_wgrass
164   RKEEP MEANDEVIANCE=rmse_i; ESTIMATES=beta_i; VCOVARIANCE=vcov_i
165   CALC DFBETAS_intercept[i] = (beta[1]-beta_i[1]) / \
166     Sqrt(rmse_i * #vcov[1;1]/rmse)
167   CALC DFBETAS_slope[i] = (beta[2]-beta_i[2]) / \
168     Sqrt(rmse_i * #vcov[2;2]/rmse)
169   CALC covratio[i] = DET(vcov_i) / DET(vcov)
170   RESTRICT yield,sqrt_wgrass
171 ENDFOR
172 RESTRICT Obs_no,raw_residual,standardized_residual,\
173   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
174   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; \
175   CONDITION=Obs_no .IN. !T('9','41','42','44','49','50','51','52')
176 PRINT Obs_no,raw_residual,standardized_residual,\
177   ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
178   DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio; DEC=2

```

Obs_no	raw_residual	standardized_residual	ex_standardized_residual	leverage
9	-2235.94	-2.22	-2.31	0.04
41	2219.34	2.19	2.28	0.03
42	-2672.52	-2.63	-2.81	0.03
44	-2046.68	-2.02	-2.09	0.03
49	376.02	0.39	0.39	0.13
50	496.72	0.52	0.52	0.14

51	1434.54	1.53	1.55	0.17
52	381.26	0.41	0.41	0.19

Press	Modified_Cooks	Cooks	DFFITS	DFBETAS_intercept
-2330.68	2.38	0.10	-0.48	-0.47
2282.09	1.91	0.07	0.38	0.03
-2748.36	2.37	0.10	-0.47	-0.03
-2108.53	1.81	0.06	-0.36	-0.01
432.91	0.76	0.01	0.15	-0.08
575.18	1.02	0.02	0.20	-0.10
1730.41	3.53	0.24	0.71	-0.38
471.71	1.00	0.02	0.20	-0.11

DFBETAS_slope	covratio
0.35	0.88
0.21	0.88
-0.26	0.79
-0.21	0.90
0.14	1.19
0.19	1.19
0.66	1.14
0.19	1.28

```

179 RESTRICT Obs_no,raw_residual,standardized_residual,\
180     ex_standardized_residual,leverage,Press,Modified_Cooks,Cooks,\
181     DFFITS,DFBETAS_intercept,DFBETAS_slope,covratio
182
183 " Table 5 "
184 CALC PRESS=SUM(Press**2)
185 RKEEP [SAVE=Example4] SUMMARY=anova
186 PRINT PRESS,anova['s.s.'][$[2]; HEADING='PRESS','RSS'

```

PRESS	RSS
57044697	52949986

```

187
188 " Spearman's correlation coefficient "
189 SPEARMAN [PRINT=test,correlations] wgrass,yield

```

Spearman's rank correlation coefficient

Variates wgrass and yield

Correlation -0.904, adjusted for ties -0.904

Sample size 52

t approximation -14.95 on 50 d.f., probability < 0.001

```

190
191 " Regression with logarithm of yield "
192 MODEL log_yield
193 TERMS wgrass
194 FIT [PRINT=model,summary,estimates; CONSTANT=estimate; FPROB=yes; \
195     TPROB=yes; SELECTION=adjustedr2,r2] wgrass

```

Regression analysis

Response variate: log_yield
Fitted terms: Constant, wgrass

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	12.870	12.86960	238.53	<.001
Residual	50	2.698	0.05395		
Total	51	15.567	0.30524		

Adjusted r-squared statistic 0.823
R-squared statistic 0.827

Message: the following units have large standardized residuals.

Unit	Response	Residual
32	7.758	-3.29
50	7.591	3.29

Message: the following units have high leverage.

Unit	Response	Leverage
46	7.462	0.161
48	7.467	0.171
50	7.591	0.250
52	6.292	0.304

Estimates of parameters

Parameter	estimate	s.e.	t(50)	t pr.
Constant	8.9807	0.0386	232.93	<.001
wgrass	-0.001861	0.000120	-15.44	<.001

```
196
197 " Non-linear regression yield=B*exp(k*wgrass) "
198 MODEL yield
199 TERMS wgrass
200 FITCURVE [PRINT=model,summary,estimates; CURVE=exponential; \
201 SENSE=right; CONSTANT=omit; FPROB=yes; SELECTION=adjustedr2,r2] \
202 wgrass
```

Nonlinear regression analysis

Response variate: yield
Explanatory: wgrass
Fitted Curve: $A + B \cdot (R^{**X})$
Constraints: $R < 1$; $A = 0.0$

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	2347169784.	1173584892.	1200.68	<.001
Residual	50	48871716.	977434.		
Total	52	2396041500.	46077721.		

Adjusted r-squared statistic 0.820

R-squared statistic 0.824

Message: the following units have large standardized residuals.

Unit	Response	Residual
17	6340.	-2.33
30	7240.	2.83

Estimates of parameters

Parameter	estimate	s.e.
R	0.997399	0.000259
B	8674.	231.

```

203  " Note: The exponential regression,  $Y = B * R^{**}X + A$ , is the same
-204  as another common form of the equation:  $Y = B * \exp(k * X) + A$ ,
-205  where  $k = \ln(R)$  "
206  EXPRESSION [VALUE=k = LOG('R')] Calc_k
207  RFUNCTION [PRINT=estimate,se; CALC=Calc_k] k

```

Estimates of functions of parameters

Estimates and standard errors

Parameter	estimate	s.e.
k	-0.002605	0.000260

```

208
209  " Non-linear regression  $yield = B * \exp(k * wgrass) + A$ 
210  MODEL yield
211  TERMS wgrass
212  FITCURVE [PRINT=model,summary,estimates; CURVE=exponential; \
213  SENSE=right; CONSTANT=estimate; FPROB=yes; SELECTION=adjustedr2,r2]\
214  wgrass

```

Nonlinear regression analysis

Response variate: yield
 Explanatory: wgrass
 Fitted Curve: $A + B * (R^{**}X)$
 Constraints: $R < 1$

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.

Regression	2	232020800.	116010400.	125.00	<.001
Residual	49	45477468.	928112.		
Total	51	277498267.	5441142.		

Adjusted r-squared statistic 0.829

R-squared statistic 0.836

Message: the following units have large standardized residuals.

Unit	Response	Residual
17	6340.	-2.52
30	7240.	3.01

Message: the following units have high leverage.

Unit	Response	Leverage
46	1740.	0.203
48	1750.	0.211
50	1980.	0.261
52	540.	0.285

Estimates of parameters

Parameter	estimate	s.e.
R	0.996530	0.000586
B	7552.	586.
A	1253.	585.

```
215  RFUNCTION [PRINT=estimate,se; CALC=Calc_k] k
```

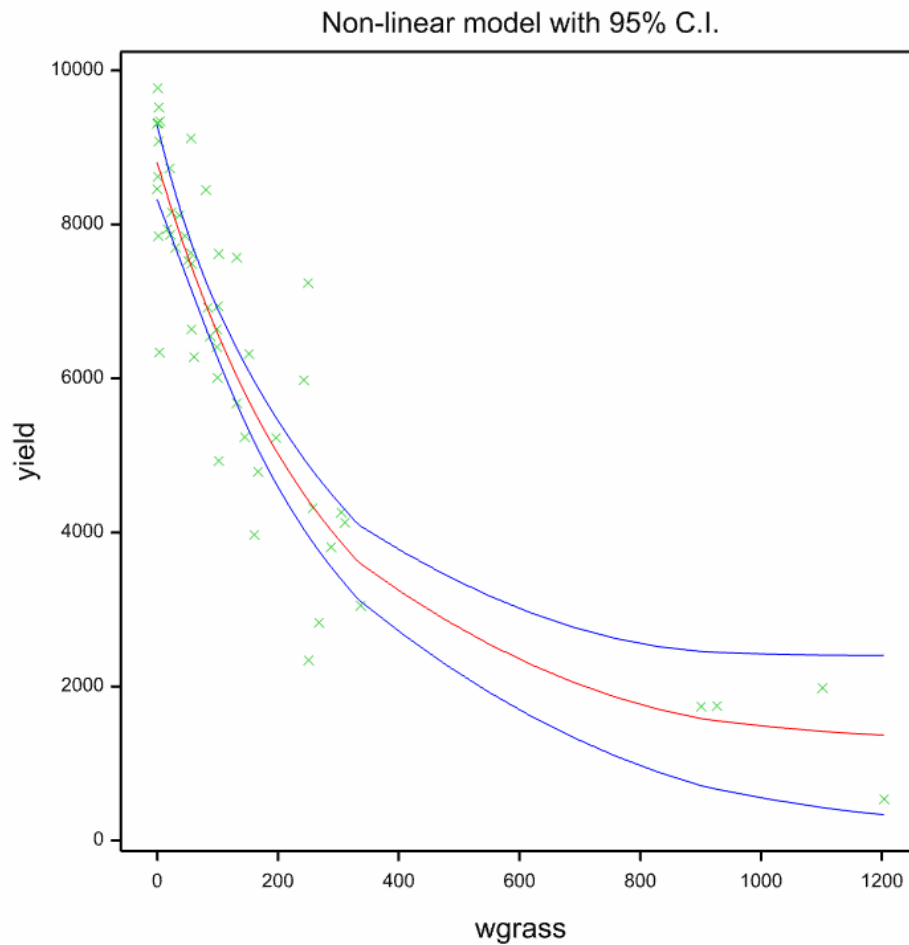
Estimates of functions of parameters

Estimates and standard errors

Parameter	estimate	s.e.
k	-0.003476	0.000588

```
216  " Figure 8 "
```

```
217  RGRAPH [TITLE='Non-linear model with 95% C.I.'; CIPLLOT=yes]
```

```
218
219  ENDJOB
```

End of job.

Example 5

Genstat Commands for Example 5

```
" ***** "
"                               Example Five                               "
" ***** "
```

JOB

```
" Load the data, where the yield for each block is in a separate
column "
```

```
READ x1, x2, yield_B1, yield_B2, yield_B3, yield_B4
30 30 5.95 5.30 6.50 6.35
30 24 7.10 6.45 6.60 5.75
30 20 7.00 6.50 6.35 8.90
30 15 8.10 5.50 6.60 7.50
```

```

24 24 8.85 7.65 7.00 7.90
24 20 7.65 6.90 8.25 8.30
24 15 7.80 6.75 8.20 7.25
20 20 8.05 6.65 8.10 8.05
20 15 9.30 8.75 8.75 8.00
15 15 9.35 8.10 7.60 7.75 :
" Stack the data "
APPEND [NEWVECTOR=x1] OLDVECTOR=4(x1)
APPEND [NEWVECTOR=x2] OLDVECTOR=4(x2)
APPEND [NEWVECTOR=yield] OLDVECTOR=yield_B1,yield_B2, \
                                yield_B3,yield_B4

CALC n = NVALUES(yield_B1)
" Create a block factor "
FACTOR [LEVELS=4; VALUES=#n(1...4)] block
" Calculate the variables area, shape_ind1 and shape_ind2 "
CALC area = x1*x2
CALC shape_ind1 = x1/x2
CALC shape_ind2 = (x1+x2)/(2*SQRT(x1*x2))
" For treatment as a factor of spacing "
CALC treatment = x1*1000+x2
GROUP treatment; treatmentF

" Estimated regression function of yield on area "
MODEL yield
TERMS area
FIT [PRINT=model,estimates; TPROB=yes] area

" Table 6: ANOVA tables "
MODEL yield
TERMS block+area+shape_ind1+shape_ind2+treatmentF
" Table 6A: Treatment as a factor of spacing "
FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
    block+treatmentF
" Table 6B: block, area and lack of fit (treatment) "
FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
    block+area+treatmentF
" Table 6C: block, area, shape index 1 and lack of fit (treatment) "
FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
    block+area+shape_ind1+treatmentF
" Table 6D: block, area, shape index 2 and lack of fit (treatment) "
FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
    block+area+shape_ind2+treatmentF

" Table 7: Raw residuals "
" Model 6B: block and area "
FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] block+area
RKEEP [RMETHOD=simple] RESIDUALS=Model_6B
" Model 6C: block, area and shape index "
FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] \
    block+area+shape_ind1
RKEEP [RMETHOD=simple] RESIDUALS=Model_6C
" Model 6C: block, area and shape index 2 "
FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] \
    block+area+shape_ind2
RKEEP [RMETHOD=simple] RESIDUALS=Model_6D
" Calculate the means "
TABULATE [PRINT=means; CLASSIFICATION=treatmentF] yield, Model_6B, \

```

```

Model_6C, Model_6D; MEANS=obs_mean,res_6B,res_6C,res_6D

" Fit final multiple regression model "
FIT [PRINT=model,estimates; TPROB=yes] area+shape_ind2

ENDJOB

```

Genstat Output from Example 5

```

2  " ***** "
3  "                               Example Five                               "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the data, where the yield for each block is in a separate
-9  column "
10 READ x1, x2, yield_B1, yield_B2, yield_B3, yield_B4

```

Identifier	Minimum	Mean	Maximum	Values	Missing
x1	15.00	24.70	30.00	10	0
x2	15.00	19.80	30.00	10	0
yield_B1	5.950	7.915	9.350	10	0
yield_B2	5.300	6.855	8.750	10	0
yield_B3	6.350	7.395	8.750	10	0
yield_B4	5.750	7.575	8.900	10	0

```

21 " Stack the data "
22 APPEND [NEWVECTOR=x1] OLDVECTOR=4(x1)
23 APPEND [NEWVECTOR=x2] OLDVECTOR=4(x2)
24 APPEND [NEWVECTOR=yield] OLDVECTOR=yield_B1,yield_B2, \
25                               yield_B3,yield_B4
26 CALC n = NVALUES(yield_B1)
27 " Create a block factor "
28 FACTOR [LEVELS=4; VALUES=#n(1...4)] block
29 " Calculate the variables area, shape_ind1 and shape_ind2 "
30 CALC area = x1*x2
31 CALC shape_ind1 = x1/x2
32 CALC shape_ind2 = (x1+x2)/(2*SQRT(x1*x2))
33 " For treatment as a factor of spacing "
34 CALC treatment = x1*1000+x2
35 GROUP treatment; treatmentF
36
37 " Estimated regression function of yield on area "
38 MODEL yield
39 TERMS area
40 FIT [PRINT=model,estimates; TPROB=yes] area

```

Regression analysis

Response variate: yield

Fitted terms: Constant, area

Estimates of parameters

Parameter	estimate	s.e.	t(38)	t pr.
Constant	9.117	0.354	25.73	<.001
area	-0.003357	0.000660	-5.09	<.001

```
41
42 " Table 6: ANOVA tables "
43 MODEL yield
44 TERMS block+area+shape_ind1+shape_ind2+treatmentF
45 " Table 6A: Treatment as a factor of spacing "
46 FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
47 block+treatment
```

Regression analysis

Response variate: yield
Fitted terms: Constant + block + treatmentF

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	12	29.02	2.4185	5.26	<.001
Residual	27	12.41	0.4598		
Total	39	41.44	1.0625		

Percentage variance accounted for 56.7
Standard error of observations is estimated to be 0.678.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.82

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ block	3	5.8800	1.9600	4.26	0.014
+ treatmentF	9	23.1423	2.5714	5.59	<.001
Residual	27	12.4137	0.4598		
Total	39	41.4360	1.0625		

```
48 " Table 6B: block, area and lack of fit (treatment) "
49 FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
50 block+area+treatmentF
```

Message: term treatmentF cannot be fully included in the model because 1 parameter is aliased with terms already in the model.

(treatmentF 30030) = - 0.3333 + (area)*0.001481 - (treatmentF 20015)*0.1111 - (treatmentF 20020)*0.2593 - (treatmentF 24015)*0.2000 - (treatmentF 24020)*0.3778 - (treatmentF 24024)*0.5200 - (treatmentF 30015)*0.3333 - (treatmentF 30020)*0.5556 - (treatmentF 30024)*0.7333

Regression analysis

Response variate: yield

Fitted terms: Constant + block + area + treatmentF

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	12	29.02	2.4185	5.26	<.001
Residual	27	12.41	0.4598		
Total	39	41.44	1.0625		

Percentage variance accounted for 56.7

Standard error of observations is estimated to be 0.678.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.82

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ block	3	5.8800	1.9600	4.26	0.014
+ area	1	16.7863	16.7863	36.51	<.001
+ treatmentF	8	6.3560	0.7945	1.73	0.137
Residual	27	12.4138	0.4598		
Total	39	41.4360	1.0625		

```

51 " Table 6C: block, area, shape index 1 and lack of fit (treatment) "
52 FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
53   block+area+shape_ind1+treatmentF

```

Message: term treatmentF cannot be fully included in the model because 2 parameters are aliased with terms already in the model.

(treatmentF 30024) = - 4.000 + (shape_ind1)*4.000 - (treatmentF 20015)*1.333 - (treatmentF 24015)*2.400 - (treatmentF 24020)*0.8000 - (treatmentF 30015)*4.000 - (treatmentF 30020)*2.000

(treatmentF 30030) = 2.600 + (area)*0.001481 - (shape_ind1)*2.933 + (treatmentF 20015)*0.8667 - (treatmentF 20020)*0.2593 + (treatmentF 24015)*1.560 + (treatmentF 24020)*0.2089 - (treatmentF 24024)*0.5200 + (treatmentF 30015)*2.600 + (treatmentF 30020)*0.9111

Regression analysis

Response variate: yield

Fitted terms: Constant + block + area + shape_ind1 + treatmentF

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	12	29.02	2.4185	5.26	<.001
Residual	27	12.41	0.4598		
Total	39	41.44	1.0625		

Percentage variance accounted for 56.7

Standard error of observations is estimated to be 0.678.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.82

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ block	3	5.8800	1.9600	4.26	0.014
+ area	1	16.7863	16.7863	36.51	<.001
+ shape_ind1	1	1.9779	1.9779	4.30	0.048
+ treatmentF	7	4.3781	0.6254	1.36	0.262
Residual	27	12.4138	0.4598		
Total	39	41.4360	1.0625		

```

54 " Table 6D: block, area, shape index 2 and lack of fit (treatment) "
55 FIT [PRINT=model,summary,accumulated; CONSTANT=estimate; FPROB=yes] \
56 block+area+shape_ind2+treatmentF

```

Message: term treatmentF cannot be fully included in the model because 2 parameters are aliased with terms already in the model.

(treatmentF 30024) = - 160.5 + (shape_ind2)*160.5 - (treatmentF 20015)*1.663 - (treatmentF 24015)*4.452 - (treatmentF 24020)*0.6674 - (treatmentF 30015)*9.736 - (treatmentF 30020)*3.310

(treatmentF 30030) = 117.4 + (area)*0.001481 - (shape_ind2)*117.7 + (treatmentF 20015)*1.109 - (treatmentF 20020)*0.2593 + (treatmentF 24015)*3.065 + (treatmentF 24020)*0.1116 - (treatmentF 24024)*0.5200 + (treatmentF 30015)*6.806 + (treatmentF 30020)*1.871

Regression analysis

Response variate: yield

Fitted terms: Constant + block + area + shape_ind2 + treatmentF

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	12	29.02	2.4185	5.26	<.001
Residual	27	12.41	0.4598		
Total	39	41.44	1.0625		

Percentage variance accounted for 56.7
Standard error of observations is estimated to be 0.678.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.82

Accumulated analysis of variance

Change	d.f.	S.S.	m.s.	v.r.	F pr.
+ block	3	5.8800	1.9600	4.26	0.014
+ area	1	16.7863	16.7863	36.51	<.001
+ shape_ind2	1	2.4937	2.4937	5.42	0.028
+ treatmentF	7	3.8622	0.5517	1.20	0.336
Residual	27	12.4138	0.4598		
Total	39	41.4360	1.0625		

```

57
58 " Table 7: Raw residuals "
59 " Model 6B: block and area "
60 FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] block+area

```

Regression analysis

Response variate: yield
Fitted terms: Constant + block + area

Summary of analysis

Source	d.f.	S.S.	m.s.	v.r.	F pr.
Regression	4	22.67	5.6666	10.57	<.001
Residual	35	18.77	0.5363		
Total	39	41.44	1.0625		

Percentage variance accounted for 49.5
Standard error of observations is estimated to be 0.732.

Message: the following units have large standardized residuals.

Unit	Response	Residual
14	5.500	-2.20
33	8.900	2.39

```

61 RKEEP [RMETHOD=simple] RESIDUALS=Model_6B
62 " Model 6C: block, area and shape index "
63 FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] \
64 block+area+shape_ind1

```

Regression analysis

Response variate: yield
Fitted terms: Constant + block + area + shape_ind1

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	5	24.64	4.9288	9.98	<.001
Residual	34	16.79	0.4939		
Total	39	41.44	1.0625		

Percentage variance accounted for 53.5

Standard error of observations is estimated to be 0.703.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.78

```
65 RKEEP [RMETHOD=simple] RESIDUALS=Model_6C
66 " Model 6C: block, area and shape index 2 "
67 FIT [PRINT=model,summary; FPROB=yes; CONSTANT=estimate] \
68   block+area+shape_ind2
```

Regression analysis

Response variate: yield

Fitted terms: Constant + block + area + shape_ind2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	5	25.16	5.0320	10.51	<.001
Residual	34	16.28	0.4787		
Total	39	41.44	1.0625		

Percentage variance accounted for 54.9

Standard error of observations is estimated to be 0.692.

Message: the following units have large standardized residuals.

Unit	Response	Residual
33	8.900	2.74

```
69 RKEEP [RMETHOD=simple] RESIDUALS=Model_6D
70 " Calculate the means "
71 TABULATE [PRINT=means; CLASSIFICATION=treatmentF] yield, Model_6B, \
72   Model_6C, Model_6D; MEANS=obs_mean,res_6B,res_6C,res_6D
```

	obs_mean	res_6B	res_6C	res_6D
treatmentF				
15015	8.200	-0.1620	-0.4231	-0.4006
20015	8.700	0.5898	0.5823	0.5105
20020	7.713	-0.0619	-0.2885	-0.2630
24015	7.500	-0.4087	-0.2134	-0.2350
24020	7.775	0.2692	0.2017	0.1427
24024	7.850	0.6665	0.4748	0.5032

30015	6.925	-0.6816	-0.1819	-0.0335
30020	7.188	0.0846	0.2557	0.2114
30024	6.475	-0.2251	-0.2092	-0.2713
30030	6.025	-0.0707	-0.1983	-0.1644

```

73
74 " Fit final multiple regression model "
75 FIT [PRINT=model,estimates; TPROB=yes] area+shape_ind2

```

Regression analysis

Response variate: yield
Fitted terms: Constant + area + shape_ind2

Estimates of parameters

Parameter	estimate	s.e.	t(37)	t pr.
Constant	23.22	6.92	3.36	0.002
area	-0.003572	0.000643	-5.56	<.001
shape_ind2	-13.82	6.77	-2.04	0.048

```

76
77 ENDJOB

```

End of job.

Example 6

Genstat Commands for Example 6

```

" ***** "
"                               Example Six                               "
" ***** "

```

JOB

```

" Load the data from file Potato.xls "
IMPORT 'Potato.xls'

" Calculate function of size or weight "
CALC size2 = size*size
CALC size3 = size*size*size
CALC log_weight = LOG(weight)
CALC log_size = LOG(size)
CALC size_reciprocal = 1/size
CALC weight1_3 = 3*weight**(1/3)

" Figure 9 "
" Scatter plot of weight against size with boxplots in the margins "
XAXIS [RESET=yes] WINDOW=3; TITLE='size (mm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='weight (g)'

```

```

FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=weight; \
  X=size; WINDOW=3; KEY=0; TITLE='Potato tuber weight against size'
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1
" Univariate measures "
GROUP size; sizeF
TABULATE [PRINT=nobs,means,variance; CLASSIFICATION=sizeF] weight

" Table 8 "
MODEL weight
TERMS size+size2+size3
" Table 8A: Analysis of variance for the regression analysis of the
  full model "
FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] \
  size+size2+size3
" Table 8B "
" Sequential and partial approach x1 - x2 - x3 "
FIT [PRINT=accumulated; CONSTANT=estimate; FPROB=yes] \
  size+size2+size3
" Sequential and partial approach x3 - x1 - x2 "
FIT [PRINT=accumulated; CONSTANT=estimate; FPROB=yes] \
  size3+size+size2
" Partial x1 | x2,x3 "
TRY [PRINT=accumulated; FPROB=yes] size
" Partial x2 | x1,x3 "
TRY [PRINT=accumulated; FPROB=yes] size2
" Partial x3 | x1,x2 "
TRY [PRINT=accumulated; FPROB=yes] size3
" Table 8C: Estimates of the fixed parameters for the full model "
FIT [PRINT=model,estimate; CONSTANT=estimate; TPROB=yes] \
  size+size2+size3
RKEEP INFLATION=vif " Note: The tolerance value (TOL) for a
  parameter estimate is the reciprocal of its
  variance inflation factor "
PRINT 1/vif; HEADING='TOL'
" Note: Genstat doesn't provide the partial correlation coefficients
  (R**2_{y|x}) directly, but they are easily computed: SS/(SS+SSE).
  For example, for size3: 249.6/(249.6+61229)"

" Table 9: Parameter estimations and selected model fit criteria "
" Note: To calculate the AIC, Genstat's regression facilities use
  the residual SS for models with a Normal distribution, rather
  than the sigma maximum likelihood value. This means that the AIC
  value from Genstat will differ to that of SAS by the constant
  -n*log(n). "
MODEL weight
TERMS size+size2+size3
" Table 9A: Models with intercept "
" Size 1,2,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
  NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
  bic] size+size2+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \

```

```

SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1,2 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size+size2
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 2,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size2+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 2 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size2
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 3 "
FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)

```

```

PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Table 9B: Models without intercept "
" Size 1,2,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size+size2+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1,2 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size+size2
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 2,3 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size2+size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 1 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 2 "
FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size2
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
" Size 3 "

```

```

FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
    bic] size3
RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
    SUMMARY=anova
CALC PRESS=SUM((raw_residual/(1-leverage))**2)
CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

" Box-Cox transformation with regressor size"
YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; UPPER=0.5; LOWER=0; \
    TERMS=size] weight " Maximum at approx lambda = 1/3 "

" Box-Cox transformation with regressor log(size)"
YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; UPPER=0.5; LOWER=0; \
    TERMS=log_size] weight " Maximum at approx lambda = 0.14 "

" Table 12 : Comparison of the results of several transformations "
" Note: the procedure YTRANSFORM is used to obtain the kernel of the
    log-likelihood. The corrected log-likelihood is obtained by
    addition of  $-N/2 \cdot \log(2 \cdot \pi)$  "
CALC N = NOBS(weight)
CALC constant =  $-N/2 \cdot \log(2 \cdot \text{CONSTANT}('pi'))$ 
" Model 1: lambda = 0, log(size) "
MODEL log_weight
FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
    NOMESSAGE=residual,inflation] log_size
YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=0; \
    TERMS=log_size] weight; SAVE=output
CALC LL1 = output[4]$(1;2)+constant
" Model 2: lambda = 0.14, log(size) "
CALC Tweight =  $(1/0.14) \cdot (\text{weight} \cdot 0.14 - 1)$ 
MODEL Tweight
FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
    NOMESSAGE=residual,inflation] log_size
YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=0.14; \
    TERMS=log_size] weight; SAVE=output
CALC LL2 = output[4]$(1;2)+constant
" Model 3: lambda = 1/3, size "
CALC Tweight =  $3 \cdot (\text{weight} \cdot (1/3) - 1)$ 
MODEL Tweight
FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
    NOMESSAGE=residual,inflation] size
YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=1/3; \
    TERMS=size] weight; SAVE=output
CALC LL3 = output[4]$(1;2)+constant
" Model 4: weight, size3 "
MODEL weight
FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
    NOMESSAGE=residual,inflation; CONSTANT=omit] size3
" Corrected -2log-likelihood for models 1,2 and 3 "
PRINT -2*LL1,LL2,LL3; HEADING='Model 1','Model 2','Model 3'; DEC=2

" Figure 10: Observed data and regression function with confidence
    and prediction intervals "
" Untransformed "
FIT [PRINT=*] size3

```

```

VARIATE xlevels; !(32.5...57.5)
PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
  CLASSIFY=size3; LEVELS=xlevels**3
PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=size3; \
  LEVELS=xlevels**3
RKEEP DF=df
VTABLE _pred, _predSE, _confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Size (mm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Weight and size of potato tubers'] \
  Y=weight; X=size
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predU,predL,confU,confL; X=xlevels
" Box-Cox transformation "
CALC Tweight = 3*(weight**(1/3) - 1) " Box-Cox with lambda = 1/3 "
MODEL Tweight
FIT [PRINT=*] size
PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
  CLASSIFY=size; LEVELS=xlevels
PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=size; \
  LEVELS=xlevels
RKEEP DF=df
VTABLE _pred, _predSE, _confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Size (mm)'
YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (transformed)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Weight and size of potato tubers'] \
  Y=Tweight; X=size
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
  Y=pred,predU,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
FRAME [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Table 14 : Comparison of unweighted regression with several
  approaches to describe the variance heterogeneity "
" Note : Power-of-x model and power-of-mean model are not directly
  available in Genstat 19, and individual variance per size model
  must be fitted using the REML facilities "

```

```

" Unweighted regression by ML "
MODEL weight
TERMS size3
FIT [PRINT=model,summary,estimate; TPROB=yes; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=aic] size3
RKEEP RESIDUALS=unweightedreg
" Unweighted regression by REML "
VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none]
REML [PRINT=model,components,effects,waldTests] weight
VAIC [PRINT=aic]
" Weighted regression (with weight 1/size) by ML "
MODEL [WEIGHTS=size_reciprocal] weight
TERMS size3
FIT [PRINT=model,summary,estimate; TPROB=yes; CONSTANT=omit; \
    NOMESSAGE=residual,inflation; SELECTION=aic] size3
" Weighted regression (with weight 1/size) by REML "
VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none]
REML [PRINT=model,components,effects,waldTests; \
    WEIGHTS=size_reciprocal] weight
VAIC [PRINT=aic]
" Individual variance per size by REML "
GROUP size; sizeF
VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none; \
    EXPERIMENTS=sizeF]
REML [PRINT=model,components,effects,waldTests] weight
VAIC [PRINT=aic]
VFRESIDUALS [RMETHOD=all; RESIDUALS=weightedreg; SERESIDUALS=se]

" Figure 13 "
FFRAME [ROWS=1; COLUMNS=2; RLOWER=0.5; MARGIN=ytitle,xtitle]
YAXIS WINDOW=1; TITLE='Studentized residuals'
XAXIS WINDOW=1,2; TITLE='Size'
DGRAPH [WINDOW=1; KEY=0; TITLE='Unweighted regression'] \
    Y=unweightedreg; X=size
DGRAPH [WINDOW=2; KEY=0; SCREEN=keep; \
    TITLE='Regression with individual variance per size'] \
    Y=weightedreg/se; X=size
XAXIS [RESET=yes] WINDOW=1,2
YAXIS [RESET=yes] WINDOW=1

ENDJOB

```

Genstat Output from Example 6

```

2  " ***** "
3  "                               Example Six                               "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the data from file Potato.xls "
9  IMPORT 'Potato.xls'

```

Loading Spreadsheet File

Catalogue of file Potato.xls

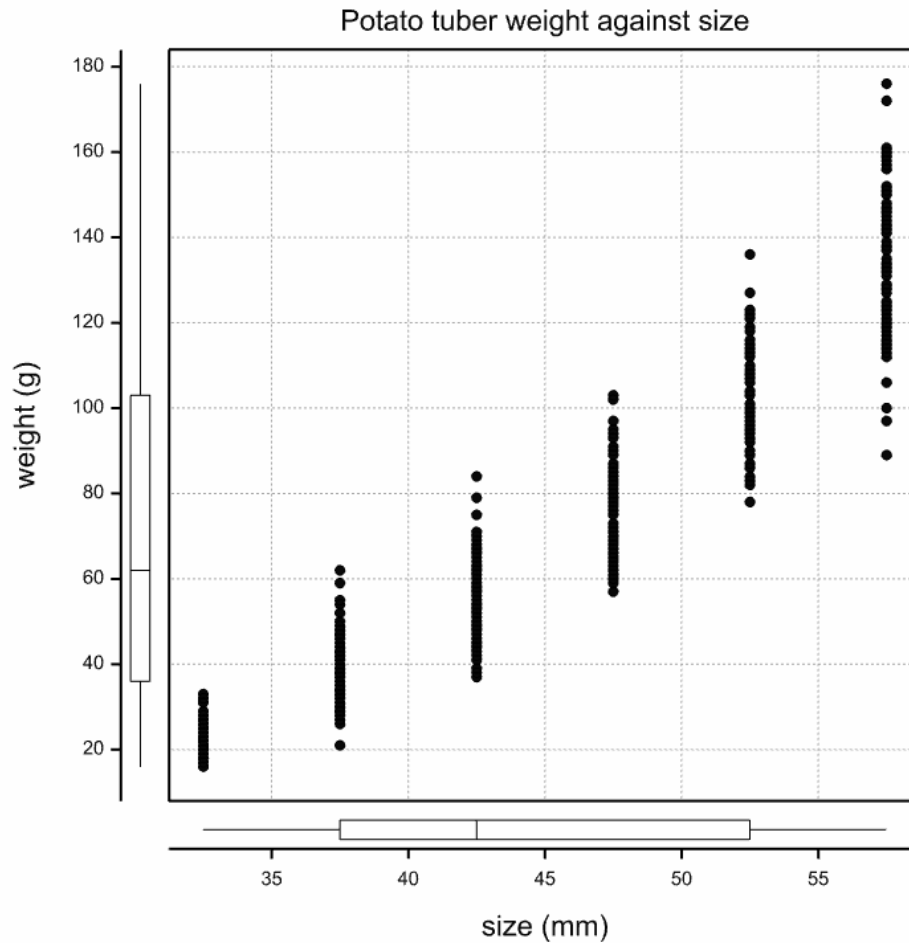
Sheet Title: Tabelle1

Description: Data read from Potato.xls [Tabelle1]A2:B525

Sheet Type: vector

Index	Type	Nval	Name
1	variate	524	size
2	variate	524	weight

```
10
11 " Calculate function of size or weight "
12 CALC size2 = size*size
13 CALC size3 = size*size*size
14 CALC log_weight = LOG(weight)
15 CALC log_size = LOG(size)
16 CALC size_reciprocal = 1/size
17 CALC weight1_3 = 3*weight**(1/3)
18
19 " Figure 9 "
20 " Scatter plot of weight against size with boxplots in the margins "
21 XAXIS [RESET=yes] WINDOW=3; TITLE='size (mm) '
22 YAXIS [RESET=yes] WINDOW=3; TITLE='weight (g) '
23 FRAME [RESET=yes; GRID=xy,yx] WINDOW=3
24 PEN [RESET=yes] 1; METHOD=point; SYMBOL='circle'; CFILL='black'
25 DXYGRAPH [XMETHOD=*; YMETHOD=boxplot; XMETHOD=boxplot] Y=weight; \
26   X=size; WINDOW=3; KEY=0; TITLE='Potato tuber weight against size'
27 XAXIS [RESET=yes] WINDOW=3
28 YAXIS [RESET=yes] WINDOW=3
29 FRAME [RESET=yes] WINDOW=3
30 PEN [RESET=yes] 1
```

```

31 " Univariate measures "
32 GROUP size; sizeF
33 TABULATE [PRINT=nobs,means,variance; CLASSIFICATION=sizeF] weight

```

	Nobservd	Mean	Variance
sizeF			
32.5	92	22.93	13.5
37.5	89	38.26	56.2
42.5	97	55.06	89.4
47.5	83	75.18	123.9
52.5	68	103.16	166.8
57.5	95	134.23	265.6

```

34
35 " Table 8 "
36 MODEL weight
37 TERMS size+size2+size3
38 " Table 8A: Analysis of variance for the regression analysis of the
-39 full model "
40 FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] \
41 size+size2+size3

```

Regression analysis

Response variate: weight
Fitted terms: Constant + size + size2 + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	783828.	261276.1	2218.95	<.001
Residual	520	61229.	117.7		
Total	523	845057.	1615.8		

Percentage variance accounted for 92.7
Standard error of observations is estimated to be 10.9.

Message: the following units have large standardized residuals.

Unit	Response	Residual
428	136.0	3.14
429	136.0	3.14
430	89.0	-4.21
431	97.0	-3.47
432	100.0	-3.19
523	172.0	3.48
524	176.0	3.85

Message: the residuals do not appear to be random; for example, fitted values in the range 55.1 to 55.1 are consistently larger than observed values and fitted values in the range 134.5 to 134.5 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

```
42 " Table 8B "  
43 " Sequential and partial approach x1 - x2 - x3 "  
44 FIT [PRINT=accumulated; CONSTANT=estimate; FPROB=yes] \  
45 size+size2+size3
```

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ size	1	767104.0	767104.0	6514.80	<.001
+ size2	1	16474.7	16474.7	139.91	<.001
+ size3	1	249.6	249.6	2.12	0.146
Residual	520	61228.9	117.7		
Total	523	845057.1	1615.8		

```

46 " Sequential and partial approach x3 - x1 - x2 "
47 FIT [PRINT=accumulated; CONSTANT=estimate; FPROB=yes] \
48 size3+size+size2

```

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ size3	1	783609.4	783609.4	6654.98	<.001
+ size	1	122.9	122.9	1.04	0.307
+ size2	1	95.9	95.9	0.81	0.367
Residual	520	61228.9	117.7		
Total	523	845057.1	1615.8		

```

49 " Partial x1 | x2,x3 "
50 TRY [PRINT=accumulated; FPROB=yes] size

```

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ size3	1	783609.4	783609.4	6654.98	<.001
+ size	1	122.9	122.9	1.04	0.307
+ size2	1	95.9	95.9	0.81	0.367
Residual	520	61228.9	117.7		
- size	-1	-106.7	106.7	0.91	0.342
Total	523	845057.1	1615.8		

```

51 " Partial x2 | x1,x3 "
52 TRY [PRINT=accumulated; FPROB=yes] size2

```

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ size3	1	783609.4	783609.4	6654.98	<.001
+ size	1	122.9	122.9	1.04	0.307
+ size2	1	95.9	95.9	0.81	0.367
Residual	520	61228.9	117.7		
- size2	-1	-95.9	95.9	0.81	0.367
Total	523	845057.1	1615.8		

```

53 " Partial x3 | x1,x2 "
54 TRY [PRINT=accumulated; FPROB=yes] size3

```

Regression analysis

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ size3	1	783609.4	783609.4	6654.98	<.001
+ size	1	122.9	122.9	1.04	0.307
+ size2	1	95.9	95.9	0.81	0.367
Residual	520	61228.9	117.7		
- size3	-1	-249.6	249.6	2.12	0.146
Total	523	845057.1	1615.8		

```

55  " Table 8C: Estimates of the fixed parameters for the full model "
56  FIT [PRINT=model,estimate; CONSTANT=estimate; TPROB=yes] \
57      size+size2+size3

```

Regression analysis

Response variate: weight
Fitted terms: Constant + size + size2 + size3

Estimates of parameters

Parameter	estimate	s.e.	t(520)	t pr.
Constant	-101.	101.	-1.00	0.317
size	6.68	7.02	0.95	0.342
size2	-0.144	0.159	-0.90	0.367
size3	0.00172	0.00118	1.46	0.146

Message: the variance of some parameter estimates is seriously inflated, due to near collinearity or aliasing between the following parameters, listed with their variance inflation factors.

size	16370.72
size2	68884.09
size3	18398.14

```

58  RKEEP INFLATION=vif " Note: The tolerance value (TOL) for a
-59                          parameter estimate is the reciprocal of its
-60                          variance inflation factor "
61  PRINT 1/vif; HEADING='TOL'

```

```

TOL
0.00002194
0.00006108
0.00001452
0.00005435

```

```

62 " Note: Genstat doesn't provide the partial correlation coefficients
-63 (R**2_{y|x}) directly, but they are easily computed: SS/(SS+SSE).
-64 For example, for size3: 249.6/(249.6+61229)"
65
66 " Table 9: Parameter estimations and selected model fit criteria "
67 " Note: To calculate the AIC, Genstat's regression facilities use
-68 the residual SS for models with a Normal distribution, rather
-69 than the sigma maximum likelihood value. This means that the AIC
-70 value from Genstat will differ to that of SAS by the constant
-71 -n*log(n). "
72 MODEL weight
73 TERMS size+size2+size3
74 " Table 9A: Models with intercept "
75 " Size 1,2,3 "
76 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
77 NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
78 bic] size+size2+size3

```

Regression analysis

Response variate: weight
 Fitted terms: Constant + size + size2 + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	783828.	261276.1	2218.95
Residual	520	61229.	117.7	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.927
 Dispersion parameter is estimated to be 118.
 Akaike information criterion is estimated to be 5784.
 Schwarz Bayes information criterion is estimated to be 5801.

Estimates of parameters

Parameter	estimate	s.e.	t(520)
Constant	-101.	101.	-1.00
size	6.68	7.02	0.95
size2	-0.144	0.159	-0.90
size3	0.00172	0.00118	1.46

```

79 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
80 SUMMARY=anova
81 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
82 CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
83 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

```

```

PRESS |RSS-PRESS|
62218.605      989.7

```

```

84 " Size 1,2 "
85 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
86     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
87     bic] size+size2

```

Regression analysis

Response variate: weight

Fitted terms: Constant + size + size2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	2	783579.	391789.3	3320.22
Residual	521	61478.	118.0	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.927

Dispersion parameter is estimated to be 118.

Akaike information criterion is estimated to be 5784.

Schwarz Bayes information criterion is estimated to be 5797.

Estimates of parameters

Parameter	estimate	s.e.	t(521)
Constant	44.4	14.8	3.01
size	-3.490	0.672	-5.19
size2	0.08777	0.00743	11.82

```

88 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
89     SUMMARY=anova
90 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
91 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS)
92 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

```

PRESS	RSS-PRESS
62236.918	758.5

```

93 " Size 1,3 "
94 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
95     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
96     bic] size+size3

```

Regression analysis

Response variate: weight

Fitted terms: Constant + size + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.

Regression	2	783732.	391866.2	3329.20
Residual	521	61325.	117.7	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.927

Dispersion parameter is estimated to be 118.

Akaike information criterion is estimated to be 5783.

Schwarz Bayes information criterion is estimated to be 5795.

Estimates of parameters

Parameter	estimate	s.e.	t(521)
Constant	-10.5	10.2	-1.03
size	0.355	0.347	1.02
size3	0.0006534	0.0000550	11.89

```

97  RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
98  SUMMARY=anova
99  CALC PRESS=SUM((raw_residual/(1-leverage))**2)
100 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
101 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

```

PRESS	RSS-PRESS
62092.654	767.9

```

102 " Size 2,3 "
103 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
104     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
105     bic] size2+size3

```

Regression analysis

Response variate: weight

Fitted terms: Constant + size2 + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	2	783722.	391860.8	3328.57
Residual	521	61336.	117.7	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.927

Dispersion parameter is estimated to be 118.

Akaike information criterion is estimated to be 5783.

Schwarz Bayes information criterion is estimated to be 5795.

Estimates of parameters

Parameter	estimate	s.e.	t(521)
Constant	-5.13	5.22	-0.98

size2	0.00768	0.00787	0.98
size3	0.000599	0.000113	5.31

```

106 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
107     SUMMARY=anova
108 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
109 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]]-PRESS)
110 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

      PRESS |RSS-PRESS|
62114.700      779.1

111 " Size 1 "
112 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
113     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
114     bic] size

```

Regression analysis

Response variate: weight
Fitted terms: Constant + size

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	767104.	767104.0	5136.78
Residual	522	77953.	149.3	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.908
Dispersion parameter is estimated to be 149.
Akaike information criterion is estimated to be 5906.
Schwarz Bayes information criterion is estimated to be 5915.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
Constant	-127.59	2.81	-45.36
size	4.4277	0.0618	71.67

```

115 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
116     SUMMARY=anova
117 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
118 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]]-PRESS)
119 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

      PRESS |RSS-PRESS|
78603.229      650.1

120 " Size 2 "
121 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \
122     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
123     bic] size2

```


Regression analysis

Response variate: weight
Fitted terms: Constant + size2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	780399.	780398.9	6300.33
Residual	522	64658.	123.9	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.923
Dispersion parameter is estimated to be 124.
Akaike information criterion is estimated to be 5808.
Schwarz Bayes information criterion is estimated to be 5817.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
Constant	-31.94	1.38	-23.19
size2	0.049338	0.000622	79.37

```
124 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \  
125     SUMMARY=anova  
126 CALC PRESS=SUM((raw_residual/(1-leverage))**2)  
127 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS)  
128 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1  
  
    PRESS |RSS-PRESS|  
    65220.094      561.9  
  
129 " Size 3 "  
130 FIT [PRINT=model,summary,estimate; CONSTANT=estimate; \  
131     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\  
132     bic] size3
```

Regression analysis

Response variate: weight
Fitted terms: Constant + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	783609.	783609.4	6656.78
Residual	522	61448.	117.7	
Total	523	845057.	1615.8	

Adjusted r-squared statistic 0.927

Dispersion parameter is estimated to be 118.
 Akaike information criterion is estimated to be 5782.
 Schwarz Bayes information criterion is estimated to be 5790.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
Constant	-0.125	0.985	-0.13
size3	0.00070890	0.00000869	81.59

```

133 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
134     SUMMARY=anova
135 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
136 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])
137 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

```

PRESS	RSS-PRESS
62008.124	560.4

```

138 " Table 9B: Models without intercept "
139 " Size 1,2,3 "
140 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
141     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
142     bic] size+size2+size3

```

Regression analysis

Response variate: weight
 Fitted terms: size + size2 + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	3376994.	1125664.7	9559.91
Residual	521	61347.	117.7	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.927
 Dispersion parameter is estimated to be 118.
 Akaike information criterion is estimated to be 5783.
 Schwarz Bayes information criterion is estimated to be 5796.

Estimates of parameters

Parameter	estimate	s.e.	t(521)
size	-0.338	0.362	-0.93
size2	0.0149	0.0160	0.93
size3	0.000548	0.000172	3.19

```

143 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
144     SUMMARY=anova
145 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
146 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS)
147 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

      PRESS |RSS-PRESS|
62137.369      790.4

148 " Size 1,2 "
149 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
150     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
151     bic] size+size2

```

Regression analysis

Response variate: weight
Fitted terms: size + size2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	2	3375795.	1687897.6	14087.02
Residual	522	62546.	119.8	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.926
Dispersion parameter is estimated to be 120.
Akaike information criterion is estimated to be 5791.
Schwarz Bayes information criterion is estimated to be 5799.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
size	-1.4766	0.0617	-23.95
size2	0.06575	0.00127	51.89

```

152 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
153     SUMMARY=anova
154 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
155 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS)
156 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

      PRESS |RSS-PRESS|
63115.328      569.6

157 " Size 1,3 "
158 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \
159     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\
160     bic] size+size3

```

Regression analysis

Response variate: weight
Fitted terms: size + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	2	3376891.	1688445.7	14342.97
Residual	522	61450.	117.7	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.927
Dispersion parameter is estimated to be 118.
Akaike information criterion is estimated to be 5782.
Schwarz Bayes information criterion is estimated to be 5790.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
size	-0.0009	0.0336	-0.03
size3	0.0007083	0.0000135	52.44

```
161 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \  
162 SUMMARY=anova  
163 CALC PRESS=SUM((raw_residual/(1-leverage))**2)  
164 CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)  
165 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
```

PRESS	RSS-PRESS
62034.419	584.9

```
166 " Size 2,3 "  
167 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \  
168 NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\  
169 bic] size2+size3
```

Regression analysis

Response variate: weight
Fitted terms: size2 + size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	2	3376892.	1688445.9	14343.05
Residual	522	61449.	117.7	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.927
Dispersion parameter is estimated to be 118.
Akaike information criterion is estimated to be 5782.

Schwarz Bayes information criterion is estimated to be 5790.

Estimates of parameters

Parameter	estimate	s.e.	t(522)
size2	0.00009	0.00148	0.06
size3	0.0007062	0.0000290	24.35

```
170 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \  
171 SUMMARY=anova  
172 CALC PRESS=SUM((raw_residual/(1-leverage))**2)  
173 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])  
174 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
```

PRESS	RSS-PRESS
62058.117	608.9

```
175 " Size 1 "  
176 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \  
177 NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\  
178 bic] size
```

Regression analysis

Response variate: weight
Fitted terms: size

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	3053143.	3053143.1	4145.39
Residual	523	385198.	736.5	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.544

Dispersion parameter is estimated to be 737.

Akaike information criterion is estimated to be 6741.

Schwarz Bayes information criterion is estimated to be 6746.

Estimates of parameters

Parameter	estimate	s.e.	t(523)
size	1.6765	0.0260	64.38

```
179 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \  
180 SUMMARY=anova  
181 CALC PRESS=SUM((raw_residual/(1-leverage))**2)  
182 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS])  
183 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
```

PRESS	RSS-PRESS

386814.481 1616.6

```
184 " Size 2 "  
185 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \  
186     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\  
187     bic] size2
```

Regression analysis

Response variate: weight
Fitted terms: size2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	3307088.	3307088.4	13177.70
Residual	523	131253.	251.0	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.845
Dispersion parameter is estimated to be 251.
Akaike information criterion is estimated to be 6177.
Schwarz Bayes information criterion is estimated to be 6182.

Estimates of parameters

Parameter	estimate	s.e.	t(523)
size2	0.035853	0.000312	114.79

```
188 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \  
189     SUMMARY=anova  
190 CALC PRESS=SUM((raw_residual/(1-leverage))**2)  
191 CALC RSS_PRESS=ABS(anova['s.s.'][$[2]-PRESS)  
192 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1
```

PRESS	RSS-PRESS
131882.920	630.3

```
193 " Size 3 "  
194 FIT [PRINT=model,summary,estimate; CONSTANT=omit; \  
195     NOMESSAGE=residual,inflation; SELECTION=adjustedr2,dispersion,aic,\  
196     bic] size3
```

Regression analysis

Response variate: weight
Fitted terms: size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.

Regression	1	3376891.	3376891.4	28740.85
Residual	523	61450.	117.5	
Total	524	3438341.	6561.7	

Adjusted r-squared statistic 0.927

Dispersion parameter is estimated to be 117.

Akaike information criterion is estimated to be 5780.

Schwarz Bayes information criterion is estimated to be 5784.

Estimates of parameters

Parameter	estimate	s.e.	t(523)
size3	0.00070793	0.00000418	169.53

```

197 RKEEP [RMETHOD=simple] RESIDUAL=raw_residual; LEVERAGES=leverage; \
198 SUMMARY=anova
199 CALC PRESS=SUM((raw_residual/(1-leverage))**2)
200 CALC RSS_PRESS=ABS(anova['s.s.'][$2]-PRESS)
201 PRINT PRESS,RSS_PRESS; HEADING='PRESS','|RSS-PRESS|'; DEC=3,1

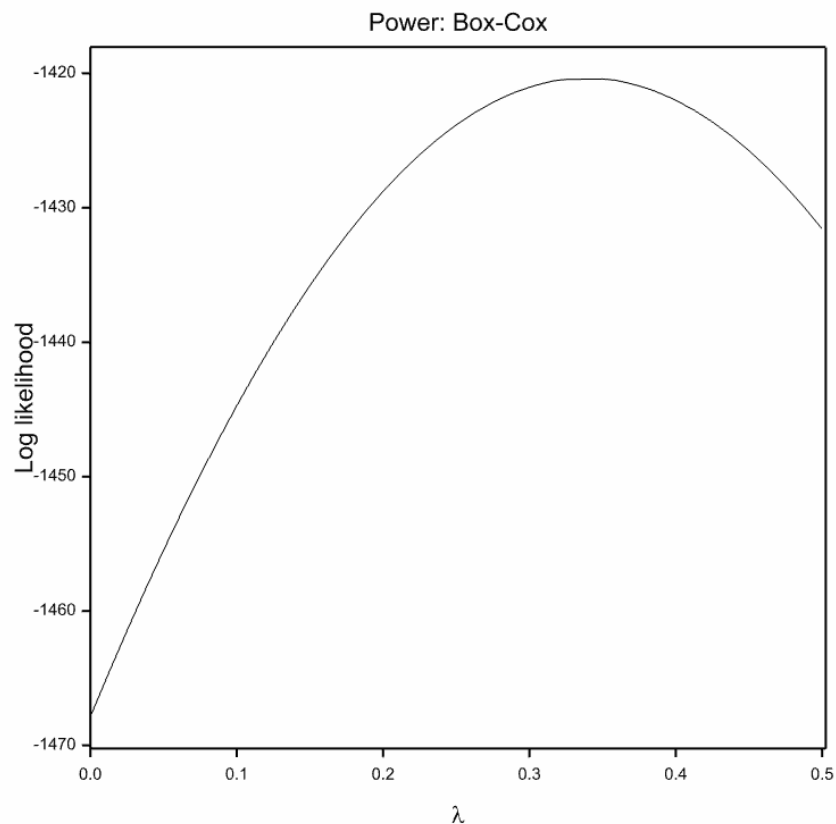
```

PRESS	RSS-PRESS
61844.399	394.8

```

202
203 " Box-Cox transformation with regressor size"
204 YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; UPPER=0.5; LOWER=0; \
205 TERMS=size] weight " Maximum at approx lambda = 1/3 "

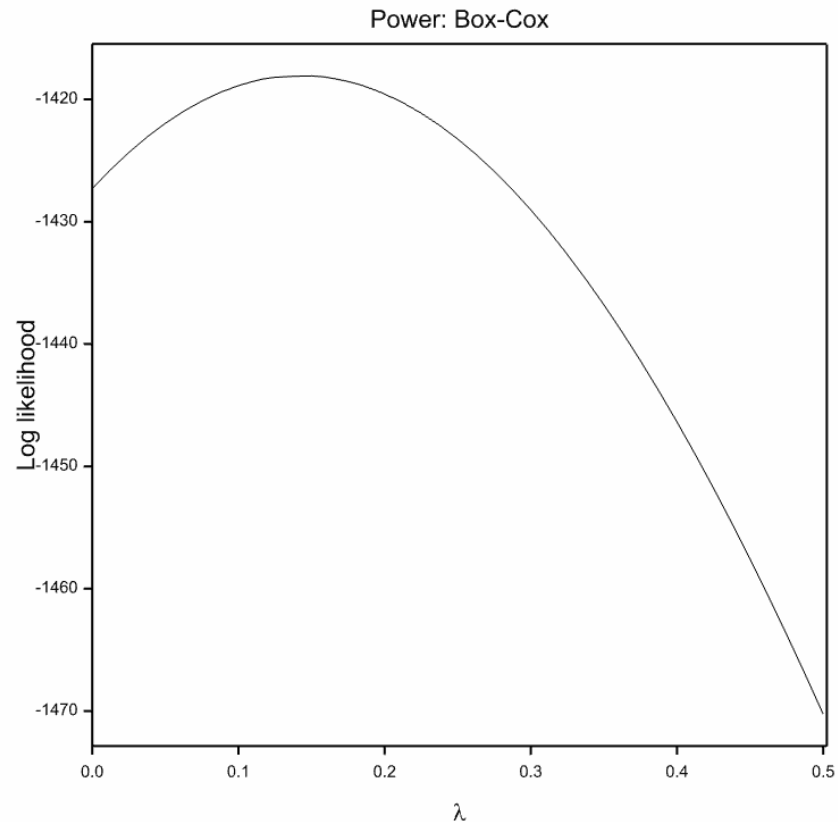
```



```

206
207 " Box-Cox transformation with regressor log(size)"
208 YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; UPPER=0.5; LOWER=0; \
209     TERMS=log_size] weight " Maximum at approx lambda = 0.14 "

```



```

210
211 " Table 12 : Comparison of the results of several transformations "
212 " Note: the procedure YTRANSFORM is used to obtain the kernel of the
-213   log-likelihood. The corrected log-likelihood is obtained by
-214   addition of  $-N/2 \cdot \log(2 \cdot \pi)$  "
215 CALC N = NOBS(weight)
216 CALC constant =  $-N/2 \cdot \log(2 \cdot \text{CONSTANT}('pi'))$ 
217 " Model 1: lambda = 0, log(size) "
218 MODEL log_weight
219 FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
220     NOMESSAGE=residual,inflation] log_size

```

Regression analysis

Response variate: log_weight
 Fitted terms: Constant, log_size

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	191.07	191.06629	7687.13
Residual	522	12.97	0.02486	

Total	523	204.04	0.39014

Percentage variance accounted for 93.6
Standard error of observations is estimated to be 0.158.

Estimates of parameters

Parameter	estimate	s.e.	t(522)	lower 95%	upper 95%
Constant	-7.544	0.133	-56.86	-7.805	-7.283
log_size	3.0725	0.0350	87.68	3.004	3.141

```

221  YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=0; \
222      TERMS=log_size] weight; SAVE=output
223  CALC LL1 = output[4]$[1;2]+constant
224  " Model 2: lambda = 0.14, log(size) "
225  CALC Tweight = (1/0.14)*(weight**0.14 - 1)
226  MODEL Tweight
227  FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
228      NOMESSAGE=residual,inflation] log_size

```

Regression analysis

Response variate: Tweight
Fitted terms: Constant, log_size

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	591.07	591.07086	7874.64
Residual	522	39.18	0.07506	
Total	523	630.25	1.20507	

Percentage variance accounted for 93.8
Standard error of observations is estimated to be 0.274.

Estimates of parameters

Parameter	estimate	s.e.	t(522)	lower 95%	upper 95%
Constant	-14.894	0.231	-64.60	-15.35	-14.44
log_size	5.4041	0.0609	88.74	5.284	5.524

```

229  YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=0.14; \
230      TERMS=log_size] weight; SAVE=output
231  CALC LL2 = output[4]$[1;2]+constant
232  " Model 3: lambda = 1/3, size "
233  CALC Tweight = 3*(weight**(1/3) - 1)
234  MODEL Tweight
235  FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \
236      NOMESSAGE=residual,inflation] size

```

Regression analysis

Response variate: Tweight
Fitted terms: Constant, size

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	2865.2	2865.1509	7832.72
Residual	522	190.9	0.3658	
Total	523	3056.1	5.8434	

Percentage variance accounted for 93.7
Standard error of observations is estimated to be 0.605.

Estimates of parameters

Parameter	estimate	s.e.	t(522)	lower 95%	upper 95%
Constant	-3.185	0.139	-22.88	-3.458	-2.911
size	0.27060	0.00306	88.50	0.2646	0.2766

```
237 YTRANSFORM [TRANSFORM=power; METHOD=BoxCox; LAMBDA=1/3; \  
238 TERMS=size] weight; SAVE=output  
239 CALC LL3 = output[4]$(1;2)+constant  
240 " Model 4: weight, size3 "  
241 MODEL weight  
242 FIT [PRINT=model,summary,estimates,confidence; PROBABILITY=0.95; \  
243 NOMESSAGE=residual,inflation; CONSTANT=omit] size3
```

Regression analysis

Response variate: weight
Fitted terms: size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	3376891.	3376891.4	28740.85
Residual	523	61450.	117.5	
Total	524	3438341.	6561.7	

Percentage variance accounted for 92.7
Standard error of observations is estimated to be 10.8.

Estimates of parameters

Parameter	estimate	s.e.	t(523)	lower 95%	upper 95%
size3	0.00070793	0.00000418	169.53	0.0006997	0.0007161

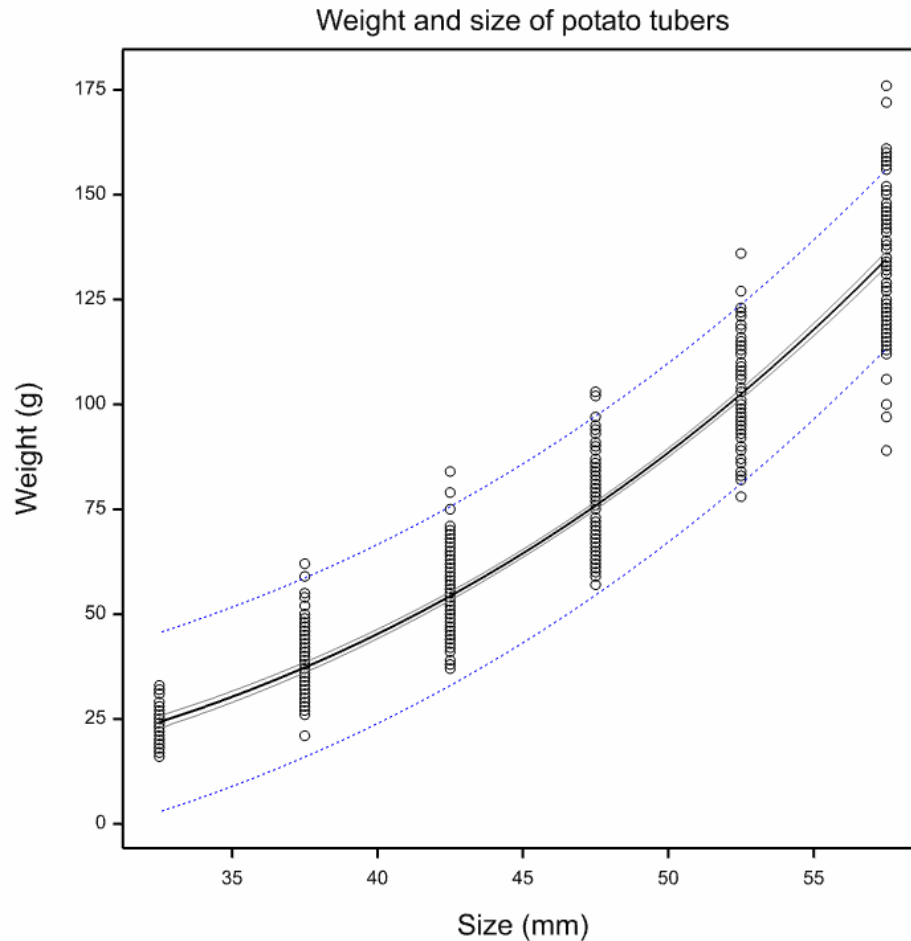
```

244 " Corrected -2log-likelihood for models 1,2 and 3 "
245 PRINT -2*LL1,LL2,LL3; HEADING='Model 1','Model 2','Model 3'; DEC=2

          -2*LL1      -2*LL2      -2*LL3
            1          1          1
1      3817.64      3799.17      3803.80

246
247 " Figure 10: Observed data and regression function with confidence
-248   and prediction intervals "
249 " Untransformed "
250 FIT [PRINT=*] size3
251 VARIATE xlevels; !(32.5...57.5)
252 PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
253   CLASSIFY=size3; LEVELS=xlevels**3
254 PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=size3; \
255   LEVELS=xlevels**3
256 RKEEP DF=df
257 VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
258 CALC predL = pred - EDT(0.975;df)*predSE
259 CALC predU = pred + EDT(0.975;df)*predSE
260 CALC confL = pred - EDT(0.975;df)*confSE
261 CALC confU = pred + EDT(0.975;df)*confSE
262 XAXIS [RESET=yes] WINDOW=3; TITLE='Size (mm)'
263 YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (g)'
264 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
265 DGRAPH [WINDOW=3; KEY=0; TITLE='Weight and size of potato tubers'] \
266   Y=weight; X=size
267 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
268 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
269   LINESTYLE='dot'
270 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
271 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
272   Y=pred,predU,predL,confU,confL; X=xlevels

```



```

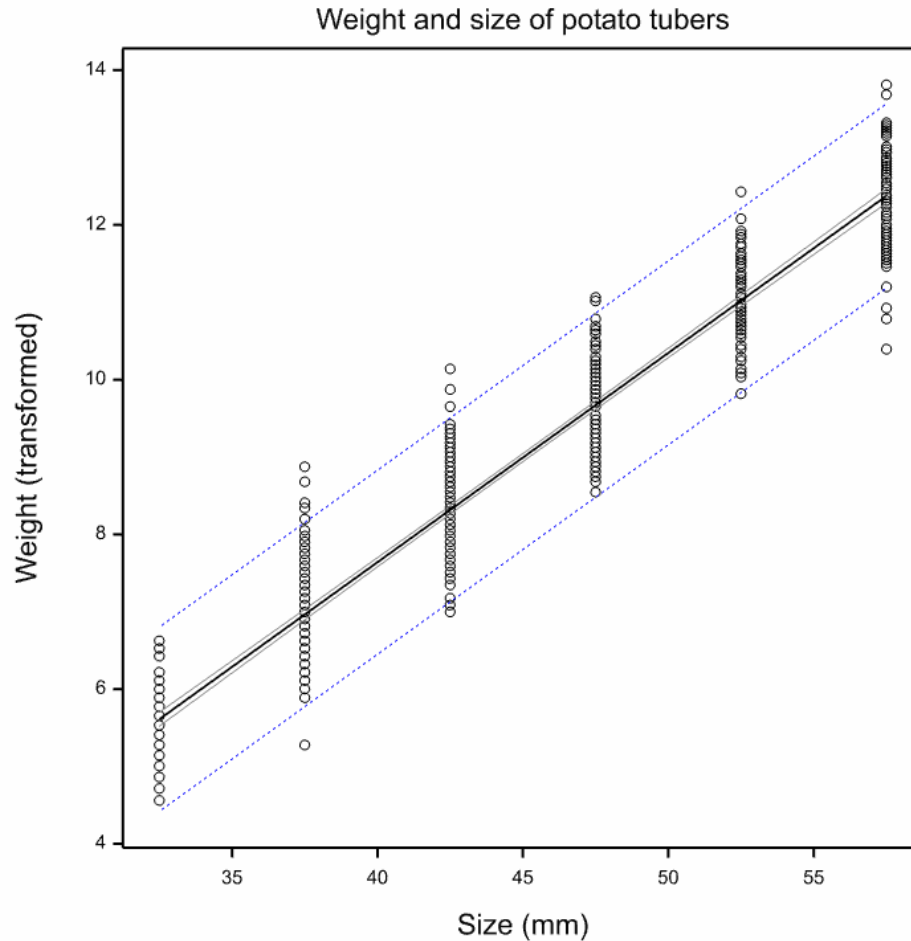
273 " Box-Cox transformation "
274 CALC Tweight = 3*(weight**(1/3) - 1) " Box-Cox with lambda = 1/3 "
275 MODEL Tweight
276 FIT [PRINT=*] size
277 PREDICT [PRINT=*, SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
278   CLASSIFY=size; LEVELS=xlevels
279 PREDICT [PRINT=*, SCOPE=data; SE=_confSE] CLASSIFY=size; \
280   LEVELS=xlevels
281 RKEEP DF=df
282 VTABLE _pred, _predSE, _confSE; VARIATE=pred, predSE, confSE
283 CALC predL = pred - EDT(0.975;df)*predSE
284 CALC predU = pred + EDT(0.975;df)*predSE
285 CALC confL = pred - EDT(0.975;df)*confSE
286 CALC confU = pred + EDT(0.975;df)*confSE
287 XAXIS [RESET=yes] WINDOW=3; TITLE='Size (mm)'
288 YAXIS [RESET=yes] WINDOW=3; TITLE='Weight (transformed)'
289 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point
290 DGRAPH [WINDOW=3; KEY=0; TITLE='Weight and size of potato tubers'] \
291   Y=Tweight; X=size
292 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
293 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
294   LINESTYLE='dot'
295 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line

```

```

296 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
297   Y=pred,predU,predL,confU,confL; X=xlevels
298 XAXIS [RESET=yes] WINDOW=3
299 YAXIS [RESET=yes] WINDOW=3
300 FRAME [RESET=yes] WINDOW=3
301 PEN [RESET=yes] 1...5

```



```

302
303 " Table 14 : Comparison of unweighted regression with several
-304 approaches to describe the variance heterogeneity "
305 " Note : Power-of-x model and power-of-mean model are not directly
-306 available in Genstat 19, and individual variance per size model
-307 must be fitted using the REML facilities "
308 " Unweighted regression by ML "
309 MODEL weight
310 TERMS size3
311 FIT [PRINT=model,summary,estimate; TPROB=yes; CONSTANT=omit; \
312   NOMESSAGE=residual,inflation; SELECTION=aic] size3

```

Regression analysis

Response variate: weight
Fitted terms: size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	3376891.	3376891.4	28740.85
Residual	523	61450.	117.5	
Total	524	3438341.	6561.7	

Akaike information criterion is estimated to be 5780.

Estimates of parameters

Parameter	estimate	s.e.	t(523)	t pr.
size3	0.00070793	0.00000418	169.53	<.001

```
313 RKEEP RESIDUALS=unweightedreg
314 " Unweighted regression by REML "
315 VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none]
316 REML [PRINT=model,components,effects,waldTests] weight
```

REML variance components analysis

Response variate: weight
Fixed model: size3
Number of units: 524

Residual term has been added to model

Sparse algorithm with AI optimisation
Covariates not centred

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	117.5	7.3

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	28740.85	1	28740.85	523.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	28740.85	1	28740.85	523.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for size3

0.0007079 Standard error: 0.00000418

```
317  VAIC [PRINT=aic]
```

Akaike information coefficient 4008.57

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
318  " Weighted regression (with weight 1/size) by ML "  
319  MODEL [WEIGHTS=size_reciprocal] weight  
320  TERMS size3  
321  FIT [PRINT=model,summary,estimate; TPROB=yes; CONSTANT=omit; \  
322  NOMESSAGE=residual,inflation; SELECTION=aic] size3
```

Regression analysis

Response variate: weight
Weight variate: size_reciprocal
Fitted terms: size3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	1	65302.	65302.118	27478.19
Residual	523	1243.	2.377	
Total	524	66545.	126.994	

Akaike information criterion is estimated to be 3736.

Estimates of parameters

Parameter	estimate	s.e.	t(523)	t pr.
size3	0.00070796	0.00000427	165.77	<.001

```
323  " Weighted regression (with weight 1/size) by REML "  
324  VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none]  
325  REML [PRINT=model,components,effects,waldTests; \  
326  WEIGHTS=size_reciprocal] weight
```

REML variance components analysis

Response variate: weight
Fixed model: size3
Number of units: 524
Weights variate: size_reciprocal

Residual term has been added to model

Sparse algorithm with AI optimisation

Covariates not centred

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.377	0.147

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	27478.19	1	27478.19	523.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	27478.19	1	27478.19	523.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using numerical derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for size3

0.0007080 Standard error: 0.00000427

327 VAIC [PRINT=aic]

Akaike information coefficient 3945.77

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
328 " Individual variance per size by REML "  
329 GROUP size; sizeF  
330 VCOMPONENTS [FIXED=size3; CONSTANT=omit; CADJUST=none; \  
331   EXPERIMENTS=sizeF]  
332 REML [PRINT=model,components,effects,waldTests] weight
```

REML variance components analysis

Response variate: weight
Fixed model: size3
Number of units: 524

Separate residual terms for each level of experiment factor: sizeF

Sparse algorithm with AI optimisation
Covariates not centred

Residual model for each experiment

Experiment factor: sizeF

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
32.50	Residual		Identity	Variance	14.87	2.21
37.50	Residual		Identity	Variance	56.95	8.55
42.50	Residual		Identity	Variance	89.67	12.90
47.50	Residual		Identity	Variance	122.7	19.1
52.50	Residual		Identity	Variance	166.4	28.6
57.50	Residual		Identity	Variance	263.8	38.3

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	23469.49	1	23469.49	466.4	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
size3	23469.49	1	23469.49	466.4	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for size3

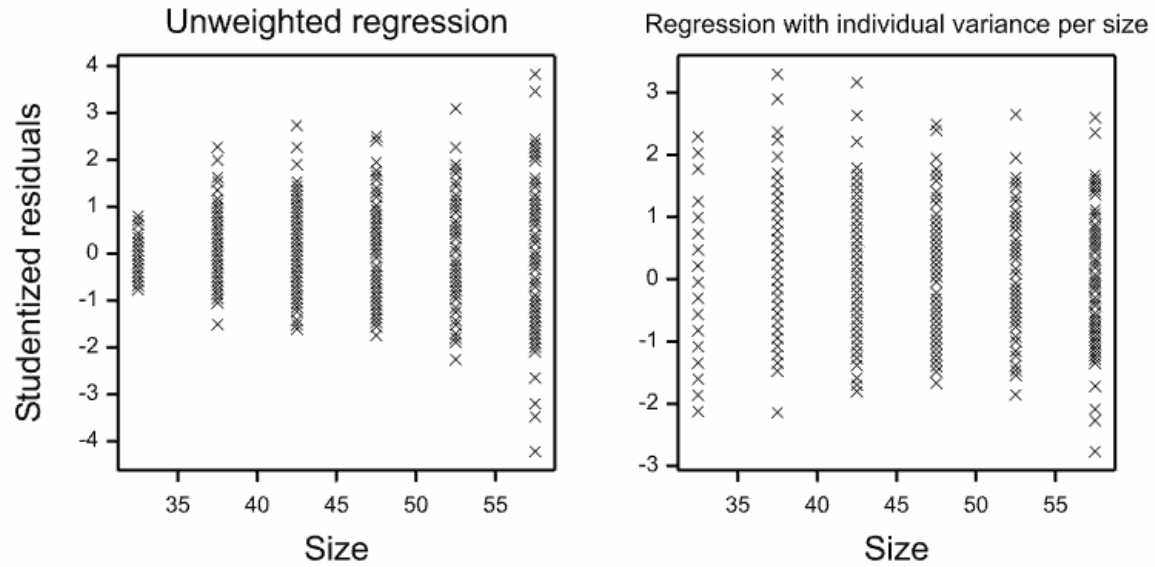
0.0007040 Standard error: 0.00000460

333 VAIC [PRINT=aic]

Akaike information coefficient 3841.63

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
334 VFRESIDUALS [RMETHOD=all; RESIDUALS=weightedreg; SERESIDUALS=se]
335
336 " Figure 13 "
337 FFRAME [ROWS=1; COLUMNS=2; RLOWER=0.5; MARGIN=ytitle,xtitle]
338 YAXIS WINDOW=1; TITLE='Studentized residuals'
339 XAXIS WINDOW=1,2; TITLE='Size'
340 DGRAPH [WINDOW=1; KEY=0; TITLE='Unweighted regression'] \
341   Y=unweightedreg; X=size
342 DGRAPH [WINDOW=2; KEY=0; SCREEN=keep; \
343   TITLE='Regression with individual variance per size'] \
344   Y=weightedreg/se; X=size
345 XAXIS [RESET=yes] WINDOW=1,2
346 YAXIS [RESET=yes] WINDOW=1
```



347
348 ENDJOB

End of job.

Example 7

Genstat Commands for Example 7

```
" ***** "
"                               Example Seven                               "
" ***** "
```

JOB

```
" Load the data, where variety is a factor "
FACTOR variety
READ variety, year1_4, year1_10; FREPRESENTATION=labels
A 22 109 A 39 137 B 23 73 B 40 93
A 27 119 A 40 142 B 27 79 B 40 96
A 28 125 A 41 148 B 27 72 B 40 91
A 30 115 A 42 154 B 29 79 B 41 99
A 33 127 A 42 152 B 30 76 B 42 87
A 34 133 A 42 160 B 30 86 B 42 92
A 34 148 A 42 155 B 31 78 B 44 91
A 34 141 A 43 144 B 32 84 B 45 97
A 36 141 A 43 161 B 33 79 B 48 99
A 36 134 A 44 170 B 35 85 B 51 100
A 37 144 A 45 165 B 35 86 B 53 105
A 37 140 A 47 165 B 36 82 B 54 101
A 38 133 A 48 164 B 37 91 B 55 110
A 38 144 A 48 167 B 37 87 B 56 108
A 39 140 A 54 190 B 38 89 B 56 113 :
```

```

" Table 15 - Separate analysis of the two varieties (and Figure 14) "
XAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 4 (kg/tree)'
YAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 10 (kg/tree)'
PEN [RESET=yes] 1,2; SYMBOL='circle'; METHOD=point; \
  COLOUR='blue','red'
DGRAPH [WINDOW=1; KEYWINDOW=2; \
  TITLE='Cumulative yield after 10 years against 4 years'] \
  Y=year1_10; X=year1_4; PEN=variety; DESCRIPTION=!T('A','B')
FOR [INDEX=i] v = 'A','B'
  RESTRICT year1_4,year1_10; CONDITION = variety .IN. v
  MODEL year1_10
  TERMS year1_4
  FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
  TPROB=yes; FPROB=yes; SELECTION=adjustedr2,r2] year1_4
  " Plot of observed data, regression functions with confidence and
    prediction intervals "
  CALC min = MIN(year1_4)
  CALC max = MAX(year1_4)
  VARIATE xlevels; !(min...max)
  PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
    CLASSIFY=year1_4; LEVELS=xlevels
  PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=year1_4; \
    LEVELS=xlevels
  RKEEP DF=df
  VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
  CALC predL = pred - EDT(0.975;df)*predSE
  CALC predU = pred + EDT(0.975;df)*predSE
  CALC confL = pred - EDT(0.975;df)*confSE
  CALC confU = pred + EDT(0.975;df)*confSE
  PEN i; SYMBOL=0; METHOD=line; THICKNESS=2
  DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=pred; X=xlevels; PEN=i
  PEN i; LINESTYLE='dot'
  DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=predU; X=xlevels; PEN=i
  DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=predL; X=xlevels; PEN=i
  PEN i; THICKNESS=1; LINESTYLE='finedot'
  DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confU; X=xlevels; PEN=i
  DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confL; X=xlevels; PEN=i
  DELETE [REDEFINE=yes] xlevels, df,_pred,_predL,_predU,_confL,\
    _confU,pred,predL,predU,confL,confU,_predSE,_confSE,predSE,confSE
  RESTRICT year1_4,year1_10
ENDFOR
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1
PEN [RESET=yes] 1,2

" Table 16 "
MODEL year1_10
" Approach A : Common intercept, common slope "
TERMS year1_4
FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
  FPROB=yes; TPROB=yes; SELECTION=adjustedr2] year1_4
" Approach B : Separate intercepts, separate slopes "
" Notes:
  * By default the reference level is the first level of the variety
    factor, A
  * Genstat will not enable marginal terms to be dropped "

```

```

TERMS year1_4*variety
FIT [PRINT=model,summary,accumulated,estimate,confidence; \
    PROBABILITY=0.95; FPROB=yes; TPROB=yes; SELECTION=adjustedr2] \
    year1_4*variety
" Fitted model "
TERMS [FULL=yes] variety+year1_4.variety
FIT [PRINT=estimate,confidence; CONSTANT=omit; PROBABILITY=0.95; \
    TPROB=yes] variety+year1_4.variety
" Approach C : Common intercept, separate slopes "
TERMS year1_4*variety
FIT [PRINT=model,summary,accumulated,estimate,confidence; \
    PROBABILITY=0.95; FPROB=yes; TPROB=yes; SELECTION=adjustedr2] \
    year1_4+year1_4.variety
" Fitted model "
TERMS [FULL=yes] year1_4.variety
FIT [PRINT=estimate,confidence;; PROBABILITY=0.95; TPROB=yes] \
    year1_4.variety

" Figure 15 upper: Regression function, confidence, and prediction
  interval for Approach A "
XAXIS [RESET=yes] WINDOW=3; TITLE='yield year 1 to 4 (kg/tree)'
YAXIS [RESET=yes] WINDOW=3; TITLE='yield year 1 to 10 (kg/tree)'
PEN [RESET=yes] 1; SYMBOL='smallcircle'; METHOD=point; \
    COLOUR='black'; LABELS=variety; CFILL='black'
DGRAPH [WINDOW=3; KEYWINDOW=0; \
    TITLE='Cumulative yield after 10 years against 4 years'] \
    Y=year1_10; X=year1_4
MODEL year1_10
TERMS year1_4
FIT [PRINT=*] year1_4
CALC min = MIN(year1_4)
CALC max = MAX(year1_4)
VARIATE xlevels; !(min...max)
PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
    CLASSIFY=year1_4; LEVELS=xlevels
PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=year1_4; \
    LEVELS=xlevels
RKEEP DF=df
VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2; LABELS=*
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
    LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
    Y=pred,predU,predL,confU,confL; X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5
DELETE [REDEFINE=yes] xlevels, df, _pred, _predL, _predU, _confL, \
    _confU, pred, predL, predU, confL, confU, _predSE, _confSE, predSE, confSE

" Figure 15 lower left: Regression function and confidence interval
  for Approach C "

```

```

XAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 4 (kg/tree)'
YAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 10 (kg/tree)'
PEN [RESET=yes] 1,2; SYMBOL='circle'; METHOD=point; \
  COLOUR='blue','red'
DGRAPH [WINDOW=1; KEYWINDOW=2; \
  TITLE='Cumulative yield after 10 years against 4 years'] \
  Y=year1_10; X=year1_4; PEN=variety; DESCRIPTION=!T('A','B')
TERMS year1_4*variety
FIT [PRINT=*] year1_4+year1_4.variety
CALC min = MIN(year1_4)
CALC max = MAX(year1_4)
VARIATE xlevels; !(min...max)
PREDICT [PRINT=*; SCOPE=data; PREDICTIONS=_pred; SE=_confSE] \
  CLASSIFY=year1_4,variety; LEVELS=xlevels,*
RKEEP DF=df
VTABLE _pred,_confSE; VARIATE=pred,confSE; CLASSIFICATION=!P(x,group)
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
PEN 1,2; SYMBOL=0; METHOD=line; THICKNESS=2; LABELS=*; \
  LINESTYLE='finedot'
DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confL,confU; \
  X=!(2(#xlevels)); PEN=group
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1
PEN [RESET=yes] 1,2
DELETE [REDEFINE=yes] xlevels,df,_pred,_confL,_confU,pred,confL,\
  confU,_confSE,confSE,group,x

" Figure 15 lower right: Externally Studentized residuals for
  Approach C "
RCHECK [RMETHOD=deletion; RESIDUAL=ex_standardized_residual] \
  XMETHOD=*
RKEEP FITTEDVALUES=fitted
XAXIS [RESET=yes] WINDOW=3; TITLE='Predicted value for year 1 to 10'
YAXIS [RESET=yes] WINDOW=3; TITLE='Studentized Residual'
PEN [RESET=yes] 1; SYMBOL='smallcircle'; METHOD=point; \
  COLOUR='black'; LABELS=variety; CFILL='black'
DGRAPH [WINDOW=3; KEY=0; TITLE='Externally Studentized Residuals'] \
  Y=ex_standardized_residual; X=fitted
DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=0; \
  LABEL=''; PEN=2

" Table 17 A and B "
" Note: to allow for variance heterogeneity between varieties,
  Genstat's REML facilities are used "
" Without variance heterogeneity across varieties "
VCOMPONENTS [FIXED=year1_4+year1_4.variety; CADJUST=none]
REML [PRINT=model,components,effects,waldTests] year1_10
VAIC [PRINT=aic]
" With variance heterogeneity across varieties "
VCOMPONENTS [FIXED=year1_4+year1_4.variety; CADJUST=none; \
  EXPERIMENTS=variety]
REML [PRINT=model,components,effects,waldTests] year1_10
VAIC [PRINT=aic]

ENDJOB

```

Genstat Output from Example 7

```

2  " ***** "
3  "                               Example Seven "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the data, where variety is a factor "
9  FACTOR variety
10 READ variety, year1_4, year1_10; FREPRESENTATION=labels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
year1_4	22.00	39.17	56.00	60	0
year1_10	72.00	117.9	190.0	60	0

Identifier	Values	Missing	Levels
variety	60	0	2

```

26
27 " Table 15 - Separate analysis of the two varieties (and Figure 14) "
28 XAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 4 (kg/tree)'
29 YAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 10 (kg/tree)'
30 PEN [RESET=yes] 1,2; SYMBOL='circle'; METHOD=point; \
31   COLOUR='blue','red'
32 DGRAPH [WINDOW=1; KEYWINDOW=2; \
33   TITLE='Cumulative yield after 10 years against 4 years'] \
34   Y=year1_10; X=year1_4; PEN=variety; DESCRIPTION=!T('A','B')
35 FOR [INDEX=i] v = 'A','B'
36   RESTRICT year1_4,year1_10; CONDITION = variety .IN. v
37   MODEL year1_10
38   TERMS year1_4
39   FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
40   TPROB=yes; FPROB=yes; SELECTION=adjustedr2,r2] year1_4
41   " Plot of observed data, regression functions with confidence and
-42   prediction intervals "
43   CALC min = MIN(year1_4)
44   CALC max = MAX(year1_4)
45   VARIATE xlevels; !(min...max)
46   PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
47     CLASSIFY=year1_4; LEVELS=xlevels
48   PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=year1_4; \
49     LEVELS=xlevels
50   RKEEP DF=df
51   VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
52   CALC predL = pred - EDT(0.975;df)*predSE
53   CALC predU = pred + EDT(0.975;df)*predSE
54   CALC confL = pred - EDT(0.975;df)*confSE
55   CALC confU = pred + EDT(0.975;df)*confSE
56   PEN i; SYMBOL=0; METHOD=line; THICKNESS=2
57   DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=pred; X=xlevels; PEN=i
58   PEN i; LINESTYLE='dot'

```

```

59 DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=predU; X=xlevels; PEN=i
60 DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=predL; X=xlevels; PEN=i
61 PEN i; THICKNESS=1; LINESTYLE='finedot'
62 DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confU; X=xlevels; PEN=i
63 DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confL; X=xlevels; PEN=i
64 DELETE [REDEFINE=yes] xlevels, df, _pred, _predL, _predU, _confL, \
65 _confU, _pred, _predL, _predU, _confL, _confU, _predSE, _confSE, _predSE, _confSE
66 RESTRICT year1_4, year1_10
67 ENDFOR

```

Regression analysis

Response variate: year1_10
Fitted terms: Constant, year1_4

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	8003.	8003.29	190.87	<.001
Residual	28	1174.	41.93		
Total	29	9177.	316.46		

Adjusted r-squared statistic 0.867
R-squared statistic 0.872

Message: the following units have large standardized residuals.

Unit	Response	Residual
25	148.00	2.22

Message: the following units have high leverage.

Unit	Response	Leverage
1	109.00	0.240
58	190.00	0.204

Estimates of parameters

Parameter	estimate	s.e.	t(28)	t pr.	lower 95%	upper 95%
Constant	51.43	6.92	7.44	<.001	37.27	65.60
year1_4	2.428	0.176	13.82	<.001	2.068	2.788

Regression analysis

Response variate: year1_10
Fitted terms: Constant, year1_4

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	3108.0	3107.98	253.06	<.001

Residual	28	343.9	12.28
Total	29	3451.9	119.03

Adjusted r-squared statistic 0.897
R-squared statistic 0.900

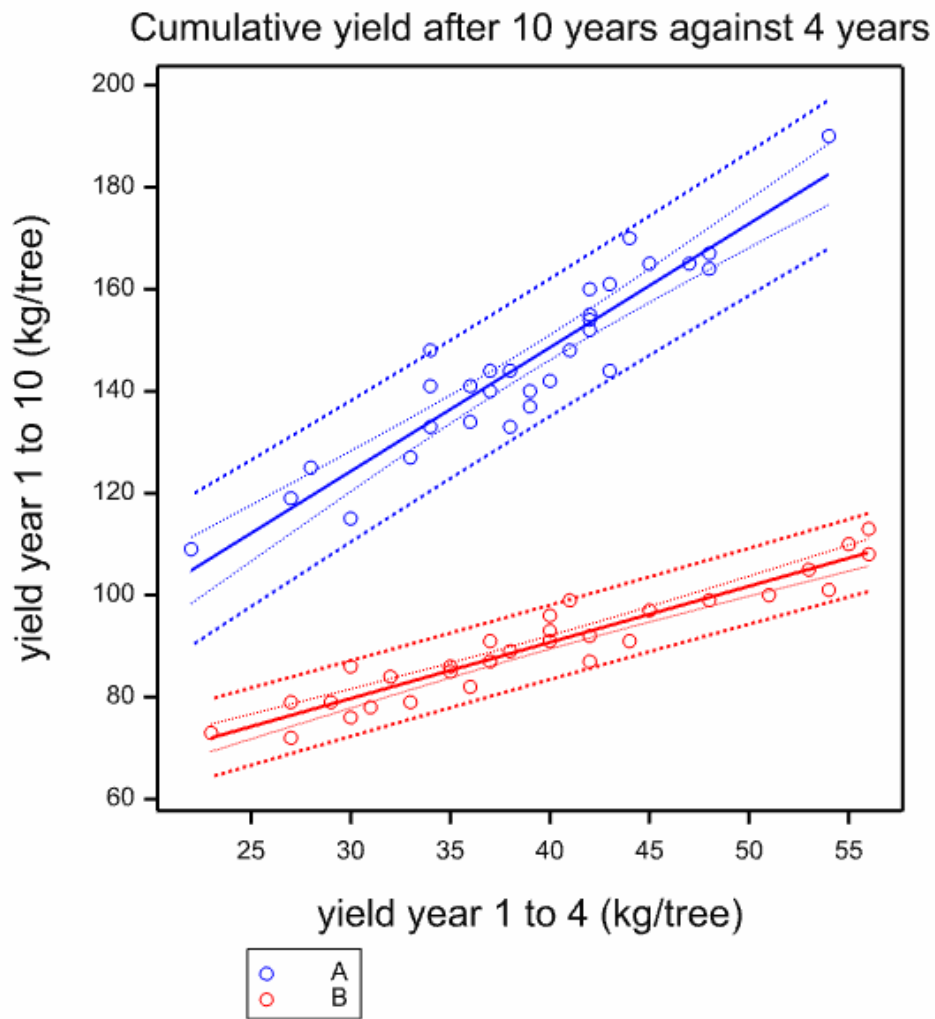
Message: the following units have high leverage.

Unit	Response	Leverage
3	73.00	0.140

Estimates of parameters

Parameter	estimate	s.e.	t(28)	t pr.	lower 95%	upper 95%
Constant	46.68	2.81	16.59	<.001	40.92	52.45
year1_4	1.1015	0.0692	15.91	<.001	0.9597	1.243

```
68 XAXIS [RESET=yes] WINDOW=1
69 YAXIS [RESET=yes] WINDOW=1
70 PEN [RESET=yes] 1,2
```




```

72 " Table 16 "
73 MODEL year1_10
74 " Approach A : Common intercept, common slope "
75 TERMS year1_4
76 FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
77     FPROB=yes; TPROB=yes; SELECTION=adjustedr2] year1_4

```

Regression analysis

Response variate: year1_10
Fitted terms: Constant, year1_4

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	7572.	7571.7	8.62	0.005
Residual	58	50929.	878.1		
Total	59	58501.	991.5		

Adjusted r-squared statistic 0.114

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Message: the following units have high leverage.

Unit	Response	Leverage
1	109.0	0.092
3	73.0	0.083
52	110.0	0.080
56	108.0	0.089
60	113.0	0.089

Estimates of parameters

Parameter	estimate	s.e.	t(58)	t pr.	lower 95%	upper 95%
Constant	63.5	18.9	3.36	0.001	25.69	101.4
year1_4	1.388	0.473	2.94	0.005	0.4420	2.335

```

78 " Approach B : Separate intercepts, separate slopes "
79 " Notes:
-80 * By default the reference level is the first level of the variety
-81 factor, A
-82 * Genstat will not enable marginal terms to be dropped "
83 TERMS year1_4*variety
84 FIT [PRINT=model,summary,accumulated,estimate,confidence; \
85     PROBABILITY=0.95; FPROB=yes; TPROB=yes; SELECTION=adjustedr2] \
86     year1_4*variety

```

Regression analysis

Response variate: year1_10
Fitted terms: Constant + year1_4 + variety + year1_4.variety

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	56983.	18994.21	700.72	<.001
Residual	56	1518.	27.11		
Total	59	58501.	991.54		

Adjusted r-squared statistic 0.973

Message: the following units have large standardized residuals.

Unit	Response	Residual
25	148.00	2.76

Message: the following units have high leverage.

Unit	Response	Leverage
1	109.00	0.240
58	190.00	0.204

Estimates of parameters

Parameter	estimate	s.e.	t(56)	t pr.
Constant	51.43	5.56	9.25	<.001
year1_4	2.428	0.141	17.18	<.001
variety B	-4.75	6.96	-0.68	0.497
year1_4.variety B	-1.327	0.175	-7.59	<.001

Parameter	lower95%	upper95%
Constant	40.29	62.57
year1_4	2.145	2.711
variety B	-18.69	9.184
year1_4.variety B	-1.677	-0.9765

Parameters for factors are differences compared with the reference level:

Factor	Reference level
variety	A

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ year1_4	1	7571.73	7571.73	279.33	<.001
+ variety	1	47849.38	47849.38	1765.23	<.001
+ year1_4.variety	1	1561.50	1561.50	57.61	<.001
Residual	56	1517.97	27.11		
Total	59	58500.58	991.54		

```

87  " Fitted model "
88  TERMS [FULL=yes] variety+year1_4.variety
89  FIT  [PRINT=estimate,confidence; CONSTANT=omit; PROBABILITY=0.95; \
90      TPROB=yes] variety+year1_4.variety

```

Regression analysis

Estimates of parameters

Parameter	estimate	s.e.	t(56)	t pr.
variety A	51.43	5.56	9.25	<.001
variety B	46.68	4.18	11.17	<.001
year1_4.variety A	2.428	0.141	17.18	<.001
year1_4.variety B	1.102	0.103	10.71	<.001

Parameter	lower95%	upper95%
variety A	40.29	62.57
variety B	38.31	55.06
year1_4.variety A	2.145	2.711
year1_4.variety B	0.8955	1.308

```
91 " Approach C : Common intercept, separate slopes "  
92 TERMS year1_4*variety  
93 FIT [PRINT=model,summary,accumulated,estimate,confidence; \  
94     PROBABILITY=0.95; FPROB=yes; TPROB=yes; SELECTION=adjustedr2] \  
95     year1_4+year1_4.variety
```

Regression analysis

Response variate: year1_10
Fitted terms: Constant + year1_4 + year1_4.variety

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	56970.	28484.99	1060.78	<.001
Residual	57	1531.	26.85		
Total	59	58501.	991.54		

Adjusted r-squared statistic 0.973

Message: the following units have large standardized residuals.

Unit	Response	Residual
25	148.00	2.84
30	144.00	-2.38

Estimates of parameters

Parameter	estimate	s.e.	t(57)	t pr.
Constant	48.40	3.33	14.55	<.001
year1_4	2.5042	0.0867	28.89	<.001
year1_4.variety B	-1.4438	0.0337	-42.89	<.001

Parameter	lower95%	upper95%
Constant	41.74	55.06

year1_4	2.331	2.678
year1_4.variety B	-1.511	-1.376

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ year1_4	1	7571.73	7571.73	281.97	<.001
+ year1_4.variety	1	49398.24	49398.24	1839.59	<.001
Residual	57	1530.61	26.85		
Total	59	58500.58	991.54		

```

96  " Fitted model "
97  TERMS [FULL=yes] year1_4.variety
98  FIT [PRINT=estimate,confidence;; PROBABILITY=0.95; TPROB=yes] \
99  year1_4.variety

```

Regression analysis

Estimates of parameters

Parameter	estimate	s.e.	t(57)	t pr.
Constant	48.40	3.33	14.55	<.001
year1_4.variety A	2.5042	0.0867	28.89	<.001
year1_4.variety B	1.0604	0.0830	12.77	<.001

Parameter	lower95%	upper95%
Constant	41.74	55.06
year1_4.variety A	2.331	2.678
year1_4.variety B	0.8942	1.227

```

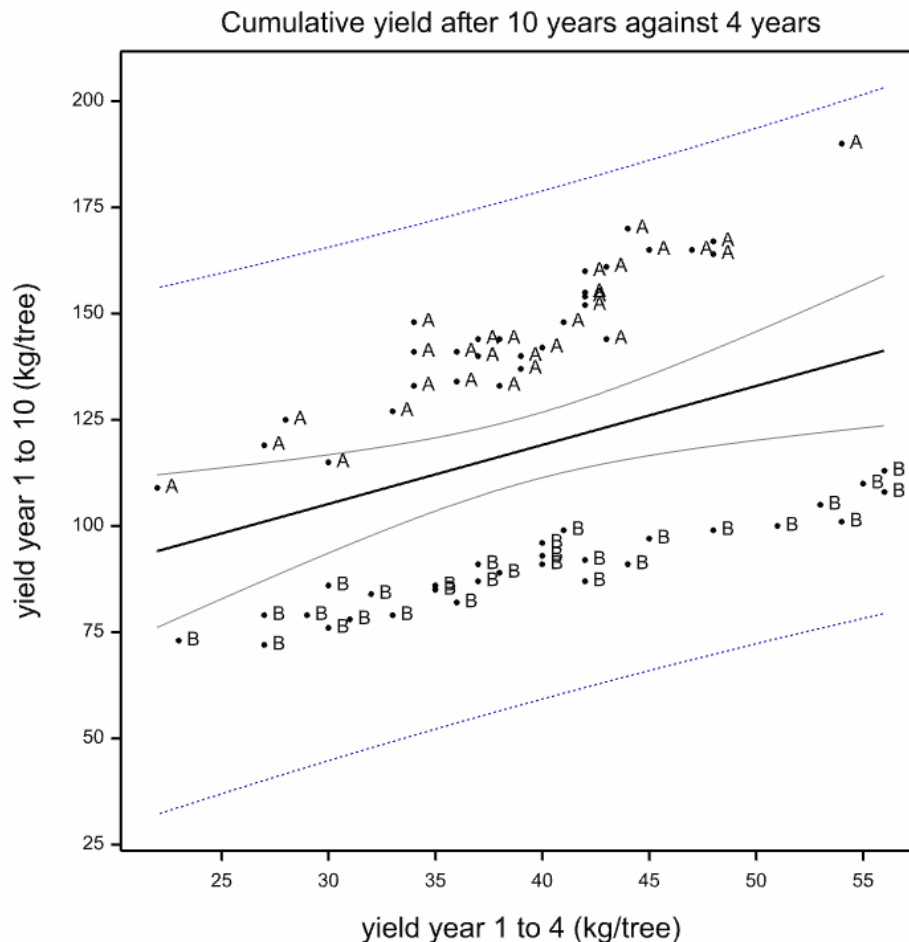
100
101  " Figure 15 upper: Regression function, confidence, and prediction
-102  interval for Approach A "
103  XAXIS [RESET=yes] WINDOW=3; TITLE='yield year 1 to 4 (kg/tree)'
104  YAXIS [RESET=yes] WINDOW=3; TITLE='yield year 1 to 10 (kg/tree)'
105  PEN [RESET=yes] 1; SYMBOL='smallcircle'; METHOD=point; \
106  COLOUR='black'; LABELS=variety; CFILL='black'
107  DGRAPH [WINDOW=3; KEYWINDOW=0; \
108  TITLE='Cumulative yield after 10 years against 4 years'] \
109  Y=year1_10; X=year1_4
110  MODEL year1_10
111  TERMS year1_4
112  FIT [PRINT=*] year1_4
113  CALC min = MIN(year1_4)
114  CALC max = MAX(year1_4)
115  VARIATE xlevels; !(min...max)
116  PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
117  CLASSIFY=year1_4; LEVELS=xlevels\

```

```

118 PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=year1_4; \
119   LEVELS=xlevels
120 RKEEP DF=df
121 VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
122 CALC predL = pred - EDT(0.975;df)*predSE
123 CALC predU = pred + EDT(0.975;df)*predSE
124 CALC confL = pred - EDT(0.975;df)*confSE
125 CALC confU = pred + EDT(0.975;df)*confSE
126 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2; LABELS=*
127 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
128   LINESTYLE='dot'
129 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
130 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
131   Y=pred,predU,predL,confU,confL; X=xlevels
132 XAXIS [RESET=yes] WINDOW=3
133 YAXIS [RESET=yes] WINDOW=3
134 PEN [RESET=yes] 1...5
135 DELETE [REDEFINE=yes] xlevels, df,_pred,_predL,_predU,_confL,\
136   _confU,pred,predL,predU,confL,confU,_predSE,_confSE,predSE,confSE

```

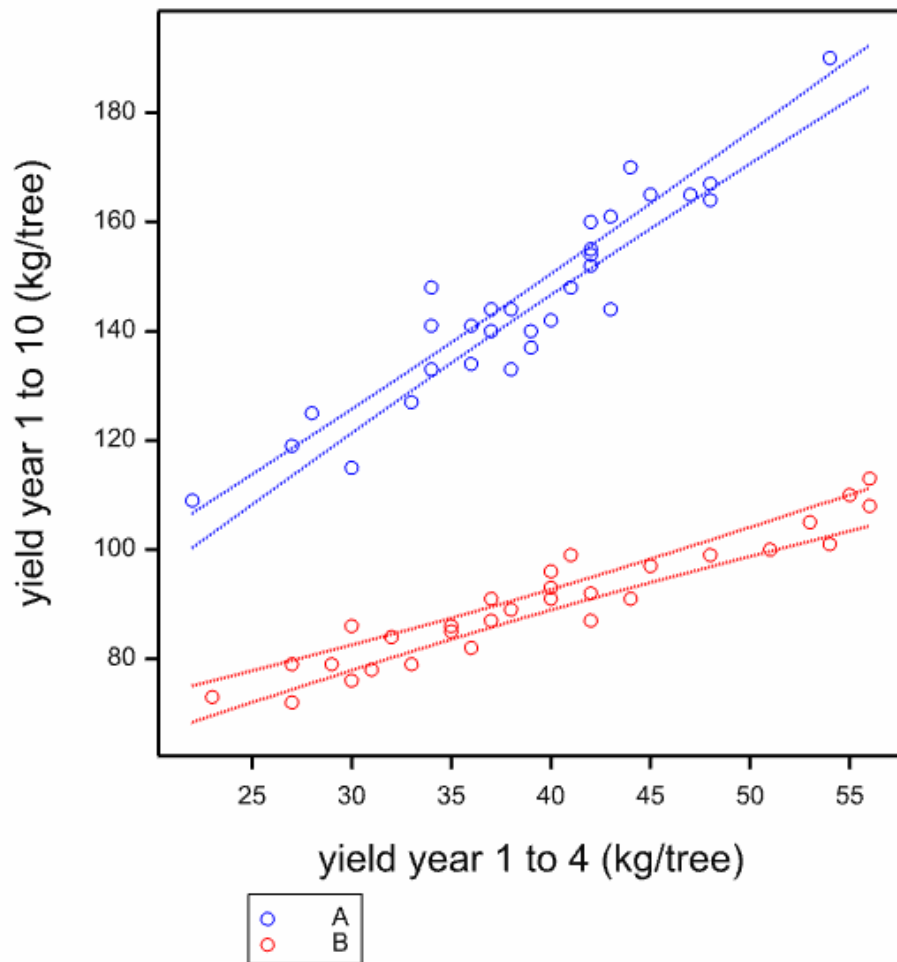


```

137
138 " Figure 15 lower left: Regression function and confidence interval
-139   for Approach C "
140 XAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 4 (kg/tree)'
141 YAXIS [RESET=yes] WINDOW=1; TITLE='yield year 1 to 10 (kg/tree)'
142 PEN [RESET=yes] 1,2; SYMBOL='circle'; METHOD=point; \
143   COLOUR='blue','red'
144 DGRAPH [WINDOW=1; KEYWINDOW=2; \
145   TITLE='Cumulative yield after 10 years against 4 years'] \
146   Y=year1_10; X=year1_4; PEN=variety; DESCRIPTION=!T('A','B')
147 TERMS year1_4*variety
148 FIT [PRINT=*] year1_4+year1_4.variety
149 CALC min = MIN(year1_4)
150 CALC max = MAX(year1_4)
151 VARIATE xlevels; !(min...max)
152 PREDICT [PRINT=*; SCOPE=data; PREDICTIONS=_pred; SE=_confSE] \
153   CLASSIFY=year1_4,variety; LEVELS=xlevels,*
154 RKEEP DF=df
155 VTABLE _pred,_confSE; VARIATE=pred,confSE; CLASSIFICATION=!P(x,group)
156 CALC confL = pred - EDT(0.975;df)*confSE
157 CALC confU = pred + EDT(0.975;df)*confSE
158 PEN 1,2; SYMBOL=0; METHOD=line; THICKNESS=2; LABELS=*; \
159   LINESTYLE='finedot'
160 DGRAPH [WINDOW=1; KEY=0; SCREEN=resize] Y=confL,confU; \
161   X=!(2(#xlevels)); PEN=group
162 XAXIS [RESET=yes] WINDOW=1
163 YAXIS [RESET=yes] WINDOW=1
164 PEN [RESET=yes] 1,2
165 DELETE [REDEFINE=yes] xlevels,df,_pred,_confL,_confU,pred,confL,\
166   confU,_confSE,confSE,group,x

```

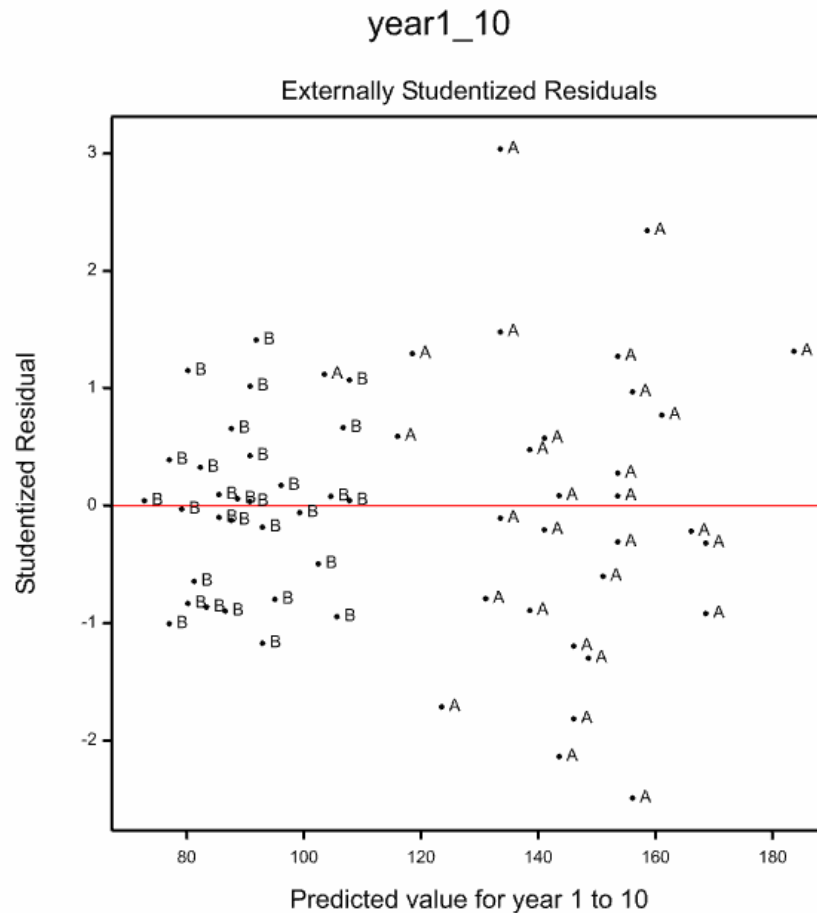
Cumulative yield after 10 years against 4 years



```

167
168 " Figure 15 lower right: Externally Studentized residuals for
-169 Approach C "
170 RCHECK [RMETHOD=deletion; RESIDUAL=ex_standardized_residual] \
171   XMETHOD=*
172 RKEEP FITTEDVALUES=fitted
173 XAXIS [RESET=yes] WINDOW=3; TITLE='Predicted value for year 1 to 10'
174 YAXIS [RESET=yes] WINDOW=3; TITLE='Studentized Residual'
175 PEN [RESET=yes] 1; SYMBOL='smallcircle'; METHOD=point; \
176   COLOUR='black'; LABELS=variety; CFILL='black'
177 DGRAPH [WINDOW=3; KEY=0; TITLE='Externally Studentized Residuals'] \
178   Y=ex_standardized_residual; X=fitted
179 DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=0; \
180   LABEL=''; PEN=2

```



```

181
182 " Table 17 A and B "
183 " Note: to allow for variance heterogeneity between varieties,
-184   Genstat's REML facilities are used "
185 " Without variance heterogeneity across varieties "
186 VCOMPONENTS [FIXED=year1_4+year1_4.variety; CADJUST=none]
187 REML [PRINT=model,components,effects,waldTests] year1_10

```

REML variance components analysis

Response variate: year1_10
Fixed model: Constant + year1_4 + year1_4.variety
Number of units: 60

Residual term has been added to model

Sparse algorithm with AI optimisation
Covariates not centred

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	26.85	5.03

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
year1_4	281.97	1	281.97	57.0	<0.001
year1_4.variety	1839.59	1	1839.59	57.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
year1_4.variety	1839.59	1	1839.59	57.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

48.40 Standard error: 3.325

Table of effects for year1_4

2.504 Standard error: 0.0867

Table of effects for year1_4.variety

variety	A	B
	0.0000	-1.4438

Standard error of differences: 0.03366

188 VAIC [PRINT=aic]

Akaike information coefficient 373.75

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
189 " With variance heterogeneity across varieties "  
190 VCOMPONENTS [FIXED=year1_4+year1_4.variety; CADJUST=none; \  
191     EXPERIMENTS=variety]  
192 REML [PRINT=model,components,effects,waldTests] year1_10
```

REML variance components analysis

Response variate: year1_10
Fixed model: Constant + year1_4 + year1_4.variety

Number of units: 60

Separate residual terms for each level of experiment factor: variety

Sparse algorithm with AI optimisation

Covariates not centred

Residual model for each experiment

Experiment factor: variety

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
A	Residual		Identity	Variance	41.19	10.85
B	Residual		Identity	Variance	12.24	3.27

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
year1_4	336.38	1	336.38	36.8	<0.001
year1_4.variety	1828.25	1	1828.25	44.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
year1_4.variety	1828.25	1	1828.25	44.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

47.37 Standard error: 2.599

Table of effects for year1_4

2.530 Standard error: 0.0716

Table of effects for year1_4.variety

variety	A	B
	0.0000	-1.4449

Standard error of differences: 0.03379

```
193  VAIC [PRINT=aic]
```

Akaike information coefficient	365.88

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
194
```

```
195  ENDJOB
```

End of job.

Example 8

Genstat Commands for Example 8

```
" ***** "
"                               Example Eight                               "
" ***** "
```

```
JOB
```

```
" Load the data "
```

```
READ Year, Temp
```

1960	8.94	1987	7.57
1961	9.35	1988	9.57
1962	7.98	1989	9.94
1963	7.79	1990	10.11
1964	8.42	1991	8.85
1965	8.02	1992	9.66
1966	8.93	1993	8.79
1967	9.50	1994	9.85
1968	8.65	1995	9.17
1969	7.78	1996	7.34
1970	7.93	1997	9.04
1971	8.89	1998	9.46
1972	8.16	1999	10.00
1973	8.53	2000	10.41
1974	9.46	2001	9.32
1975	9.47	2002	9.82
1976	8.51	2003	9.46
1977	9.05	2004	9.04
1978	8.20	2005	9.31
1979	8.00	2006	9.89
1980	7.56	2007	10.42
1981	8.42	2008	10.06
1982	9.42	2009	9.43
1983	9.48	2010	8.02
1984	8.58	2011	10.14
1985	8.00	2012	9.27
1986	8.27	2013	9.34 :

```
" Table 21: Analysis of variance, estimates, and tests of the fixed
parameters (model with independent errors) "
```

```
MODEL Temp
```

```

TERMS Year
FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
    FPROB=yes; TPROB=yes; SELECTION=adjustedr2,r2] Year
" Alternatively, fit using REML "
VCOMPONENTS [FIXED=Year; CADJUST=none]
REML [PRINT=model,components,effects,waldTests] Temp
VAIC

" Figure 17 left: Observed data, fitted regression function,
  confidence, and prediction intervals with conspicuous points
  highlighted as follows. R=Externally Studentized residual
  D=DFITTS "
" Externally Studentized residual "
RCHECK [RMETHOD=deletion; RESIDUAL=ex_standardized_residual] \
    XMETHOD=*
" DFITTS "
RKEEP LEVERAGES=leverage
CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
" Plot "
VARIATE xlevels; !(1960...2013)
PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
    CLASSIFY=Year; LEVELS=xlevels
PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=Year; \
    LEVELS=xlevels
RKEEP DF=df
VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
CALC predL = pred - EDT(0.975;df)*predSE
CALC predU = pred + EDT(0.975;df)*predSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
YAXIS [RESET=yes] WINDOW=3; TITLE='Temperature (~^oC)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='Mean air temperature over years'] \
    Y=Temp; X=Year
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
    LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
    Y=pred,predU,predL,confU,confL; X=xlevels
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point;\
    CFILL='black'; LABEL='R'; XLPOSITION=right
RESTRICT Temp,Year; CONDITION=ABS(ex_standardized_residual) .GE. 2
DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=Temp; X=Year
RESTRICT Temp,Year
PEN 1; LABEL='D'; XLPOSITION=left
CALC N = NOBS(Temp)
RESTRICT Temp,Year; CONDITION=ABS(DFFITS) .GE. 2*SQRT(2/N)
DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=Temp; X=Year
RESTRICT Temp,Year
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Figure 17 right: Studentized residuals against regressor values "
RKEEP RESIDUAL=residual

```

```

XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
YAXIS [RESET=yes] WINDOW=3; TITLE='Residual'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; TITLE='Residuals for air temperature'] \
  Y=residual; X=Year
DREFERENCeline [WINDOW=3; ORIENTATION=horizontal] POSITION=0; \
  LABEL=''; PEN=2

" Calculate the autocorrelations "
" Order residuals by Year "
SORT [INDEX=Year] OLDVECTOR=residual; NEWVECTOR=OrderedResidual
CORRELATE [PRINT=auto] OrderedResidual

" Table 22: Estimates assuming first-order autocorrelation (AR1) "
" Note: The REML facilities of Genstat don't accommodate AR models
  of order > 2 "
GROUP Year; YearF
VCOMPONENTS [FIXED=Year; CADJUST=none] RANDOM=YearF
VSTRUCTURE [TERMS=YearF] MODEL=AR; ORDER=1; FACTOR=YearF
REML [PRINT=model,components,effects,waldTests] Temp
VAIC

" Figure 18 upper left: AR 1 model with 95% confidence intervals "
VPREDICT [PRINT=*; PREDICT=_pred; SE=_confSE] CLASSIFY=Year; \
  LEVELS=xlevels; PARALLEL=*
VKEEP DDF=df
VTABLE _pred,_confSE; VARIATE=pred,confSE
CALC confL = pred - EDT(0.975;df)*confSE
CALC confU = pred + EDT(0.975;df)*confSE
XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
YAXIS [RESET=yes] WINDOW=3; TITLE='Temperature (~°C)'
PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=point
DGRAPH [WINDOW=3; KEY=0; TITLE='AR'] \
  Y=Temp; X=Year
PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
  LINESTYLE='dot'
PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] Y=pred,confU,confL; \
  X=xlevels
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...5

" Figure 18 lower: Sine model "
EXPRESSION [VALUE=fit=a+b*SIN((Year-c)*2*CONSTANT('pi')/d)+e*Year] \
  SineModel
MODEL Temp; FITTED=fit
RCYCLE [MAXCYCLE=30] a,b,c,d,e; INITIAL=-41,-0.5,1969,8,0.03
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
  CALC=SineModel; SELINEAR=yes; FPROB=yes; SELECTION=r2,\
  %variance,seobservations]
RGRAPH [WINDOW=3; TITLE='Sine Model'] INDEX=Year

" Piecewise regression with break point at 1972, and a constant
  linear trend before the break "
" Note: procedure R2LINES can be used to estimate the breakpoint "

```

```

" Year >= 1972 "
EXPRESSION [VALUE=R=(a1+b1*Year)*(Year.GE.1972)+a2*(Year.LT.1972)] \
  piecewisemodel
MODEL [DISTRIBUTION=normal; LINK=identity] Temp; FITTED=R
RCYCLE [METHOD=Newton] a1,b1,a2
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=estimate; \
  CALC=piecewisemodel; SELINEAR=yes]
"Note: a1 is the intercept and b1 is the slope for the regression
  function when Year >= 1972, whereas a2 is the constant when
  Year <1972 "
RGRAPH [WINDOW=3; TITLE='Piecewise Model'] INDEX=Year

ENDJOB

```

Genstat Output from Example 8

```

2  " ***** "
3  "                               Example Eight                               "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8
9  " Load the data "
10 READ Year, Temp

```

Identifier	Minimum	Mean	Maximum	Values	Missing
Year	1960	1986	2013	54	0
Temp	7.340	8.974	10.42	54	0

```

38
39 " Table 21: Analysis of variance, estimates, and tests of the fixed
-40 parameters (model with independent errors) "
41 MODEL Temp
42 TERMS Year
43 FIT [PRINT=model,summary,estimate,confidence; PROBABILITY=0.95; \
44   FPROB=yes; TPROB=yes; SELECTION=adjustedr2,r2] Year

```

Regression analysis

Response variate: Temp
Fitted terms: Constant, Year

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	8.09	8.0857	16.21	<.001
Residual	52	25.94	0.4988		
Total	53	34.03	0.6420		

Adjusted r-squared statistic 0.223
R-squared statistic 0.238

Message: the following units have large standardized residuals.

Unit	Response	Residual
20	7.340	-2.68

Estimates of parameters

Parameter	estimate	s.e.	t(52)	t pr.	lower 95%	upper 95%
Constant	-40.3	12.3	-3.29	0.002	-64.93	-15.76
Year	0.02483	0.00617	4.03	<.001	0.01245	0.03720

```

45 " Alternatively, fit using REML "
46 VCOMPONENTS [FIXED=Year; CADJUST=none]
47 REML [PRINT=model,components,effects,waldTests] Temp

```

REML variance components analysis

Response variate: Temp
Fixed model: Constant + Year
Number of units: 54

Residual term has been added to model

Sparse algorithm with AI optimisation
Covariates not centred

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.499	0.0978

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	16.21	1	16.21	52.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	16.21	1	16.21	52.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

-40.35 Standard error: 12.251

Table of effects for Year

0.02483 Standard error: 0.006167

48 VAIC

Akaike information coefficient 126.88

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

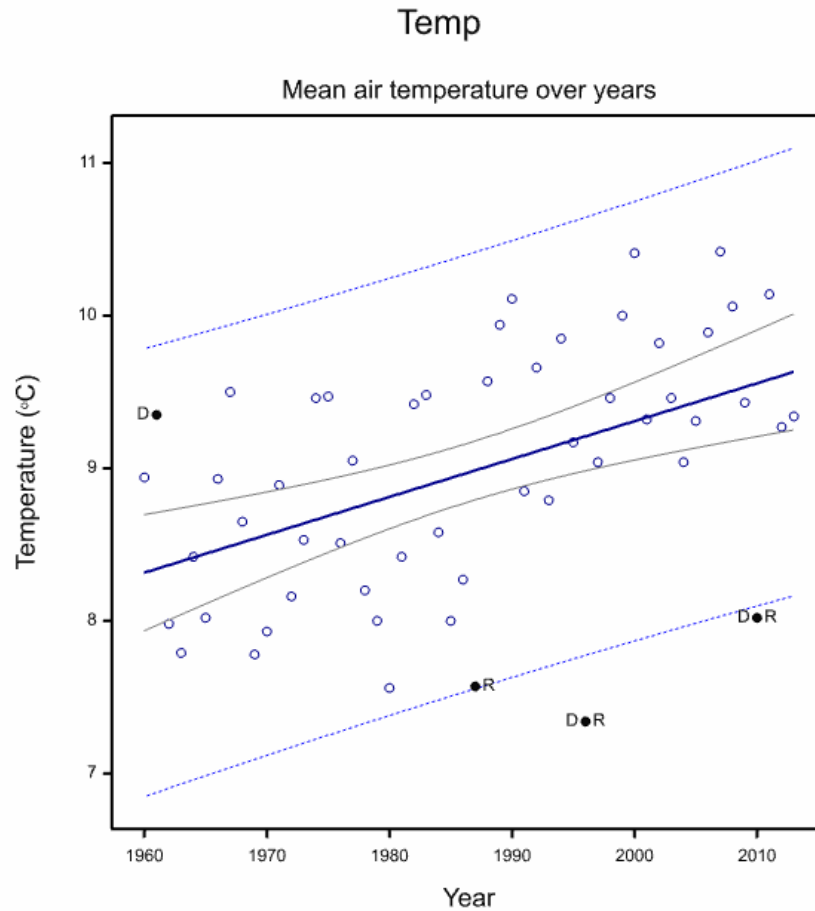
```
49
50 " Figure 17 left: Observed data, fitted regression function,
-51 confidence, and prediction intervals with conspicuous points
-52 highlighted as follows. R=Externally Studentized residual
-53 D=DFITTS "
54 " Externally Studentized residual "
55 RCHECK [RMETHOD=deletion; RESIDUAL=ex_standardized_residual] \
56 XMETHOD=*
57 " DFITTS "
58 RKEEP LEVERAGES=leverage
59 CALC DFFITS = ex_standardized_residual*sqrt(leverage/(1-leverage))
60 " Plot "
61 VARIATE xlevels; !(1960...2013)
62 PREDICT [PRINT=*; SCOPE=new; PREDICTIONS=_pred; SE=_predSE] \
63 CLASSIFY=Year; LEVELS=xlevels
64 PREDICT [PRINT=*; SCOPE=data; SE=_confSE] CLASSIFY=Year; \
65 LEVELS=xlevels
66 RKEEP DF=df
67 VTABLE _pred,_predSE,_confSE; VARIATE=pred,predSE,confSE
68 CALC predL = pred - EDT(0.975;df)*predSE
69 CALC predU = pred + EDT(0.975;df)*predSE
70 CALC confL = pred - EDT(0.975;df)*confSE
71 CALC confU = pred + EDT(0.975;df)*confSE
72 XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
73 YAXIS [RESET=yes] WINDOW=3; TITLE='Temperature (~^oC)'
74 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=point
75 DGRAPH [WINDOW=3; KEY=0; TITLE='Mean air temperature over years'] \
76 Y=Temp; X=Year
77 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
78 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
79 LINSTYLE='dot'
80 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
81 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] \
82 Y=pred,predU,predL,confU,confL; X=xlevels
83 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='black'; METHOD=point;\
84 CFILL='black'; LABEL='R'; XLPOSITION=right
85 RESTRICT Temp,Year; CONDITION=ABS(ex_standardized_residual) .GE. 2
86 DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=Temp; X=Year
87 RESTRICT Temp,Year
88 PEN 1; LABEL='D'; XLPOSITION=left
89 CALC N = NOBS(Temp)
```



```

90 RESTRICT Temp,Year; CONDITION=ABS(DFFITS) .GE. 2*SQRT(2/N)
91 DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=Temp; X=Year
92 RESTRICT Temp,Year
93 XAXIS [RESET=yes] WINDOW=3
94 YAXIS [RESET=yes] WINDOW=3
95 PEN [RESET=yes] 1...5

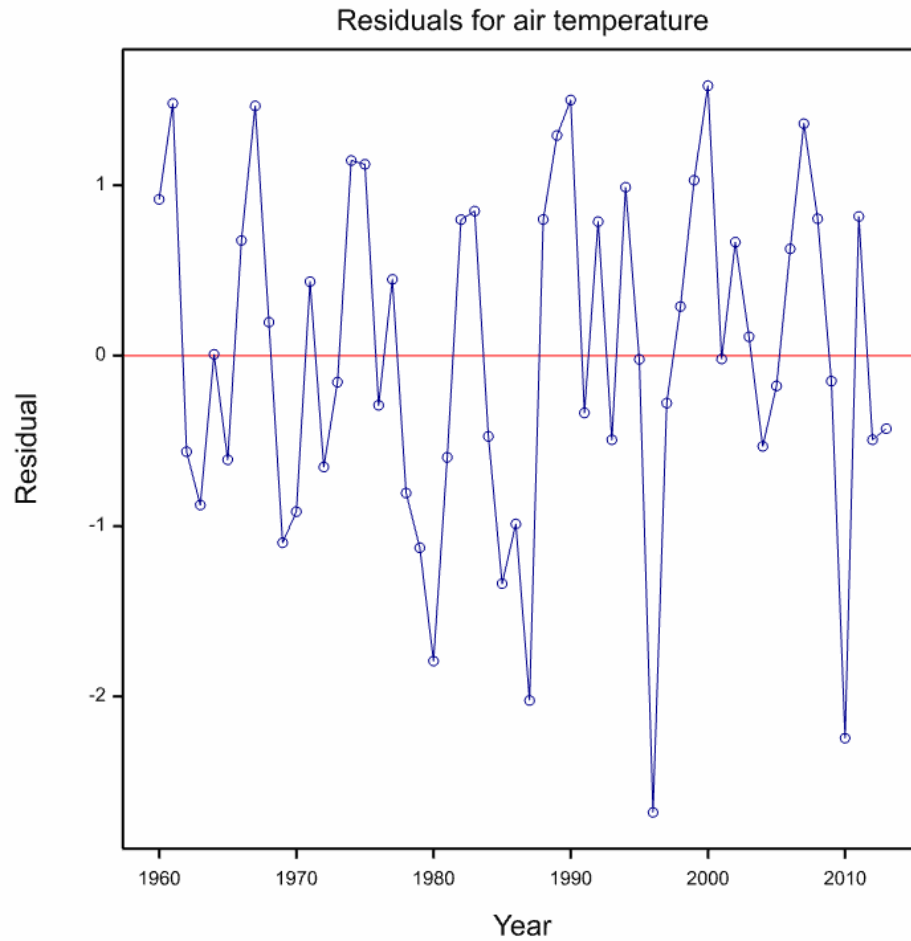
```



```

96
97 " Figure 17 right: Studentized residuals against regressor values "
98 RKEEP RESIDUAL=residual
99 XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
100 YAXIS [RESET=yes] WINDOW=3; TITLE='Residual'
101 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=line
102 DGRAPH [WINDOW=3; KEY=0; TITLE='Residuals for air temperature'] \
103   Y=residual; X=Year
104 DREFERENCELINE [WINDOW=3; ORIENTATION=horizontal] POSITION=0; \
105   LABEL=''; PEN=2

```



```

106
107 " Calculate the autocorrelations "
108 " Order residuals by Year "
109 SORT [INDEX=Year] OLDVECTOR=residual; NEWVECTOR=OrderedResidual
110 CORRELATE [PRINT=auto] OrderedResidual

```

Correlations

Unit	ACF
1	1.000
2	0.233
3	-0.139
4	-0.285
5	-0.279
6	-0.105
7	0.083
8	0.157
9	0.139
10	0.088
11	-0.082
12	-0.056
13	-0.179
14	-0.162
15	0.026

16	0.066
17	0.167
18	0.276
19	0.022
20	-0.151
21	-0.331
22	-0.213
23	-0.072
24	0.133
25	0.069
26	0.074
27	-0.020

```

111
112 " Table 22: Estimates assuming first-order autocorrelation (AR1) "
113 " Note: The REML facilities of Genstat don't accommodate AR models
-114   of order > 2 "
115 GROUP Year; YearF
116 VCOMPONENTS [FIXED=Year; CADJUST=none] RANDOM=YearF
117 VSTRUCTURE [TERMS=YearF] MODEL=AR; ORDER=1; FACTOR=YearF
118 REML [PRINT=model,components,effects,waldTests] Temp

```

REML variance components analysis

Response variate: Temp
 Fixed model: Constant + Year
 Random model: YearF
 Number of units: 54

YearF used as residual term with covariance structure as below

Sparse algorithm with AI optimisation
 Covariates not centred

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No. rows
YearF	YearF	Auto-regressive (+ scalar)	1	54

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
YearF			Sigma2	0.513	0.1161
	YearF	AR(1)	phi_1	0.2832	0.1605

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	8.66	1	8.66	9.0	0.016

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	8.66	1	8.66	9.0	0.016

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

-38.88 Standard error: 16.260

Table of effects for Year

0.02409 Standard error: 0.008185

119 VAIC

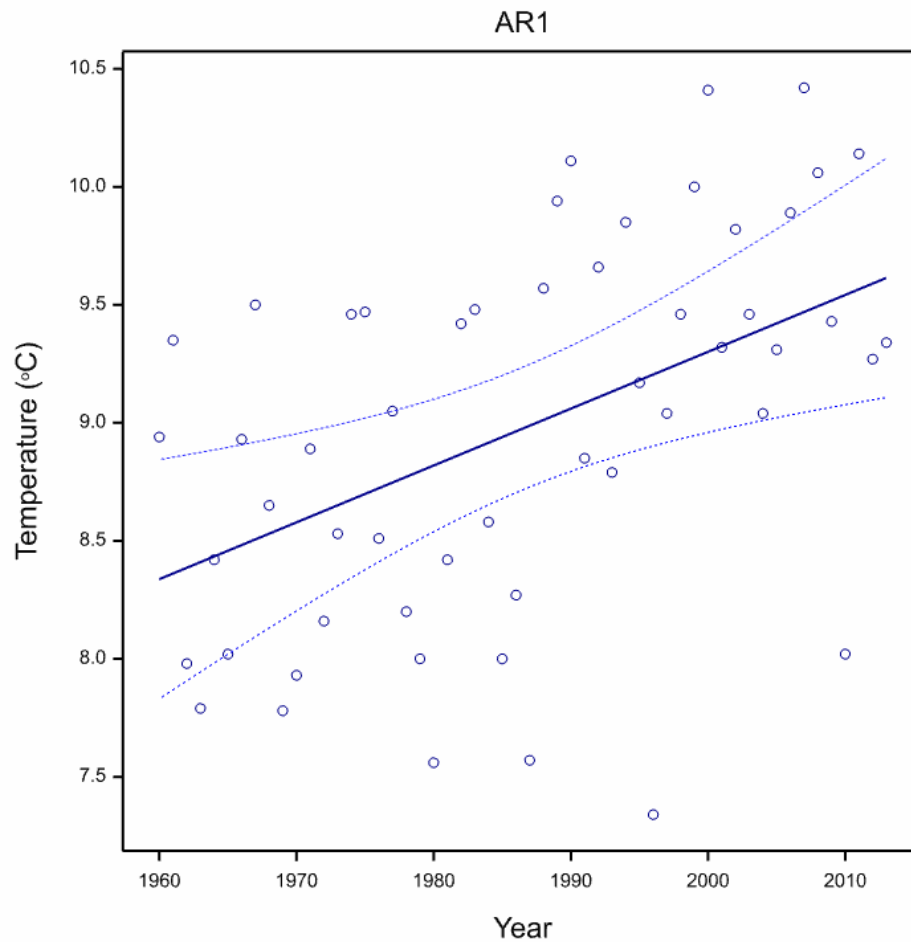
Akaike information coefficient 124.77

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```

120
121 " Figure 18 upper left: AR 1 model with 95% confidence intervals "
122 VPREDICT [PRINT=*, PREDICT=_pred; SE=_confSE] CLASSIFY=Year; \
123   LEVELS=xlevels; PARALLEL=*
124 VKEEP DDF=df
125 VTABLE _pred,_confSE; VARIATE=pred,confSE
126 CALC confL = pred - EDT(0.975;df)*confSE
127 CALC confU = pred + EDT(0.975;df)*confSE
128 XAXIS [RESET=yes] WINDOW=3; TITLE='Year'
129 YAXIS [RESET=yes] WINDOW=3; TITLE='Temperature (~^oC)'
130 PEN [RESET=yes] 1; SYMBOL='circle'; COLOUR='darkblue'; METHOD=point
131 DGRAPH [WINDOW=3; KEY=0; TITLE='AR1'] \
132   Y=Temp; X=Year
133 PEN 1; SYMBOL=0; METHOD=line; THICKNESS=2
134 PEN [RESET=yes] 2,3; SYMBOL=0; COLOUR='blue'; METHOD=line; \
135   LINSTYLE='dot'
136 PEN [RESET=yes] 4,5; SYMBOL=0; COLOUR='grey'; METHOD=line
137 DGRAPH [WINDOW=3; KEY=0; SCREEN=resize] Y=pred,confU,confL; \
138   X=xlevels
139 XAXIS [RESET=yes] WINDOW=3
140 YAXIS [RESET=yes] WINDOW=3
141 PEN [RESET=yes] 1...5
142

```



```

143 " Figure 18 lower: Sine model "
144 EXPRESSION [VALUE=fit=a+b*SIN((Year-c)*2*CONSTANT('pi')/d)+e*Year] \
145   SineModel
146 MODEL Temp; FITTED=fit
147 RCYCLE [MAXCYCLE=30] a,b,c,d,e; INITIAL=-41,-0.5,1969,8,0.03
148 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
149   CALC=SineModel; SELINEAR=yes; FPROB=yes; SELECTION=r2,\
150   %variance,seobservations]

```

Nonlinear regression analysis

Response variate: Temp
 Nonlinear parameters: a, b, c, d, e
 Model calculations: SineModel

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	5	4364.23	872.8467	2364.29	<.001
Residual	49	18.09	0.3692		
Total	54	4382.32	81.1541		

Percentage variance accounted for 42.5
R-squared statistic 0.468
Standard error of observations is estimated to be 0.608.

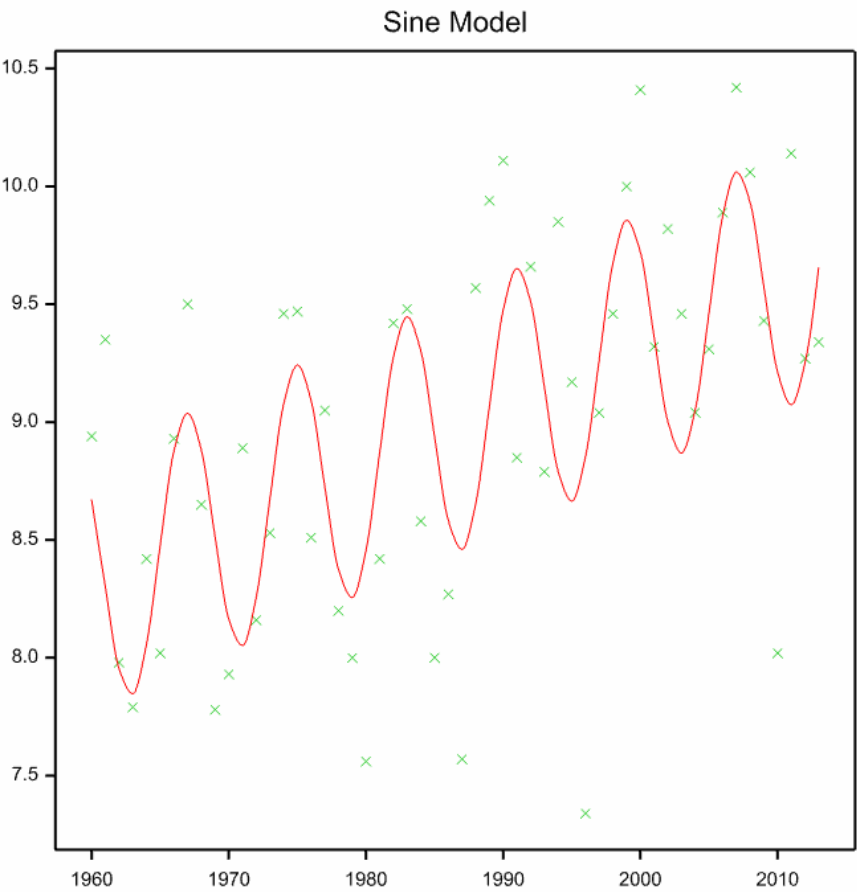
Message: the following units have large standardized residuals.

Unit	Response	Residual
20	7.340	-2.49

Estimates of parameters

Parameter	estimate	s.e.
a	-41.8	10.6
b	0.545	0.118
c	1964.917	0.460
d	8.018	0.137
e	0.02557	0.00533

```
151 RGRAPH [WINDOW=3; TITLE='Sine Model'] INDEX=Year
```



```

152
153 " Piecewise regression with break point at 1972, and a constant
-154 linear trend before the break "
155 " Note: procedure R2LINES can be used to estimate the breakpoint "
156 " Year >= 1972 "
157 EXPRESSION [VALUE=R=(a1+b1*Year)*(Year.GE.1972)+a2*(Year.LT.1972)] \
158 piecewisemodel
159 MODEL [DISTRIBUTION=normal; LINK=identity] Temp; FITTED=R
160 RCYCLE [METHOD=Newton] a1,b1,a2
161 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=estimate; \
162 CALC=piecewisemodel; SELINEAR=yes]

```

Nonlinear regression analysis

Response variate: Temp
 Nonlinear parameters: a1, b1, a2
 Model calculations: piecewisemodel

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	4356.81	1452.2691	2902.69
Residual	51	25.52	0.5003	
Total	54	4382.32	81.1541	

Percentage variance accounted for 22.1
 Standard error of observations is estimated to be 0.707.

Message: the following units have large standardized residuals.

Unit	Response	Residual
20	7.340	-2.64

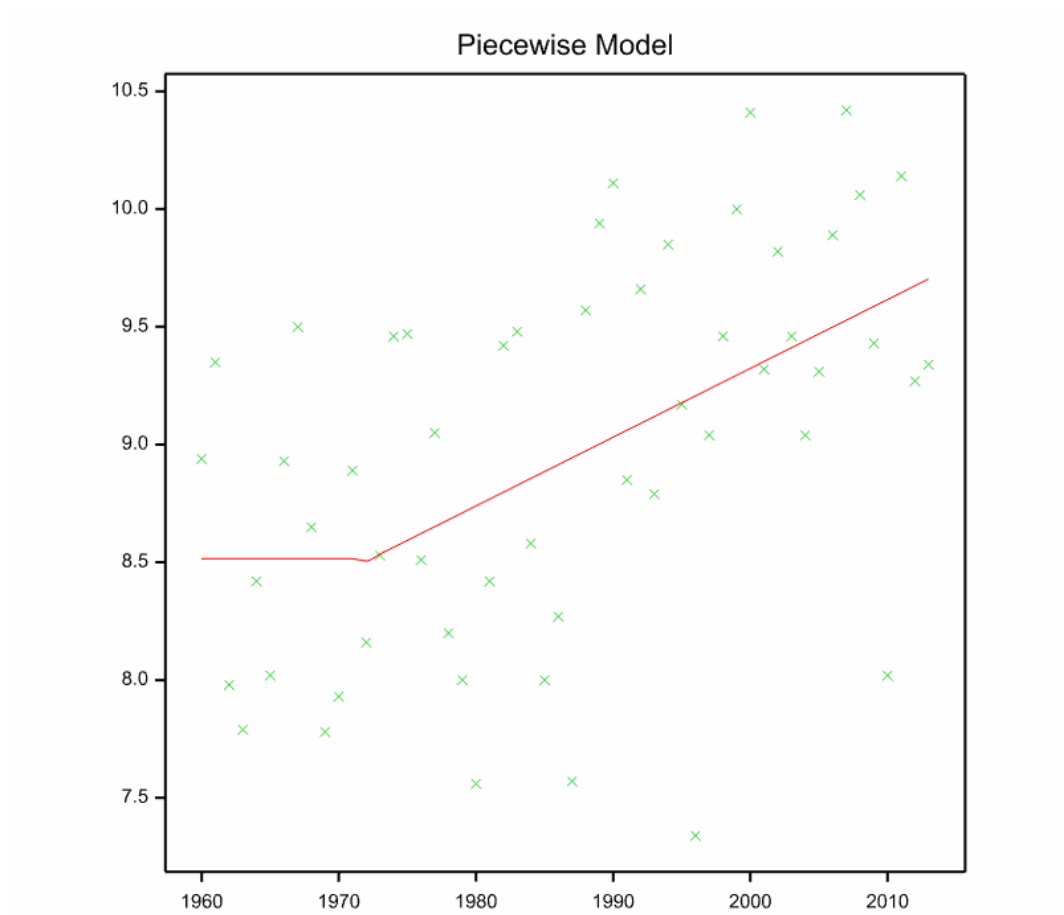
Estimates of parameters

Parameter	estimate	s.e.
a1	-49.1	17.9
b1	0.02921	0.00900
a2	8.515	0.204

```

163 "Note: a1 is the intercept and b1 is the slope for the regression
-164 function when Year >= 1972, whereas a2 is the constant when
-165 Year <1972 "
166 RGRAPH [WINDOW=3; TITLE='Piecewise Model'] INDEX=Year

```



167

168 ENDJOB

End of job.

Chapter 7. Analysis and Interpretation of Interactions of Fixed and Random Effects by Mateo Vargas, Barry Glaz, Jose Crossa, and Alex Morgounov

Genstat code developed by Vanessa M. Cave and output are provided here for the examples and the homework exercises presented in Chapter 7.

Section One: Looking for the Best Model

Genstat Commands

```
" ***** "
"           Section One: Looking for the Best Model           "
" ***** "

JOB

" Import the data "
IMPORT 'Data Wheat Section 1.csv'

" Convert Soil from a text structure to a factor, and convert N, P,
  Rep and Year from variates to factors "
GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year

" The complete model: Analyzing main effects and their two-way,
  three-way, and four-way interactions "
VCOMPONENTS [FIXED=Year*Soil*N*P; FACTORIAL=4] RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield

" The reduced model "
VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
  RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield

" Interpreting the Year by Soil by N interaction "
VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=N; \
  GROUPS=!P(Soil,Year)
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
  Year.Soil.N
" Refer to the Appendix Two code to generate Figure 1.1 "

" Interpreting Year by Soil by P interaction "
VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; \
  GROUPS=!P(Soil,Year)
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
  Year.Soil.P
" Refer to the Appendix Two code to generate Figure 1.2 "

" Interpreting Soil by N by P interaction "
VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; \
  GROUPS=!P(N,Soil)
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
  Soil.N.P
" Refer to the Appendix Two code to generate Figure 1.3 "
```

```

" Interpreting the adjusted means "
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Year]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Soil]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=N]
VMCOMPARISON [DIRECTION=descending] P
VMCOMPARISON [DIRECTION=descending] Year.Soil
VMCOMPARISON [DIRECTION=descending] Year.N
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Soil.N
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Year.P
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Soil.P
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Year.Soil.N
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Year.Soil.P
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
    Soil.N.P

" Notes: * REML uses the Kenward-Roger method for computing the ddf,
          whereas SAS, by default, uses the containment method.
          * As the data are balanced and normality is assumed, the
            ANOVA directive can also be used to analyse these data. "

ENDJOB

```

Genstat Output

```

2  " ***** "
3  "                Section One: Looking for the Best Model                "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Import the data "
9  IMPORT 'Data Wheat Section 1.csv'

```

Loading Spreadsheet File

Catalogue of file Data Wheat Section 1.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	64	Year
2	text	64	Soil
3	variate	64	N
4	variate	64	P

```

5          variate      64  Rep
6          variate      64  Yield

10
11  " Convert Soil from a text structure to a factor, and convert N, P,
-12    Rep and Year from variates to factors "
13  GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year
14
15  " The complete model: Analyzing main effects and their two-way,
-16    three-way, and four-way interactions "
17  VCOMPONENTS [FIXED=Year*Soil*N*P; FACTORIAL=4] RANDOM=Year.Soil.Rep
18  REML [PRINT=model,components,waldTests] Yield

```

REML variance components analysis

Response variate: Yield
Fixed model: Constant + Year + Soil + N + P + Year.Soil + Year.N + Soil.N + Year.P + Soil.P + N.P + Year.Soil.N + Year.Soil.P + Year.N.P + Soil.N.P + Year.Soil.N.P
Random model: Year.Soil.Rep
Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year.Soil.Rep	0.000292	0.000955

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00804	0.002148

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001
N	12.15	1	12.15	28.0	0.002
P	121.11	3	40.37	28.0	<0.001
Year.Soil	125.30	1	125.30	4.0	<0.001
Year.N	10.11	1	10.11	28.0	0.004
Soil.N	21.17	1	21.17	28.0	<0.001
Year.P	20.53	3	6.84	28.0	0.001
Soil.P	44.00	3	14.67	28.0	<0.001
N.P	4.46	3	1.49	28.0	0.240
Year.Soil.N	35.62	1	35.62	28.0	<0.001

Year.Soil.P	25.49	3	8.50	28.0	<0.001
Year.N.P	1.95	3	0.65	28.0	0.589
Soil.N.P	16.16	3	5.39	28.0	0.005
Year.Soil.N.P	6.40	3	2.13	28.0	0.118

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N.P	6.40	3	2.13	28.0	0.118

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

19
20 " The reduced model "
21 VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
22   RANDOM=Year.Soil.Rep
23 REML [PRINT=model,components,waldTests] Yield

```

REML variance components analysis

Response variate: Yield
Fixed model: Constant + Year + Soil + N + P + Year.Soil + Year.N + Soil.N + Year.P + Soil.P + Year.Soil.N + Year.Soil.P + Soil.N.P
Random model: Year.Soil.Rep
Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year.Soil.Rep	0.000222	0.000953

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00859	0.002084

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001
N	11.36	1	11.36	34.0	0.002
P	113.26	3	37.75	34.0	<0.001
Year.Soil	125.30	1	125.30	4.0	<0.001

Year.N	9.45	1	9.45	34.0	0.004
Soil.N	19.80	1	19.80	34.0	<0.001
Year.P	19.20	3	6.40	34.0	0.001
Soil.P	41.15	3	13.72	34.0	<0.001
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P	23.83	3	7.94	34.0	<0.001
Soil.N.P	19.28	6	3.21	34.0	0.013

Dropping individual terms from full fixed model

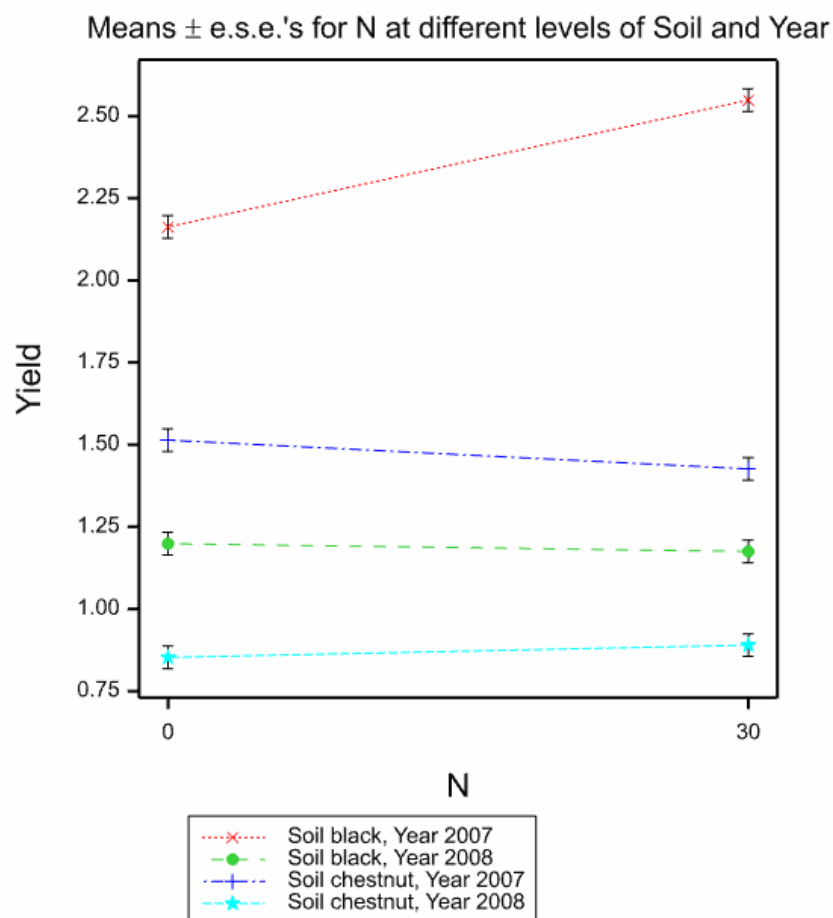
Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P	23.83	3	7.94	34.0	<0.001
Soil.N.P	19.28	6	3.21	34.0	0.013

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

24
25 " Interpreting the Year by Soil by N interaction "
26 VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=N; \
27     GROUPS=!P(Soil,Year)

```



```

28  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
29  Year.Soil.N

```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil.N means

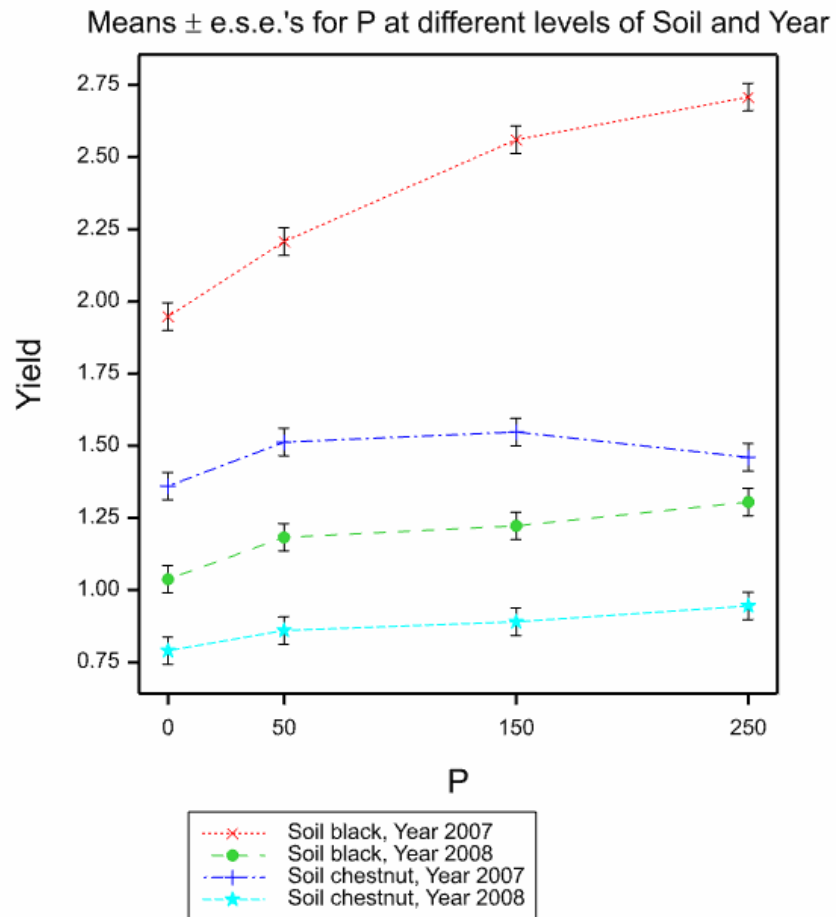
	Mean	
2007 black 30	2.549	a
2007 black 0	2.162	b
2007 chestnut 0	1.514	c
2007 chestnut 30	1.426	c
2008 black 0	1.199	d
2008 black 30	1.175	d
2008 chestnut 30	0.890	e
2008 chestnut 0	0.853	e

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

30  " Refer to the Appendix Two code to generate Figure 1.1 "
31
32  " Interpreting Year by Soil by P interaction "
33  VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; \
34  GROUPS=!P(Soil,Year)

```



```
35 VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
36     Year.Soil.P
```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil.P means

	Mean	
2007 black 250	2.707	a
2007 black 150	2.560	b
2007 black 50	2.207	c
2007 black 0	1.947	d
2007 chestnut 150	1.547	e
2007 chestnut 50	1.512	e
2007 chestnut 250	1.460	ef
2007 chestnut 0	1.360	fg
2008 black 250	1.305	gh
2008 black 150	1.223	h
2008 black 50	1.183	h
2008 black 0	1.038	i
2008 chestnut 250	0.945	ij

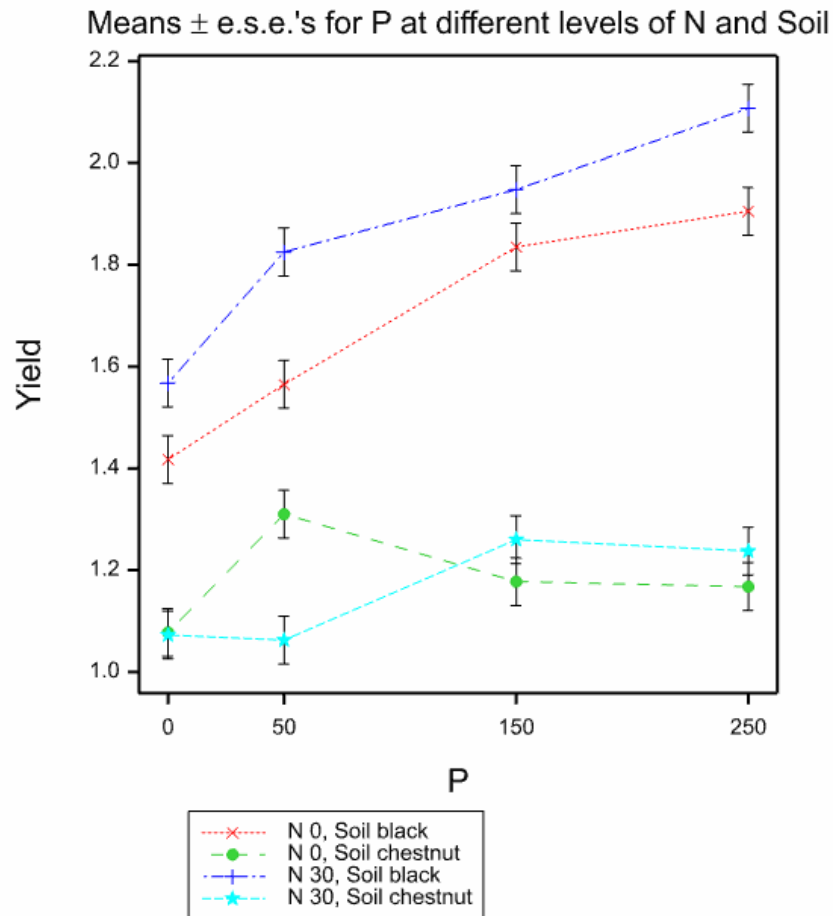
2008 chestnut 150	0.890	jk
2008 chestnut 50	0.860	jk
2008 chestnut 0	0.790	k

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

37 " Refer to the Appendix Two code to generate Figure 1.2 "
38
39 " Interpreting Soil by N by P interaction "
40 VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; \
41     GROUPS=!P(N,Soil)

```



```

42 VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
43     Soil.N.P

```

Fisher's unprotected least significant difference test

Comparisons between Soil.N.P means

	Mean	
black 30 250	2.107	a

black 30 150	1.947	b
black 0 250	1.905	b
black 0 150	1.835	b
black 30 50	1.825	b
black 30 0	1.567	c
black 0 50	1.565	c
black 0 0	1.417	d
chestnut 0 50	1.310	de
chestnut 30 150	1.260	ef
chestnut 30 250	1.238	ef
chestnut 0 150	1.178	efg
chestnut 0 250	1.167	fg
chestnut 0 0	1.077	g
chestnut 30 0	1.073	g
chestnut 30 50	1.062	g

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

44 " Refer to the Appendix Two code to generate Figure 1.3 "
45
46 " Interpreting the adjusted means "
47 VDISPLAY [PRINT=means; PSE=differences; PTERMS=Year]

```

Table of predicted means for Year

Year	2007	2008
	1.913	1.029

Standard error of differences: 0.02546

```

48 VDISPLAY [PRINT=means; PSE=differences; PTERMS=Soil]

```

Table of predicted means for Soil

Soil	black	chestnut
	1.771	1.171

Standard error of differences: 0.02546

```

49 VDISPLAY [PRINT=means; PSE=differences; PTERMS=N]

```

Table of predicted means for N

N	0	30
	1.432	1.510

Standard error of differences: 0.02317

```
50  VMCOMPARISON [DIRECTION=descending] P
```

Fisher's unprotected least significant difference test

Comparisons between P means

	Mean	
250	1.604	a
150	1.555	a
50	1.441	b
0	1.284	c

```
51  VMCOMPARISON [DIRECTION=descending] Year.Soil
```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil means

	Mean	
2007 black	2.356	a
2007 chestnut	1.470	b
2008 black	1.187	c
2008 chestnut	0.871	d

```
52  VMCOMPARISON [DIRECTION=descending] Year.N
```

Fisher's unprotected least significant difference test

Comparisons between Year.N means

Message: d.d.f from contributing terms vary between 4.00 and 34.00; comparisons will be assessed using 4.00 d.f.

	Mean	
2007 30	1.987	a
2007 0	1.838	b
2008 30	1.033	c
2008 0	1.026	c

```
53  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \  
54  Soil.N
```

Fisher's unprotected least significant difference test

Comparisons between Soil.N means

	Mean	
black 30	1.862	a
black 0	1.681	b
chestnut 0	1.183	c
chestnut 30	1.158	c

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```
55  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
56  Year.P
```

Fisher's unprotected least significant difference test

Comparisons between Year.P means

	Mean	
2007 250	2.084	a
2007 150	2.054	a
2007 50	1.860	b
2007 0	1.654	c
2008 250	1.125	d
2008 150	1.056	de
2008 50	1.021	e
2008 0	0.914	f

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```
57  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
58  Soil.P
```

Fisher's unprotected least significant difference test

Comparisons between Soil.P means

	Mean	
black 250	2.006	a
black 150	1.891	b
black 50	1.695	c
black 0	1.492	d
chestnut 150	1.219	e
chestnut 250	1.203	e
chestnut 50	1.186	e
chestnut 0	1.075	f

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

59  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
60      Year.Soil.N

```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil.N means

	Mean	
2007 black 30	2.549	a
2007 black 0	2.162	b
2007 chestnut 0	1.514	c
2007 chestnut 30	1.426	c
2008 black 0	1.199	d
2008 black 30	1.175	d
2008 chestnut 30	0.890	e
2008 chestnut 0	0.853	e

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

61  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
62      Year.Soil.P

```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil.P means

	Mean	
2007 black 250	2.707	a
2007 black 150	2.560	b
2007 black 50	2.207	c
2007 black 0	1.947	d
2007 chestnut 150	1.547	e
2007 chestnut 50	1.512	e
2007 chestnut 250	1.460	ef
2007 chestnut 0	1.360	fg
2008 black 250	1.305	gh
2008 black 150	1.223	h
2008 black 50	1.183	h
2008 black 0	1.038	i
2008 chestnut 250	0.945	ij
2008 chestnut 150	0.890	jk
2008 chestnut 50	0.860	jk
2008 chestnut 0	0.790	k

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

63  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
64      Soil.N.P

```

Fisher's unprotected least significant difference test

Comparisons between Soil.N.P means

	Mean	
black 30 250	2.107	a
black 30 150	1.947	b
black 0 250	1.905	b
black 0 150	1.835	b
black 30 50	1.825	b
black 30 0	1.567	c
black 0 50	1.565	c
black 0 0	1.417	d
chestnut 0 50	1.310	de
chestnut 30 150	1.260	ef
chestnut 30 250	1.238	ef
chestnut 0 150	1.178	efg
chestnut 0 250	1.167	fg
chestnut 0 0	1.077	g
chestnut 30 0	1.073	g
chestnut 30 50	1.062	g

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```
65
66  " Notes: * REML uses the Kenward-Roger method for computing the ddf,
-67           whereas SAS, by default, uses the containment method.
-68           * As the data are balanced and normality is assumed, the
-69           ANOVA directive can also be used to analyse the data. "
70
71  ENDJOB
```

End of job.

Appendix One: Orthogonal Polynomial Contrasts and Graph

Genstat Commands

```
" ***** "
"   Appendix One: Orthogonal Polynomial Contrasts and Graphs   "
" ***** "
```

JOB

```
" Import the data "
IMPORT 'Data Wheat Section 1.csv'

" Convert Soil from a text structure to a factor, and convert N, P,
  Rep and Year from variates to factors "
GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year
```

```

" ***** Polynomial Contrasts ***** "

" In the reduced model, partition the rate of P into linear,
  quadratic and cubic polynomial contrasts "
GETATTRIBUTE [ATTRIBUTE=levels] P; Plev
FCONTRASTS [FORMULA=Year*Soil*N*P - N.P - Year.N.P; \
  NEWFORMULA=polyP] P; ORDER=3; XCONTRASTS=#Plev
VCOMPONENTS [FIXED=#polyP; FACTORIAL=3] RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield

" ***** Graphing Interactions ***** "

" Graphing the Year by P interaction "
" Fit the reduced model "
VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
  RANDOM=Year.Soil.Rep
REML [PRINT=*] Yield

" Display the Year by P means with standard errors & LSD groupings "
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=P.Year]
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
  Year.P

" Plot the means as points joined by straight lines, with plus and
  minus the effective standard error around every mean "
VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; GROUPS=Year; \
  YTITLE='Grain yield (Mg ha-1)'; \
  XTITLE='P fertilizer rate (kg ha-1)'

" Alternatively, construct a plot with 95% confidence limits around
  the means "
VKEEP TERMS=Year.P; MEANS=means
CALC lower = means - 0.03361*ABS(EDT(0.025;34))
CALC upper = means + 0.03361*ABS(EDT(0.025;34))
PEN [RESET=yes] 1,2; COLOUR='red','limegreen'; METHOD=line; \
  SYMBOLS=2; CFILL='red','limegreen'; LINESTYLE=2,3
DTABLE [METHOD=linesandpoints] means; BAR=!P(lower,upper); \
  TITLE='LS-Means for Year*P with 95% Confidence Limits'; \
  YTITLE='Grain yield (Mg ha-1)'; \
  XTITLE='P fertilizer rate (kg ha-1)'; PENS=!(1,2)

" Notes: * REML uses the Kenward-Roger method for computing the ddf,
  whereas SAS, by default, uses the containment method.
  * As the data are balanced and normality is assumed, the
  ANOVA directive can also be used to analyse these data. "

ENDJOB

```

Genstat Output

```

2 " ***** "
3 "     Appendix One: Orthogonal Polynomial Contrasts and Graphs     "
4 " ***** "
5
6 JOB

```

End of job.

```
7
8 " Import the data "
9 IMPORT 'Data Wheat Section 1.csv'
```

Loading Spreadsheet File

Catalogue of file Data Wheat Section 1.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	64	Year
2	text	64	Soil
3	variate	64	N
4	variate	64	P
5	variate	64	Rep
6	variate	64	Yield

```
10
11 " Convert Soil from a text structure to a factor, and convert N, P,
-12   Rep and Year from variates to factors "
13 GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year
14
15 " ***** Polynomial Contrasts ***** "
16
17 " In the reduced model, partition the rate of P into linear,
-18   quadratic and cubic polynomial contrasts "
19 GETATTRIBUTE [ATTRIBUTE=levels] P; Plev
20 FCONTRASTS [FORMULA=Year*Soil*N*P - N.P - Year.N.P; \
21   NEWFORMULA=polyP] P; ORDER=3; XCONTRASTS=#Plev
22 VCOMPONENTS [FIXED=#polyP; FACTORIAL=3] RANDOM=Year.Soil.Rep
23 REML [PRINT=model,components,waldTests] Yield
```

REML variance components analysis

Response variate: Yield
Fixed model: Constant + Year + Soil + N + P lin + P quad + P cub + Year.Soil + Year.N +
Soil.N + Year.P lin + Year.P quad + Year.P cub + Soil.P lin + Soil.P quad + Soil.P cub + Year.Soil.N +
Year.Soil.P lin + Year.Soil.P quad + Year.Soil.P cub + Soil.N.P lin + Soil.N.P quad + Soil.N.P cub
Random model: Year.Soil.Rep
Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation
All covariates centred

Estimated variance components

Random term	component	s.e.

Year.Soil.Rep	0.000222	0.000953

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00859	0.002084

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001
N	11.36	1	11.36	34.0	0.002
P lin	99.78	1	99.78	34.0	<0.001
P quad	11.79	1	11.79	34.0	0.002
P cub	1.70	1	1.70	34.0	0.201
Year.Soil	125.30	1	125.30	4.0	<0.001
Year.N	9.45	1	9.45	34.0	0.004
Soil.N	19.80	1	19.80	34.0	<0.001
Year.P lin	14.22	1	14.22	34.0	<0.001
Year.P quad	4.76	1	4.76	34.0	0.036
Year.P cub	0.22	1	0.22	34.0	0.639
Soil.P lin	40.97	1	40.97	34.0	<0.001
Soil.P quad	0.18	1	0.18	34.0	0.673
Soil.P cub	0.00	1	0.00	34.0	0.981
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P lin	23.34	1	23.34	34.0	<0.001
Year.Soil.P quad	0.02	1	0.02	34.0	0.883
Year.Soil.P cub	0.47	1	0.47	34.0	0.497
Soil.N.P lin	5.22	2	2.61	34.0	0.088
Soil.N.P quad	0.52	2	0.26	34.0	0.772
Soil.N.P cub	13.54	2	6.77	34.0	0.003

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P lin	0.03	1	0.03	34.0	0.863
Year.Soil.P quad	0.49	1	0.49	34.0	0.488
Year.Soil.P cub	0.47	1	0.47	34.0	0.497
Soil.N.P lin	11.04	2	5.52	34.0	0.008
Soil.N.P quad	13.74	2	6.87	34.0	0.003
Soil.N.P cub	13.54	2	6.77	34.0	0.003

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.


```

24
25 " ***** Graphing Interactions ***** "
26
27 " Graphing the Year by P interaction "
28 " Fit the reduced model "
29 VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
30   RANDOM=Year.Soil.Rep
31 REML [PRINT=*] Yield
32
33 " Display the Year by P means with standard errors & LSD groupings "
34 VDISPLAY [PRINT=means; PSE=estimates; PTERMS=P.Year]

```

Table of predicted means for Year.P

P	0	50	150	250
Year				
2007	1.654	1.860	2.054	2.084
2008	0.914	1.021	1.056	1.125

Standard error: 0.03361

```

35 VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
36   Year.P

```

Fisher's unprotected least significant difference test

Comparisons between Year.P means

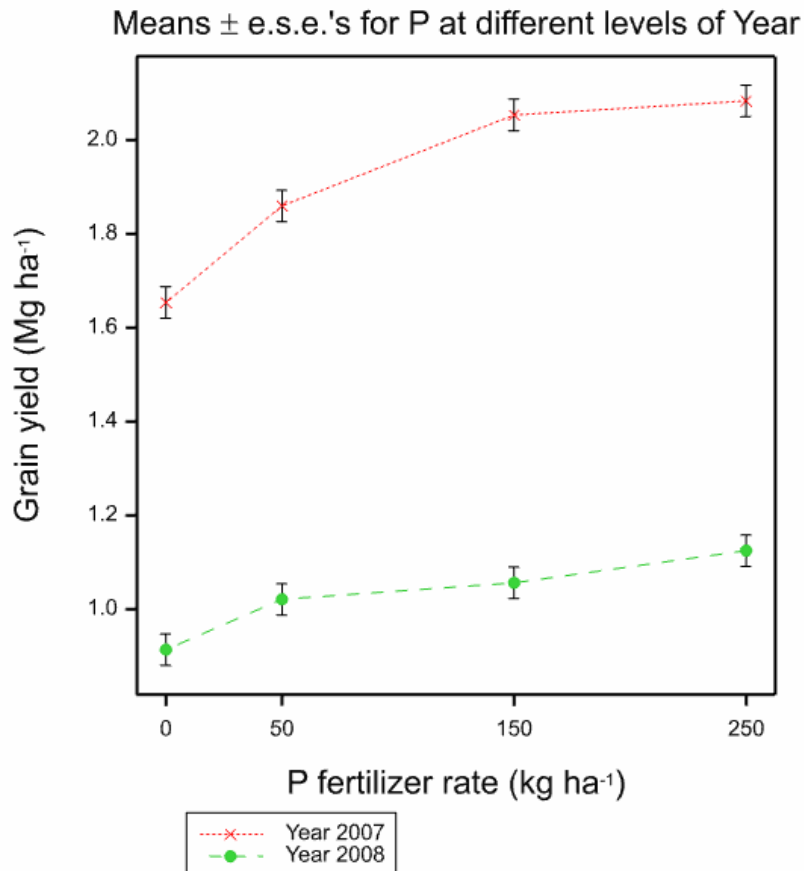
	Mean	
2007 250	2.084	a
2007 150	2.054	a
2007 50	1.860	b
2007 0	1.654	c
2008 250	1.125	d
2008 150	1.056	de
2008 50	1.021	e
2008 0	0.914	f

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

37
38 " Plot the means as points joined by straight lines, with plus and
-39 minus the effective standard error around every mean "
40 VGRAPH [METHOD=lines; PSE=allmeans] XFACTOR=P; GROUPS=Year;\
41   YTITLE='Grain yield (Mg ha-1)'; \
42   XTITLE='P fertilizer rate (kg ha-1)'

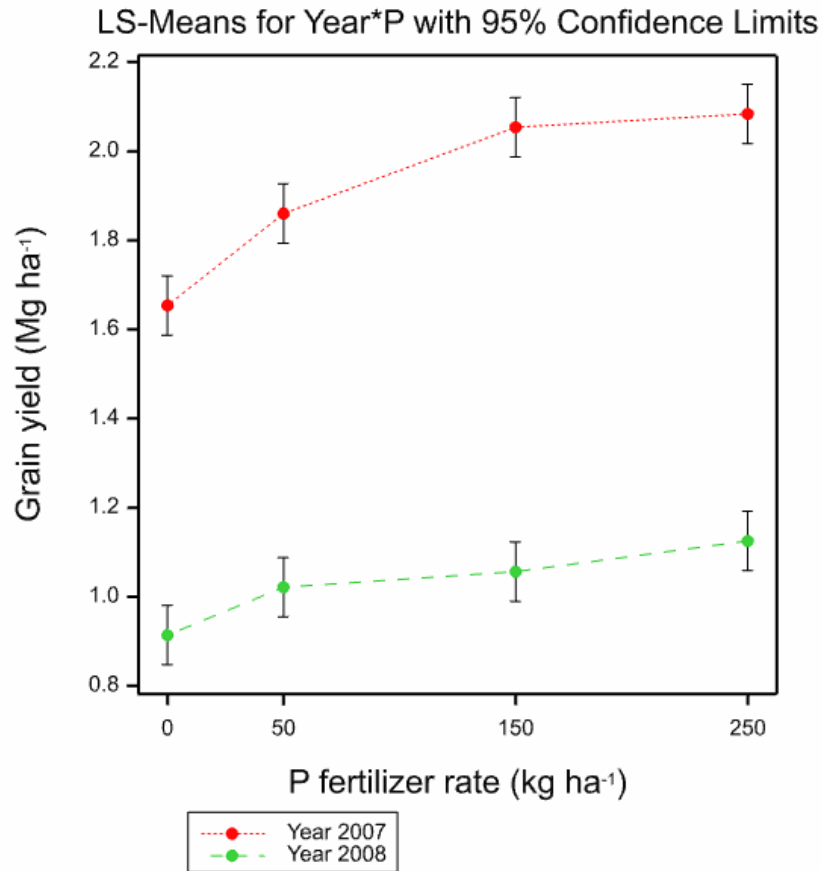
```



```

43
44 " Alternatively, construct a plot with 95% confidence limits around
-45 the means "
46 VKEEP TERMS=Year.P; MEANS=means
47 CALC lower = means - 0.03361*ABS(EDT(0.025;34))
48 CALC upper = means + 0.03361*ABS(EDT(0.025;34))
49 PEN [RESET=yes] 1,2; COLOUR='red','limegreen'; METHOD=line; \
50     SYMBOLS=2; CFILL='red','limegreen'; LINESTYLE=2,3
51 DTABLE [METHOD=linesandpoints] means; BAR=!P(lower,upper); \
52     TITLE='LS-Means for Year*P with 95% Confidence Limits'; \
53     YTITLE='Grain yield (Mg ha^{-1})'; \
54     XTITLE='P fertilizer rate (kg ha^{-1})'; PENS=!(1,2)

```



```

55
56  " Notes: * REML uses the Kenward-Roger method for computing the ddf,
-57             whereas SAS, by default, uses the containment method.
-58             * As the data are balanced and normality is assumed, the
-59             ANOVA directive can also be used to analyse these data. "
60
61  ENDJOB

```

End of job.

Appendix Two: Extension to code shown in Appendix One

Genstat Commands

```

" ***** "
"           Appendix Two: Extension to code shown in Appendix One           "
" ***** "

JOB

" Import the data "
IMPORT 'Data Wheat Section 1.csv'

" Convert Soil from a text structure to a factor, and convert N, P,
  Rep and Year from variates to factors "

```

```

GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year

" ***** Polynomial Contrasts ***** "

" In the complete model, partition the rate of P into linear,
  quadratic and cubic polynomial contrasts "
GETATTRIBUTE [ATTRIBUTE=levels] P; Plev
FCONTRASTS [FORMULA=Year*Soil*N*P; NEWFORMULA=polyP; FACTORIAL=4] \
  P; ORDER=3; XCONTRASTS=#Plev
VCOMPONENTS [FIXED=#polyP; FACTORIAL=4] RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield

" ***** Graphing the three-way interaction Year by Soil by P ***** "

" Fit the reduced model "
VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
  RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield

" Display the Year by Soil by P means with standard errors, and the
  LSD groupings "
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Year.Soil.P]
VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
  Year.Soil.P

" Display the Year by Soil means with standard errors, and the
  LSD groupings "
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Year.Soil]
VMCOMPARISON [DIRECTION=descending] Year.Soil

" ***** Construct Figure 1.1 ***** "

" Save means and standard errors "
VKEEP TERMS=Year.Soil.N; MEANS=meansT; VARMEANS=varmeans
VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
" Form variates from the table containing the means "
VTABLE TABLE=meansT; VARIATE=means; \
  CLASSIFICATION=!P(Year_lev,Soil_lev,N_lev)
" Calculate the LSD bars (maximum LSD is used) "
DELETE [REDEFINE=y] lsdsM
VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Year.Soil.N; LSD=lsdsM
CALC lsd = MAX(lsdsM)
" Plot means as points joined by straight lines, with LSD bars "
PEN [RESET=yes] 1,2,3,4; COLOUR='black','green','blue','red'; \
  METHOD=line; SYMBOLS=2; CFILL='black','green','blue','red'; \
  LINESTYLE=1
YAXIS [RESET=yes] WINDOW=1; TITLE='Grain yield (Mg ha-1)'
GETATTRIBUTE [ATTRIBUTE=levels] N; SAVE=Nlev
XAXIS [RESET=yes] WINDOW=1; TITLE='N fertilizer rate (kg ha-1)'; \
  MARKS=#Nlev
FACPRODUCT !P(Soil_lev,Year_lev); SY
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=N_lev; PEN=SY; \
  YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
" Add labels to the series "
GETATTRIBUTE [ATTRIBUTE=labels] SY; SAVE=SYlabels
TXCONSTRUCT [TEXT=labels] #SYlabels
CALC yloc=0.1+(!(means$[1,5,3,7]))+(means$[2,6,4,8])/2

```

```

DTEXT [WINDOW=1] Y=yloc; X=!(4(10)); TEXT=labels; PEN=!(1,2,3,4)
" Letters "
PEN [RESET=yes] 1,2,3,4
VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
  DFGIVEN=34] Soil.Year.N; LETTER=letters
VARIATE xN_lev; VALUES=N_lev
SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xN_lev; \
  NEWVECTOR=meansO,xN_levO
DTEXT [WINDOW=1] Y=meansO-0.1; X=xN_levO+0.5; TEXT=letters; PEN=1

" ***** Construct Figure 1.2 ***** "

" Save means and standard errors "
VKEEP TERMS=Year.Soil.P; MEANS=meansT; VARMEANS=varmeans
VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
" Form variates from the table containing the means "
VTABLE TABLE=meansT; VARIATE=means; \
  CLASSIFICATION=!P(Year_lev,Soil_lev,P_lev)
" Calculate the LSD bars (maximum LSD is used) "
DELETE [REDEFINE=y] lsdsM
VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Year.Soil.P; LSD=lsdsM
CALC lsd = MAX(lsdsM)
" Plot means as points, with LSD bars "
PEN [RESET=yes] 1,2,3,4; COLOUR='black','green','blue','red'; \
  METHOD=point; SYMBOLS=2; CFILL='black','green','blue','red'
YAXIS WINDOW=1; TITLE='Grain yield (Mg ha-1)'
GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
XAXIS WINDOW=1; TITLE='P fertilizer rate (kg ha-1)'; \
  MARKS=#Plev; UPPER=270
FACPRODUCT !P(Soil_lev,Year_lev); SY
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=P_lev; PEN=SY; \
  YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
" Add labels to the series "
GETATTRIBUTE [ATTRIBUTE=labels] SY; SAVE=SYlabels
TXCONSTRUCT [TEXT=labels] #SYlabels
CALC yloc=!(means$[3,11,7,15])+!(0.15,0.1,0.1,0.1)
DTEXT [WINDOW=1] Y=yloc; X=!(4(155)); TEXT=labels; PEN=!(1,2,3,4)
" Letters "
PEN [RESET=yes] 1,2,3,4
VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
  DFGIVEN=34] Year.Soil.P; LETTER=letters
VARIATE xP_lev; VALUES=P_lev
SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xP_lev; \
  NEWVECTOR=meansO,xP_levO
DTEXT [WINDOW=1] Y=meansO-0.1; X=xP_levO+3; TEXT=letters; PEN=1
" Adding independently fitted linear regression lines "
CALC P_levV = P_lev
MODEL means
TERMS P_levV*SY
DELETE [REDEFINE=yes] fit,fitP,fitSY,xfitP
FIT [PRINT=*] P_levV*SY
PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SY; \
  LEVELS=!(0,50,150,250),*
VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSY)
CALC xfitP = fitP
PEN 1,2,3,4; COLOUR='black','green','blue','red'; \
  METHOD=line,line,point,line; SYMBOLS=0; LINESTYLE=1

```

```

DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSY
" Adding independently fitted quadratic regression lines "
CALC P_levV_sq = P_lev**2
MODEL means
TERMS POL(P_levV;2)*SY
FIT [PRINT=*] POL(P_levV;2)*SY
DELETE [REDEFINE=yes] fit,fitP,fitSY,xfitP
PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SY; \
    LEVELS=!(0,50,150,250),*
VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSY)
CALC xfitP = fitP
PEN 1,2,3,4; COLOUR='black','green','blue','red'; \
    METHOD=point,point,monotonic,point; SYMBOLS=0; LINSTYLE=1
DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSY

" ***** Construct Figure 1.3 ***** "

" Save means and standard errors "
VKEEP TERMS=Soil.N.P; MEANS=meansT; VARMEANS=varmeans
VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
" Form variates from the table containing the means "
VTABLE TABLE=meansT; VARIATE=means; \
    CLASSIFICATION=!P(Soil_lev,N_lev,P_lev)
" Calculate the LSD bars "
DELETE [REDEFINE=y] lsdsM
VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Soil.N.P; LSD=lsdsM
CALC lsd = MAX(lsdsM)
" Plot means as points, with LSD bars "
PEN [RESET=yes] 1,2,3,4; COLOUR='blue','black','red','green'; \
    METHOD=point; SYMBOLS=2; CFILL='blue','black','red','green'
YAXIS WINDOW=1; TITLE='Grain yield (Mg ha-1)'
GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
XAXIS WINDOW=1; TITLE='P fertilizer rate (kg ha-1)'; \
    MARKS=#Plev; UPPER=280
FACPRODUCT !P(Soil_lev,N_lev); SN
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=P_lev; PEN=SN; \
    YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
" Add labels to the series "
GETATTRIBUTE [ATTRIBUTE=labels] SN; SAVE=SNlabels
TXCONSTRUCT [TEXT=labels] #SNlabels
CALC yloc=!(means$[3,7,11,15])+!(-0.15,0.15,-0.15,0.15)
DTEXT [WINDOW=1] Y=yloc; X=!(4(165)); TEXT=labels; \
    PEN=!(1,2,3,4)
" Letters "
PEN [RESET=yes] 1,2,3,4
VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
    DFGIVEN=34] Soil.N.P; LETTER=letters
VARIATE xP_lev; VALUES=P_lev
SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xP_lev; \
    NEWVECTOR=meansO,xP_levO
DTEXT [WINDOW=1] Y=meansO-0.05; X=xP_levO+3; TEXT=letters; PEN=1
" Adding independently fitted linear regression lines "
CALC P_levV = P_lev
MODEL means
TERMS P_levV*SN
DELETE [REDEFINE=yes] fit,fitP,fitSN,xfitP
FIT [PRINT=*] P_levV*SN

```

```

PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SN; \
  LEVELS=!(0,50,150,250),*
VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSN)
CALC xfitP = fitP
PEN 1,2,3,4; COLOUR='blue','black','red','green'; \
  METHOD=line,line,point,point; SYMBOLS=0; LINESTYLE=1
DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSN
" Adding independently fitted quadratic regression lines "
CALC P_levV_sq = P_lev**2
MODEL means
TERMS POL(P_levV;3)*SN
FIT [PRINT=*] POL(P_levV;3)*SN
DELETE [REDEFINE=yes] fit,fitP,fitSN,xfitP
PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SN; \
  LEVELS=!(0,10,20...250),*
VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSN)
CALC xfitP = fitP
PEN 1,2,3,4; COLOUR='blue','black','red','green'; \
  METHOD=point,point,monotonic,monotonic; SYMBOLS=0; LINESTYLE=1
DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSN

" Notes: * REML uses the Kenward-Roger method for computing the ddf,
          whereas SAS, by default, uses the containment method.
          * As the data are balanced and normality is assumed, the
          ANOVA directive can also be used to analyse these data. "

ENDJOB

```

Genstat Output

```

2  " ***** "
3  "           Appendix Two: Extension to code shown in Appendix One "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Import the data "
9  IMPORT 'Data Wheat Section 1.csv'

```

Loading Spreadsheet File

Catalogue of file Data Wheat Section 1.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	64	Year
2	text	64	Soil
3	variate	64	N
4	variate	64	P

```

5          variate      64  Rep
6          variate      64  Yield

10
11  " Convert Soil from a text structure to a factor, and convert N, P,
-12  Rep and Year from variates to factors "
13  GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year
14
15  " ***** Polynomial Contrasts ***** "
16
17  " In the complete model, partition the rate of P into linear,
-18  quadratic and cubic polynomial contrasts "
19  GETATTRIBUTE [ATTRIBUTE=levels] P; Plev
20  FCONTRASTS [FORMULA=Year*Soil*N*P; NEWFORMULA=polyP; FACTORIAL=4] \
21  P; ORDER=3; XCONTRASTS=#Plev
22  VCOMPONENTS [FIXED=#polyP; FACTORIAL=4] RANDOM=Year.Soil.Rep
23  REML [PRINT=model,components,waldTests] Yield

```

REML variance components analysis

Response variate: Yield
Fixed model: Constant + Year + Soil + N + P lin + P quad + P cub + Year.Soil + Year.N + Soil.N + Year.P lin + Year.P quad + Year.P cub + Soil.P lin + Soil.P quad + Soil.P cub + N.P lin + N.P quad + N.P cub + Year.Soil.N + Year.Soil.P lin + Year.Soil.P quad + Year.Soil.P cub + Year.N.P lin + Year.N.P quad + Year.N.P cub + Soil.N.P lin + Soil.N.P quad + Soil.N.P cub + Year.Soil.N.P lin + Year.Soil.N.P quad + Year.Soil.N.P cub
Random model: Year.Soil.Rep
Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation
All covariates centred

Estimated variance components

Random term	component	s.e.
Year.Soil.Rep	0.000292	0.000955

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00804	0.002148

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001

N	12.15	1	12.15	28.0	0.002
P lin	106.69	1	106.69	28.0	<0.001
P quad	12.60	1	12.60	28.0	0.001
P cub	1.82	1	1.82	28.0	0.189
Year.Soil	125.30	1	125.30	4.0	<0.001
Year.N	10.11	1	10.11	28.0	0.004
Soil.N	21.17	1	21.17	28.0	<0.001
Year.P lin	15.21	1	15.21	28.0	<0.001
Year.P quad	5.09	1	5.09	28.0	0.032
Year.P cub	0.24	1	0.24	28.0	0.628
Soil.P lin	43.81	1	43.81	28.0	<0.001
Soil.P quad	0.19	1	0.19	28.0	0.664
Soil.P cub	0.00	1	0.00	28.0	0.980
N.P lin	2.59	1	2.59	28.0	0.119
N.P quad	0.48	1	0.48	28.0	0.493
N.P cub	1.39	1	1.39	28.0	0.249
Year.Soil.N	35.62	1	35.62	28.0	<0.001
Year.Soil.P lin	24.96	1	24.96	28.0	<0.001
Year.Soil.P quad	0.02	1	0.02	28.0	0.879
Year.Soil.P cub	0.50	1	0.50	28.0	0.483
Year.N.P lin	0.82	1	0.82	28.0	0.372
Year.N.P quad	0.49	1	0.49	28.0	0.490
Year.N.P cub	0.64	1	0.64	28.0	0.431
Soil.N.P lin	3.00	1	3.00	28.0	0.094
Soil.N.P quad	0.07	1	0.07	28.0	0.787
Soil.N.P cub	13.09	1	13.09	28.0	0.001
Year.Soil.N.P lin	0.50	1	0.50	28.0	0.487
Year.Soil.N.P quad	0.01	1	0.01	28.0	0.944
Year.Soil.N.P cub	5.90	1	5.90	28.0	0.022

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N.P lin	5.39	1	5.39	28.0	0.028
Year.Soil.N.P quad	5.82	1	5.82	28.0	0.023
Year.Soil.N.P cub	5.90	1	5.90	28.0	0.022

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

24
25 " ***** Graphing the three-way interaction Year by Soil by P ***** "
26
27 " Fit the reduced model "
28 VCOMPONENTS [FIXED=Year*Soil*N*P - N.P - Year.N.P; FACTORIAL=3] \
29     RANDOM=Year.Soil.Rep
30 REML [PRINT=model,components,waldTests] Yield

```

REML variance components analysis

Response variate: Yield
Fixed model: Constant + Year + Soil + N + P + Year.Soil + Year.N + Soil.N + Year.P +
Soil.P + Year.Soil.N + Year.Soil.P + Soil.N.P
Random model: Year.Soil.Rep
Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year.Soil.Rep	0.000222	0.000953

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00859	0.002084

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001
N	11.36	1	11.36	34.0	0.002
P	113.26	3	37.75	34.0	<0.001
Year.Soil	125.30	1	125.30	4.0	<0.001
Year.N	9.45	1	9.45	34.0	0.004
Soil.N	19.80	1	19.80	34.0	<0.001
Year.P	19.20	3	6.40	34.0	0.001
Soil.P	41.15	3	13.72	34.0	<0.001
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P	23.83	3	7.94	34.0	<0.001
Soil.N.P	19.28	6	3.21	34.0	0.013

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N	33.31	1	33.31	34.0	<0.001
Year.Soil.P	23.83	3	7.94	34.0	<0.001
Soil.N.P	19.28	6	3.21	34.0	0.013

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
31
32 " Display the Year by Soil by P means with standard errors, and the
-33 LSD groupings "
34 VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Year.Soil.P]
```

Table of predicted means for Year.Soil.P

	P	0	50	150	250
Year	Soil				
2007	black	1.947	2.207	2.560	2.708
	chestnut	1.360	1.512	1.547	1.460
2008	black	1.038	1.182	1.222	1.305
	chestnut	0.790	0.860	0.890	0.945

Standard error: 0.04753

```
35  VMCOMPARISON [DIRECTION=descending; DFMETHOD=given; DFGIVEN=34] \
36  Year.Soil.P
```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil.P means

	Mean	
2007 black 250	2.708	a
2007 black 150	2.560	b
2007 black 50	2.207	c
2007 black 0	1.947	d
2007 chestnut 150	1.547	e
2007 chestnut 50	1.512	e
2007 chestnut 250	1.460	ef
2007 chestnut 0	1.360	fg
2008 black 250	1.305	gh
2008 black 150	1.222	h
2008 black 50	1.182	h
2008 black 0	1.038	i
2008 chestnut 250	0.945	ij
2008 chestnut 150	0.890	jk
2008 chestnut 50	0.860	jk
2008 chestnut 0	0.790	k

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```
37
38  " Display the Year by Soil means with standard errors, and the
-39  LSD groupings "
40  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Year.Soil]
```

Table of predicted means for Year.Soil

Soil	black	chestnut
Year		
2007	2.356	1.470
2008	1.187	0.871

Standard error: 0.02546

```
41  VMCOMPARISON [DIRECTION=descending] Year.Soil
```

Fisher's unprotected least significant difference test

Comparisons between Year.Soil means

	Mean	
2007 black	2.356	a
2007 chestnut	1.470	b
2008 black	1.187	c
2008 chestnut	0.871	d

```
42
43  " ***** Construct Figure 1.1 ***** "
44
45  " Save means and standard errors "
46  VKEEP TERMS=Year.Soil.N; MEANS=meansT; VARMEANS=varmeans
47  VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
48  " Form variates from the table containing the means "
49  VTABLE TABLE=meansT; VARIATE=means; \
50  CLASSIFICATION=!P(Year_lev,Soil_lev,N_lev)
51  " Calculate the LSD bars (maximum LSD is used) "
52  DELETE [REDEFINE=y] lsdsM
53  VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Year.Soil.N; LSD=lsdsM
```

Message: the supplied residual d.f. may not be accurate, so the LSD's should be used with care.

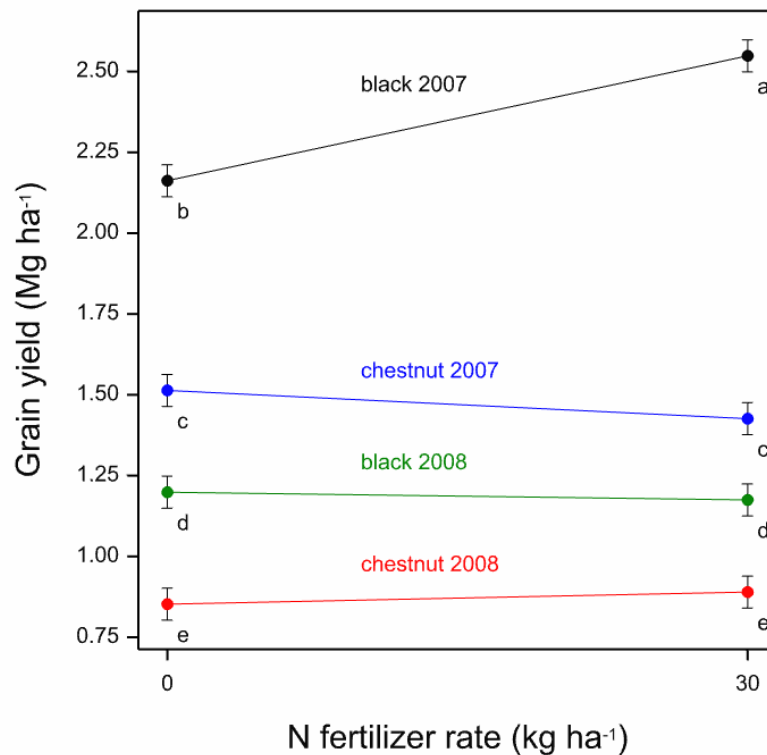
```
54  CALC lsd = MAX(lsdsM)
55  " Plot means as points joined by straight lines, with LSD bars "
56  PEN [RESET=yes] 1,2,3,4; COLOUR='black','green','blue','red'; \
57  METHOD=line; SYMBOLS=2; CFILL='black','green','blue','red'; \
58  LINSTYLE=1
59  YAXIS [RESET=yes] WINDOW=1; TITLE='Grain yield (Mg ha{}^{-1})'
60  GETATTRIBUTE [ATTRIBUTE=levels] N; SAVE=Nlev
61  XAXIS [RESET=yes] WINDOW=1; TITLE='N fertilizer rate (kg ha{}^{-1})';\
62  MARKS=#Nlev
63  FACPRODUCT !P(Soil_lev,Year_lev); SY
64  DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=N_lev; PEN=SY; \
65  YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
66  " Add labels to the series "
67  GETATTRIBUTE [ATTRIBUTE=labels] SY; SAVE=SYlabels
68  TXCONSTRUCT [TEXT=labels] #SYlabels
69  CALC yloc=0.1+(! (means$[1,5,3,7])+!(means$[2,6,4,8]))/2
70  DTEXT [WINDOW=1] Y=yloc; X=!(4(10)); TEXT=labels; PEN=!(1,2,3,4)
71  " Letters "
72  PEN [RESET=yes] 1,2,3,4
73  VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
74  DFGIVEN=34] Soil.Year.N; LETTER=letters
```

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

75 VARIATE xN_lev; VALUES=N_lev
76 SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xN_lev; \
77 NEWVECTOR=meansO,xN_levO
78 DTEXT [WINDOW=1] Y=meansO-0.1; X=xN_levO+0.5; TEXT=letters; PEN=1

```



```

79
80 " ***** Construct Figure 1.2 ***** "
81
82 " Save means and standard errors "
83 VKEEP TERMS=Year.Soil.P; MEANS=meansT; VARMEANS=varmeans
84 VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
85 " Form variates from the table containing the means "
86 VTABLE TABLE=meansT; VARIATE=means; \
87 CLASSIFICATION=!P(Year_lev,Soil_lev,P_lev)
88 " Calculate the LSD bars (maximum LSD is used) "
89 DELETE [REDEFINE=y] lsdsm
90 VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Year.Soil.P; LSD=lsdsm

```

Message: the supplied residual d.f. may not be accurate, so the LSD's should be used with care.

```

91  CALC lsd = MAX(lsdsm)
92  " Plot means as points, with LSD bars "
93  PEN [RESET=yes] 1,2,3,4; COLOUR='black','green','blue','red'; \
94  METHOD=point; SYMBOLS=2; CFILL='black','green','blue','red'
95  YAXIS WINDOW=1; TITLE='Grain yield (Mg ha-1)'
96  GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
97  XAXIS WINDOW=1; TITLE='P fertilizer rate (kg ha-1)'; \
98  MARKS=#Plev; UPPER=270
99  FACPRODUCT !P(Soil_lev,Year_lev); SY
100 DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=P_lev; PEN=SY; \
101 YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
102 " Add labels to the series "
103 GETATTRIBUTE [ATTRIBUTE=labels] SY; SAVE=SYlabels
104 TXCONSTRUCT [TEXT=labels] #SYlabels
105 CALC yloc=!(means$[3,11,7,15])+!(0.15,0.1,0.1,0.1)
106 DTEXT [WINDOW=1] Y=yloc; X=!(4(155)); TEXT=labels; PEN=!(1,2,3,4)
107 " Letters "
108 PEN [RESET=yes] 1,2,3,4
109 VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
110   DFGIVEN=34] Year.Soil.P; LETTER=letters

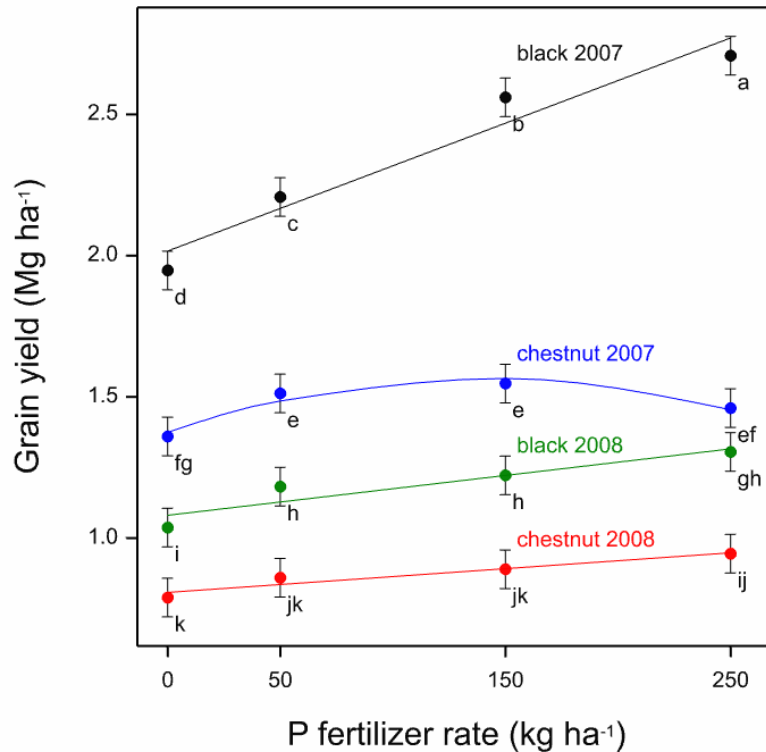
```

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

111 VARIATE xP_lev; VALUES=P_lev
112 SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xP_lev; \
113   NEWVECTOR=meansO,xP_levO
114 DTEXT [WINDOW=1] Y=meansO-0.1; X=xP_levO+3; TEXT=letters; PEN=1
115 " Adding independently fitted linear regression lines "
116 CALC P_levV = P_lev
117 MODEL means
118 TERMS P_levV*SY
119 DELETE [REDEFINE=yes] fit,fitP,fitSY,xfitP
120 FIT [PRINT=*] P_levV*SY
121 PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SY; \
122   LEVELS=!(0,50,150,250),*
123 VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSY)
124 CALC xfitP = fitP
125 PEN 1,2,3,4; COLOUR='black','green','blue','red'; \
126   METHOD=line,line,point,line; SYMBOLS=0; LINESTYLE=1
127 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSY
128 " Adding independently fitted quadratic regression lines "
129 CALC P_levV_sq = P_lev**2
130 MODEL means
131 TERMS POL(P_levV;2)*SY
132 FIT [PRINT=*] POL(P_levV;2)*SY
133 DELETE [REDEFINE=yes] fit,fitP,fitSY,xfitP
134 PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SY; \
135   LEVELS=!(0,50,150,250),*
136 VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSY)
137 CALC xfitP = fitP
138 PEN 1,2,3,4; COLOUR='black','green','blue','red'; \
139   METHOD=point,point,monotonic,point; SYMBOLS=0; LINESTYLE=1
140 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSY

```



```

141
142 " ***** Construct Figure 1.3 ***** "
143
144 " Save means and standard errors "
145 VKEEP TERMS=Soil.N.P; MEANS=meansT; VARMEANS=varmeans
146 VARIATE semsV; VALUES=SQRT(DIAGONAL(varmeans))
147 " Form variates from the table containing the means "
148 VTABLE TABLE=meansT; VARIATE=means; \
149     CLASSIFICATION=!P(Soil_lev,N_lev,P_lev)
150 " Calculate the LSD bars "
151 DELETE [REDEFINE=y] lsdsM
152 VLSD [PRINT=*; DFMETHOD=given; DFGIVEN=34] Soil.N.P; LSD=lsdsM

```

Message: the supplied residual d.f. may not be accurate, so the LSD's should be used with care.

```

153 CALC lsd = MAX(lsdsM)
154 " Plot means as points, with LSD bars "
155 PEN [RESET=yes] 1,2,3,4; COLOUR='blue','black','red','green'; \
156     METHOD=point; SYMBOLS=2; CFILL='blue','black','red','green'
157 YAXIS WINDOW=1; TITLE='Grain yield (Mg ha-1)'
158 GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
159 XAXIS WINDOW=1; TITLE='P fertilizer rate (kg ha-1)'; \
160     MARKS=#Plev; UPPER=280
161 FACPRODUCT !P(Soil_lev,N_lev); SN
162 DGRAPH [WINDOW=1; KEYWINDOW=0] Y=means; X=P_lev; PEN=SN; \
163     YLOWER=means-(lsd)/2; YUPPER=means+(lsd)/2
164 " Add labels to the series "
165 GETATTRIBUTE [ATTRIBUTE=labels] SN; SAVE=SNlabels
166 TXCONSTRUCT [TEXT=labels] #SNlabels

```

```

167 CALC yloc=!(means$[3,7,11,15])+!(-0.15,0.15,-0.15,0.15)
168 DTEXT [WINDOW=1] Y=yloc; X=!(4(165)); TEXT=labels; \
169     PEN=!(1,2,3,4)
170 " Letters "
171 PEN [RESET=yes] 1,2,3,4
172 VMCOMPARISON [PRINT=*; DIRECTION=descending; DFMETHOD=given; \
173     DFGIVEN=34] Soil.N.P; LETTER=letters

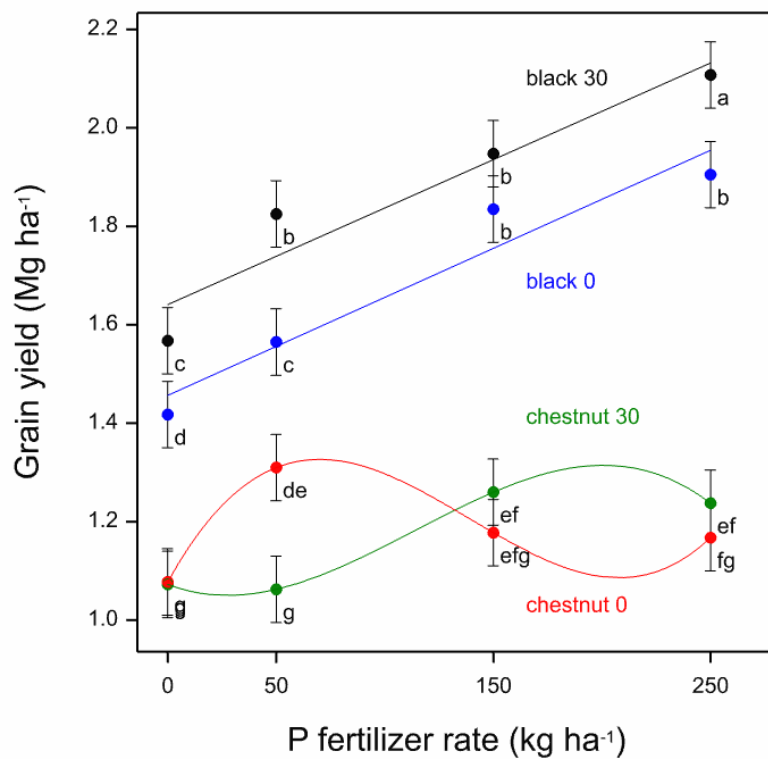
```

Message: The tests have been made using the supplied residual d.f. of 34; these may not be accurate, so the tests should be used with caution.

```

174 VARIATE xP_lev; VALUES=P_lev
175 SORT [INDEX=means; DIRECTION=descending] OLDVECTOR=means,xP_lev; \
176     NEWVECTOR=meansO,xP_levO
177 DTEXT [WINDOW=1] Y=meansO-0.05; X=xP_levO+3; TEXT=letters; PEN=1
178 " Adding independently fitted linear regression lines "
179 CALC P_levV = P_lev
180 MODEL means
181 TERMS P_levV*SN
182 DELETE [REDEFINE=yes] fit,fitP,fitSN,xfitP
183 FIT [PRINT=*] P_levV*SN
184 PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SN; \
185     LEVELS=!(0,50,150,250),*
186 VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSN)
187 CALC xfitP = fitP
188 PEN 1,2,3,4; COLOUR='blue','black','red','green'; \
189     METHOD=line,line,point,point; SYMBOLS=0; LINESTYLE=1
190 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSN
191 " Adding independently fitted quadratic regression lines "
192 CALC P_levV_sq = P_lev**2
193 MODEL means
194 TERMS POL(P_levV;3)*SN
195 FIT [PRINT=*] POL(P_levV;3)*SN
196 DELETE [REDEFINE=yes] fit,fitP,fitSN,xfitP
197 PREDICT [PRINT=*; PREDICTIONS=fit] P_levV,SN; \
198     LEVELS=!(0,10,20...250),*
199 VTABLE TABLE=fit; VARIATE=fitV; CLASSIFICATION=!P(fitP,fitSN)
200 CALC xfitP = fitP
201 PEN 1,2,3,4; COLOUR='blue','black','red','green'; \
202     METHOD=point,point,monotonic,monotonic; SYMBOLS=0; LINESTYLE=1
203 DGRAPH [SCREEN=resize; KEYWINDOW=0] Y=fitV; X=xfitP; PEN=fitSN

```

```

204
205 " Notes: * REML uses the Kenward-Roger method for computing the ddf,
-206           whereas SAS, by default, uses the containment method.
-207           * As the data are balanced and normality is assumed, the
-208             ANOVA directive can also be used to analyse these data. "
209
210 ENDJOB

```

End of job.

Section Two: Mixed Models

Genstat Commands

```

" ***** "
"           Section Two: Mixed Models           "
" ***** "

" ***** Example 1 ***** "

JOB

" Import the data "
IMPORT 'Appendix A FixRnd2 Data.csv'

" Convert YEAR, REP, TILLAGE, SUMCRP, MANURE and NLEVEL from variates
  to factors "
GROUP [REDEFINE=yes] YEAR, REP, TILLAGE, SUMCRP, MANURE, NLEVEL; \

```

```

Year,Rep,Till,SumCrop,Man,N

" Model 1: Year and Rep.Year are random effects, and all four
  agronomic factors are fixed effects that don't interact with Year "
VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] RANDOM=Year/Rep
REML [PRINT=model,components,waldTests] YIELD

" Model 2: Each main effect interacts with Year and Rep.Year and each
  Year x main effect interaction is a random effect, while the four
  main agronomic effects and their interactions are fixed effects "
VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
  RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N); CONSTRAINTS=p
REML [PRINT=model,components,waldTests] YIELD

" Model 3: Each interaction of Year x main effect is random and each
  interaction of Year x two-factor interaction is a random effect.
  The four agronomic main effects and their interactions are fixed
  effects "
VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
  RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
    Year.Till.(SumCrop+Man+N) + Year.SumCrop.(Man+N) + \
    Year.Man.N; CONSTRAINTS=p
REML [PRINT=model,components,waldTests] YIELD

" Note: As the estimation of the ddf has failed, Wald tests are given
  instead of F-tests. These tend to give significant results rather
  too frequently. The VCRITICAL procedure offers an alternative
  (and more reliable) method for assessing fixed terms when F-tests
  aren't available. "

" Model 4: The interactions of Year x main effects, Year x two-way
  interactions of main effects, and Year x three-way interactions of
  main effects are random effects, and the remaining four agronomic
  factors and their interactions are fixed effects "
" Fitted using REML "
VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
  RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
    Year.Till.(SumCrop+Man+N) + Year.SumCrop.(Man+N) + \
    Year.Man.N + Year.Till.SumCrop.(Man+N) + \
    Year.Till.Man.N + Year.SumCrop.Man.N; CONSTRAINTS=p
REML [PRINT=model,components,waldTests] YIELD

" Model 5: The saturated model which includes all possible random and
  fixed terms "
VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
  RANDOM=Year/Rep + Year.(Till*SumCrop*Man*N); CONSTRAINTS=p
REML [PRINT=model,components,waldTests] YIELD

" Model 6: Fixed effects model "
" Fitted using REML "
VCOMPONENTS [FIXED=Year*Till*SumCrop*Man*N; FACTORIAL=5] \
  RANDOM=Year.Rep; CONSTRAINTS=p
REML [PRINT=model,components,waldTests] YIELD

" Notes: * REML uses the Kenward-Roger method for computing the ddf,
  whereas SAS, by default, uses the containment method.
  * REML provides only sequential F-tests, not Type 3 tests.
  * As the data are balanced and normality is assumed, the

```

ANOVA directive can also be used to analyse these data.
The advantage of using ANOVA is that an analysis-of-
variance table is produced. "

ENDJOB

" ***** Example 2 ***** "

JOB

" Import the data "

IMPORT 'Appendix A FixRnd10 Data.csv'

" Convert YEAR, REP, TILLAGE, SUMCRP, MANURE and NLEVEL from variates
to factors "

GROUP [REDEFINE=yes] YEAR, REP, TILLAGE, SUMCRP, MANURE, NLEVEL; \
Year, Rep, Till, SumCrop, Man, N

" First model: Saturated model, including all possible random and
fixed terms "

VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
RANDOM=Year/Rep + Year.(Till*SumCrop*Man*N); CONSTRAINTS=p
REML [PRINT=model, components, waldTests] YIELD

" Second model: The first ten lowest order random terms and all
possible fixed terms "

VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
Year.Till.(SumCrop+N) + Year.SumCrop.(Man+N) + Year.Man.N; \
CONSTRAINTS=p
REML [PRINT=model, components, waldTests] YIELD

" Notes: * REML uses the Kenward-Roger method for computing the ddf,
whereas SAS, by default, uses the containment method.
* REML provides only sequential F-tests.
* As the data are balanced and normality is assumed, the
ANOVA directive can also be used to analyse these data. "

ENDJOB

Genstat Output

```

2 " *****
3 "                               Section Two: Mixed Models
4 " *****
5
6 " ***** Example 1 *****
7
8 JOB

```

End of job.

```

9
10 " Import the data "
11 IMPORT 'Appendix A FixRnd2 Data.csv'

```

Loading Spreadsheet File

Catalogue of file Appendix A FixRnd2 Data.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	144	YEAR
2	variate	144	REP
3	variate	144	TREAT
4	variate	144	TILLAGE
5	variate	144	SUMCRP
6	variate	144	MANURE
7	variate	144	NLEVEL
8	variate	144	YIELD

```
12
13 " Convert YEAR, REP, TILLAGE, SUMCRP, MANURE and NLEVEL from variates
-14 to factors "
15 GROUP [REDEFINE=yes] YEAR,REP,TILLAGE,SUMCRP,MANURE,NLEVEL; \
16 Year,Rep,Till,SumCrop,Man,N
17
18 " Model 1: Year and Rep.Year are random effects, and all four
-19 agronomic factors are fixed effects that don't interact with Year "
20 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] RANDOM=Year/Rep
21 REML [PRINT=model,components,waldTests] YIELD
```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep
Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	237357.	376585.
Year.Rep	56421.	60678.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	701195.	92471.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	19.04	1	19.04	115.0	<0.001
SumCrop	7.97	1	7.97	115.0	0.006
Man	48.20	1	48.20	115.0	<0.001
N	144.64	2	72.32	115.0	<0.001
Till.SumCrop	0.01	1	0.01	115.0	0.938
Till.Man	0.93	1	0.93	115.0	0.336
SumCrop.Man	1.18	1	1.18	115.0	0.280
Till.N	0.32	2	0.16	115.0	0.851
SumCrop.N	6.20	2	3.10	115.0	0.049
Man.N	41.48	2	20.74	115.0	<0.001
Till.SumCrop.Man	0.22	1	0.22	115.0	0.639
Till.SumCrop.N	0.61	2	0.30	115.0	0.738
Till.Man.N	2.18	2	1.09	115.0	0.340
SumCrop.Man.N	1.83	2	0.91	115.0	0.404
Till.SumCrop.Man.N	2.03	2	1.02	115.0	0.366

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	2.03	2	1.02	115.0	0.366

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

22
23 " Model 2: Each main effect interacts with Year and Rep.Year and each
-24 Year x main effect interaction is a random effect, while the four
-25 main agronomic effects and their interactions are fixed effects "
26 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
27 RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N); CONSTRAINTS=p
28 REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N
Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	0.	bound
Year.Rep	68607.	60111.
Year.Till	200557.	280863.
Year.SumCrop	38679.	69646.
Year.Man	155899.	225543.
Year.N	389604.	387828.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	398432.	53728.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	1.75	1	1.75	1.1	0.392
SumCrop	3.12	1	3.12	1.0	0.324
Man	5.62	1	5.62	1.1	0.236
N	10.40	2	5.20	2.2	0.147
Till.SumCrop	0.01	1	0.01	110.0	0.918
Till.Man	1.64	1	1.64	110.0	0.202
SumCrop.Man	2.07	1	2.07	110.0	0.153
Till.N	0.57	2	0.28	110.0	0.754
SumCrop.N	10.91	2	5.46	110.0	0.006
Man.N	72.99	2	36.50	110.0	<0.001
Till.SumCrop.Man	0.39	1	0.39	110.0	0.533
Till.SumCrop.N	1.07	2	0.53	110.0	0.587
Till.Man.N	3.83	2	1.92	110.0	0.152
SumCrop.Man.N	3.22	2	1.61	110.0	0.205
Till.SumCrop.Man.N	3.57	2	1.79	110.0	0.172

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	3.57	2	1.79	110.0	0.172

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

29
30 " Model 3: Each interaction of Year x main effect is random and each
-31 interaction of Year x two-factor interaction is a random effect.
-32 The four agronomic main effects and their interactions are fixed
-33 effects "
34 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
35 RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
36 Year.Till.(SumCrop+Man+N) + Year.SumCrop.(Man+N) + \
37 Year.Man.N; CONSTRAINTS=p
38 REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N + Year.Till.SumCrop + Year.Till.Man + Year.Till.N + Year.SumCrop.Man + Year.SumCrop.N + Year.Man.N
Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	0.	bound
Year.Rep	71194.	60227.
Year.Till	206028.	285470.
Year.SumCrop	40561.	70120.
Year.Man	68575.	248479.
Year.N	259849.	416588.
Year.Till.SumCrop	0.	bound
Year.Till.Man	0.	bound
Year.Till.N	0.	bound
Year.SumCrop.Man	0.	bound
Year.SumCrop.N	0.	bound
Year.Man.N	274216.	303260.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	339447.	46194.

Warning 69, code VD 39, statement 1 on line 38

Command: REML [PRINT=model,components,waldTests] YIELD
Error in AI algorithm when forming denominator DF for approximate F-tests.

Wald tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Till	1.72	1	1.72	0.190
SumCrop	3.10	1	3.10	0.078
Man	5.54	1	5.54	0.019
N	10.28	2	5.14	0.006
Till.SumCrop	0.01	1	0.01	0.911
Till.Man	1.93	1	1.93	0.165
SumCrop.Man	2.43	1	2.43	0.119
Till.N	0.67	2	0.33	0.717
SumCrop.N	12.81	2	6.40	0.002
Man.N	8.01	2	4.01	0.018
Till.SumCrop.Man	0.46	1	0.46	0.499
Till.SumCrop.N	1.26	2	0.63	0.534
Till.Man.N	4.50	2	2.25	0.105
SumCrop.Man.N	3.78	2	1.89	0.151
Till.SumCrop.Man.N	4.19	2	2.10	0.123

Dropping individual terms from full fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Till.SumCrop.Man.N	4.19	2	2.10	0.123

Message: chi-square distribution for Wald tests is an asymptotic approximation (i.e. for large samples) and underestimates the probabilities in other cases.

```
39 " Note: As the estimation of the ddf has failed, Wald tests are given
-40 instead of F-tests. These tend to give significant results rather
-41 too frequently. The VCRITICAL procedure offers an alternative
-42 (and more reliable) method for assessing fixed terms when F-tests
-43 aren't available. "
44
45 " Model 4: The interactions of Year x main effects, Year x two-way
-46 interactions of main effects, and Year x three-way interactions of
-47 main effects are random effects, and the remaining four agronomic
-48 factors and their interactions are fixed effects "
49 " Fitted using REML "
50 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
51   RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
52     Year.Till.(SumCrop+Man+N) + Year.SumCrop.(Man+N) + \
53     Year.Man.N + Year.Till.SumCrop.(Man+N) + \
54     Year.Till.Man.N + Year.SumCrop.Man.N; CONSTRAINTS=p
55 REML [PRINT=model,components,waldTests] YIELD
```

REML variance components analysis

Response variate: YIELD

Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man +
SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N +
SumCrop.Man.N + Till.SumCrop.Man.N

Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N +
 Year.Till.SumCrop + Year.Till.Man + Year.Till.N + Year.SumCrop.Man + Year.SumCrop.N +
 Year.Man.N + Year.Till.SumCrop.Man + Year.Till.SumCrop.N + Year.Till.Man.N + Year.SumCrop.Man.N
 Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	0.	bound
Year.Rep	71181.	60214.
Year.Till	206075.	285563.
Year.SumCrop	40538.	70335.
Year.Man	68629.	248508.
Year.N	259942.	416635.
Year.Till.SumCrop	0.	bound
Year.Till.Man	0.	bound
Year.Till.N	0.	bound
Year.SumCrop.Man	0.	bound
Year.SumCrop.N	0.	bound
Year.Man.N	274095.	303641.
Year.Till.SumCrop.Man	0.	bound
Year.Till.SumCrop.N	0.	bound
Year.Till.Man.N	0.	bound
Year.SumCrop.Man.N	69.	36688.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	339430.	47299.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	1.72	1	1.72	1.1	0.394
SumCrop	3.11	1	3.11	1.0	0.325
Man	5.54	1	5.54	1.1	0.238
N	10.28	2	5.14	2.2	0.148
Till.SumCrop	0.01	1	0.01	103.0	0.912
Till.Man	1.93	1	1.93	103.0	0.168
SumCrop.Man	2.43	1	2.43	5.0	0.180
Till.N	0.67	2	0.33	103.0	0.718
SumCrop.N	12.79	2	6.40	5.0	0.042
Man.N	8.01	2	4.01	2.0	0.200
Till.SumCrop.Man	0.46	1	0.46	103.0	0.500
Till.SumCrop.N	1.26	2	0.63	103.0	0.536
Till.Man.N	4.50	2	2.25	103.0	0.111

SumCrop.Man.N	3.77	2	1.89	5.0	0.245
Till.SumCrop.Man.N	4.19	2	2.10	103.0	0.128

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	4.19	2	2.10	103.0	0.128

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

56
57 " Model 5: The saturated model which includes all possible random and
-58 fixed terms "
59 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
60 RANDOM=Year/Rep + Year.(Till*SumCrop*Man*N); CONSTRAINTS=p
61 REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N + Year.Till.SumCrop + Year.Till.Man + Year.SumCrop.Man + Year.Till.N + Year.SumCrop.N + Year.Man.N + Year.Till.SumCrop.Man + Year.Till.SumCrop.N + Year.Till.Man.N + Year.SumCrop.Man.N + Year.Till.SumCrop.Man.N
Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	0.	bound
Year.Rep	71180.	60212.
Year.Till	206074.	285561.
Year.SumCrop	40549.	70094.
Year.Man	68628.	248508.
Year.N	259941.	416634.
Year.Till.SumCrop	0.	bound
Year.Till.Man	0.	bound
Year.SumCrop.Man	0.	bound
Year.Till.N	0.	bound
Year.SumCrop.N	0.	bound
Year.Man.N	274128.	303129.
Year.Till.SumCrop.Man	0.	bound
Year.Till.SumCrop.N	0.	bound
Year.Till.Man.N	0.	bound
Year.SumCrop.Man.N	0.	bound
Year.Till.SumCrop.Man.N	0.	bound

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	339449.	46194.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	1.72	1	1.72	1.1	0.394
SumCrop	3.11	1	3.11	1.0	0.325
Man	5.54	1	5.54	1.1	0.238
N	10.28	2	5.14	2.2	0.148
Till.SumCrop	0.01	1	0.01	108.0	0.912
Till.Man	1.93	1	1.93	108.0	0.168
SumCrop.Man	2.43	1	2.43	108.0	0.122
Till.N	0.67	2	0.33	108.0	0.718
SumCrop.N	12.81	2	6.40	108.0	0.002
Man.N	8.01	2	4.01	2.0	0.200
Till.SumCrop.Man	0.46	1	0.46	108.0	0.500
Till.SumCrop.N	1.26	2	0.63	108.0	0.536
Till.Man.N	4.50	2	2.25	108.0	0.110
SumCrop.Man.N	3.78	2	1.89	108.0	0.156
Till.SumCrop.Man.N	4.19	2	2.10	108.0	0.128

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	4.19	2	2.10	108.0	0.128

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

62
63 " Model 6: Fixed effects model "
64 " Fitted using REML "
65 VCOMPONENTS [FIXED=Year*Till*SumCrop*Man*N; FACTORIAL=5] \
66   RANDOM=Year.Rep; CONSTRAINTS=p
67 REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Year + Till + SumCrop + Man + N + Year.Till + Year.SumCrop + Till.SumCrop + Year.Man + Till.Man + SumCrop.Man + Year.N + Till.N + SumCrop.N + Man.N + Year.Till.SumCrop + Year.Till.Man + Year.SumCrop.Man + Till.SumCrop.Man + Year.Till.N + Year.SumCrop.N + Till.SumCrop.N + Year.Man.N + Till.Man.N + SumCrop.Man.N + Year.Till.SumCrop.Man + Year.Till.SumCrop.N + Year.Till.Man.N + Year.SumCrop.Man.N + Till.SumCrop.Man.N + Year.Till.SumCrop.Man.N
Random model: Year.Rep

Number of units: 144

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year.Rep	70512.	60596.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	363020.	53524.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	9.31	1	9.31	4.0	0.038
Till	36.77	1	36.77	92.0	<0.001
SumCrop	15.39	1	15.39	92.0	<0.001
Man	93.10	1	93.10	92.0	<0.001
N	279.38	2	139.69	92.0	<0.001
Year.Till	22.56	1	22.56	92.0	<0.001
Year.SumCrop	5.02	1	5.02	92.0	0.027
Till.SumCrop	0.01	1	0.01	92.0	0.915
Year.Man	17.54	1	17.54	92.0	<0.001
Till.Man	1.81	1	1.81	92.0	0.182
SumCrop.Man	2.27	1	2.27	92.0	0.135
Year.N	56.29	2	28.15	92.0	<0.001
Till.N	0.62	2	0.31	92.0	0.734
SumCrop.N	11.97	2	5.99	92.0	0.004
Man.N	80.11	2	40.06	92.0	<0.001
Year.Till.SumCrop	0.26	1	0.26	92.0	0.610
Year.Till.Man	0.27	1	0.27	92.0	0.601
Year.SumCrop.Man	0.06	1	0.06	92.0	0.800
Till.SumCrop.Man	0.43	1	0.43	92.0	0.514
Year.Till.N	0.29	2	0.15	92.0	0.864
Year.SumCrop.N	0.02	2	0.01	92.0	0.992
Till.SumCrop.N	1.17	2	0.59	92.0	0.558
Year.Man.N	19.73	2	9.87	92.0	<0.001
Till.Man.N	4.21	2	2.10	92.0	0.128
SumCrop.Man.N	3.53	2	1.77	92.0	0.177
Year.Till.SumCrop.Man	1.82	1	1.82	92.0	0.180
Year.Till.SumCrop.N	0.58	2	0.29	92.0	0.750
Year.Till.Man.N	0.55	2	0.28	92.0	0.759
Year.SumCrop.Man.N	4.60	2	2.30	92.0	0.106
Till.SumCrop.Man.N	3.92	2	1.96	92.0	0.147
Year.Till.SumCrop.Man.N	0.52	2	0.26	92.0	0.771

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Till.SumCrop.Man.N	0.52	2	0.26	92.0	0.771

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
68
69  " Notes: * REML uses the Kenward-Roger method for computing the ddf,
-70           whereas SAS, by default, uses the containment method.
-71           * REML provides only sequential F-tests, not Type 3 tests.
-72           * As the data are balanced and normality is assumed, the
-73             ANOVA directive can also be used to analyse these data.
-74           The advantage of using ANOVA is that an analysis-of-
-75             variance table is produced. "
76  ENDJOB
```

End of job.

```
77
78  " ***** Example 2 ***** "
79
80  JOB
81
82  " Import the data "
83  IMPORT 'Appendix A FixRnd10 Data.csv'
```

Loading Spreadsheet File

Catalogue of file Appendix A FixRnd10 Data.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	720	YEAR
2	variate	720	REP
3	variate	720	TREAT
4	variate	720	TILLAGE
5	variate	720	SUMCRP
6	variate	720	MANURE
7	variate	720	NLEVEL
8	variate	720	YIELD

```

84
85 " Convert YEAR, REP, TILLAGE, SUMCRP, MANURE and NLEVEL from variates
-86 to factors "
87 GROUP [REDEFINE=yes] YEAR,REP,TILLAGE,SUMCRP,MANURE,NLEVEL; \
88 Year,Rep,Till,SumCrop,Man,N
89
90 " First model: Saturated model, including all possible random and
-91 fixed terms "
92 VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
93 RANDOM=Year/Rep + Year.(Till*SumCrop*Man*N); CONSTRAINTS=p
94 REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N + Year.Till.SumCrop + Year.Till.Man + Year.SumCrop.Man + Year.Till.N + Year.SumCrop.N + Year.Man.N + Year.Till.SumCrop.Man + Year.Till.SumCrop.N + Year.Till.Man.N + Year.SumCrop.Man.N + Year.Till.SumCrop.Man.N
Number of units: 720

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	411678.	275414.
Year.Rep	13123.	7356.
Year.Till	56615.	30712.
Year.SumCrop	0.	bound
Year.Man	67505.	56973.
Year.N	191869.	101554.
Year.Till.SumCrop	0.	bound
Year.Till.Man	0.	bound
Year.SumCrop.Man	0.	bound
Year.Till.N	0.	bound
Year.SumCrop.N	54602.	24657.
Year.Man.N	120237.	48879.
Year.Till.SumCrop.Man	0.	bound
Year.Till.SumCrop.N	7848.	13457.
Year.Till.Man.N	0.	bound
Year.SumCrop.Man.N	7251.	15885.
Year.Till.SumCrop.Man.N	5057.	17268.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	241025.	15893.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	6.90	1	6.90	9.0	0.028
SumCrop	18.73	1	18.73	27.0	<0.001
Man	23.64	1	23.64	9.0	<0.001
N	76.03	2	38.02	18.0	<0.001
Till.SumCrop	0.68	1	0.68	45.0	0.413
Till.Man	4.67	1	4.67	54.0	0.035
SumCrop.Man	1.49	1	1.49	27.0	0.233
Till.N	3.19	2	1.60	45.0	0.214
SumCrop.N	17.75	2	8.87	27.0	0.001
Man.N	44.76	2	22.38	18.0	<0.001
Till.SumCrop.Man	0.61	1	0.61	54.0	0.438
Till.SumCrop.N	7.04	2	3.52	45.0	0.038
Till.Man.N	7.17	2	3.59	54.0	0.034
SumCrop.Man.N	0.62	2	0.31	27.0	0.735
Till.SumCrop.Man.N	5.91	2	2.95	54.0	0.061

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	5.91	2	2.95	54.0	0.061

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

95
96  " Second model: The first ten lowest order random terms and all
-97  possible fixed terms "
98  VCOMPONENTS [FIXED=Till*SumCrop*Man*N; FACTORIAL=4] \
99  RANDOM=Year/Rep + Year.(Till+SumCrop+Man+N) + \
100  Year.Till.(SumCrop+N) + Year.SumCrop.(Man+N) + Year.Man.N; \
101  CONSTRAINTS=p
102  REML [PRINT=model,components,waldTests] YIELD

```

REML variance components analysis

Response variate: YIELD
Fixed model: Constant + Till + SumCrop + Man + N + Till.SumCrop + Till.Man + SumCrop.Man + Till.N + SumCrop.N + Man.N + Till.SumCrop.Man + Till.SumCrop.N + Till.Man.N + SumCrop.Man.N + Till.SumCrop.Man.N
Random model: Year + Year.Rep + Year.Till + Year.SumCrop + Year.Man + Year.N + Year.Till.SumCrop + Year.Till.N + Year.SumCrop.Man + Year.SumCrop.N + Year.Man.N
Number of units: 720

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year	411381.	275416.
Year.Rep	12829.	7352.
Year.Till	55658.	31017.
Year.SumCrop	0.	bound
Year.Man	67505.	56973.
Year.N	189353.	101590.
Year.Till.SumCrop	3496.	7875.
Year.Till.N	2228.	7733.
Year.SumCrop.Man	0.	bound
Year.SumCrop.N	61329.	23009.
Year.Man.N	124539.	48420.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	248082.	14837.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till	6.90	1	6.90	9.0	0.028
SumCrop	17.93	1	17.93	25.8	<0.001
Man	23.64	1	23.64	9.0	<0.001
N	76.03	2	38.02	18.0	<0.001
Till.SumCrop	0.67	1	0.67	9.7	0.434
Till.Man	4.83	1	4.83	559.2	0.028
SumCrop.Man	1.80	1	1.80	559.2	0.180
Till.N	3.52	2	1.76	18.0	0.200
SumCrop.N	18.07	2	9.04	25.4	0.001
Man.N	44.76	2	22.38	18.0	<0.001
Till.SumCrop.Man	0.63	1	0.63	559.2	0.427
Till.SumCrop.N	8.61	2	4.30	559.2	0.014
Till.Man.N	7.41	2	3.70	559.2	0.025
SumCrop.Man.N	0.75	2	0.38	559.2	0.687
Till.SumCrop.Man.N	6.10	2	3.05	559.2	0.048

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Till.SumCrop.Man.N	6.10	2	3.05	559.2	0.048

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.


```

103
104 " Notes: * REML uses the Kenward-Roger method for computing the ddf,
-105           whereas SAS, by default, uses the containment method.
-106           * REML provides only sequential F-tests.
-107           * As the data are balanced and normality is assumed, the
-108           ANOVA directive can also be used to analyse these data. "
109
110 ENDJOB

```

End of job.

Exercises (Appendix Three)

Genstat Commands

```

" ***** "
"           Exercises (Appendix Three)           "
" ***** "

JOB

" Import the data "
IMPORT 'Data Wheat Section 1.csv'

" Convert Soil from a text structure to a factor, and convert N, P,
  Rep and Year from variates to factors "
GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year

" ***** Exercise 1 ***** "

" Model 1: Main effects only "

" Automatic calculation of coefficients "
BLOCK Year.Soil.Rep
TREATMENTS Year+Soil+N+POL(P;3)
ANOVA [PRINT=aovtable; FPROB=yes] Yield

" Manual insertion of coefficients "
" Obtain the coefficients "
GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
ORTHOPOLYNOMIAL [MAX=3] #Plev/250; POLYNOMIAL=coeff
PRINT #coeff
" Store the contrasts in a matrix "
MATRIX [ROWS=!T(LinearP,QuadraticP,CubicP); COLUMNS=#Plev; \
        VALUES=#coeff] Contrasts
" Fit ANOVA with contrasts "
BLOCK Year.Soil.Rep
TREATMENTS Year+Soil+N+COMP(P;3;Contrasts)
ANOVA [PRINT=aovtable; FPROB=yes] Yield

" Model 2: Two-way interactions "

" Fit ANOVA with contrasts "
BLOCK Year.Soil.Rep
TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)

```

```

ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=2] Yield

" Model 3: Three-way interactions "

" Fit ANOVA with contrasts "
BLOCK Year.Soil.Rep
TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)
ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=3; CONTRASTS=5] Yield

" Model 4: Four-way interactions "

" Fit ANOVA with contrasts "
BLOCK Year.Soil.Rep
TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)
ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=4; CONTRASTS=6] Yield

" ***** Exercise 2 ***** "

" Approach 1 "
VCOMPONENTS [FIXED=Year*Soil*N*P; FACTORIAL=4] RANDOM=Year.Soil.Rep
REML [PRINT=model,components,waldTests] Yield
VKEEP [SIGMA2=var] Year.Soil.Rep; COMPONENTS=COMP_RepYearSoil
CALC MSE_RepYearSoil_1 = var + 8*COMP_RepYearSoil
PRINT MSE_RepYearSoil_1

" Approach 2 "
" To calculate using the MSE for Rep.Year.Soil, we use the OMITTERMS
  option to control how the predictions are calculated "
VPREDICT [PRINT=*; SED=sed; OMITTERMS=Rep.Year.Soil] \
  Year,Soil
CALC ased = MEAN(sed)
CALC MSE_RepYearSoil_2 = 16*(ased**2)/2
PRINT MSE_RepYearSoil_2

ENDJOB

```

Genstat Output

```

2 " ***** "
3 " Exercises (Appendix Three) "
4 " ***** "
5
6 JOB

```

End of job.

```

7
8 " Import the data "
9 IMPORT 'Data Wheat Section 1.csv'

```

Loading Spreadsheet File

Catalogue of file Data Wheat Section 1.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	64	Year
2	text	64	Soil
3	variate	64	N
4	variate	64	P
5	variate	64	Rep
6	variate	64	Yield

```
10
11 " Convert Soil from a text structure to a factor, and convert N, P,
-12 Rep and Year from variates to factors "
13 GROUP [REDEFINE=yes] Soil,N,P,Rep,Year; Soil,N,P,Rep,Year
14
15 " ***** Exercise 1 ***** "
16
17 " Model 1: Main effects only "
18
19 " Automatic calculation of coefficients "
20 BLOCK Year.Soil.Rep
21 TREATMENTS Year+Soil+N+POL(P;3)
22 ANOVA [PRINT=aovtable; FPROB=yes] Yield
```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Soil.Rep stratum					
Year	1	12.49622	12.49622	46.59	0.001
Soil	1	5.77201	5.77201	21.52	0.006
Residual	5	1.34109	0.26822	8.11	
Year.Soil.Rep.*Units* stratum					
N	1	0.09766	0.09766	2.95	0.092
P	3	0.97328	0.32443	9.81	<.001
Lin	1	0.85742	0.85742	25.94	<.001
Quad	1	0.10127	0.10127	3.06	0.086
Cub	1	0.01459	0.01459	0.44	0.509
Residual	52	1.71889	0.03306		
Total	63	22.39914			

```
23
24 " Manual insertion of coefficients "
25 " Obtain the coefficients "
26 GETATTRIBUTE [ATTRIBUTE=levels] P; SAVE=Plev
27 ORTHPOLYNOMIAL [MAX=3] #Plev/250; POLYNOMIAL=coeff
28 PRINT #coeff
```

coeff[1]	coeff[2]	coeff[3]
-0.4500	0.10305	-0.01930
-0.2500	-0.05831	0.03618

0.1500	-0.14102	-0.02412
0.5500	0.09627	0.00724

```

29 " Store the contrasts in a matrix "
30 MATRIX [ROWS=!T(LinearP,QuadraticP,CubicP); COLUMNS=#Plev; \
31     VALUES=#coeff] Contrasts
32 " Fit ANOVA with contrasts "
33 BLOCK Year.Soil.Rep
34 TREATMENTS Year+Soil+N+COMP(P;3;Contrasts)
35 ANOVA [PRINT=aovtable; FPROB=yes] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Soil.Rep stratum					
Year	1	12.49622	12.49622	46.59	0.001
Soil	1	5.77201	5.77201	21.52	0.006
Residual	5	1.34109	0.26822	8.11	
Year.Soil.Rep.*Units* stratum					
N	1	0.09766	0.09766	2.95	0.092
P	3	0.97328	0.32443	9.81	<.001
LinearP	1	0.85742	0.85742	25.94	<.001
QuadraticP	1	0.10127	0.10127	3.06	0.086
CubicP	1	0.01459	0.01459	0.44	0.509
Residual	52	1.71889	0.03306		
Total	63	22.39914			

```

36
37 " Model 2: Two-way interactions "
38
39 " Fit ANOVA with contrasts "
40 BLOCK Year.Soil.Rep
41 TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)
42 ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=2] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Soil.Rep stratum					
Year	1	12.49622	12.49622	1204.82	<.001
Soil	1	5.77201	5.77201	556.51	<.001
Year.Soil	1	1.29960	1.29960	125.30	<.001
Residual	4	0.04149	0.01037	0.47	
Year.Soil.Rep.*Units* stratum					
N	1	0.09766	0.09766	4.39	0.042
P	3	0.97328	0.32443	14.57	<.001

LinearP	1	0.85742	0.85742	38.50	<.001
QuadraticP	1	0.10127	0.10127	4.55	0.039
CubicP	1	0.01459	0.01459	0.66	0.423
Year.N	1	0.08123	0.08123	3.65	0.063
Soil.N	1	0.17016	0.17016	7.64	0.009
Year.P	3	0.16501	0.05500	2.47	0.075
Year.LinearP	1	0.12219	0.12219	5.49	0.024
Year.QuadraticP	1	0.04090	0.04090	1.84	0.183
Year.CubicP	1	0.00192	0.00192	0.09	0.770
Soil.P	3	0.35361	0.11787	5.29	0.004
Soil.LinearP	1	0.35205	0.35205	15.81	<.001
Soil.QuadraticP	1	0.00155	0.00155	0.07	0.793
Soil.CubicP	1	0.00001	0.00001	0.00	0.988
N.P	3	0.03581	0.01194	0.54	0.660
N.LinearP	1	0.02079	0.02079	0.93	0.340
N.QuadraticP	1	0.00388	0.00388	0.17	0.678
N.CubicP	1	0.01113	0.01113	0.50	0.484
Residual	41	0.91308	0.02227		

Total 63 22.39914

```

43
44 " Model 3: Three-way interactions "
45
46 " Fit ANOVA with contrasts "
47 BLOCK Year.Soil.Rep
48 TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)
49 ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=3; CONTRASTS=5] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Soil.Rep stratum					
Year	1	12.496225	12.496225	1204.82	<.001
Soil	1	5.772006	5.772006	556.51	<.001
Year.Soil	1	1.299600	1.299600	125.30	<.001
Residual	4	0.041487	0.010372	1.16	
Year.Soil.Rep.*Units* stratum					
N	1	0.097656	0.097656	10.95	0.002
P	3	0.973281	0.324427	36.38	<.001
LinearP	1	0.857418	0.857418	96.14	<.001
QuadraticP	1	0.101270	0.101270	11.36	0.002
CubicP	1	0.014593	0.014593	1.64	0.210
Year.N	1	0.081225	0.081225	9.11	0.005
Soil.N	1	0.170156	0.170156	19.08	<.001
Year.P	3	0.165013	0.055004	6.17	0.002
Year.LinearP	1	0.122190	0.122190	13.70	<.001
Year.QuadraticP	1	0.040899	0.040899	4.59	0.040
Year.CubicP	1	0.001924	0.001924	0.22	0.646
Soil.P	3	0.353606	0.117869	13.22	<.001
Soil.LinearP	1	0.352048	0.352048	39.47	<.001

Soil.QuadraticP	1	0.001554	0.001554	0.17	0.679
Soil.CubicP	1	0.000005	0.000005	0.00	0.981
N.P	3	0.035806	0.011935	1.34	0.280
N.LinearP	1	0.020789	0.020789	2.33	0.137
N.QuadraticP	1	0.003884	0.003884	0.44	0.514
N.CubicP	1	0.011133	0.011133	1.25	0.272
Year.Soil.N	1	0.286225	0.286225	32.09	<.001
Year.Soil.P	3	0.204812	0.068271	7.65	<.001
Year.Soil.LinearP	1	0.200569	0.200569	22.49	<.001
Year.Soil.QuadraticP	1	0.000190	0.000190	0.02	0.885
Year.Soil.CubicP	1	0.004053	0.004053	0.45	0.505
Year.N.P	3	0.015688	0.005229	0.59	0.629
Year.N.LinearP	1	0.006621	0.006621	0.74	0.396
Year.N.QuadraticP	1	0.003929	0.003929	0.44	0.512
Year.N.CubicP	1	0.005138	0.005138	0.58	0.454
Soil.N.P	3	0.129881	0.043294	4.85	0.007
Soil.N.LinearP	1	0.024103	0.024103	2.70	0.110
Soil.N.QuadraticP	1	0.000600	0.000600	0.07	0.797
Soil.N.CubicP	1	0.105178	0.105178	11.79	0.002
Residual	31	0.276475	0.008919		

Total 63 22.399144

```

50
51 " Model 4: Four-way interactions "
52
53 " Fit ANOVA with contrasts "
54 BLOCK Year.Soil.Rep
55 TREATMENTS Year*Soil*N*COMP(P;3;Contrasts)
56 ANOVA [PRINT=aovtable; FPROB=yes; FACTORIAL=4; CONTRASTS=6] Yield

```

Analysis of variance

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Soil.Rep stratum					
Year	1	12.496225	12.496225	1204.82	<.001
Soil	1	5.772006	5.772006	556.51	<.001
Year.Soil	1	1.299600	1.299600	125.30	<.001
Residual	4	0.041487	0.010372	1.29	
Year.Soil.Rep.*Units* stratum					
N	1	0.097656	0.097656	12.15	0.002
P	3	0.973281	0.324427	40.37	<.001
LinearP	1	0.857418	0.857418	106.69	<.001
QuadraticP	1	0.101270	0.101270	12.60	0.001
CubicP	1	0.014593	0.014593	1.82	0.189
Year.N	1	0.081225	0.081225	10.11	0.004
Soil.N	1	0.170156	0.170156	21.17	<.001
Year.P	3	0.165013	0.055004	6.84	0.001
Year.LinearP	1	0.122190	0.122190	15.21	<.001
Year.QuadraticP	1	0.040899	0.040899	5.09	0.032
Year.CubicP	1	0.001924	0.001924	0.24	0.628

Soil.P	3	0.353606	0.117869	14.67	<.001
Soil.LinearP	1	0.352048	0.352048	43.81	<.001
Soil.QuadraticP	1	0.001554	0.001554	0.19	0.664
Soil.CubicP	1	0.000005	0.000005	0.00	0.980
N.P	3	0.035806	0.011935	1.49	0.240
N.LinearP	1	0.020789	0.020789	2.59	0.119
N.QuadraticP	1	0.003884	0.003884	0.48	0.493
N.CubicP	1	0.011133	0.011133	1.39	0.249
Year.Soil.N	1	0.286225	0.286225	35.62	<.001
Year.Soil.P	3	0.204812	0.068271	8.50	<.001
Year.Soil.LinearP	1	0.200569	0.200569	24.96	<.001
Year.Soil.QuadraticP	1	0.000190	0.000190	0.02	0.879
Year.Soil.CubicP	1	0.004053	0.004053	0.50	0.483
Year.N.P	3	0.015688	0.005229	0.65	0.589
Year.N.LinearP	1	0.006621	0.006621	0.82	0.372
Year.N.QuadraticP	1	0.003929	0.003929	0.49	0.490
Year.N.CubicP	1	0.005138	0.005138	0.64	0.431
Soil.N.P	3	0.129881	0.043294	5.39	0.005
Soil.N.LinearP	1	0.024103	0.024103	3.00	0.094
Soil.N.QuadraticP	1	0.000600	0.000600	0.07	0.787
Soil.N.CubicP	1	0.105178	0.105178	13.09	0.001
Year.Soil.N.P	3	0.051462	0.017154	2.13	0.118
Year.Soil.N.LinearP	1	0.003987	0.003987	0.50	0.487
Year.Soil.N.QuadraticP	1	0.000041	0.000041	0.01	0.944
Year.Soil.N.CubicP	1	0.047435	0.047435	5.90	0.022
Residual	28	0.225013	0.008036		
Total	63	22.399144			

```

57
58 " ***** Exercise 2 ***** "
59
60 " Approach 1 "
61 VCOMPONENTS [FIXED=Year*Soil*N*P; FACTORIAL=4] RANDOM=Year.Soil.Rep
62 REML [PRINT=model,components,waldTests] Yield

```

REML variance components analysis

Response variate: Yield
 Fixed model: Constant + Year + Soil + N + P + Year.Soil + Year.N + Soil.N + Year.P +
 Soil.P + N.P + Year.Soil.N + Year.Soil.P + Year.N.P + Soil.N.P + Year.Soil.N.P
 Random model: Year.Soil.Rep
 Number of units: 64

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Year.Soil.Rep	0.000292	0.000955

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.00804	0.002148

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	1204.82	1	1204.82	4.0	<0.001
Soil	556.51	1	556.51	4.0	<0.001
N	12.15	1	12.15	28.0	0.002
P	121.11	3	40.37	28.0	<0.001
Year.Soil	125.30	1	125.30	4.0	<0.001
Year.N	10.11	1	10.11	28.0	0.004
Soil.N	21.17	1	21.17	28.0	<0.001
Year.P	20.53	3	6.84	28.0	0.001
Soil.P	44.00	3	14.67	28.0	<0.001
N.P	4.46	3	1.49	28.0	0.240
Year.Soil.N	35.62	1	35.62	28.0	<0.001
Year.Soil.P	25.49	3	8.50	28.0	<0.001
Year.N.P	1.95	3	0.65	28.0	0.589
Soil.N.P	16.16	3	5.39	28.0	0.005
Year.Soil.N.P	6.40	3	2.13	28.0	0.118

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Soil.N.P	6.40	3	2.13	28.0	0.118

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
63 VKEEP [SIGMA2=var] Year.Soil.Rep; COMPONENTS=COMP_RepYearSoil
64 CALC MSE_RepYearSoil_1 = var + 8*COMP_RepYearSoil
65 PRINT MSE_RepYearSoil_1
```

MSE_RepYearSoil_1
0.01037

```
66
67 " Approach 2 "
68 " To calculate using the MSE for Rep.Year.Soil, we use the OMITTERMS
-69 option to control how the predictions are calculated "
70 VPREDICT [PRINT=*; SED=sed; OMITTERMS=Rep.Year.Soil] \
71   Year,Soil
72 CALC ased = MEAN(sed)
73 CALC MSE_RepYearSoil_2 = 16*(ased**2)/2
74 PRINT MSE_RepYearSoil_2
```

MSE_RepYearSoil_2
0.01037

75

76 ENDJOB

End of job.

Chapter 8. The Analysis of Combined Experiments by Philip M. Dixon, Kenneth J. Moore and Edzard van Santen

Genstat code developed by Vanessa M. Cave and output are provided here for the three examples presented in Chapter 8.

Triglyceride Measurements in Meat Example

Genstat Commands for the Triglyceride Measurements in Meat Example

JOB

```
" ***** "
" Example: Triglyceride measurements in meat "
" ***** "

" Import the data "
IMPORT 'triglybook.txt'

" Convert method and day from variates to factors "
GROUP [REDEFINE=yes] method, day; method, day

" Plot of the triglyceride data with lines connecting the
  method-specific averages across the days (Figure 1) "
XAXIS [RESET=yes] WINDOW=3; TITLE='Day'; MARKS=1
YAXIS [RESET=yes] WINDOW=3; TITLE='Triglyceride'
PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='triangle','circle'; \
  COLOUR='black'; CFILL='grey',*
DGRAPH [WINDOW=3; KEY=0] Y=y; X=day; PEN=method
TABULATE [PRINT=*; CLASSIFICATION=day,method] y; MEANS=means
VTABLE means; meansV; CLASSIFICATION=classification
PEN 1,2; METHOD=line; LINESTYLE='solid','dot'; SYMBOL=0
DGRAPH [WINDOW=3; SCREEN=keep; KEY=0] Y=meansV; \
  X=classification['day']; PEN=classification['method']
PEN 1,2; SYMBOL='triangle','circle'; COLOUR='black'; CFILL='grey',*;
FRAME WINDOW=2; YUPPER=1
DKEY [WINDOW=2; NCOLUMNS=1; BORDER=none] \
  DESCRIPTION=!T('Method 1','Method 2')
PEN [RESET=yes] 1,2
FRAME [RESET=yes] WINDOW=2
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3

" Narrow sense: ANOVA (Box 1, Tables 2, 3) "
CAPTION 'Triglyceride example: Narrow sense inference'; STYLE=meta
BLOCK "No Blocking"
TREATMENTS day*method
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff,lsd; LSDLEVEL=5] y
" Note: 95% confidence interval for the difference between two means
  (m1 and m2) is given by (m1 - m2) +/- LSD(5%) "

" Broad sense: REML (Box 2, Table 3) "
```

```

" Note: Genstat uses the Kenward-Roger method for estimating the
  denominator degrees of freedom "
CAPTION 'Triglyceride example: Broad sense inference'; STYLE=meta
VCOMPONENTS [FIXED=method] RANDOM=day+method*day
REML [PRINT=model,components,means,waldTests; PSE=differences] y
VLSLSD [PRINT=lsd; LSDLEVEL=5] method

" Additional code for analyses not discussed in the Chapter "
CAPTION 'Additional analyses not discussed in the Chapter'; \
  STYLE=meta

" Broad sense inference, separate error variances by day "
CAPTION 'Random interaction, separate error variances by day'; \
  STYLE=major
VCOMPONENTS [FIXED=method; EXPERIMENTS=day] RANDOM=day+method*day
REML [PRINT=model,components,means,waldTests; PSE=differences] y
VLSLSD [PRINT=lsd; LSDLEVEL=5] method

" Broad sense inference, separate error variances by method "
CAPTION 'Random interaction, separate error variances by method'; \
  STYLE=major
VCOMPONENTS [FIXED=method; EXPERIMENTS=method] RANDOM=day+method*day
REML [PRINT=model,components,means,waldTests; PSE=differences] y
VLSLSD [PRINT=lsd; LSDLEVEL=5] method

" Narrow sense inference, separate error variances by day "
CAPTION 'Fixed interaction, separate error variances by day'; \
  STYLE=major
VCOMPONENTS [FIXED=method*day; EXPERIMENTS=day]
REML [PRINT=model,components,means,waldTests; PSE=differences] y
VLSLSD [PRINT=lsd; LSDLEVEL=5] method

" Narrow sense inference, no interaction, separate error variances
  by day "
CAPTION 'No interaction, separate error variances by day'; \
  STYLE=major
VCOMPONENTS [FIXED=method+day; EXPERIMENTS=day]
REML [PRINT=model,components,means,waldTests; PSE=differences] y
VLSLSD [PRINT=lsd; LSDLEVEL=5] method

ENDJOB

```

Genstat Output from the Triglyceride Measurements in Meat Example

2 JOB

End of job.

```

3
4 " ***** "
5 " Example: Triglyceride measurements in meat "
6 " ***** "
7
8 " Import the data "
9 IMPORT 'triglybook.txt'

```

Loading Spreadsheet File

Catalogue of file triglybook.txt

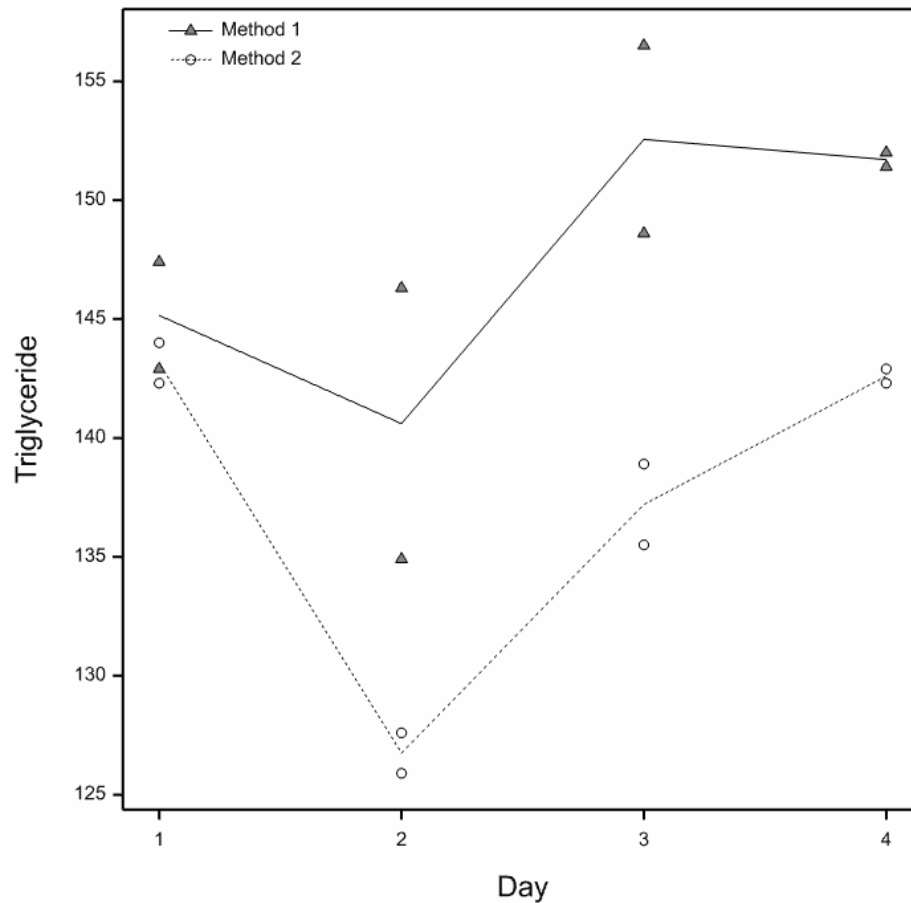
Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	16	method
2	variate	16	day
3	variate	16	y

```
10
11 " Convert method and day from variates to factors "
12 GROUP [REDEFINE=yes] method,day; method,day
13
14 " Plot of the triglyceride data with lines connecting the
-15 method-specific averages across the days (Figure 1) "
16 XAXIS [RESET=yes] WINDOW=3; TITLE='Day'; MARKS=1
17 YAXIS [RESET=yes] WINDOW=3; TITLE='Triglyceride'
18 PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='triangle','circle'; \
19 COLOUR='black'; CFILL='grey',*
20 DGRAPH [WINDOW=3; KEY=0] Y=y; X=day; PEN=method
21 TABULATE [PRINT=*; CLASSIFICATION=day,method] y; MEANS=means
22 VTABLE means; meansV; CLASSIFICATION=classification
23 PEN 1,2; METHOD=line; LINESTYLE='solid','dot'; SYMBOL=0
24 DGRAPH [WINDOW=3; SCREEN=keep; KEY=0] Y=meansV; \
25 X=classification['day']; PEN=classification['method']
26 PEN 1,2; SYMBOL='triangle','circle'; COLOUR='black'; CFILL='grey',*;
27 FRAME WINDOW=2; YUPPER=1
28 DKEY [WINDOW=2; NCOLUMNS=1; BORDER=none] \
29 DESCRIPTION=!T('Method 1','Method 2')
30 PEN [RESET=yes] 1,2
31 FRAME [RESET=yes] WINDOW=2
32 XAXIS [RESET=yes] WINDOW=3
33 YAXIS [RESET=yes] WINDOW=3
```



```

34
35 " Narrow sense: ANOVA (Box 1, Tables 2, 3) "
36 CAPTION 'Triglyceride example: Narrow sense inference'; STYLE=meta

```

Triglyceride example: Narrow sense inference

```

37 BLOCK "No Blocking"
38 TREATMENTS day*method
39 COVARIATE "No Covariate"
40 ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff,lsd; LSDLEVEL=5] y

```

Analysis of variance

Variate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
day	3	431.44	143.81	9.97	0.004
method	1	406.02	406.02	28.16	<.001
day.method	3	108.23	36.08	2.50	0.133
Residual	8	115.34	14.42		
Total	15	1061.04			

Tables of means

Variate: y

Grand mean 142.46

day		1	2	3	4
		144.15	133.68	144.88	147.15
method		1	2		
		147.50	137.43		
day	method	1	2		
1		145.15	143.15		
2		140.60	126.75		
3		152.55	137.20		
4		151.70	142.60		

Standard errors of differences of means

Table	day	method	day method
rep.	4	8	2
d.f.	8	8	8
s.e.d.	2.685	1.899	3.797

Least significant differences of means (5% level)

Table	day	method	day method
rep.	4	8	2
d.f.	8	8	8
l.s.d.	6.191	4.378	8.756

```
41 " Note: 95% confidence interval for the difference between two means
-42 (m1 and m2) is given by (m1 - m2) +/- LSD(5%) "
43
44 " Broad sense: REML (Box 2, Table 3) "
45 " Note: Genstat uses the Kenward-Roger method for estimating the
-46 denominator degrees of freedom "
47 CAPTION 'Triglyceride example: Broad sense inference'; STYLE=meta
```

Triglyceride example: Broad sense inference

```
48 VCOMPONENTS [FIXED=method] RANDOM=day+method*day
49 REML [PRINT=model,components,means,waldTests; PSE=differences] y
```

REML variance components analysis

Response variate: y
Fixed model: Constant + method

Random model: day + day.method
Number of units: 16

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
day	26.93	30.27
day.method	10.83	15.16

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	14.42	7.21

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	11.25	1	11.25	3.0	0.044

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	11.25	1	11.25	3.0	0.044

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

142.5 Standard error: 3.00

Table of predicted means for method

method	1	2
	147.5	137.4

Standard error of differences: 3.003

```
50  VLSD [PRINT=lsd; LSDLEVEL=5] method
```

Approximate least significant differences (5% level) of REML means

method

method 1	1		*
method 2	2	9.558	*
		1	2

```
51
52 " Additional code for analyses not discussed in the Chapter "
53 CAPTION 'Additional analyses not discussed in the Chapter'; \
54     STYLE=meta
```

Additional analyses not discussed in the Chapter

```
55
56 " Broad sense inference, separate error variances by day "
57 CAPTION 'Random interaction, separate error variances by day'; \
58     STYLE=major
```

Random interaction, separate error variances by day

```
59 VCOMPONENTS [FIXED=method; EXPERIMENTS=day] RANDOM=day+method*day
60 REML [PRINT=model,components,means,waldTests; PSE=differences] y
```

REML variance components analysis

Response variate: y
Fixed model: Constant + method
Random model: day + day.method
Number of units: 16

Separate residual terms for each level of experiment factor: day

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
day	20.2471	26.9995
day.method	11.9593	14.8934

Residual model for each experiment

Experiment factor: day

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
1.000	Residual		Identity	Variance	6.268	6.513
2.000	Residual		Identity	Variance	35.78	36.00
3.000	Residual		Identity	Variance	18.23	17.72
4.000	Residual		Identity	Variance	0.180	0.179

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	9.40	1	9.40	2.3	0.076

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	9.40	1	9.40	2.3	0.076

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

143.0 Standard error: 2.72

Table of predicted means for method

method	1	2
	147.5	138.4

Standard error of differences: 2.948

```
61  VLSD [PRINT=lsd; LSDLEVEL=5] method
```

Approximate least significant differences (5% level) of REML means

method

method 1	1	*	
method 2	2	11.14	*
		1	2

```

62
63 " Broad sense inference, separate error variances by method "
64 CAPTION 'Random interaction, separate error variances by method'; \
65     STYLE=major

```

Random interaction, separate error variances by method

```

66 VCOMPONENTS [FIXED=method; EXPERIMENTS=method] RANDOM=day+method*day
67 REML [PRINT=model,components,means,waldTests; PSE=differences] y

```

REML variance components analysis

Response variate: y
 Fixed model: Constant + method
 Random model: day + day.method
 Number of units: 16

Separate residual terms for each level of experiment factor: method

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
day	30.569	34.490
day.method	13.855	16.694

Residual model for each experiment

Experiment factor: method

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
1.000	Residual		Identity	Variance	24.24	16.20
2.000	Residual		Identity	Variance	2.233	1.586

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	9.92	1	9.92	3.1	0.050

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	9.92	1	9.92	3.1	0.050

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

142.5 Standard error: 3.19

Table of predicted means for method

method	1	2
	147.5	137.4

Standard error of differences: 3.199

```
68  VLSD [PRINT=lsd; LSDLEVEL=5] method
```

Approximate least significant differences (5% level) of REML means

method

method 1	1		*
method 2	2	10.05	*
		1	2

```
69
70 " Narrow sense inference, separate error variances by day "
71 CAPTION 'Fixed interaction, separate error variances by day';\
72   STYLE=major
```

Fixed interaction, separate error variances by day

```
73 VCOMPONENTS [FIXED=method*day; EXPERIMENTS=day]
74 REML [PRINT=model,components,means,waldTests; PSE=differences] y
```

REML variance components analysis

Response variate: y
Fixed model: Constant + method + day + method.day
Number of units: 16

Separate residual terms for each level of experiment factor: day

Sparse algorithm with AI optimisation

Residual model for each experiment

Experiment factor: day

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
1.000	Residual		Identity	Variance	5.785	5.785
2.000	Residual		Identity	Variance	33.21	33.21
3.000	Residual		Identity	Variance	18.49	18.49
4.000	Residual		Identity	Variance	0.180	0.180

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	467.85	1	467.85	2.2	0.001
day	28.46	3	0.55	4.0	0.676
method.day	11.41	3	0.22	4.0	0.878

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method.day	11.41	3	0.22	4.0	0.878

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

142.5 Standard error: 0.95

Table of predicted means for method

method	1	2
	147.5	137.4

Standard error of differences: 1.899

Table of predicted means for day

day	1	2	3	4
	144.2	133.7	144.9	147.1

Standard errors of differences

Average:	2.575
Maximum:	3.595
Minimum:	1.221

Average variance of differences: 7.209

Table of predicted means for method.day

day method	1	2	3	4
1	145.2	140.6	152.6	151.7
2	143.1	126.7	137.2	142.6

Standard errors of differences

Average: 3.582
Maximum: 5.763
Minimum: 0.4243

Average variance of differences: 14.42

Standard error of differences for same level of factor:

	method	day
Average:	3.642	3.223
Maximum:	5.085	5.763
Minimum:	1.727	0.4243

Average variance of differences:

14.42 14.42

75 VLSD [PRINT=lsd; LSDLEVEL=5] method

Approximate least significant differences (5% level) of REML means

method

method 1	1		*
method 2	2	7.535	*
		1	2

```

76
77 " Narrow sense inference, no interaction, separate error variances
-78 by day "
79 CAPTION 'No interaction, separate error variances by day'; \
80 STYLE=major

```

No interaction, separate error variances by day

```

81 VCOMPONENTS [FIXED=method+day; EXPERIMENTS=day]
82 REML [PRINT=model,components,means,waldTests; PSE=differences] y

```

REML variance components analysis

Response variate: y
 Fixed model: Constant + method + day
 Number of units: 16

Separate residual terms for each level of experiment factor: day

Sparse algorithm with AI optimisation

Residual model for each experiment

Experiment factor: day

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
1.000	Residual		Identity	Variance	20.77	17.04
2.000	Residual		Identity	Variance	29.68	24.28
3.000	Residual		Identity	Variance	25.36	20.77
4.000	Residual		Identity	Variance	0.178	0.177

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	475.98	1	475.98	2.1	0.002
day	26.69	3	6.53	3.7	0.057

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
method	475.98	1	475.98	2.1	0.002
day	26.69	3	6.53	3.7	0.057

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

142.5 Standard error: 1.09

Table of predicted means for method

method	1	2
	147.0	137.9

Standard error of differences: 0.4176

Table of predicted means for day

day	1	2	3	4
	144.2	133.7	144.9	147.1

Standard errors of differences

Average:	3.034
Maximum:	3.710
Minimum:	2.289

Average variance of differences: 9.499

```
83  VLSD [PRINT=lsd; LSDLEVEL=5] method
```

Approximate least significant differences (5% level) of REML means

method

method 1	1	*	
method 2	2	1.711	*
		1	2

```
84
```

```
85  ENDJOB
```

End of job.

Oats Cultivar Example

Genstat Commands for the Oats Cultivar Example

JOB

```
" ***** "
" Example: Oat cultivar trial "
" ***** "

" Import the data "
IMPORT 'oats.csv'

" Convert Cultivar and Location from text structures to factors, and
Year and Block from variates to factors "
GROUP [REDEFINE=yes] Cultivar,Location,Year,Block; \
Cultivar,Location,Year,Block

" Construct an Environment factor (from the six combinations of
Location and Year) "
FACPRODUCT !P(Location,Year); Environment

" Plot the Harvest Index (HI) data "
" Plot raw data with Cultivar means separately for each Environment "
TRELLIS [GROUPS=Environment; YTITLE='Harvest Index'; \
XTITLE='Cultivar'; KEY=0] Y=HI; X=Cultivar; METHOD=point,mean
" Plot the Cultivars means at each Environment "
TRELLIS [PENGROUPS=Cultivar; YTITLE='Harvest Index'; \
XTITLE='Environment'] Y=HI; X=Environment; METHOD=mean
" Plot just three Cultivar means (Cherokee, Don, Larry) at each
environment (Figure 2) "
" Create a table of means "
TABULATE [PRINT=means; CLASSIFICATION=Environment,Cultivar] HI; \
MEANS=MeanHI
" Subset table to contain means only for Cherokee (factor level 1),
Don (factor level 2) & Larry (factor level 6) "
FACTOR [labels=!T('Cherokee','Don','Larry')] Cultivar_Subset
TABLE [CLASS=Environment,Cultivar_Subset] MeanHI_Subset
COMBINE [OLDSTRUCTURE=MeanHI; NEWSTRUCTURE=MeanHI_Subset] \
OLDDIMENSION=2; NEWDIMENSION=Cultivar_Subset; OLDPOSITION=!(1,2,6)
" Plot "
PEN [RESET=yes] 1,2,6; LINESSTYLE=1,2,3; THICKNESS=2
DTABLE [METHOD=onlylines; XFREPRESENTATION=labels] MeanHI_Subset; \
XFACTOR=Environment; GROUPS=Cultivar_Subset; PENS=!(1,2,6); \
YTITLE='Average Harvest Index'; XTITLE='Location, Year'; TITLE=''

" Narrow sense: Fixed Environments, random Blocks within Environment
(Box 3, Tables 4, 6) "
CAPTION 'Oats example: Narrow sense inference, random Blocks'; \
STYLE=meta
BLOCK Environment.Block
TREATMENTS Environment*Cultivar
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
PSE=means,diff,lsd; LSDLEVEL=5] HI
" Alternatively, fit using REML "
```



```

CAPTION 'Alternatively, fit using REML '; STYLE=stress
VCOMPONENTS [FIXED=Environment*Cultivar] RANDOM=Environment.Block
REML [PRINT=model,components,waldTests,means; PSE=estimates] HI
VDISPLAY [PRINT=means; PSE=differences]

" 'Slicing' the interaction "
" Note: Two methods of 'slicing' the interaction are presented here:
  1) Partitioning the interaction
  2) Splitting the dataset
  Both methods require some care to ensure the correct analysis
  is performed "

" Testing for differences among Environments within each Cultivar
  (Table 5) "
CAPTION 'Cultivar-specific tests'; STYLE=major
" Method 1 - Partition the interaction "
CAPTION 'Method 1: Partition the interaction'; STYLE=stress
" Steps a) Create a pointer of factors that partitions the
  interaction into Cultivar-specific components
  b) Define the BLOCK model. As the interaction and the main
  effect of Environment (the factor whose means are to be
  compared) are in different strata, the analysis needs to
  'merge' across these two strata. In this example, this
  can be achieved by omitting the Environment.Block stratum
  from the BLOCK model
  c) Define the TREATMENT model such that the pointer of
  Cultivar-specific components are nested within the
  Cultivar main effect
  d) Fit the ANOVA model "
GETATTRIBUTE [ATTRIBUTE=labels] Environment; SAVE=Elab
CALC Enlev = NLEVELS(Environment)
GETATTRIBUTE [ATTRIBUTE=labels] Cultivar; SAVE=Clab
CALC Cnlev = NLEVELS(Cultivar)
FACTOR [LABELS='T('-',#Elab); LEVELS=!(0...Enlev); IPRINT=extra] \
  Eslice[1...Cnlev]; EXTRA=#Clab[1]${1...Cnlev]
CALCULATE Eslice[1...#Cnlev] = Environment * (Cultivar.EQ.1...Cnlev)
BLOCK ""
TREATMENTS Cultivar/Eslice[]
ANOVA [PRINT=aovtable; FPROB=yes] HI
" Method 2 - Splitting the dataset "
CAPTION 'Method 2: Splitting the dataset'; STYLE=stress
" Steps a) Restrict the dataset to include only the Cultivar of
  interest
  b) Fit the model (using REML) constraining the variance
  components to the appropriate pooled estimates. In this
  example, the Environment.Block variability must be taken
  into account as the means with the same level of Cultivar
  aren't calculated from the same set of Environment.Blocks.
  (Note, it's reassuring to check that the SED matches that
  from the full ANOVA)
  c) Obtain the F-statistic
  d) Calculate F probability using the appropriate
  denominator degrees of freedom. (Note, the DDF can be
  found in the table of SEDs from the full ANOVA) "
SCALAR ndf; 5
SCALAR ddf; 119.32
"Note: The total variance is equal to the sum of the variance

```

```

    components (Environment.Block.*Units* + Environment.Block) "
SCALAR residvar; 11.59+(-0.28)
FOR i=1...Cnlev
RESTRICT HI; CONDITION = Cultivar .EQ. i
VCOMPONENTS [FIXED=Environment] RANDOM=Environment.Block; \
    INITIAL=residvar; CONSTRAINTS=fixabsolute
REML [PRINT=*] HI
VKEEP TERMS=Environment; FSTATISTIC=f
CONCATENATE [NEWTEXT=heading] OLDTEXT='P-value: ', Clab[1]$[i]
PRINT CUF(f;ndf;ddf); HEADING=heading; DEC=4
RESTRICT HI
ENDFOR

" Testing for differences among Cultivars within each Environment
  (Table 5) "
CAPTION 'Environment-specific tests'; STYLE=major
" Method 1 - Partition the interaction "
CAPTION 'Method 1: Partition the interaction'; STYLE=stress
" Steps a) Create a pointer of factors that partitions the
    interaction into Environment-specific components
    b) Define the BLOCK model. As the interaction and the main
    effect of Cultivar are in different strata, 'merging'
    across strata is not needed
    c) Define the TREATMENT model such that the pointer of
    Environment-specific components are nested within the
    Environment main effect
    d) Fit the ANOVA model "
FACTOR [LABELS=!T('-',#Clab); LEVELS=!(0...Cnlev); IPRINT=extra] \
    Cslice[1...Enlev]; EXTRA=#Elab[1]$[1...Enlev]
CALCULATE Cslice[1...#Enlev] = Cultivar * (Environment.EQ.1...Enlev)
BLOCK Environment.Block
TREATMENTS Environment/(Cslice[])
ANOVA [PRINT=aovtable; FPROB=yes] HI
" Method 2 - Splitting the dataset "
CAPTION 'Method 2: Splitting the dataset'; STYLE=stress
" Steps a) Restrict the dataset to include only the Environment of
    interest
    b) Fit the model (using REML) constraining the variance
    components to the appropriate pooled estimates. In this
    example, means with the same level of Environment are all
    calculated from the same set of Environment.Blocks, so
    any Environment.Block variability cancels out
    c) Obtain the F-statistic
    d) Calculate F probability using the appropriate
    denominator degrees of freedom "
SCALAR ndf; 9
SCALAR ddf; 108
SCALAR residvar; 11.59
FOR i=1...Enlev
RESTRICT HI; CONDITION = Environment .IN. i
VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment.Block; \
    INITIAL=residvar; CONSTRAINTS=fixabsolute
REML [PRINT=*] HI
VKEEP TERMS=Cultivar; FSTATISTIC=f
CONCATENATE [NEWTEXT=heading] OLDTEXT='P-value: ',Elab[1]$[i]
PRINT CUF(f;ndf;ddf); HEADING=heading; DEC=4
RESTRICT HI

```

ENDFOR

" Additional code for narrow sense analysis not discussed in the
Chapter: Environment separated into Year by Location "

```
CAPTION 'Additional analysis not discussed in the Chapter'; \
  STYLE=meta
CAPTION 'Environment separated into Year by Location'; STYLE=major
BLOCK Location.Year.Block
TREATMENTS Location*Year*Cultivar
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] HI
```

" Broad sense (Box 4, Table 6) "

```
CAPTION 'Oats example: Broad sense inference'; STYLE=meta
VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment/Block+ \
  Environment.Cultivar
REML [PRINT=model,components,waldTests,means; PSE=estimates] HI
VDISPLAY [PRINT=means; PSE=differences]
TABLE [CLASSIFICATION=Environment,Cultivar] CherokeeDonAmes1985; \
  VALUES=(1,-1,8(0),10(0),10(0),10(0),10(0),10(0))
VTCOMPARISONS CherokeeDonAmes1985
```

" Broad sense: subdivided interaction (Box 5, Table 7) "

```
CAPTION 'Oats example: Broad sense inference,\
  Environment separated into Year by Location'; STYLE=meta
VCOMPONENTS [FIXED=Cultivar] RANDOM=(Year*Location)/Block+ \
  Cultivar*Year*Location
REML [PRINT=model,components,waldTests,means; PSE=estimates; \
  METHOD=Fisher] HI
" Note: The VCRITICAL procedure provides an alternative method for
  assessing fixed terms (and contrasts) when the DDF can't be
  estimated "
VDISPLAY [PRINT=means; PSE=differences]
TABLE [CLASSIFICATION=Location,Year,Cultivar] CherokeeDonAmes1985; \
  VALUES=(1,-1,58(0))
VTCOMPARISONS CherokeeDonAmes1985
```

" Levene's tests (Table 8) "

```
CAPTION 'Oats example: Levene's test'; STYLE=meta
BLOCK Environment.Block
TREATMENTS Environment*Cultivar
COVARIATE "No Covariate"
ANOVA [PRINT=*] HI
AKEEP [RESIDUAL=resid]
CALC absresid = ABS(resid)
CAPTION 'Levene's test on factor structure'; STYLE=major
BLOCK ""
TREATMENTS Year*Location
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] absresid
CAPTION 'Levene's test for the 6 environments (no structure)'; \
  STYLE=major
BLOCK ""
TREATMENTS Year.Location
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] absresid
```

```

" Fit models to explore structure of error variances "
CAPTION 'Oats example: Exploring structure of error variances'; \
  STYLE=meta

" Models in Table 8 "
CAPTION 'Narrow sense inference, single error variance'; STYLE=major
VCOMPONENTS [FIXED=Cultivar*Year*Location] \
  RANDOM=Block.Year.Location
REML [PRINT=model,components,waldTests] HI
VAIC
CAPTION 'Narrow sense inference, Location specific variances'; \
  STYLE=major
VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Location] \
  RANDOM=Block.Year.Location
REML [PRINT=model,components,waldTests] HI
VAIC
CAPTION 'Narrow sense inference, Year specific variances'; \
  STYLE=major
VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Year] \
  RANDOM=Block.Year.Location
REML [PRINT=model,components,waldTests] HI
VAIC
CAPTION 'Narrow sense inference, Environment specific variances'; \
  STYLE=major
VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Environment]\
  RANDOM=Block.Year.Location
REML [PRINT=model,components,waldTests; MAXCYCLE=1000] HI
VAIC

" Models in Table 9 and Box 6 "
CAPTION 'Narrow sense inference, single error variance'; STYLE=major
VCOMPONENTS [FIXED=Cultivar*Environment] RANDOM=Block.Environment
REML [PRINT=components] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
TABLE [CLASSIFICATION=Environment,Cultivar] CherokeeDonAmes1985; \
  VALUES=(1,-1,8(0),10(0),10(0),10(0),10(0),10(0))
VTCOMPARISONS CherokeeDonAmes1985
CAPTION 'Narrow sense inference, Location specific variances'; \
  STYLE=major
VCOMPONENTS [FIXED=Cultivar*Environment; EXPERIMENTS=Location] \
  RANDOM=Block.Environment
REML [PRINT=components] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
VTCOMPARISONS CherokeeDonAmes1985
CAPTION 'Broad sense inference, single error variance'; STYLE=major
VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment/Block+ \
  Environment.Cultivar
REML [PRINT=components] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
VTCOMPARISONS CherokeeDonAmes1985
CAPTION 'Broad sense inference, Location specific variances'; \
  STYLE=major
VCOMPONENTS [FIXED=Cultivar; EXPERIMENTS=Location] \
  RANDOM=Environment/Block+Environment.Cultivar

```

```

REML [PRINT=components] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
VTCOMPARISONS CherokeeDonAmes1985
CAPTION 'Broad sense inference, subdivided interaction,\
pooled variance'; STYLE=major
VCOMPONENTS [FIXED=Cultivar] RANDOM=(Year*Location)/Block+\
Cultivar*Year*Location
REML [PRINT=components; METHOD=Fisher] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
TABLE [CLASSIFICATION=Location,Year,Cultivar] CherokeeDonAmes1985; \
VALUES=!(1,-1,58(0))
VTCOMPARISONS CherokeeDonAmes1985
CAPTION 'Broad sense inference, subdivided interaction,\
Location specific variances'; STYLE=major
VCOMPONENTS [FIXED=Cultivar; EXPERIMENTS=Location] \
RANDOM=(Year*Location)/Block+Cultivar*Year*Location; \
CONSTRAINTS=positive
REML [PRINT=components] HI
VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
VTCOMPARISONS CherokeeDonAmes1985

ENDJOB

```

Genstat Output from the Oats Cultivar Example

2 JOB

End of job.

```

3
4 " ***** "
5 " Example: Oat cultivar trial "
6 " ***** "
7
8 " Import the data "
9 IMPORT 'oats.csv'

```

Loading Spreadsheet File

Catalogue of file oats.csv

Sheet Title: Sheet1

Description: <none>

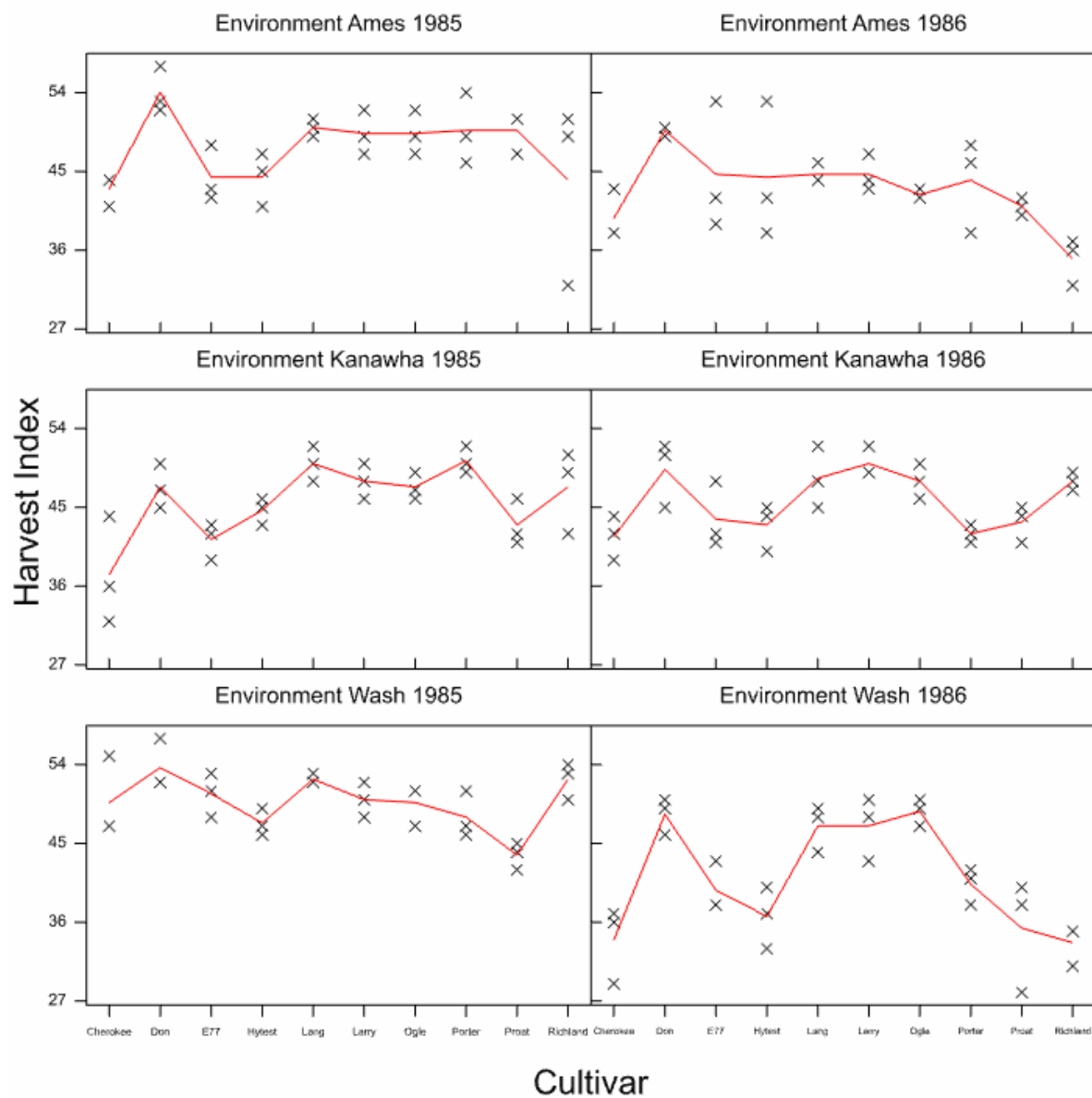
Sheet Type: vector

Index	Type	Nval	Name
1	variate	180	Year
2	text	180	Location
3	variate	180	Block
4	text	180	Cultivar
5	variate	180	HI

```

10
11 " Convert Cultivar and Location from text structures to factors, and
-12 Year and Block from variates to factors "
13 GROUP [REDEFINE=yes] Cultivar,Location,Year,Block; \
14 Cultivar,Location,Year,Block
15
16 " Construct an Environment factor (from the six combinations of
-17 Location and Year) "
18 FACPRODUCT !P(Location,Year); Environment
19
20 " Plot the Harvest Index (HI) data "
21 " Plot raw data with Cultivar means separately for each Environment "
22 TRELLIS [GROUPS=Environment; YTITLE='Harvest Index'; \
23 XTITLE='Cultivar'; KEY=0] Y=HI; X=Cultivar; METHOD=point,mean

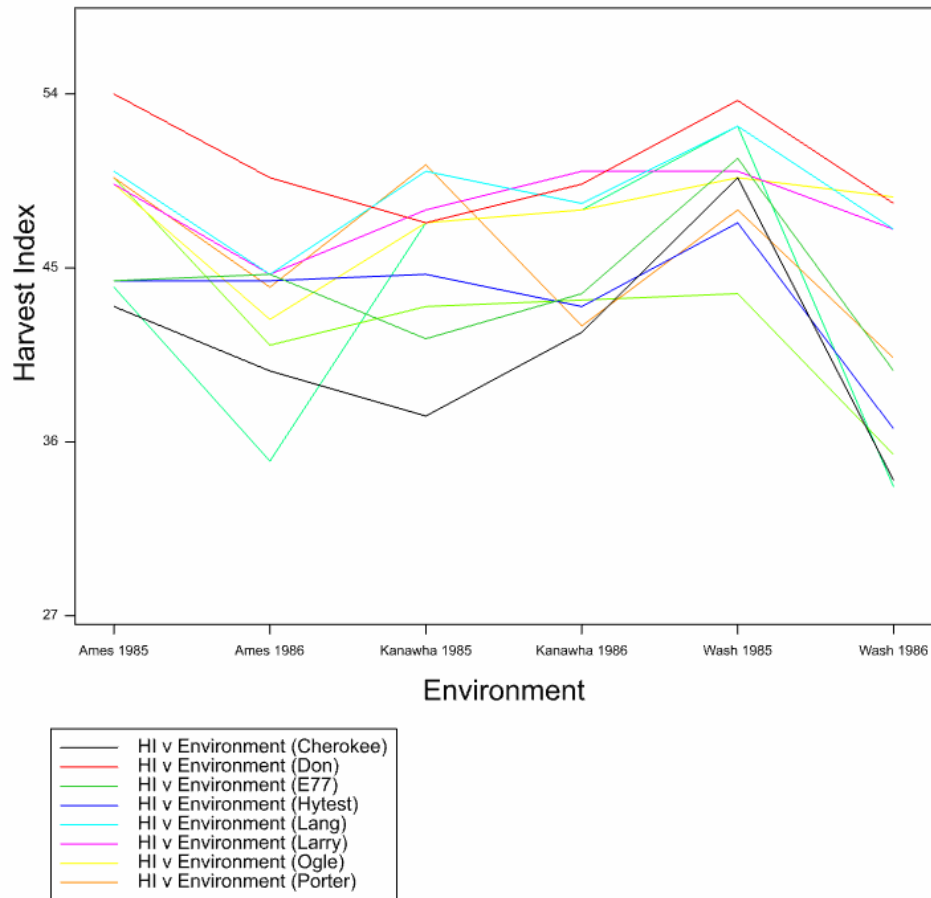
```



```

24 " Plot the Cultivars means at each Environment "
25 TRELLIS [PENGROUPS=Cultivar; YTITLE='Harvest Index'; \
26   XTITLE='Environment'] Y=HI; X=Environment; METHOD=mean

```



```

27 " Plot just three Cultivar means (Cherokee, Don, Larry) at each
-28 environment (Figure 2) "
29 " Create a table of means "
30 TABULATE [PRINT=means; CLASSIFICATION=Environment,Cultivar] HI; \
31   MEANS=MeanHI

```

Cultivar Environment	MeanHI				
	Cherokee	Don	E77	Hytest	Lang
Ames 1985	43.00	54.00	44.33	44.33	50.00
Ames 1986	39.67	49.67	44.67	44.33	44.67
Kanawha 1985	37.33	47.33	41.33	44.67	50.00
Kanawha 1986	41.67	49.33	43.67	43.00	48.33
Wash 1985	49.67	53.67	50.67	47.33	52.33
Wash 1986	34.00	48.33	39.67	36.67	47.00

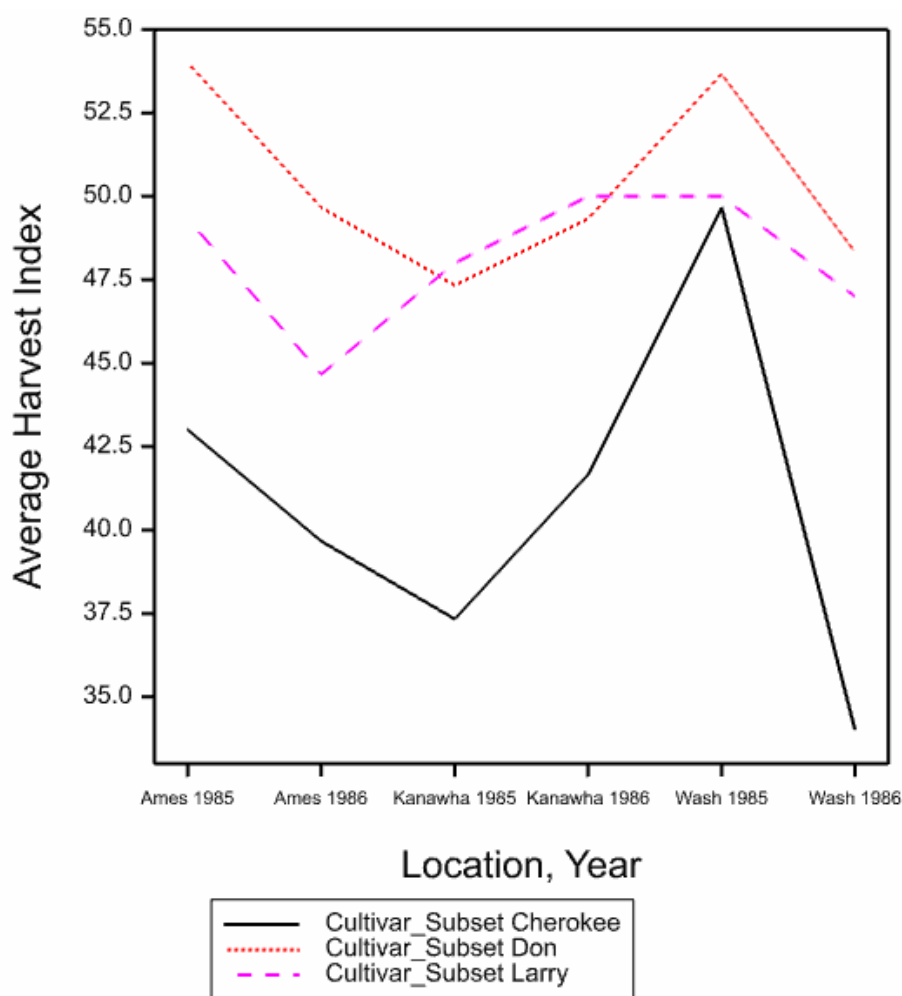
Cultivar Environment	Larry	Ogle	Porter	Proat	Richland
Ames 1985	49.33	49.33	49.67	49.67	44.00
Ames 1986	44.67	42.33	44.00	41.00	35.00
Kanawha 1985	48.00	47.33	50.33	43.00	47.33

Kanawha 1986	50.00	48.00	42.00	43.33	48.00
Wash 1985	50.00	49.67	48.00	43.67	52.33
Wash 1986	47.00	48.67	40.33	35.33	33.67

```

32  " Subset table to contain means only for Cherokee (factor level 1),
-33  Don (factor level 2) & Larry (factor level 6) "
34  FACTOR [labels=!T('Cherokee','Don','Larry')] Cultivar_Subset
35  TABLE [CLASS=Environment,Cultivar_Subset] MeanHI_Subset
36  COMBINE [OLDSTRUCTURE=MeanHI; NEWSTRUCTURE=MeanHI_Subset] \
37  OLDDIMENSION=2; NEWDIMENSION=Cultivar_Subset; OLDPOSITION=!(1,2,6)
38  " Plot "
39  PEN [RESET=yes] 1,2,6; LINESSTYLE=1,2,3; THICKNESS=2
40  DTABLE [METHOD=onlylines; XFREPRESENTATION=labels] MeanHI_Subset; \
41  XFACTOR=Environment; GROUPS=Cultivar_Subset; PENS=!(1,2,6); \
42  YTITLE='Average Harvest Index'; XTITLE='Location, Year'; TITLE=''

```



```

43
44  " Narrow sense: Fixed Environments, random Blocks within Environment
-45  (Box 3, Tables 4, 6) "
46  CAPTION 'Oats example: Narrow sense inference, random Blocks'; \
47  STYLE=meta

```


Oats example: Narrow sense inference, random Blocks

```

48 BLOCK Environment.Block
49 TREATMENTS Environment*Cultivar
50 COVARIATE "No Covariate"
51 ANOVA [PRINT=aovtable,means,stratumvariances; FPROB=yes; \
52     PSE=means,diff,lsd; LSDLEVEL=5] HI

```

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment.Block stratum					
Environment	5	1471.36	294.27	33.65	<.001
Residual	12	104.93	8.74	0.75	
Environment.Block.*Units* stratum					
Cultivar	9	1547.27	171.92	14.83	<.001
Environment.Cultivar	45	1195.69	26.57	2.29	<.001
Residual	108	1251.73	11.59		
Total	179	5570.99			

Tables of means

Variate: HI

Grand mean 45.49

Environment	Ames 1985 47.77	Ames 1986 43.00	Kanawha 1985 45.67	Kanawha 1986 45.73	Wash 1985 49.73

Environment	Wash 1986 41.07

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72	Larry 48.17	Ogle 47.56

Cultivar	Porter 45.72	Proat 42.67	Richland 43.39

Environment	Cultivar	Cherokee	Don	E77	Hytest	Lang	Larry
Ames 1985		43.00	54.00	44.33	44.33	50.00	49.33
Ames 1986		39.67	49.67	44.67	44.33	44.67	44.67
Kanawha 1985		37.33	47.33	41.33	44.67	50.00	48.00
Kanawha 1986		41.67	49.33	43.67	43.00	48.33	50.00
Wash 1985		49.67	53.67	50.67	47.33	52.33	50.00
Wash 1986		34.00	48.33	39.67	36.67	47.00	47.00

Environment	Cultivar	Ogle	Porter	Proat	Richland
Ames 1985		49.33	49.67	49.67	44.00

Ames 1986	42.33	44.00	41.00	35.00
Kanawha 1985	47.33	50.33	43.00	47.33
Kanawha 1986	48.00	42.00	43.33	48.00
Wash 1985	49.67	48.00	43.67	52.33
Wash 1986	48.67	40.33	35.33	33.67

Standard errors of means

Table	Environment	Cultivar	Environment Cultivar
rep.	30	18	3
e.s.e.	0.540	0.802	1.941
d.f.	12	108	119.32
Except when comparing means with the same level(s) of Environment			1.966
d.f.			108

Standard errors of differences of means

Table	Environment	Cultivar	Environment Cultivar
rep.	30	18	3
s.e.d.	0.764	1.135	2.745
d.f.	12	108	119.32
Except when comparing means with the same level(s) of Environment			2.780
d.f.			108

Least significant differences of means (5% level)

Table	Environment	Cultivar	Environment Cultivar
rep.	30	18	3
l.s.d.	1.664	2.249	5.436
d.f.	12	108	119.32
Except when comparing means with the same level(s) of Environment			5.510
d.f.			108

Estimated stratum variances

Variate: HI

Stratum	variance	effective d.f.	variance component
Environment.Block	8.744	12.000	-0.285
Environment.Block.*Units*	11.590	108.000	11.590

```

53 " Alternatively, fit using REML "
54 CAPTION 'Alternatively, fit using REML '; STYLE=stress

```

Alternatively, fit using REML

```

55 VCOMPONENTS [FIXED=Environment*Cultivar] RANDOM=Environment.Block
56 REML [PRINT=model,components,waldTests,means; PSE=estimates] HI

```

REML variance components analysis

Response variate: HI
 Fixed model: Constant + Environment + Cultivar + Environment.Cultivar
 Random model: Environment.Block
 Number of units: 180

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Environment.Block	-0.28	0.39

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Environment	168.26	5	33.65	12.0	<0.001
Cultivar	133.50	9	14.83	108.0	<0.001
Environment.Cultivar	103.16	45	2.29	108.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Environment.Cultivar	103.16	45	2.29	108.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of predicted means for Constant

45.49 Standard error: 0.220

Table of predicted means for Environment

Environment	
Ames 1985	47.77
Ames 1986	43.00
Kanawha 1985	45.67
Kanawha 1986	45.73
Wash 1985	49.73
Wash 1986	41.07

Standard error: 0.5399

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error: 0.7925

Table of predicted means for Environment.Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
Environment					
Ames 1985	43.00	54.00	44.33	44.33	50.00
Ames 1986	39.67	49.67	44.67	44.33	44.67
Kanawha 1985	37.33	47.33	41.33	44.67	50.00
Kanawha 1986	41.67	49.33	43.67	43.00	48.33
Wash 1985	49.67	53.67	50.67	47.33	52.33
Wash 1986	34.00	48.33	39.67	36.67	47.00
Cultivar	Larry	Ogle	Porter	Proat	Richland
Environment					
Ames 1985	49.33	49.33	49.67	49.67	44.00
Ames 1986	44.67	42.33	44.00	41.00	35.00
Kanawha 1985	48.00	47.33	50.33	43.00	47.33
Kanawha 1986	50.00	48.00	42.00	43.33	48.00
Wash 1985	50.00	49.67	48.00	43.67	52.33
Wash 1986	47.00	48.67	40.33	35.33	33.67

Standard error: 1.941

```
57  VDISPLAY [PRINT=means; PSE=differences]
```

Table of predicted means for Constant

45.49 Standard error: 0.220

Table of predicted means for Environment

Environment	
Ames 1985	47.77
Ames 1986	43.00
Kanawha 1985	45.67
Kanawha 1986	45.73
Wash 1985	49.73
Wash 1986	41.07

Standard error of differences: 0.7635

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error of differences: 1.135

Table of predicted means for Environment.Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
Environment					
Ames 1985	43.00	54.00	44.33	44.33	50.00
Ames 1986	39.67	49.67	44.67	44.33	44.67
Kanawha 1985	37.33	47.33	41.33	44.67	50.00
Kanawha 1986	41.67	49.33	43.67	43.00	48.33
Wash 1985	49.67	53.67	50.67	47.33	52.33
Wash 1986	34.00	48.33	39.67	36.67	47.00
Cultivar	Larry	Ogle	Porter	Proat	Richland

Environment					
Ames 1985	49.33	49.33	49.67	49.67	44.00
Ames 1986	44.67	42.33	44.00	41.00	35.00
Kanawha 1985	48.00	47.33	50.33	43.00	47.33
Kanawha 1986	50.00	48.00	42.00	43.33	48.00
Wash 1985	50.00	49.67	48.00	43.67	52.33
Wash 1986	47.00	48.67	40.33	35.33	33.67

Standard errors of differences

Average: 2.751
Maximum: 2.780
Minimum: 2.745

Average variance of differences: 7.566

Standard error of differences for same level of factor:

	Environment	Cultivar
Average:	2.780	2.745
Maximum:	2.780	2.745
Minimum:	2.780	2.745

```

58
59 " 'Slicing' the interaction "
60 " Note: Two methods of 'slicing' the interaction are presented here:
-61 1) Partitioning the interaction
-62 2) Splitting the dataset
-63 Both methods require some care to ensure the correct analysis
-64 is performed "
65
66 " Testing for differences among Environments within each Cultivar
-67 (Table 5) "
68 CAPTION 'Cultivar-specific tests'; STYLE=major

```

Cultivar-specific tests

```

69 " Method 1 - Partition the interaction "
70 CAPTION 'Method 1: Partition the interaction'; STYLE=stress

```

Method 1: Partition the interaction

```

71 " Steps a) Create a pointer of factors that partitions the
-72 interaction into Cultivar-specific components
-73 b) Define the BLOCK model. As the interaction and the main
-74 effect of Environment (the factor whose means are to be
-75 compared) are in different strata, the analysis needs to
-76 'merge' across these two strata. In this example, this
-77 can be achieved by omitting the Environment.Block stratum
-78 from the BLOCK model

```

```

-79          c) Define the TREATMENT model such that the pointer of
-80          Cultivar-specific components are nested within the
-81          Cultivar main effect
-82          d) Fit the ANOVA model "
83  GETATTRIBUTE [ATTRIBUTE=labels] Environment; SAVE=Elab
84  CALC Enlev = NLEVELS(Environment)
85  GETATTRIBUTE [ATTRIBUTE=labels] Cultivar; SAVE=Clab
86  CALC Cnlev = NLEVELS(Cultivar)
87  FACTOR [LABELS=!T('-',#Elab); LEVELS=!(0...Enlev); IPRINT=extra] \
88    Eslice[1...Cnlev]; EXTRA=#Clab[1]${1...Cnlev]
89  CALCULATE Eslice[1...#Cnlev] = Environment * (Cultivar.EQ.1...Cnlev)
90  BLOCK ""
91  TREATMENTS Cultivar/Eslice[]
92  ANOVA [PRINT=aovtable; FPROB=yes] HI

```

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1547.27	171.92	15.21	<.001
Cultivar.Cherokee	5	431.11	86.22	7.63	<.001
Cultivar.Don	5	116.94	23.39	2.07	0.074
Cultivar.E77	5	212.94	42.59	3.77	0.003
Cultivar.Hytest	5	192.94	38.59	3.41	0.006
Cultivar.Lang	5	107.61	21.52	1.90	0.099
Cultivar.Larry	5	65.17	13.03	1.15	0.337
Cultivar.Ogle	5	109.11	21.82	1.93	0.094
Cultivar.Porter	5	263.61	52.72	4.66	<.001
Cultivar.Proat	5	321.33	64.27	5.68	<.001
Cultivar.Richland	5	846.28	169.26	14.97	<.001
Residual	120	1356.67	11.31		
Total	179	5570.99			

```

93  " Method 2 - Splitting the dataset "
94  CAPTION 'Method 2: Splitting the dataset'; STYLE=stress

```

Method 2: Splitting the dataset

```

95  " Steps a) Restrict the dataset to include only the Cultivar of
-96  interest
-97  b) Fit the model (using REML) constraining the variance
-98  components to the appropriate pooled estimates. In this
-99  example, the Environment.Block variability must be taken
-100 into account as the means with the same level of Cultivar
-101 aren't calculated from the same set of Environment.Blocks.
-102 (Note, it's reassuring to check that the SED matches that
-103 from the full ANOVA)
-104 c) Obtain the F-statistic
-105 d) Calculate F probability using the appropriate
-106 denominator degrees of freedom. (Note, the DDF can be
-107 found in the table of SEDs from the full ANOVA) "
108 SCALAR ndf; 5
109 SCALAR ddf; 119.32
110 "Note: The total variance is equal to the sum of the variance
-111 components (Environment.Block.*Units* + Environment.Block) "
112 SCALAR residvar; 11.59+(-0.28)

```

```

113 FOR i=1...Cnlev
114 RESTRICT HI; CONDITION = Cultivar .EQ. i
115 VCOMPONENTS [FIXED=Environment] RANDOM=Environment.Block; \
116   INITIAL=residvar; CONSTRAINTS=fixabsolute
117 REML [PRINT=*] HI
118 VKEEP TERMS=Environment; FSTATISTIC=f
119 CONCATENATE [NEWTEXT=heading] OLDTEXT='P-value: ', Clab[1]$[i]
120 PRINT CUF(f;ndf;ddf); HEADING=heading; DEC=4
121 RESTRICT HI
122 ENDFOR

```

P-value: Cherokee
0.0000

P-value: Don
0.0741

P-value: E77
0.0033

P-value: Hytest
0.0064

P-value: Lang
0.0988

P-value: Larry
0.3368

P-value: Ogle
0.0944

P-value: Porter
0.0006

P-value: Proat
0.0001

P-value: Richland
0.0000

```

123
124 " Testing for differences among Cultivars within each Environment
-125 (Table 5) "
126 CAPTION 'Environment-specific tests'; STYLE=major

```


Environment-specific tests

```
127 " Method 1 - Partition the interaction "  
128 CAPTION 'Method 1: Partition the interaction'; STYLE=stress
```

Method 1: Partition the interaction

```
129 " Steps a) Create a pointer of factors that partitions the  
-130 interaction into Environment-specific components  
-131 b) Define the BLOCK model. As the interaction and the main  
-132 effect of Cultivar are in different strata, 'merging'  
-133 across strata is not needed  
-134 c) Define the TREATMENT model such that the pointer of  
-135 Environment-specific components are nested within the  
-136 Environment main effect  
-137 d) Fit the ANOVA model "  
138 FACTOR [LABELS=!T('-',#Clab); LEVELS=!(0...Cnlev); IPRINT=extra] \  
139 Cslice[1...Enlev]; EXTRA=#Elab[1]${1...Enlev]  
140 CALCULATE Cslice[1...#Enlev] = Cultivar * (Environment.EQ.1...Enlev)  
141 BLOCK Environment.Block  
142 TREATMENTS Environment/(Cslice[])  
143 ANOVA [PRINT=aovtable; FPROB=yes] HI
```

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment.Block stratum					
Environment	5	1471.36	294.27	33.65	<.001
Residual	12	104.93	8.74	0.75	
Environment.Block.*Units* stratum					
Environment.Ames 1985	9	349.37	38.82	3.35	0.001
Environment.Ames 1986	9	405.33	45.04	3.89	<.001
Environment.Kanawha 1985	9	452.00	50.22	4.33	<.001
Environment.Kanawha 1986	9	288.53	32.06	2.77	0.006
Environment.Wash 1985	9	226.53	25.17	2.17	0.029
Environment.Wash 1986	9	1021.20	113.47	9.79	<.001
Residual	108	1251.73	11.59		
Total	179	5570.99			

```
144 " Method 2 - Splitting the dataset "  
145 CAPTION 'Method 2: Splitting the dataset'; STYLE=stress
```

Method 2: Splitting the dataset

```
146 " Steps a) Restrict the dataset to include only the Environment of  
-147 interest
```

```

-148         b) Fit the model (using REML) constraining the variance
-149             components to the appropriate pooled estimates. In this
-150             example, means with the same level of Environment are all
-151             calculated from the same set of Environment.Blocks, so
-152             any Environment.Block variability cancels out
-153         c) Obtain the F-statistic
-154         d) Calculate F probability using the appropriate
-155             denominator degrees of freedom "
156     SCALAR ndf; 9
157     SCALAR ddf; 108
158     SCALAR residvar; 11.59
159     FOR i=1...Enlev
160     RESTRICT HI; CONDITION = Environment .IN. i
161     VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment.Block; \
162         INITIAL=residvar; CONSTRAINTS=fixabsolute
163     REML [PRINT=*] HI
164     VKEEP TERMS=Cultivar; FSTATISTIC=f
165     CONCATENATE [NEWTEXT=heading] OLDTEXT='P-value: ',Elab[1]$,[i]
166     PRINT CUF(f;ndf;ddf); HEADING=heading; DEC=4
167     RESTRICT HI
168     ENDFOR

```

P-value: Ames 1985
0.0012

P-value: Ames 1986
0.0003

P-value: Kanawha 1985
0.0001

P-value: Kanawha 1986
0.0060

P-value: Wash 1985
0.0295

P-value: Wash 1986
0.0000

```

169
170     " Additional code for narrow sense analysis not discussed in the
-171     Chapter: Environment separated into Year by Location "
172     CAPTION 'Additional analysis not discussed in the Chapter'; \
173     STYLE=meta

```

Additional analysis not discussed in the Chapter

```

174     CAPTION 'Environment separated into Year by Location'; STYLE=major

```

Environment separated into Year by Location

```

175 BLOCK Location.Year.Block
176 TREATMENTS Location*Year*Cultivar
177 COVARIATE "No Covariate"
178 ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] HI

```

Analysis of variance

Variate: HI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Location.Year.Block stratum					
Location	2	3.81	1.91	0.22	0.807
Year	1	893.34	893.34	102.16	<.001
Location.Year	2	574.21	287.11	32.83	<.001
Residual	12	104.93	8.74	0.75	
Location.Year.Block.*Units* stratum					
Cultivar	9	1547.27	171.92	14.83	<.001
Location.Cultivar	18	489.08	27.17	2.34	0.004
Year.Cultivar	9	211.49	23.50	2.03	0.043
Location.Year.Cultivar	18	495.12	27.51	2.37	0.003
Residual	108	1251.73	11.59		
Total	179	5570.99			

Tables of means

Variate: HI

Grand mean 45.49

Location	Ames	Kanawha	Wash				
	45.38	45.70	45.40				
Year	1985	1986					
	47.72	43.27					
Cultivar	Cherokee	Don	E77	Hytest	Lang	Larry	Ogle
	40.89	50.39	44.06	43.39	48.72	48.17	47.56
Cultivar	Porter	Proat	Richland				
	45.72	42.67	43.39				
Location	Year	1985	1986				
Ames		47.77	43.00				
Kanawha		45.67	45.73				
Wash		49.73	41.07				
Location	Cultivar	Cherokee	Don	E77	Hytest	Lang	Larry
Ames		41.33	51.83	44.50	44.33	47.33	47.00

Kanawha		39.50	48.33	42.50	43.83	49.17	49.00
Wash		41.83	51.00	45.17	42.00	49.67	48.50
Location	Cultivar	Ogle	Porter	Proat	Richland		
Ames		45.83	46.83	45.33	39.50		
Kanawha		47.67	46.17	43.17	47.67		
Wash		49.17	44.17	39.50	43.00		
Year	Cultivar	Cherokee	Don	E77	Hytest	Lang	Larry
1985		43.33	51.67	45.44	45.44	50.78	49.11
1986		38.44	49.11	42.67	41.33	46.67	47.22
Year	Cultivar	Ogle	Porter	Proat	Richland		
1985		48.78	49.33	45.44	47.89		
1986		46.33	42.11	39.89	38.89		
Location	Year	Cultivar	Cherokee	Don	E77	Hytest	Lang
Ames	1985		43.00	54.00	44.33	44.33	50.00
	1986		39.67	49.67	44.67	44.33	44.67
Kanawha	1985		37.33	47.33	41.33	44.67	50.00
	1986		41.67	49.33	43.67	43.00	48.33
Wash	1985		49.67	53.67	50.67	47.33	52.33
	1986		34.00	48.33	39.67	36.67	47.00
Location	Year	Cultivar	Larry	Ogle	Porter	Proat	Richland
Ames	1985		49.33	49.33	49.67	49.67	44.00
	1986		44.67	42.33	44.00	41.00	35.00
Kanawha	1985		48.00	47.33	50.33	43.00	47.33
	1986		50.00	48.00	42.00	43.33	48.00
Wash	1985		50.00	49.67	48.00	43.67	52.33
	1986		47.00	48.67	40.33	35.33	33.67

Standard errors of differences of means

Table	Location	Year	Cultivar	Location Year
rep.	60	90	18	30
d.f.	12	12	108	12
s.e.d.	0.540	0.441	1.135	0.764

Table	Location Cultivar	Year Cultivar	Location Year Cultivar
rep.	6	9	3
s.e.d.	1.941	1.585	2.745
d.f.	119.32	119.32	119.32

Except when comparing means with the same level(s) of

Location	1.966		
d.f.	108		
Year		1.605	
d.f.		108	
Location.Year			2.780
d.f.			108

```

179
180 " Broad sense (Box 4, Table 6) "
181 CAPTION 'Oats example: Broad sense inference'; STYLE=meta

```

Oats example: Broad sense inference

```

182 VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment/Block+ \
183     Environment.Cultivar
184 REML [PRINT=model,components,waldTests,means; PSE=estimates] HI

```

REML variance components analysis

Response variate: HI
 Fixed model: Constant + Cultivar
 Random model: Environment + Environment.Block + Environment.Cultivar
 Number of units: 180

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Environment	9.02	6.21
Environment.Block	-0.28	0.39
Environment.Cultivar	4.99	1.94

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Cultivar	58.23	9	6.47	45.0	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Cultivar	58.23	9	6.47	45.0	<0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Constant

45.49 Standard error: 1.279

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error: 1.721

```
185 VDISPLAY [PRINT=means; PSE=differences]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Constant

45.49 Standard error: 1.279

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error of differences: 1.718

```
186 TABLE [CLASSIFICATION=Environment,Cultivar] CherokeeDonAmes1985; \
187 VALUES=(1,-1,8(0),10(0),10(0),10(0),10(0),10(0))
188 VTCOMPARISONS CherokeeDonAmes1985
```

Warning 38, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.346	2.218	21.76	<0.001

```

189
190 " Broad sense: subdivided interaction (Box 5, Table 7) "
191 CAPTION 'Oats example: Broad sense inference,\
-192 Environment separated into Year by Location'; STYLE=meta

```

Oats example: Broad sense inference, Environment separated into Year by Location

```

193 VCOMPONENTS [FIXED=Cultivar] RANDOM=(Year*Location)/Block+\
194 Cultivar*Year*Location
195 REML [PRINT=model,components,waldTests,means; PSE=estimates; \
196 METHOD=Fisher] HI

```

REML variance components analysis

Response variate: HI
Fixed model: Constant + Cultivar
Random model: Year + Location + Year.Location + Year.Location.Block + Year.Cultivar + Location.Cultivar + Year.Location.Cultivar
Number of units: 180

Residual term has been added to model

Non-sparse algorithm with Fisher scoring

Estimated variance components

Random term	component	s.e.
Year	6.78	14.40
Location	-4.75	4.79
Year.Location	8.75	9.58
Year.Location.Block	-0.28	0.39
Year.Cultivar	-0.45	1.60
Location.Cultivar	-0.06	2.15
Year.Location.Cultivar	5.31	3.10

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

Warning 39, code VD 39, statement 1 on line 196

Command: REML [PRINT=model,components,waldTests,means; PSE=estimates; METHOD=Fi
Error in AI algorithm when forming denominator DF for approximate F-tests.

Wald tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Cultivar	66.80	9	7.42	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Cultivar	66.80	9	7.42	<0.001

Message: chi-square distribution for Wald tests is an asymptotic approximation (i.e. for large samples) and underestimates the probabilities in other cases.

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Constant

45.49 Standard error: 1.838

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error: 2.130


```

197 " Note: The VCRITICAL procedure provides an alternative method for
-198 assessing fixed terms (and contrasts) when the DDF can't be
-199 estimated "
200 VDISPLAY [PRINT=means; PSE=differences]

```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Constant

45.49 Standard error: 1.838

Table of predicted means for Cultivar

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72
Cultivar	Larry 48.17	Ogle 47.56	Porter 45.72	Proat 42.67	Richland 43.39

Standard error of differences: 1.604

```

201 TABLE [CLASSIFICATION=Location,Year,Cultivar] CherokeeDonAmes1985; \
202 VALUES=(1,-1,58(0))
203 VTCOMPARISONS CherokeeDonAmes1985

```

Warning 40, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.447	2.215	22.24	<0.001

```

204
205 " Levene's tests (Table 8) "
206 CAPTION 'Oats example: Levene's test'; STYLE=meta

```

Oats example: Levene's test

```

207 BLOCK Environment.Block
208 TREATMENTS Environment*Cultivar
209 COVARIATE "No Covariate"
210 ANOVA [PRINT=*] HI
211 AKEEP [RESIDUAL=resid]
212 CALC absresid = ABS(resid)
213 CAPTION 'Levene''s test on factor structure'; STYLE=major

```

Levene's test on factor structure

```

214 BLOCK ""
215 TREATMENTS Year*Location
216 COVARIATE "No Covariate"
217 ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] absresid

```

Analysis of variance

Variate: absresid

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year	1	1.978	1.978	0.66	0.418
Location	2	10.734	5.367	1.79	0.171
Year.Location	2	4.136	2.068	0.69	0.504
Residual	174	523.128	3.006		
Total	179	539.976			

Tables of means

Variate: absresid

Grand mean 1.99

Year		1985	1986		
		1.88	2.09		
Location		Ames	Kanawha	Wash	
		2.32	1.75	1.89	
Year	Location	Ames	Kanawha	Wash	
1985		2.34	1.74	1.58	
1986		2.31	1.76	2.21	

Standard errors of differences of means

Table	Year	Location	Year Location
rep.	90	60	30
d.f.	174	174	174
s.e.d.	0.258	0.317	0.448

```

218  CAPTION 'Levene''s test for the 6 environments (no structure)'; \
219      STYLE=major

```

Levene's test for the 6 environments (no structure)

```

220  BLOCK ""
221  TREATMENTS Year.Location
222  COVARIATE "No Covariate"
223  ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=diff] absresid

```

Analysis of variance

Variate: absresid

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Year.Location	5	16.848	3.370	1.12	0.351
Residual	174	523.128	3.006		
Total	179	539.976			

Tables of means

Variate: absresid

Grand mean 1.99

Year	Location	Ames	Kanawha	Wash
1985		2.34	1.74	1.58
1986		2.31	1.76	2.21

Standard errors of differences of means

Table	Year
	Location
rep.	30
d.f.	174
s.e.d.	0.448

```

224
225  " Fit models to explore structure of error variances "
226  CAPTION 'Oats example: Exploring structure of error variances'; \
227      STYLE=meta

```

Oats example: Exploring structure of error variances

```

228
229  " Models in Table 8 "
230  CAPTION 'Narrow sense inference, single error variance'; STYLE=major

```

Narrow sense inference, single error variance

```

231 VCOMPONENTS [FIXED=Cultivar*Year*Location] \
232     RANDOM=Block.Year.Location
233 REML [PRINT=model,components,waldTests] HI

```

REML variance components analysis

Response variate: HI
 Fixed model: Constant + Year + Location + Cultivar + Year.Location + Year.Cultivar +
 Location.Cultivar + Year.Location.Cultivar
 Random model: Block.Year.Location
 Number of units: 180

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Block.Year.Location	-0.28	0.39

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	102.16	1	102.16	12.0	<0.001
Location	0.44	2	0.22	12.0	0.807
Cultivar	133.50	9	14.83	108.0	<0.001
Year.Location	65.67	2	32.83	12.0	<0.001
Year.Cultivar	18.25	9	2.03	108.0	0.043
Location.Cultivar	42.20	18	2.34	108.0	0.004
Year.Location.Cultivar	42.72	18	2.37	108.0	0.003

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Location.Cultivar	42.72	18	2.37	108.0	0.003

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
234 VAIC
```

Akaike information coefficient 701.10

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
235  CAPTION 'Narrow sense inference, Location specific variances'; \
236  STYLE=major
```

Narrow sense inference, Location specific variances

```
237  VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Location] \
238  RANDOM=Block.Year.Location
239  REML [PRINT=model,components,waldTests] HI
```

REML variance components analysis

Response variate: HI
 Fixed model: Constant + Year + Location + Cultivar + Year.Location + Year.Cultivar + Location.Cultivar + Year.Location.Cultivar
 Random model: Block.Year.Location
 Number of units: 180

Separate residual terms for each level of experiment factor: Location

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Block.Year.Location	-0.158	0.357

Residual model for each experiment

Experiment factor: Location

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
Ames	Residual		Identity	Variance	17.03	3.79
Kanawha	Residual		Identity	Variance	8.176	1.862
Wash	Residual		Identity	Variance	9.135	2.066

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	89.90	1	89.90	11.2	<0.001
Location	0.48	2	0.24	12.8	0.793
Cultivar	155.64	9	17.29	99.6	<0.001
Year.Location	81.32	2	40.06	12.8	<0.001
Year.Cultivar	23.21	9	2.58	99.6	0.010
Location.Cultivar	43.26	18	2.37	91.1	0.004
Year.Location.Cultivar	49.36	18	2.71	91.1	0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Location.Cultivar	49.36	18	2.71	91.1	0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

240 VAIC

Akaike information coefficient 698.39

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
241 CAPTION 'Narrow sense inference, Year specific variances'; \
242 STYLE=major
```

Narrow sense inference, Year specific variances

```
243 VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Year] \
244 RANDOM=Block.Year.Location
245 REML [PRINT=model,components,waldTests] HI
```

REML variance components analysis

Response variate: HI
Fixed model: Constant + Year + Location + Cultivar + Year.Location + Year.Cultivar + Location.Cultivar + Year.Location.Cultivar
Random model: Block.Year.Location
Number of units: 180

Separate residual terms for each level of experiment factor: Year

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Block.Year.Location	-0.27	0.39

Residual model for each experiment

Experiment factor: Year

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
1985.	Residual		Identity	Variance	11.33	2.13
1986.	Residual		Identity	Variance	11.82	2.15

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	101.03	1	101.03	12.0	<0.001
Location	0.22	2	0.11	12.0	0.895
Cultivar	132.65	9	14.74	107.8	<0.001
Year.Location	64.94	2	32.47	12.0	<0.001
Year.Cultivar	18.27	9	2.03	108.1	0.043
Location.Cultivar	42.09	18	2.34	107.8	0.004
Year.Location.Cultivar	42.77	18	2.38	108.1	0.003

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year.Location.Cultivar	42.77	18	2.38	108.1	0.003

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

246 VAIC

Akaike information coefficient 703.07

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
247 CAPTION 'Narrow sense inference, Environment specific variances'; \
248 STYLE=major
```

Narrow sense inference, Environment specific variances

```
249 VCOMPONENTS [FIXED=Cultivar*Year*Location; EXPERIMENTS=Environment]\
250 RANDOM=Block.Year.Location
251 REML [PRINT=model,components,waldTests; MAXCYCLE=1000] HI
```

REML variance components analysis

Response variate: HI
Fixed model: Constant + Year + Location + Cultivar + Year.Location + Year.Cultivar + Location.Cultivar + Year.Location.Cultivar
Random model: Block.Year.Location
Number of units: 180

Separate residual terms for each level of experiment factor: Environment

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Block.Year.Location	-0.51	0.15

Residual model for each experiment

Experiment factor: Environment

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
Ames 1985	Residual		Identity	Variance	17.77	5.39
Ames 1986	Residual		Identity	Variance	16.96	5.12
Kanawha 1985						
	Residual		Identity	Variance	11.37	3.14
Kanawha 1986						
	Residual		Identity	Variance	5.706	1.456
Wash 1985	Residual		Identity	Variance	8.287	2.138
Wash 1986	Residual		Identity	Variance	12.71	3.67

Warning 41, code VD 39, statement 1 on line 251

Command: REML [PRINT=model,components,waldTests; MAXCYCLE=1000] HI
Error in AI algorithm when forming denominator DF for approximate F-tests.

Wald tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Year	114.42	1	114.42	<0.001
Location	14.73	2	7.37	<0.001
Cultivar	136.72	9	15.19	<0.001
Year.Location	131.19	2	65.60	<0.001
Year.Cultivar	15.76	9	1.75	0.072
Location.Cultivar	43.85	18	2.44	<0.001
Year.Location.Cultivar	45.26	18	2.51	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Year.Location.Cultivar	45.26	18	2.51	<0.001

Message: chi-square distribution for Wald tests is an asymptotic approximation (i.e. for large samples) and underestimates the probabilities in other cases.

252 VAIC

Akaike information coefficient 701.28

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

253

254 " Models in Table 9 and Box 6 "

255 CAPTION 'Narrow sense inference, single error variance'; STYLE=major

Narrow sense inference, single error variance


```

256  VCOMPONENTS [FIXED=Cultivar*Environment] RANDOM=Block.Environment
257  REML [PRINT=components] HI

```

Estimated variance components

Random term	component	s.e.
Block.Environment	-0.28	0.39

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

```

258  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]

```

Table of predicted means for Cultivar

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72
Cultivar	Larry 48.17	Ogle 47.56	Porter 45.72	Proat 42.67	Richland 43.39

Standard error: 0.7925

```

259  VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]

```

Table of predicted means for Cultivar

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72
Cultivar	Larry 48.17	Ogle 47.56	Porter 45.72	Proat 42.67	Richland 43.39

Standard error of differences: 1.135

```

260  TABLE [CLASSIFICATION=Environment,Cultivar] CherokeeDonAmes1985; \
261  VALUES=! (1,-1,8(0),10(0),10(0),10(0),10(0),10(0))
262  VTCOMPARISONS CherokeeDonAmes1985

```

Message: d.d.f for Environment.Cultivar and its marginal terms (required for CherokeeDonAmes1985) vary between 12.00 and 108.00; probabilities will be calculated using 12.00 d.f.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	t	d.f.	pr.
CherokeeDonAmes1985	-11.000	2.780	-3.96	12.00	0.002

```
263  CAPTION 'Narrow sense inference, Location specific variances'; \  
264  STYLE=major
```

Narrow sense inference, Location specific variances

```
265  VCOMPONENTS [FIXED=Cultivar*Environment; EXPERIMENTS=Location] \  
266  RANDOM=Block.Environment  
267  REML [PRINT=components] HI
```

Estimated variance components

Random term	component	s.e.
Block.Environment	-0.158	0.357

Residual model for each experiment

Experiment factor: Location

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
Ames	Residual		Identity	Variance	17.03	3.79
Kanawha	Residual		Identity	Variance	8.176	1.862
Wash	Residual		Identity	Variance	9.135	2.066

```
268  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
```

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72

Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error: 0.7920

```
269  VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
```

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72

Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error of differences: 1.128

```
270  VTCOMPARISONS CherokeeDonAmes1985
```

Message: d.d.f for Environment.Cultivar and its marginal terms (required for CherokeeDonAmes1985) vary between 11.75 and 99.58; probabilities will be calculated using 11.75 d.f.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	t	d.f.	pr.
CherokeeDonAmes1985	-11.000	3.370	-3.26	11.75	0.007

```
271  CAPTION 'Broad sense inference, single error variance'; STYLE=major
```

Broad sense inference, single error variance

```
272  VCOMPONENTS [FIXED=Cultivar] RANDOM=Environment/Block+ \
273  Environment.Cultivar
274  REML [PRINT=components] HI
```

Estimated variance components

Random term	component	s.e.
Environment	9.02	6.21
Environment.Block	-0.28	0.39
Environment.Cultivar	4.99	1.94

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

```
275  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72

Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error: 1.721

```
276 VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.89	50.39	44.06	43.39	48.72

Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.17	47.56	45.72	42.67	43.39

Standard error of differences: 1.718

```
277 VTCOMPARISONS CherokeeDonAmes1985
```

Warning 42, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.346	2.218	21.76	<0.001

```
278 CAPTION 'Broad sense inference, Location specific variances'; \
279 STYLE=major
```

Broad sense inference, Location specific variances

```
280 VCOMPONENTS [FIXED=Cultivar; EXPERIMENTS=Location] \
281 RANDOM=Environment/Block+Environment.Cultivar
282 REML [PRINT=components] HI
```

Estimated variance components

Random term	component	s.e.
Environment	8.958	6.212
Environment.Block	-0.166	0.357
Environment.Cultivar	5.410	1.948

Residual model for each experiment

Experiment factor: Location

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
Ames	Residual		Identity	Variance	16.20	3.44
Kanawha	Residual		Identity	Variance	8.055	1.811
Wash	Residual		Identity	Variance	9.630	2.193

```
283  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee 40.81	Don 50.23	E77 43.98	Hytest 43.32	Lang 48.82
Cultivar	Larry 48.26	Ogle 47.67	Porter 45.64	Proat 42.48	Richland 43.75

Standard error: 1.730

```
284  VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee 40.81	Don 50.23	E77 43.98	Hytest 43.32	Lang 48.82
Cultivar	Larry	Ogle	Porter	Proat	Richland

48.26	47.67	45.64	42.48	43.75

Standard error of differences: 1.735

```
285  VTCOMPARISONS CherokeeDonAmes1985
```

Warning 43, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.208	2.481	16.92	<0.001

```
286  CAPTION 'Broad sense inference, subdivided interaction,\
-287  pooled variance'; STYLE=major
```

Broad sense inference, subdivided interaction, pooled variance

```
288  VCOMPONENTS [FIXED=Cultivar] RANDOM=(Year*Location)/Block+\
289  Cultivar*Year*Location
290  REML [PRINT=components; METHOD=Fisher] HI
```

Estimated variance components

Random term	component	s.e.
Year	6.78	14.40
Location	-4.75	4.79
Year.Location	8.75	9.58
Year.Location.Block	-0.28	0.39
Year.Cultivar	-0.45	1.60
Location.Cultivar	-0.06	2.15
Year.Location.Cultivar	5.31	3.10

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	11.59	1.58

```
291  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72

Cultivar	Larry 48.17	Ogle 47.56	Porter 45.72	Proat 42.67	Richland 43.39

Standard error: 2.130

```
292  VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]
```

Message: negative variance components present. Fitting of fixed model terms is not sequential. Effects and means for any aliased fixed model terms may therefore be misleading. Wald tests, likelihood tests and fitted values are unaffected.

Table of predicted means for Cultivar

Cultivar	Cherokee 40.89	Don 50.39	E77 44.06	Hytest 43.39	Lang 48.72

Cultivar	Larry 48.17	Ogle 47.56	Porter 45.72	Proat 42.67	Richland 43.39

Standard error of differences: 1.604

```
293  TABLE [CLASSIFICATION=Location,Year,Cultivar] CherokeeDonAmes1985; \
294  VALUES=!(1,-1,58(0))
295  VTCOMPARISONS CherokeeDonAmes1985
```

Warning 44, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.447	2.215	22.24	<0.001

```

296  CAPTION 'Broad sense inference, subdivided interaction,\
-297  Location specific variances'; STYLE=major

```

Broad sense inference, subdivided interaction, Location specific variances

```

298  VCOMPONENTS [FIXED=Cultivar; EXPERIMENTS=Location] \
299  RANDOM=(Year*Location)/Block+Cultivar*Year*Location; \
300  CONSTRAINTS=positive
301  REML [PRINT=components] HI

```

Estimated variance components

Random term	component	s.e.
Year	8.178	13.952
Location	0.000	bound
Year.Location	4.052	3.489
Year.Location.Block	0.000	bound
Year.Cultivar	0.000	bound
Location.Cultivar	0.000	bound
Year.Location.Cultivar	5.471	1.941

Residual model for each experiment

Experiment factor: Location

Experiment	Term	Factor	Model(order)	Parameter	Estimate	s.e.
Ames	Residual		Identity	Variance	16.08	3.43
Kanawha	Residual		Identity	Variance	7.872	1.732
Wash	Residual		Identity	Variance	9.437	2.134

```

302  VDISPLAY [PRINT=means; PSE=estimates; PTERMS=Cultivar]

```

Table of predicted means for Cultivar

Cultivar	Cherokee	Don	E77	Hytest	Lang
	40.82	50.23	43.98	43.32	48.82
Cultivar	Larry	Ogle	Porter	Proat	Richland
	48.26	47.67	45.64	42.48	43.75

Standard error: 2.504

```

303  VDISPLAY [PRINT=means; PSE=differences; PTERMS=Cultivar]

```

Table of predicted means for Cultivar

Cultivar	Cherokee 40.82	Don 50.23	E77 43.98	Hytest 43.32	Lang 48.82
Cultivar	Larry 48.26	Ogle 47.67	Porter 45.64	Proat 42.48	Richland 43.75

Standard error of differences: 1.736

```
304  VTCOMPARISONS CherokeeDonAmes1985
```

Warning 45, code UF 2, statement 72 in procedure VTCOMPARISONS

Residual d.f. unavailable for fixed terms; t-probabilities cannot be calculated, and Wald tests will be done instead. These are biased (giving too many significant results), so the results must be interpreted with caution.

Comparisons between REML means

Response variate: HI

Contrast	estimate	s.e.	Wald statistic (1 d.f.)	pr.
CherokeeDonAmes1985	-10.215	2.481	16.96	<0.001

```
305
```

```
306  ENDJOB
```

Antigua Fertilization Study Example

Genstat Commands for the Antigua Fertilization Study Example

```
" ***** "
" Example:  Antigua Island corn yield response to fertilizer "
" ***** "
```

```
JOB
```

```
" Import the data "
IMPORT 'antigua.csv'
```

```
" Convert location from a text structures to a factor, and
  block, fert and plot from variates to factors "
GROUP [REDEFINE=yes] location,block,fert,plot; \
  location,block,fert,plot
```

```
" Create a factor version of N "
GROUP N; N_f
```

```
" Plot of grain weight against N at each location (Figure 3) "
TRELLIS [GROUPS=location; TITLE='Grain weight vs N level by\
  location'; XTITLE='N amount'; YTITLE='Grain weight (kg)'] \
```

```

Y=wt; X=N; METHOD=Point

" Assessing heterogeneity in error variances between locations and
  N levels "
CAPTION 'Antigua example: Assessing in heterogeneity in error\
variances'; STYLE=meta
VCOMPONENTS [FIXED=location+N_f+N_f.location+block.location]
REML [PRINT=model] wt
VPLOT [TITLE='Residual vs predicted value coloured by N level']; \
  METHOD=fittedvalues; PEN=N_f
VPLOT [TITLE='Residual vs predicted value coloured by location']; \
  METHOD=fittedvalues; PEN=location
VKEEP [RESIDUAL=resid]
CALC absresid = ABS(resid)
CAPTION 'Levene''s test comparing locations and N treatments'; \
  STYLE=major
VCOMPONENTS [FIXED=location+N_f]
REML [PRINT=model,waldtests] absresid

" Fit a means model of N, a means model of N with contrasts, and a
  polynomial regression of N to data from the DBAN location (Box 7) "
RESTRICT wt; CONDITION = location .IN. 'DBAN'
CAPTION 'Antigua example: DBAN location, different forms of the\
response to N level'; STYLE=meta
CAPTION 'Analysis of means for each N level'; STYLE=major
BLOCK block
TREATMENTS N_f
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=means,diff] wt
CAPTION 'Orthogonal polynomial trends'; STYLE=major
BLOCK block
TREATMENTS POL(N_f;3)
COVARIATE "No Covariate"
ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=means,diff] wt
CAPTION 'Regression analysis'; STYLE=major
CALC N2=N*N
MODEL wt
TERMS block+N+N2
FIT [PRINT=model,summary,estimates,accumulated; CONSTANT=estimate; \
  FPROB=yes; TPROB=yes] block+N+N2
RESTRICT wt

" Evaluating the form of the N response, narrow sense (Box 8) "
CAPTION 'Antigua example: Evaluating the form of the N response\
(narrow sense)'; STYLE=meta
CAPTION 'Quantitative N, with quadratic interaction'; STYLE=major
VCOMPONENTS [FIXED=N+N2+N.location+N2.location+location] \
  RANDOM=location+location.block
REML [PRINT=model,components,waldTests] wt
CAPTION 'Quantitative N, without quadratic interaction'; STYLE=major
VCOMPONENTS [FIXED=N+N2+N.location] \
  RANDOM=location+location.block
REML [PRINT=model,components,waldTests] wt
VPLOT [TITLE='Residual vs predicted value coloured by location']; \
  METHOD=fittedvalues; PEN=location

" Evaluating the form of the N response, broad sense (Box 9,

```

```

Table 10) "
CAPT 'Antigua example: Broad sense model, quantitative treatments'; \
STYLE=meta
VCOMPONENTS [FIXED=N+N2; CADJUST=no] \
RANDOM=location+location.block+N.location
VSTRUCTURE [TERMS=location/N; CORRELATE=unrest]
REML [PRINT=model,components,waldTests,effects] wt
" Calculate location-specific intercepts (Table 11) "
CAPTION 'location-specific intercepts'; STYLE=major
VKEEP 'Constant'; EFFECTS=overall_intercept
VKEEP location; EFFECTS=loc_effects
PRINT [CLPRINT=*] loc_effects+overall_intercept; DEC=2
" Calculate location-specific slopes (Table 11) "
CAPTION 'location-specific slopes'; STYLE=major
VKEEP N; EFFECTS=overall_slope
VKEEP location.N; EFFECTS=locN_effects
PRINT [CLPRINT=*] locN_effects+overall_slope; DEC=2
" Plot the overall mean N response curve +/- SE (Figure 5a) "
VARIATE [VALUES=0,0.1...3] n
CALC n2 = n*n
VPREDICT [PRINT=*; PREDICT=overall_pred; SE=overall_SE] \
CLASSIFY=N,N2; LEVELS=n,n2; PARALLEL=*,N
CALC plusSE = overall_pred+overall_SE
CALC minusSE = overall_pred-overall_SE
XAXIS [RESET=yes] WINDOW=3; TITLE='N level'; MARKS=1
YAXIS [RESET=yes] WINDOW=3; TITLE='Predicted weight (kg)'; \
UPPER=8; LOWER=2
PEN [RESET=yes] 1,2,3; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
THICKNESS=2; LINESTYLE='solid',2('dot')
DGRAPH [WINDOW=3; KEY=0] Y=overall_pred,plusSE,minusSE; X=n
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3
PEN [RESET=yes] 1...3
" Plot the location-specific N response curve (Figure 5b) "
XAXIS [RESET=yes] WINDOW=3; TITLE='N level'; MARKS=1; UPPER=3.5
YAXIS [RESET=yes] WINDOW=3; TITLE='Predicted weight (kg)'; \
UPPER=8; LOWER=2
DCLEAR
PEN [RESET=yes] 1; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
THICKNESS=2; LINESTYLE='solid'
GETATTRIBUTE [ATTRIBUTE=labels] location; SAVE=Loclab
CALC Loclev = NLEVELS(location)
FOR i = 1...Loclev
VPREDICT [PRINT=*; PREDICT=location_pred] CLASSIFY=location,N,N2;\
LEVELS=i,n,n2; PARALLEL=*,*,N
VTABLE location_pred; VARIATE=location_predV
DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=location_pred; X=n
" Add label "
DELETE [REDEFINE=yes] pred
VPREDICT [PRINT=*; PREDICT=pred] CLASSIFY=location,N,N2;\
LEVELS=i,3,9; PARALLEL=*,*,N
DTEXT [WINDOW=3] Y=pred; X=3.1; TEXT=#Loclab[1]${i}
ENDFOR
PEN [RESET=yes] 1
" Add +/- SE curve error bars to ORAN (3rd level of the location \
factor) "
VPREDICT [PRINT=*; PREDICT=ORAN_pred; SE=ORAN_SE] \

```

```

CLASSIFY=location,N,N2; LEVELS=!T(ORAN),n,n2; PARALLEL=*,*,N
CALC ORAN_plusSE = ORAN_pred+ORAN_SE
CALC ORAN_minusSE = ORAN_pred-ORAN_SE
PEN [RESET=yes] 1,2; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
  THICKNESS=2; LINESTYLE=2('dot')
DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=ORAN_plusSE,ORAN_minusSE; \
  X=n
PEN [RESET=yes] 1,2

ENDJOB

```

Genstat Output from the Antigua Fertilization Study Example

```

2  " ***** "
3  "  Example:  Antigua Island corn yield response to fertilizer  "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Import the data "
9  IMPORT 'antigua.csv'

```

Loading Spreadsheet File

Catalogue of file antigua.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	text	165	location
2	variate	165	block
3	variate	165	plot
4	variate	165	fert
5	variate	165	nEars
6	variate	165	wt
7	variate	165	N
8	variate	165	P
9	variate	165	K

```

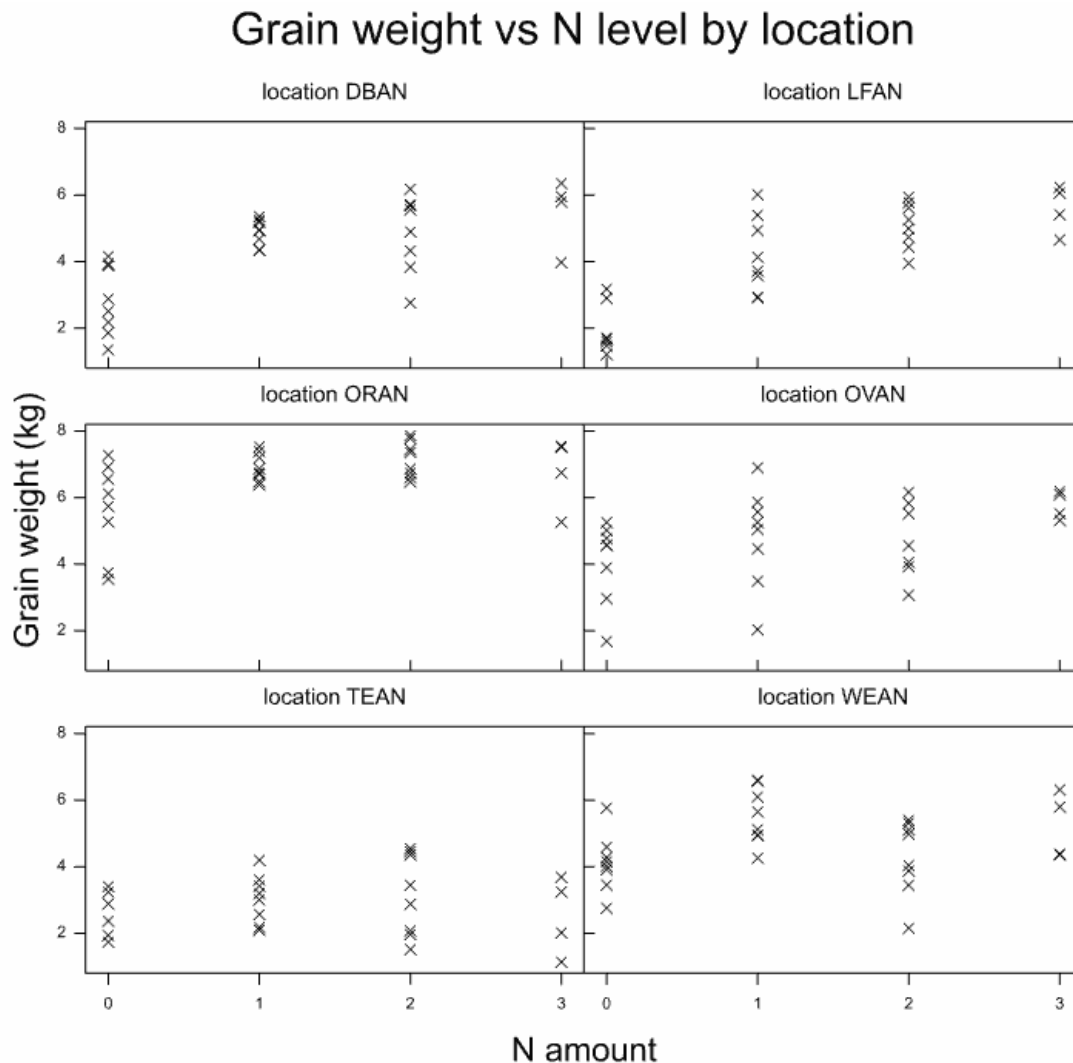
10
11  " Convert location from a text structures to a factor, and
-12  block, fert and plot from variates to factors "
13  GROUP [REDEFINE=yes] location,block,fert,plot; \
14  location,block,fert,plot
15
16  " Create a factor version of N "
17  GROUP N; N_f
18

```

```

19 " Plot of grain weight against N at each location (Figure 3) "
20 TRELLIS [GROUPS=location; TITLE='Grain weight vs N level by\
-21 location'; XTITLE='N amount'; YTITLE='Grain weight (kg)'] \
22 Y=wt; X=N; METHOD=Point

```



```

23
24 " Assessing heterogeneity in error variances between locations and
-25 N levels "
26 CAPTION 'Antigua example: Assessing in heterogeneity in error\
-27 variances'; STYLE=meta

```

Antigua example: Assessing in heterogeneity in error variances

```

28 VCOMPONENTS [FIXED=location+N_f+N_f.location+block.location]
29 REML [PRINT=model] wt

```

REML variance components analysis

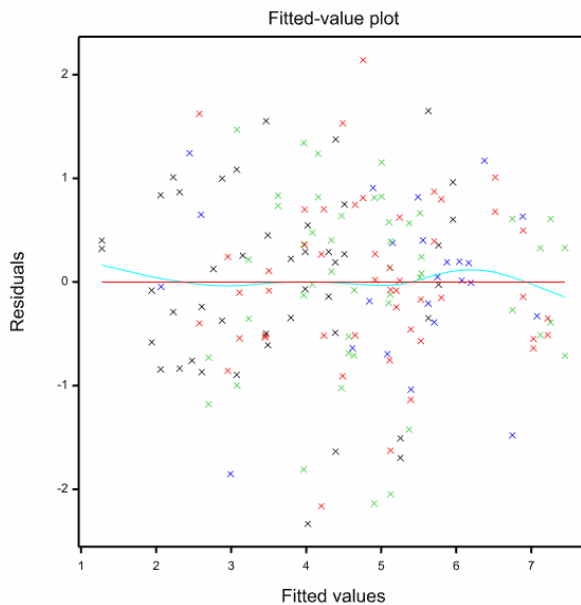
Response variate: wt
 Fixed model: Constant + location + N_f + location.N_f + location.block
 Number of units: 165

Residual term has been added to model

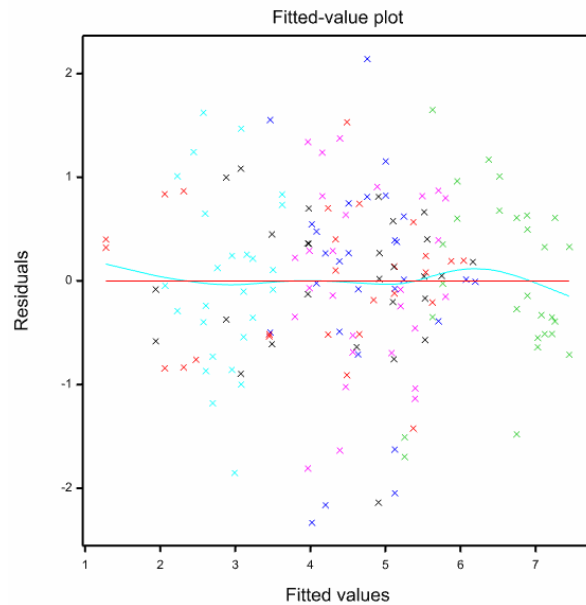
Sparse algorithm with AI optimisation

```
30 VPLOT [TITLE='Residual vs predicted value coloured by N level']; \
31 METHOD=fittedvalues; PEN=N_f
32 VPLOT [TITLE='Residual vs predicted value coloured by location']; \
33 METHOD=fittedvalues; PEN=location
```

Residual vs predicted value coloured by N level



Residual vs predicted value coloured by location



```
34 VKEEP [RESIDUAL=resid]
35 CALC absresid = ABS(resid)
36 CAPTION 'Levene's test comparing locations and N treatments'; \
37 STYLE=major
```

Levene's test comparing locations and N treatments

```
38 VCOMPONENTS [FIXED=location+N_f]
39 REML [PRINT=model,waldtests] absresid
```

REML variance components analysis

Response variate: absresid
 Fixed model: Constant + location + N_f
 Number of units: 165

Residual term has been added to model

Sparse algorithm with AI optimisation

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
location	4.67	5	0.93	156.0	0.461
N_f	1.12	3	0.37	156.0	0.774

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
location	4.65	5	0.93	156.0	0.464
N_f	1.12	3	0.37	156.0	0.774

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
40
41 " Fit a means model of N, a means model of N with contrasts, and a
-42 polynomial regression of N to data from the DBAN location (Box 7) "
43 RESTRICT wt; CONDITION = location .IN. 'DBAN'
44 CAPTION 'Antigua example: DBAN location, different forms of the\
-45 response to N level'; STYLE=meta
```

Antigua example: DBAN location, different forms of the response to N level

```
46 CAPTION 'Analysis of means for each N level'; STYLE=major
```

Analysis of means for each N level

```
47 BLOCK block
48 TREATMENTS N_f
49 COVARIATE "No Covariate"
50 ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=means,diff] wt
```

Analysis of variance

Variate: wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	9.0090	3.0030	5.06	
block.*Units* stratum					
N_f	3	28.0182	9.3394	15.74	<.001
Residual	21	12.4634	0.5935		
Total	27	49.4906			

Tables of means

Variate: wt

Grand mean 4.39

N_f	0	1	2	3
	2.85	4.88	4.87	5.52
rep.	8	8	8	4

Standard errors of means

Table	N_f	
rep.	unequal	
d.f.	21	
e.s.e.	0.385	min.rep
	0.272	max.rep

Standard errors of differences of means

Table	N_f	
rep.	unequal	
d.f.	21	
s.e.d.	0.545X	min.rep
	0.472	max-min
	0.385	max.rep

(No comparisons in categories where s.e.d. marked with an X)

```
51  CAPTION 'Orthogonal polynomial trends'; STYLE=major
```

Orthogonal polynomial trends

```
52  BLOCK block
53  TREATMENTS POL(N_f;3)
54  COVARIATE "No Covariate"
55  ANOVA [PRINT=aovtable,means; FPROB=yes; PSE=means,diff] wt
```

Analysis of variance

Variate: wt

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	9.0090	3.0030	5.06	
block.*Units* stratum					
N_f	3	28.0182	9.3394	15.74	<.001
Lin	1	21.4904	21.4904	36.21	<.001
Quad	1	3.7223	3.7223	6.27	0.021

Cub	1	2.8055	2.8055	4.73	0.041
Residual	21	12.4634	0.5935		
Total	27	49.4906			

Tables of means

Variate: wt

Grand mean 4.39

N_f	0	1	2	3
	2.85	4.88	4.87	5.52
rep.	8	8	8	4

Standard errors of means

Table	N_f	
rep.	unequal	
d.f.	21	
e.s.e.	0.385	min.rep
	0.272	max.rep

Standard errors of differences of means

Table	N_f	
rep.	unequal	
d.f.	21	
s.e.d.	0.545X	min.rep
	0.472	max-min
	0.385	max.rep

(No comparisons in categories where s.e.d. marked with an X)

```
56  CAPTION 'Regression analysis'; STYLE=major
```

Regression analysis

```
57  CALC N2=N*N
58  MODEL wt
59  TERMS block+N+N2
60  FIT [PRINT=model,summary,estimates,accumulated; CONSTANT=estimate; \
61      FPROB=yes; TPROB=yes] block+N+N2
```

Regression analysis

Response variate: wt
Fitted terms: Constant + block + N + N2

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	5	34.22	6.8443	9.86	<.001
Residual	22	15.27	0.6940		
Total	27	49.49	1.8330		

Percentage variance accounted for 62.1

Standard error of observations is estimated to be 0.833.

Message: the following units have large standardized residuals.

Unit	Response	Residual
21	2.770	-3.34

Estimates of parameters

Parameter	estimate	s.e.	t(22)	t pr.
Constant	3.618	0.396	9.13	<.001
block 2	-0.414	0.445	-0.93	0.362
block 3	-0.609	0.445	-1.37	0.186
block 4	-1.549	0.445	-3.48	0.002
N	1.901	0.479	3.97	<.001
N2	-0.379	0.164	-2.32	0.030

Parameters for factors are differences compared with the reference level:

Factor	Reference level
block	1

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ block	3	9.0090	3.0030	4.33	0.015
+ N	1	21.4904	21.4904	30.96	<.001
+ N2	1	3.7223	3.7223	5.36	0.030
Residual	22	15.2689	0.6940		
Total	27	49.4906	1.8330		

```

62 RESTRICT wt
63
64 " Evaluating the form of the N response, narrow sense (Box 8) "
65 CAPTION 'Antigua example: Evaluating the form of the N response\
-66 (narrow sense)'; STYLE=meta

```

Antigua example: Evaluating the form of the N response (narrow sense)

```

67 CAPTION 'Quantitative N, with quadratic interaction'; STYLE=major

```

Quantitative N, with quadratic interaction

```

68  VCOMPONENTS [FIXED=N+N2+N.location+N2.location+location] \
69  RANDOM=location+location.block
70  REML [PRINT=model,components,waldTests] wt

```

REML variance components analysis

Response variate: wt
 Fixed model: Constant + N + N2 + location.N + location.N2
 Random model: location + location.block
 Number of units: 165

Residual term has been added to model

Sparse algorithm with AI optimisation
 All covariates centred

Estimated variance components

Random term	component	s.e.
location	1.4198	0.9312
location.block	0.0676	0.0714

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.963	0.1199

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
N	51.34	1	51.34	129.6	<0.001
N2	11.46	1	11.46	129.4	<0.001
location.N	28.68	5	5.74	129.7	<0.001
location.N2	4.74	5	0.95	129.4	0.452

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
location.N	10.72	5	2.14	129.7	0.064
location.N2	4.74	5	0.95	129.4	0.452

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

71  CAPTION 'Quantitative N, without quadratic interaction'; STYLE=major

```

Quantitative N, without quadratic interaction

```

72  VCOMPONENTS [FIXED=N+N2+N.location] \
73    RANDOM=location+location.block
74  REML [PRINT=model,components,waldTests] wt

```

REML variance components analysis

Response variate: wt
 Fixed model: Constant + N + N2 + location.N
 Random model: location + location.block
 Number of units: 165

Residual term has been added to model

Sparse algorithm with AI optimisation
 All covariates centred

Estimated variance components

Random term	component	s.e.
location	1.4179	0.9302
location.block	0.0690	0.0717

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.961	0.1173

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
N	51.46	1	51.46	134.6	<0.001
N2	11.49	1	11.49	134.4	<0.001
location.N	28.75	5	5.75	134.6	<0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
N2	11.28	1	11.28	134.4	0.001
location.N	28.75	5	5.75	134.6	<0.001

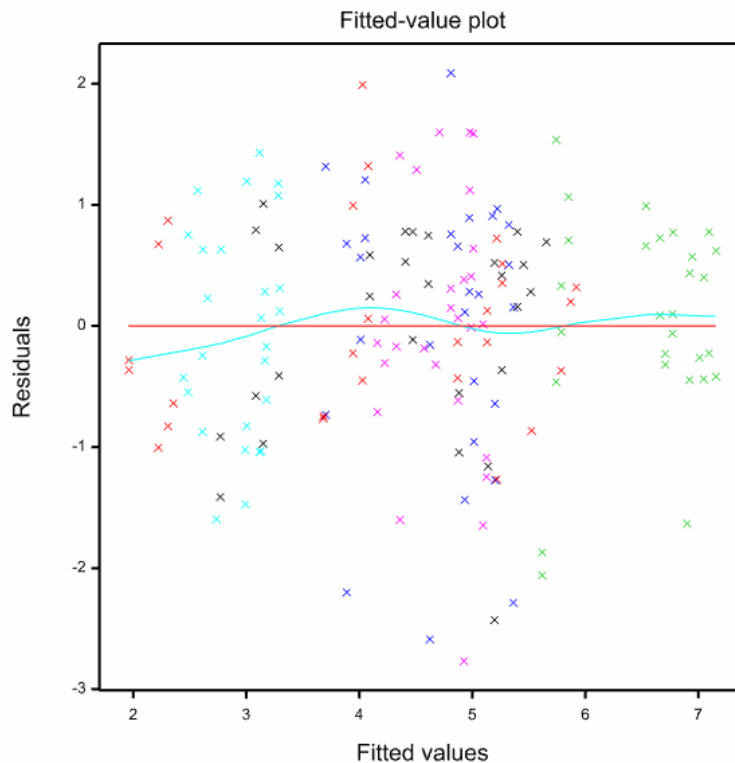
Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```

75  VPLOT [TITLE='Residual vs predicted value coloured by location']; \
76    METHOD=fittedvalues; PEN=location

```

Residual vs predicted value coloured by location



```

77
78 " Evaluating the form of the N response, broad sense (Box 9,
-79 Table 10) "
80 CAPT 'Antigua example: Broad sense model, quantitative treatments'; \
81 STYLE=meta

```

Antigua example: Broad sense model, quantitative treatments

```

82 VCOMPONENTS [FIXED=N+N2; CADJUST=no] \
83   RANDOM=location+location.block+N.location
84 VSTRUCTURE [TERMS=location/N; CORRELATE=unrest]
85 REML [PRINT=model,components,waldTests,effects] wt

```

REML variance components analysis

Response variate: wt
Fixed model: Constant + N + N2
Random model: location + location.N + location.block
Number of units: 165

Residual term has been added to model

Sparse algorithm with AI optimisation
Covariates not centred

Covariance structures defined for random model

Correlated terms:

Set Correlation across terms
1 Unstructured

Set Terms
1 location
1 location.N

Covariance model within term
Identity
Identity

Estimated variance components

Random term	component	s.e.
location.block	0.0692	0.0717

Estimated parameters for covariance models

Random term(s)	Factor	Model(order)	Parameter	Estimate	s.e.
location + location.N	Across terms	Unstructured	v_11	1.689	1.160
			v_21	-0.1902	0.2923
			v_22	0.1691	0.1317
	Within terms	Identity	-	-	-

Note: the covariance matrix for each term is calculated as G or R where $\text{var}(y) = \text{Sigma}2(ZGZ' + R)$, i.e. relative to the residual variance, $\text{Sigma}2$.

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.961	0.1173

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
N	8.67	1	8.67	28.7	0.006
N2	11.31	1	11.31	134.5	0.001

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
N	19.96	1	19.96	28.7	<0.001
N2	11.31	1	11.31	134.5	0.001

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

3.641 Standard error: 0.5419

Table of effects for N

1.277 Standard error: 0.2859

Table of effects for N2

-0.2670 Standard error: 0.07937

```
86 " Calculate location-specific intercepts (Table 11) "  
87 CAPTION 'location-specific intercepts'; STYLE=major
```

location-specific intercepts

```
88 VKEEP 'Constant'; EFFECTS=overall_intercept  
89 VKEEP location; EFFECTS=loc_effects  
90 PRINT [CLPRINT=*] loc_effects+overall_intercept; DEC=2
```

location	
DBAN	3.15
LFAN	2.39
ORAN	5.70
OVAN	3.89
TEAN	2.53
WEAN	4.19

```
91 " Calculate location-specific slopes (Table 11) "  
92 CAPTION 'location-specific slopes'; STYLE=major
```

location-specific slopes

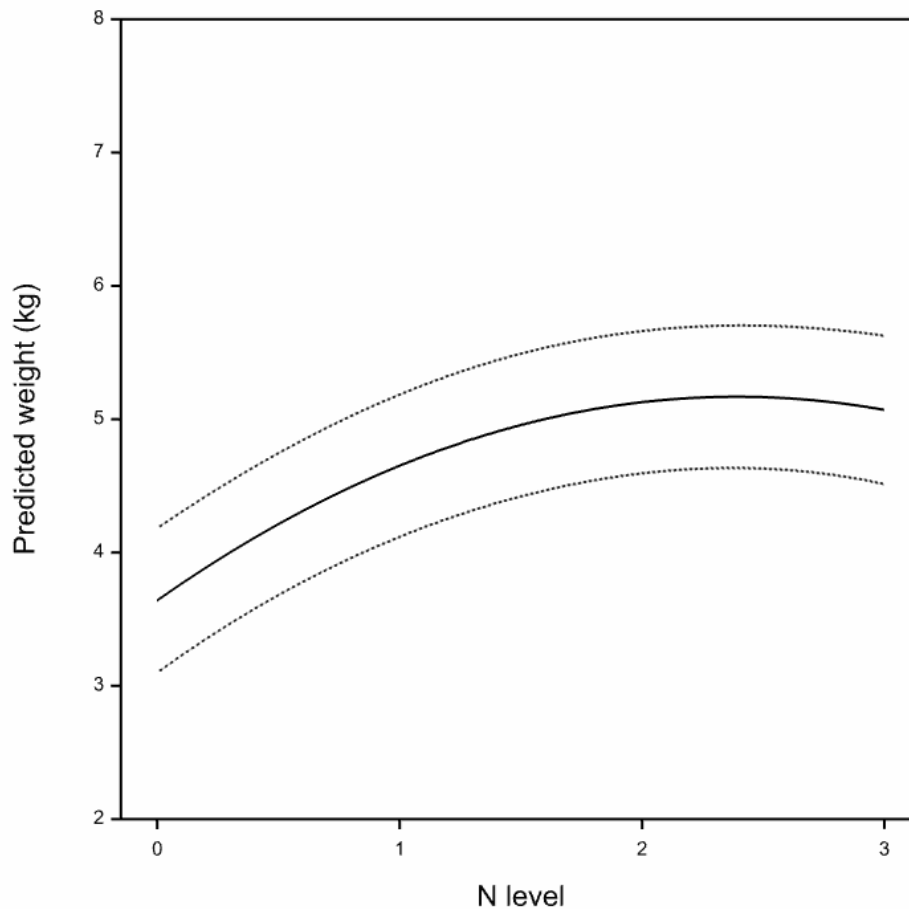
```
93 VKEEP N; EFFECTS=overall_slope  
94 VKEEP location.N; EFFECTS=locN_effects  
95 PRINT [CLPRINT=*] locN_effects+overall_slope; DEC=2
```

location	
DBAN	1.54
LFAN	1.86
ORAN	1.21
OVAN	1.21
TEAN	0.87
WEAN	0.98

```

96 " Plot the overall mean N response curve +/- SE (Figure 5a) "
97 VARIATE [VALUES=0,0.1...3] n
98 CALC n2 = n*n
99 VPREDICT [PRINT=*; PREDICT=overall_pred; SE=overall_SE] \
100   CLASSIFY=N,N2; LEVELS=n,n2; PARALLEL=*,N
101 CALC plusSE = overall_pred+overall_SE
102 CALC minusSE = overall_pred-overall_SE
103 XAXIS [RESET=yes] WINDOW=3; TITLE='N level'; MARKS=1
104 YAXIS [RESET=yes] WINDOW=3; TITLE='Predicted weight (kg)'; \
105   UPPER=8; LOWER=2
106 PEN [RESET=yes] 1,2,3; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
107   THICKNESS=2; LINESTYLE='solid',2('dot')
108 DGRAPH [WINDOW=3; KEY=0] Y=overall_pred,plusSE,minusSE; X=n
109 XAXIS [RESET=yes] WINDOW=3
110 YAXIS [RESET=yes] WINDOW=3
111 PEN [RESET=yes] 1...3

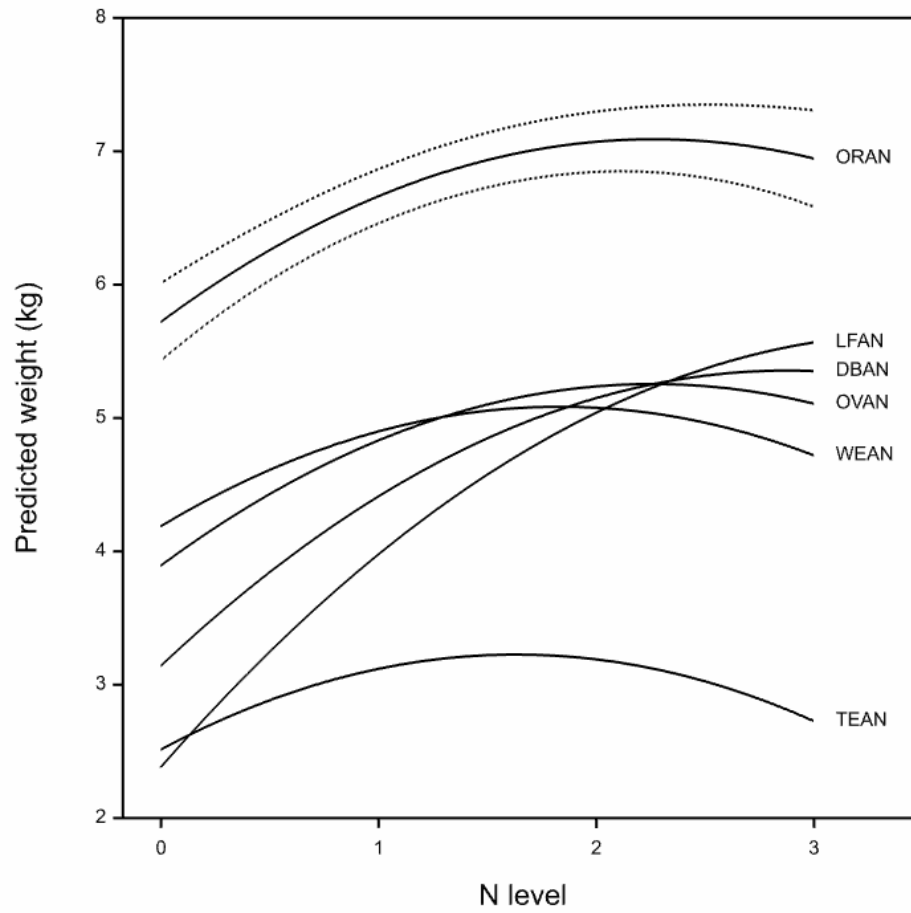
```




```

112 " Plot the location-specific N response curve (Figure 5b) "
113 XAXIS [RESET=yes] WINDOW=3; TITLE='N level'; MARKS=1; UPPER=3.5
114 YAXIS [RESET=yes] WINDOW=3; TITLE='Predicted weight (kg)'; \
115     UPPER=8; LOWER=2
116 DCLEAR
117 PEN [RESET=yes] 1; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
118     THICKNESS=2; LINESTYLE='solid'
119 GETATTRIBUTE [ATTRIBUTE=labels] location; SAVE=Loclab
120 CALC Loclev = NLEVELS(location)
121 FOR i = 1...Loclev
122     VPREDICT [PRINT=*; PREDICT=location_pred] CLASSIFY=location,N,N2;\
123     LEVELS=i,n,n2; PARALLEL=*,*,N
124     VTABLE location_pred; VARIATE=location_predV
125     DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=location_pred; X=n
126     " Add label "
127     DELETE [REDEFINE=yes] pred
128     VPREDICT [PRINT=*; PREDICT=pred] CLASSIFY=location,N,N2;\
129     LEVELS=i,3,9; PARALLEL=*,*,N
130     DTEXT [WINDOW=3] Y=pred; X=3.1; TEXT=#Loclab[1]${i}
131 ENDFOR
132 PEN [RESET=yes] 1
133 " Add +/- SE curve error bars to ORAN (3rd level of the location \
-134     factor) "
135 VPREDICT [PRINT=*; PREDICT=ORAN_pred; SE=ORAN_SE] \
136     CLASSIFY=location,N,N2; LEVELS=!T(ORAN),n,n2; PARALLEL=*,*,N
137 CALC ORAN_plusSE = ORAN_pred+ORAN_SE
138 CALC ORAN_minusSE = ORAN_pred-ORAN_SE
139 PEN [RESET=yes] 1,2; SYMBOL=0; COLOUR='black'; METHOD=monotonic; \
140     THICKNESS=2; LINESTYLE=2('dot')
141 DGRAPH [WINDOW=3; KEY=0; SCREEN=keep] Y=ORAN_plusSE,ORAN_minusSE; \
142     X=n
143 PEN [RESET=yes] 1,2

```



144
145 ENDJOB

End of job.

Chapter 9. Analysis of Covariance by Kevin S. McCarter

Genstat code developed by Vanessa M. Cave is given here for analysing the four example datasets and five exercise datasets of Chapter 9. For brevity, output is only provided for the four examples.

Genstat Commands for the Examples and Exercises

```
" ***** "  
"           Sample Genstat code for examples and exercises           "  
" ***** "  
  
JOB  
  
" Load the datasets, where group is a factor (cf Figure 1) "  
FACTOR grp_eg1,grp_eg2,grp_eg3,grp_eg4,grp_ex1,grp_ex2,grp_ex3,\  
      grp_ex4,grp_ex5  
"Example 1, cf Table 1"  
READ [PRINT=*] grp_eg1, y_eg1, x_eg1; FREPRESENTATION=labels  
A 71.3 12.7 A 63.4 13.3 A 55.0 8.6 A 54.0 7.3 A 54.6 8.2  
A 47.7 6.4 A 49.1 7.0 A 88.1 14.2 A 59.4 8.6 A 70.5 10.7  
B 63.0 7.6 B 80.9 13.4 B 78.7 10.3 B 85.1 14.8 B 78.5 13.6  
B 73.0 13.5 B 53.0 5.3 B 76.3 9.9 B 68.7 9.4 B 84.9 14.2 :  
POINTER Example_1; VALUES=!P(grp_eg1,y_eg1,x_eg1)  
  
"Example 2, cf Table 6"  
READ [PRINT=*] grp_eg2, y_eg2, x_eg2; FREPRESENTATION=labels  
A 69.2 10.8 A 59.4 10.7 A 70.2 13.1 A 52.3 6.6 A 61.0 9.6  
A 73.9 13.4 A 57.1 7.3 A 64.9 10.0 A 68.2 13.8 A 75.1 14.8  
B 89.9 17.4 B 101.3 21.2 B 73.2 13.4 B 96.4 20.1 B 86.4 17.6  
B 74.8 14.8 B 81.2 17.2 B 97.3 20.2 B 99.4 21.9 B 79.3 13.9 :  
POINTER Example_2; VALUES=!P(grp_eg2,y_eg2,x_eg2)  
  
"Example 3, cf Table 10"  
READ [PRINT=*] grp_eg3, y_eg3, x_eg3; FREPRESENTATION=labels  
A 81.2 14.1 A 58.7 8.8 A 47.4 5.7 A 49.4 5.5 A 66.1 9.1  
A 72.5 14.6 A 71.1 12.7 A 53.5 6.2 A 62.2 8.0 A 68.5 12.4  
B 56.6 15.9 B 57.5 17.9 B 75.6 21.6 B 68.5 19.9 B 58.0 14.1  
B 57.7 15.1 B 62.6 16.8 B 73.9 20.6 B 77.0 20.9 B 44.4 13.0 :  
POINTER Example_3; VALUES=!P(grp_eg3,y_eg3,x_eg3)  
  
"Example 4, cf Table 16"  
READ [PRINT=*] grp_eg4, y_eg4, x_eg4; FREPRESENTATION=labels  
A 55.1 8.2 A 67.1 11.0 A 73.6 14.8 A 64.6 9.3 A 76.4 13.8  
A 45.5 5.3 A 47.3 6.4 A 57.4 6.6 A 78.5 12.9 A 61.9 8.4  
B 61.7 9.5 B 56.3 11.3 B 54.2 12.0 B 68.0 9.8 B 58.5 12.6  
B 59.2 10.5 B 60.8 10.7 B 68.2 9.8 B 52.7 13.1 B 78.5 6.4 :  
POINTER Example_4; VALUES=!P(grp_eg4,y_eg4,x_eg4)  
  
"Exercise 1"  
READ [PRINT=*] grp_ex1, y_ex1, x_ex1; FREPRESENTATION=labels  
A 49.4 5.2 A 72.2 13.2 A 61.6 9.2 A 63.4 11.3 A 71.0 12.3  
A 49.6 7.2 A 56.6 8.3 A 61.1 6.7 A 66.1 9.7 A 71.9 12.0  
B 95.3 20.2 B 96.7 20.5 B 75.8 12.5 B 102.6 21.9 B 78.5 15.3  
B 101.4 20.8 B 100.8 21.3 B 88.2 17.2 B 79.1 14.4 B 108.0 21.2 :
```

```

POINTER Exercise_1; VALUES=!P(grp_ex1,y_ex1,x_ex1)

"Exercise 2"
READ [PRINT=*] grp_ex2, y_ex2, x_ex2; FREPRESENTATION=labels
A 56.7 7.0 A 46.3 5.7 A 71.2 14.6 A 69.0 11.9 A 59.7 10.8
A 59.8 10.2 A 60.1 8.1 A 66.8 10.8 A 72.5 14.5 A 57.6 7.9
B 70.3 10.5 B 78.0 12.8 B 63.1 9.4 B 57.1 6.6 B 68.7 11.3
B 70.4 9.5 B 73.3 9.4 B 61.7 6.8 B 73.7 11.9 B 77.4 11.6 :
POINTER Exercise_2; VALUES=!P(grp_ex2,y_ex2,x_ex2)

"Exercise 3"
READ [PRINT=*] grp_ex3, y_ex3, x_ex3; FREPRESENTATION=labels
A 54.8 8.9 A 54.6 8.3 A 52.5 10.0 A 68.2 12.6 A 59.6 9.4
A 76.8 13.2 A 56.3 7.9 A 71.2 15.0 A 62.0 9.2 A 68.0 13.8
B 54.4 14.7 B 55.8 19.1 B 69.4 20.3 B 51.7 15.3 B 67.2 21.3
B 43.9 12.2 B 71.6 21.6 B 66.7 20.5 B 42.4 13.4 B 55.7 15.9 :
POINTER Exercise_3; VALUES=!P(grp_ex3,y_ex3,x_ex3)

"Exercise 4"
READ [PRINT=*] grp_ex4, y_ex4, x_ex4; FREPRESENTATION=labels
A 73.9 14.4 A 46.7 6.1 A 48.9 6.3 A 83.0 14.6 A 80.7 15.0
A 73.1 12.1 A 54.8 7.2 A 53.4 7.3 A 79.3 13.5 A 60.6 11.5
B 68.6 9.6 B 66.9 9.9 B 53.5 5.0 B 79.6 13.3 B 82.0 13.2
B 72.4 12.2 B 67.6 9.9 B 77.4 13.4 B 70.6 10.0 B 75.4 11.1 :
POINTER Exercise_4; VALUES=!P(grp_ex4,y_ex4,x_ex4)

"Exercise 5"
READ [PRINT=*] grp_ex5, y_ex5, x_ex5; FREPRESENTATION=labels
A 70.9 12.6 A 71.8 13.5 A 61.0 10.9 A 71.4 13.9 A 56.9 6.4
A 55.8 9.1 A 62.1 7.4 A 80.8 13.2 A 54.8 8.8 A 50.8 5.6
B 52.4 12.3 B 57.9 10.7 B 68.9 11.1 B 62.7 11.6 B 62.4 10.2
B 78.5 6.5 B 55.0 14.8 B 79.2 6.8 B 82.6 5.5 B 51.6 13.7 :
POINTER Exercise_5; VALUES=!P(grp_ex5,y_ex5,x_ex5)

" FOR loop to perform analyses on all nine datasets "
FOR data=Example_1,Example_2,Example_3,Example_4, \
    Exercise_1,Exercise_2,Exercise_3,Exercise_4,Exercise_5
GETATTRIBUTE [ATTRIBUTE=labels] data[1]; SAVE=lab
FACTOR [LABELS=#lab] grp; VALUES=data[1]
CALC y = data[2]
CALC x = data[3]

" ----- "
" Print listing of dataset "
" ----- "

GETATTRIBUTE [ATTRIBUTE=identifier] data; SAVE=identifier
TXCONSTRUCT [TEXT=name] 'Analysis of Dataset ',#identifier
CAPTION name; STYLE=meta

" ----- "
" Calculate summary statistics and perform exploratory analysis "
" cf Figure 2 "
" ----- "

CAPTION 'Mean and standard deviation of Y and X by group'; \
    STYLE=stress

```

```

" cf Tables 2, 11, 13, 17, 19 "
TABULATE [PRINT=means,sd; CLASSIFICATION=grp] y
TABULATE [PRINT=means,sd; CLASSIFICATION=grp] x

" Boxplots of response variable Y for each group "
" cf Figures 3, 7, 11, 14 "
BOXPLOT [TITLE='Boxplots of response variable Y for each group'; \
        AXISITITLE='Y'; BOXTITLE='group'] y; GROUPS=grp

" Boxplots of covariate X for each group "
" cf Figures 4, 8, 12, 15 "
BOXPLOT [TITLE='Boxplots of covariate X for each group'; \
        AXISITITLE='X'; BOXTITLE='group'; ORIENTATION=horizontal] x; \
        GROUPS=grp

" Scatter plot of response Y vrs covariate X "
" cf Figure 9 "
XAXIS [RESET=yes] WINDOW=1; TITLE='X'
YAXIS [RESET=yes] WINDOW=1; TITLE='Y'
GETATTRIBUTE [ATTRIBUTE=labels] grp; grplab
DGRAPH [WIN=1; TITLE='Scatter plot of response Y vrs covariate X'] \
        Y=y; X=x; DESCRIPTION=#grplab; PEN=grp
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1

" ----- "
" ANCOVA which forces the relationship between the response and the "
" covariate to be the same across treatment groups (cf Figure 5) "
" ----- "

CAPTION 'ANOVA to compare mean of response variable Y across\
        groups'; STYLE=stress
" cf Tables 3, 7, 12, 18 "
COVARIATE "no covariate"
TREATMENTS grp
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
        LSDLEVEL=5] y

CAPTION 'ANOVA to compare mean of covariate X across groups'; \
        STYLE=stress
" cf Tables 5, 9, 14, 20 "
COVARIATE "no covariate"
TREATMENTS grp
ANOVA [PRINT=aovtable,information; FPROB=yes] x

CAPTION 'ANCOVA to compare mean of response variable Y across\
        groups, adjusting for covariate X - parallel slopes'; STYLE=stress
" cf Tables 4, 8, 15, 21 "
COVARIATE x
TREATMENTS grp
ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
        LSDLEVEL=5] y
" Alternatively fit using Genstat's linear regression facilities,
  enabling the ANCOVA plot to be produced "
MODEL y
TERMS [FULL=yes] x*grp
FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] x+grp

```

```

RWALD
PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
        COMBINATIONS=present] grp
" cf Figures 6, 10, 13, 16 "
FIT [PRINT=*; CONSTANT=omit] x*grp
RGRAPH [TITLE='Analysis of covariance for Y (parallel slopes)']

" ----- "
" ANCOVA which allows for the relationship between the response and "
" the covariate to differ across treatment groups "
" ----- "

CAPTION 'ANCOVA to compare mean of response variable y across\
        groups, adjusting for covariate X - non-parallel slopes'; \
        STYLE=stress
" cf Table 22 "
MODEL y
TERMS [FULL=yes] x*grp
FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] x*grp
RWALD
PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
        COMBINATIONS=present] grp
" cf Figure 17 "
FIT [PRINT=*; CONSTANT=omit] x*grp
RGRAPH [TITLE='Analysis of covariance for y (non-parallel slopes)']

" cf Table 23 "
IF #identifier .IN. 'Example_4'
PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
        COMBINATIONS=full] x,grp; LEVELS=!(8,8.5...11.5),*
ENDIF
ENDFOR

ENDJOB

```

Genstat Output for the Four Examples

```

2  " ***** "
3  "           Sample Genstat code for examples and exercises "
4  " ***** "
5
6  JOB

```

End of job.

```

7
8  " Load the datasets, where group is a factor (cf Figure 1) "
9  FACTOR grp_eg1,grp_eg2,grp_eg3,grp_eg4,grp_ex1,grp_ex2,grp_ex3,\
10     grp_ex4,grp_ex5
11  "Example 1, cf Table 1"
12  READ [PRINT=*] grp_eg1, y_eg1, x_eg1; FREPRESENTATION=labels
17  POINTER Example_1; VALUES=!P(grp_eg1,y_eg1,x_eg1)
18
19  "Example 2, cf Table 6"

```

```

20 READ [PRINT=*] grp_eg2, y_eg2, x_eg2; FREPRESENTATION=labels
25 POINTER Example_2; VALUES=!P(grp_eg2,y_eg2,x_eg2)
26
27 "Example 3, cf Table 10"
28 READ [PRINT=*] grp_eg3, y_eg3, x_eg3; FREPRESENTATION=labels
33 POINTER Example_3; VALUES=!P(grp_eg3,y_eg3,x_eg3)
34
35 "Example 4, cf Table 16"
36 READ [PRINT=*] grp_eg4, y_eg4, x_eg4; FREPRESENTATION=labels
41 POINTER Example_4; VALUES=!P(grp_eg4,y_eg4,x_eg4)
42
43 "Exercise 1"
44 READ [PRINT=*] grp_ex1, y_ex1, x_ex1; FREPRESENTATION=labels
49 POINTER Exercise_1; VALUES=!P(grp_ex1,y_ex1,x_ex1)
50
51 "Exercise 2"
52 READ [PRINT=*] grp_ex2, y_ex2, x_ex2; FREPRESENTATION=labels
57 POINTER Exercise_2; VALUES=!P(grp_ex2,y_ex2,x_ex2)
58
59 "Exercise 3"
60 READ [PRINT=*] grp_ex3, y_ex3, x_ex3; FREPRESENTATION=labels
65 POINTER Exercise_3; VALUES=!P(grp_ex3,y_ex3,x_ex3)
66
67 "Exercise 4"
68 READ [PRINT=*] grp_ex4, y_ex4, x_ex4; FREPRESENTATION=labels
73 POINTER Exercise_4; VALUES=!P(grp_ex4,y_ex4,x_ex4)
74
75 "Exercise 5"
76 READ [PRINT=*] grp_ex5, y_ex5, x_ex5; FREPRESENTATION=labels
81 POINTER Exercise_5; VALUES=!P(grp_ex5,y_ex5,x_ex5)
82
83 " FOR loop to perform analyses on all nine datasets "
84 FOR data=Example_1,Example_2,Example_3,Example_4", \
-85     Exercise_1,Exercise_2,Exercise_3,Exercise_4,Exercise_5"
86 GETATTRIBUTE [ATTRIBUTE=labels] data[1]; SAVE=lab
87 FACTOR [LABELS=#lab] grp; VALUES=data[1]
88 CALC y = data[2]
89 CALC x = data[3]
90
91 " ----- "
92 " Print listing of dataset "
93 " ----- "
94
95 GETATTRIBUTE [ATTRIBUTE=identifier] data; SAVE=identifier
96 TXCONSTRUCT [TEXT=name] 'Analysis of Dataset ',#identifier
97 CAPTION name; STYLE=meta
98
99 " ----- "
100 " Calculate summary statistics and perform exploratory analysis "
101 " cf Figure 2 "
102 " ----- "
103
104 CAPTION 'Mean and standard deviation of Y and X by group'; \

```

```

105     STYLE=stress
106 " cf Tables 2, 11, 13, 17, 19 "
107 TABULATE [PRINT=means,sd; CLASSIFICATION=grp] y
108 TABULATE [PRINT=means,sd; CLASSIFICATION=grp] x
109
110 " Boxplots of response variable Y for each group "
111 " cf Figures 3, 7, 11, 14 "
112 BOXPLOT [TITLE='Boxplots of response variable Y for each group'; \
113     AXISTITLE='Y'; BOXTITLE='group'] y; GROUPS=grp
114
115 " Boxplots of covariate X for each group "
116 " cf Figures 4, 8, 12, 15 "
117 BOXPLOT [TITLE='Boxplots of covariate X for each group'; \
118     AXISTITLE='X'; BOXTITLE='group'; ORIENTATION=horizontal] x; \
119     GROUPS=grp
120
121 " Scatter plot of response Y vrs covariate X "
122 " cf Figure 9 "
123 XAXIS [RESET=yes] WINDOW=1; TITLE='X'
124 YAXIS [RESET=yes] WINDOW=1; TITLE='Y'
125 GETATTRIBUTE [ATTRIBUTE=labels] grp; grplab
126 DGRAPH [WIN=1; TITLE='Scatter plot of response Y vrs covariate X'] \
127     Y=y; X=x; DESCRIPTION=#grplab; PEN=grp
128 XAXIS [RESET=yes] WINDOW=1
129 YAXIS [RESET=yes] WINDOW=1
130
131 " ----- "
132 " ANCOVA which forces the relationship between the response and the "
133 " covariate to be the same across treatment groups (cf Figure 5) "
134 " ----- "
135
136 CAPTION 'ANOVA to compare mean of response variable Y across\
-137 groups'; STYLE=stress
138 " cf Tables 3, 7, 12, 18 "
139 COVARIATE "no covariate"
140 TREATMENTS grp
141 ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
142     LSDLEVEL=5] y
143
144 CAPTION 'ANOVA to compare mean of covariate X across groups'; \
145     STYLE=stress
146 " cf Tables 5, 9, 14, 20 "
147 COVARIATE "no covariate"
148 TREATMENTS grp
149 ANOVA [PRINT=aovtable,information; FPROB=yes] x
150
151 CAPTION 'ANCOVA to compare mean of response variable Y across\
-152 groups, adjusting for covariate X - parallel slopes'; STYLE=stress
153 " cf Tables 4, 8, 15, 21 "
154 COVARIATE x
155 TREATMENTS grp
156 ANOVA [PRINT=aovtable,information,means; FPROB=yes; PSE=lsd; \
157     LSDLEVEL=5] y

```



```

158 " Alternatively fit using Genstat's linear regression facilities,
-159     enabling the ANCOVA plot to be produced "
160 MODEL y
161 TERMS [FULL=yes] x*grp
162 FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] x+grp
163 RWALD
164 PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
165     COMBINATIONS=present] grp
166 " cf Figures 6, 10, 13, 16 "
167 FIT [PRINT=*; CONSTANT=omit] x+grp
168 RGRAPH [TITLE='Analysis of covariance for Y (parallel slopes)']
169
170 " ----- "
171 " ANCOVA which allows for the relationship between the response and "
172 " the covariate to differ across treatment groups "
173 " ----- "
174
175 CAPTION 'ANCOVA to compare mean of response variable y across\
-176     groups, adjusting for covariate X - non-parallel slopes'; \
177     STYLE=stress
178 " cf Table 22 "
179 MODEL y
180 TERMS [FULL=yes] x*grp
181 FIT [PRINT=model,summary; CONSTANT=estimate; FPROB=yes] x*grp
182 RWALD
183 PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
184     COMBINATIONS=present] grp
185 " cf Figure 17 "
186 FIT [PRINT=*; CONSTANT=omit] x*grp
187 RGRAPH [TITLE='Analysis of covariance for y (non-parallel slopes)']
188
189 " cf Table 23 "
190 IF #identifier .IN. 'Example_4'
191 PREDICT [PRINT=description,predictions,lsd; LSDLEVEL=5; \
192     COMBINATIONS=full] x,grp; LEVELS=!(8,8.5...11.5),*
193 ENDIF
194 ENDFOR

```

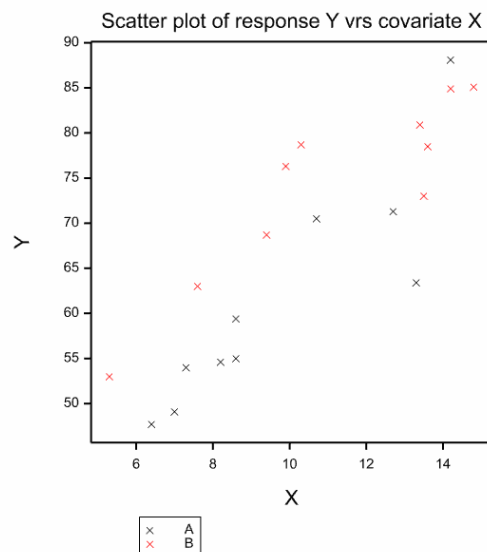
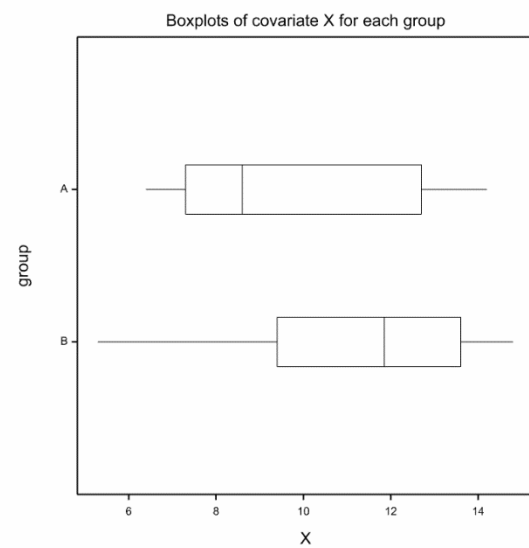
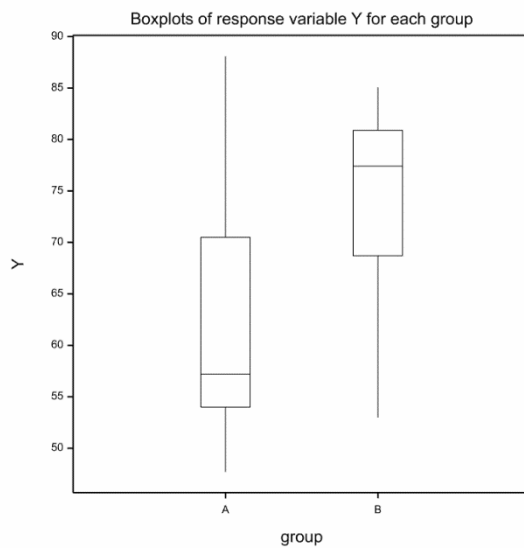
Analysis of Dataset Example_1

Mean and standard deviation of Y and X by group

	Mean	s.d.
grp		
A	61.31	12.39
B	74.21	10.15

	Mean	s.d.
grp		

A	9.70	2.825
B	11.20	3.186



ANOVA to compare mean of response variable Y across groups

Analysis of variance

Variate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	832.1	832.1	6.48	0.020
Residual	18	2310.5	128.4		
Total	19	3142.5			

units 8	26.8	s.e. 10.7

Tables of means

Variate: y

Grand mean 67.8

grp	A	B
	61.3	74.2

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	18
l.s.d.	10.64

ANOVA to compare mean of covariate X across groups

Analysis of variance

Variate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	11.250	11.250	1.24	0.280
Residual	18	163.180	9.066		
Total	19	174.430			

Message: the following units have large residuals.

units 17	-5.90	s.e. 2.86

ANCOVA to compare mean of response variable Y across groups, adjusting for covariate X - parallel slopes

Analysis of variance (adjusted for covariate)

Variate: y

Covariate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
grp	1	291.93	291.93	9.98	0.94	0.006
Covariate	1	1813.09	1813.09	61.97		<.001
Residual	17	497.39	29.26		4.39	

Total	19	3142.53

Message: the following units have large residuals.

units 8	11.8	s.e. 5.0

Tables of means (adjusted for covariate)

Variate: y
Covariate: x

Grand mean 67.8

grp	A	B
	63.8	71.7

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	17
l.s.d.	5.28

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	2645.1	1322.57	45.20	<.001
Residual	17	497.4	29.26		
Total	19	3142.5	165.40		

Percentage variance accounted for 82.3
Standard error of observations is estimated to be 5.41.

Message: the following units have large standardized residuals.

Unit	Response	Residual
2	63.40	-2.02
8	88.10	2.47

Message: the following units have high leverage.

Unit	Response	Leverage
17	53.00	0.31

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x	61.97	1	61.97	<0.001
grp	9.98	1	9.98	0.006

Residual d.f. 17

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

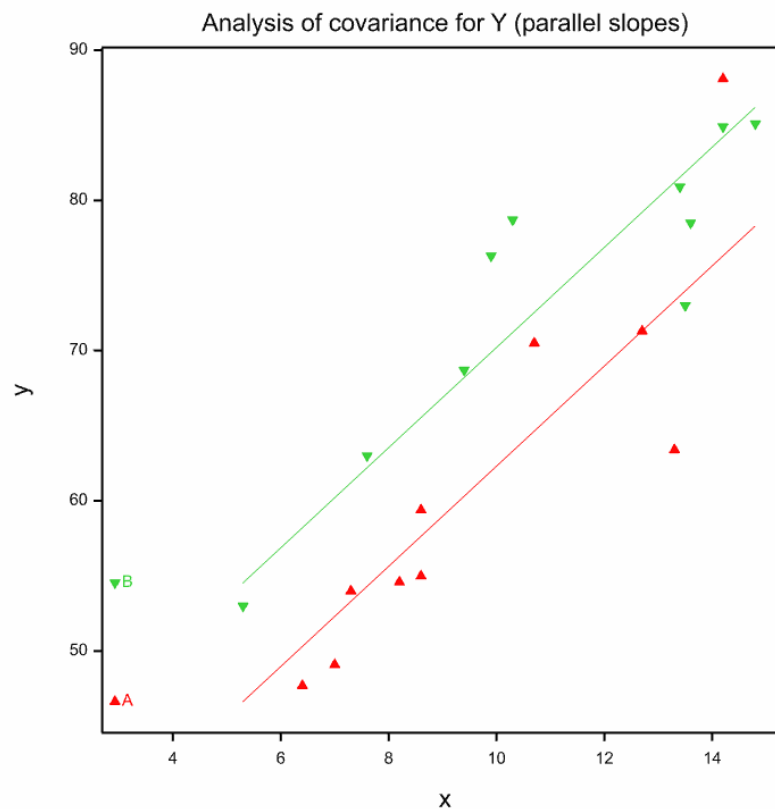
Variate	Fixed value	Source of value
x	10.45	Mean of variate

Response variate: y

	Prediction
grp	
A	63.81
B	71.71

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	5.277	*
		1	2



ANCOVA to compare mean of response variable y across groups, adjusting for covariate X - non-parallel slopes

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp + x.grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2689.8	896.60	31.69	<.001
Residual	16	452.7	28.30		
Total	19	3142.5	165.40		

Percentage variance accounted for 82.9

Standard error of observations is estimated to be 5.32.

Message: the following units have large standardized residuals.

Unit	Response	Residual
2	63.40	-2.67
8	88.10	2.18

Message: the following units have high leverage.

Unit	Response	Leverage
17	53.00	0.48

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x.grp	1.578	1	1.58	0.227

Residual d.f. 16

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

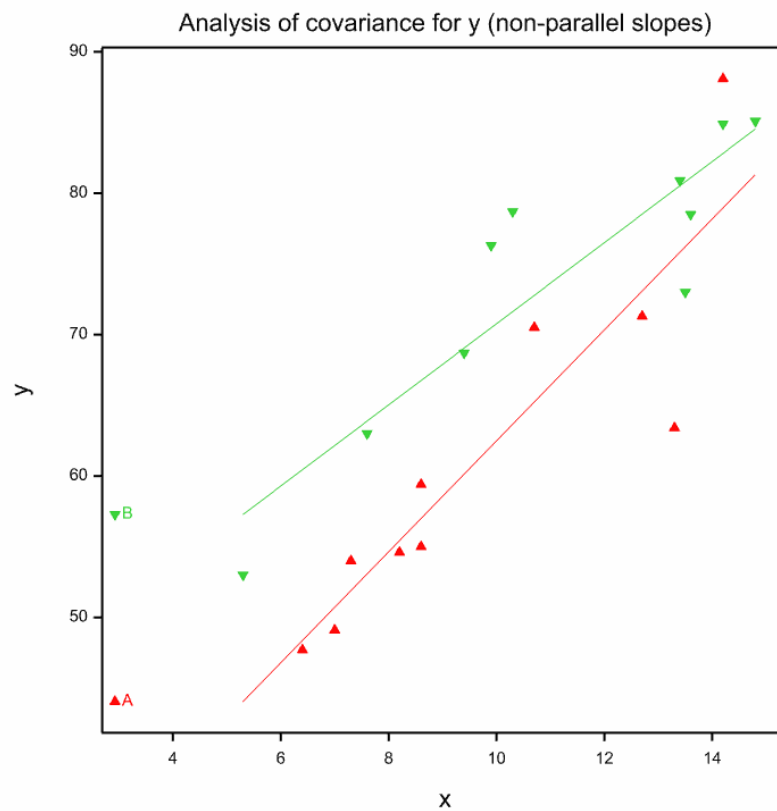
Variate	Fixed value	Source of value
x	10.45	Mean of variate

Response variate: y

	Prediction
grp	
A	64.25
B	72.06

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	5.216	*
		1	2

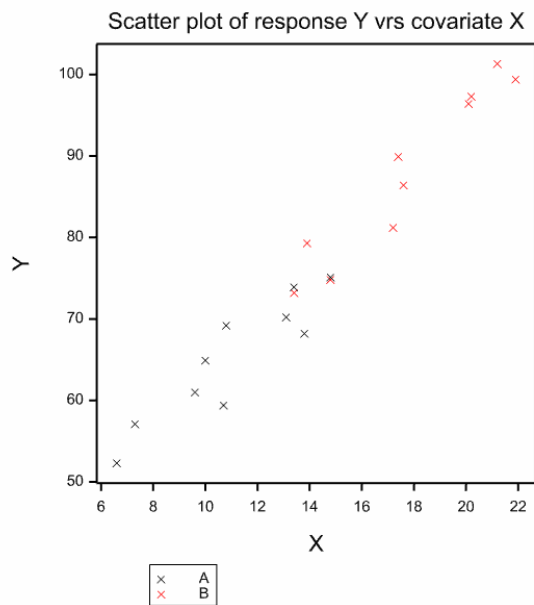
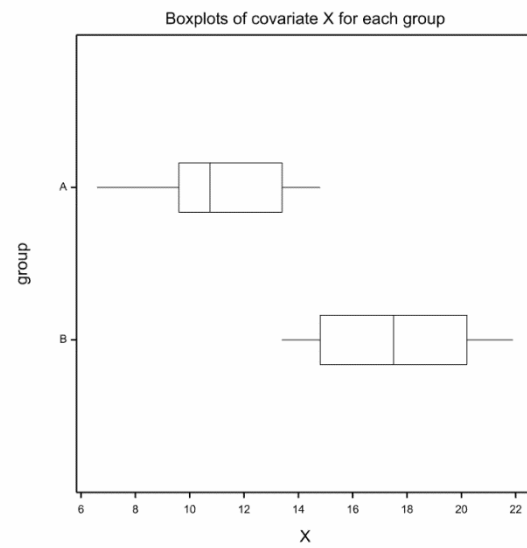
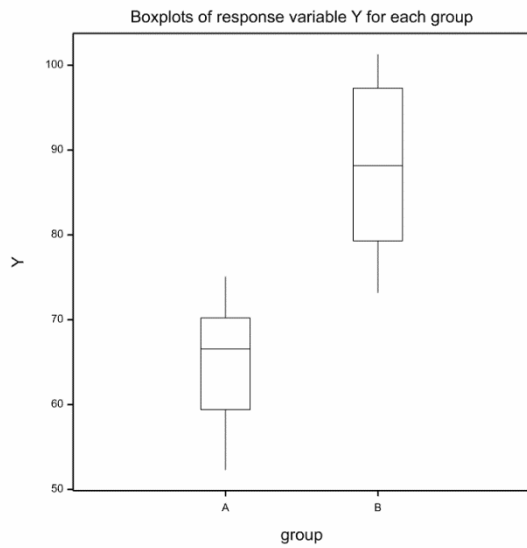


Analysis of Dataset Example_2

Mean and standard deviation of Y and X by group

	Mean	s.d.
grp		
A	65.13	7.506
B	87.92	10.463

	Mean	s.d.
grp		
A	11.01	2.761
B	17.77	3.047



ANOVA to compare mean of response variable Y across groups

Analysis of variance

Variate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	2596.92	2596.92	31.32	<.001
Residual	18	1492.26	82.90		
Total	19	4089.18			

Tables of means

Variate: y

Grand mean 76.5

grp	A	B
	65.1	87.9

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	18
l.s.d.	8.55

ANOVA to compare mean of covariate X across groups

Analysis of variance

Variate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	228.488	228.488	27.03	<.001
Residual	18	152.130	8.452		
Total	19	380.618			

ANCOVA to compare mean of response variable Y across groups, adjusting for covariate X - parallel slopes

Analysis of variance (adjusted for covariate)

Variate: y

Covariate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
grp	1	17.06	17.06	1.63	0.40	0.219
Covariate	1	1314.13	1314.13	125.42		<.001
Residual	17	178.12	10.48		7.91	
Total	19	4089.18				

Tables of means (adjusted for covariate)

Variate: y

Covariate: x

Grand mean 76.53

grp	A	B
	75.06	77.99

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	17
l.s.d.	4.831

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	3911.1	1955.53	186.63	<.001
Residual	17	178.1	10.48		
Total	19	4089.2	215.22		

Percentage variance accounted for 95.1
Standard error of observations is estimated to be 3.24.

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x	125.42	1	125.42	<0.001
grp	1.63	1	1.63	0.219

Residual d.f. 17

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

Variate	Fixed value	Source of value
x	14.39	Mean of variate

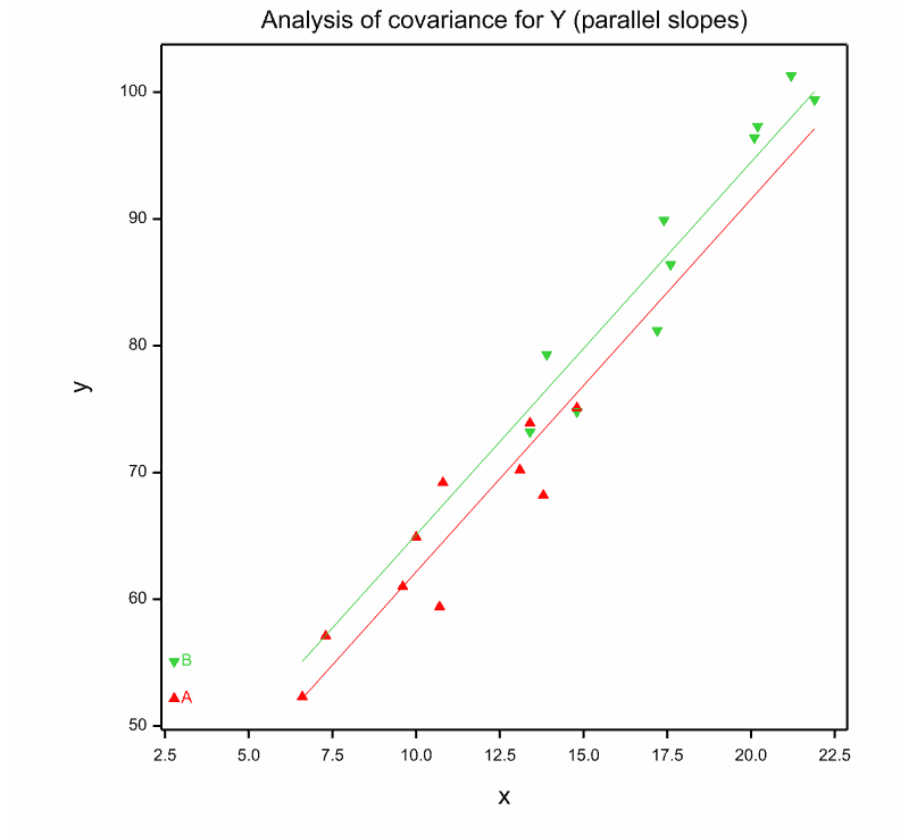
Response variate: y

	Prediction
grp	
A	75.06

B 77.99

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	4.831	*
	1		2



ANCOVA to compare mean of response variable y across groups, adjusting for covariate X - non-parallel slopes

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp + x.grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3935.5	1311.826	136.56	<.001

Residual	16	153.7	9.606
Total	19	4089.2	215.220

Percentage variance accounted for 95.5
Standard error of observations is estimated to be 3.10.

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x.grp	2.543	1	2.54	0.130

Residual d.f. 16

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

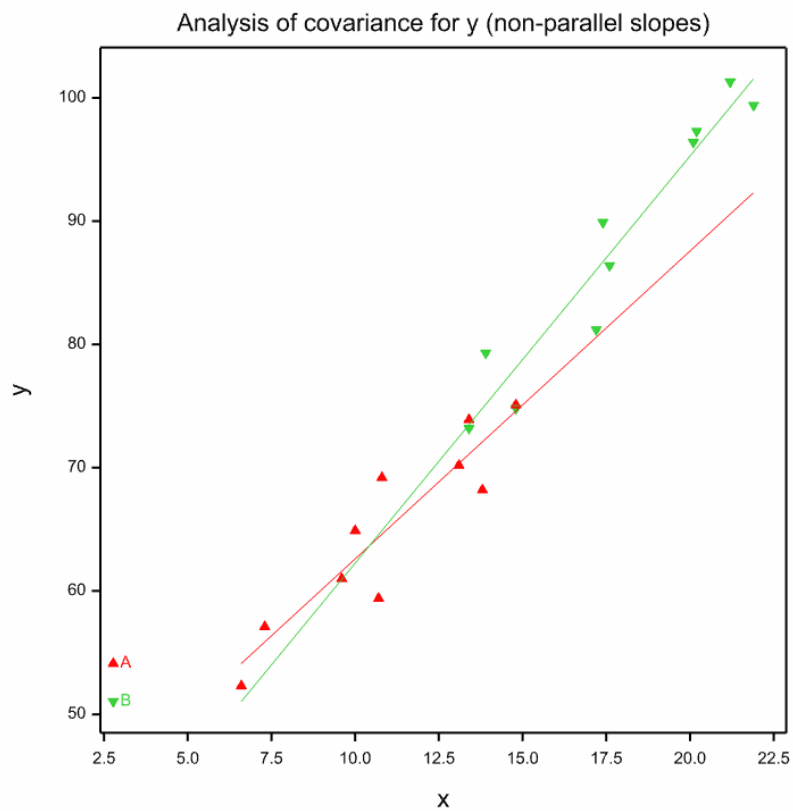
Variate	Fixed value	Source of value
x	14.39	Mean of variate

Response variate: y

	Prediction
grp	
A	73.57
B	76.76

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	4.661	*
		1	2

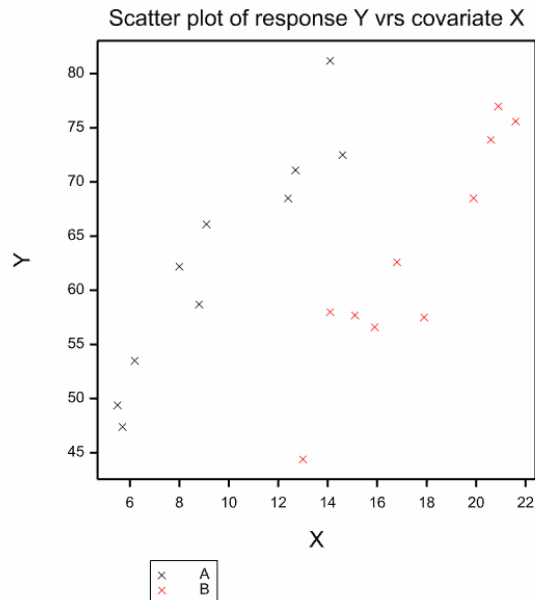
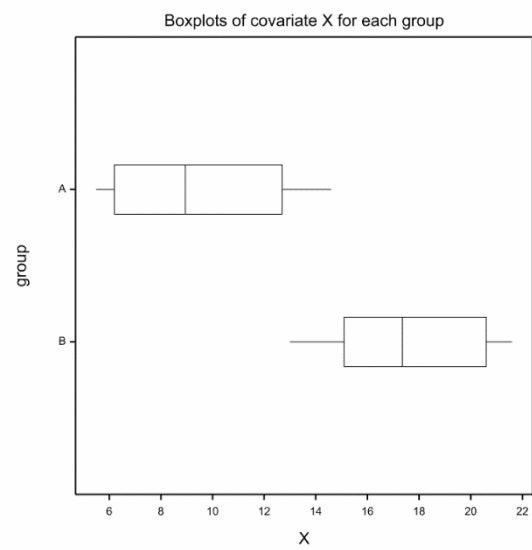
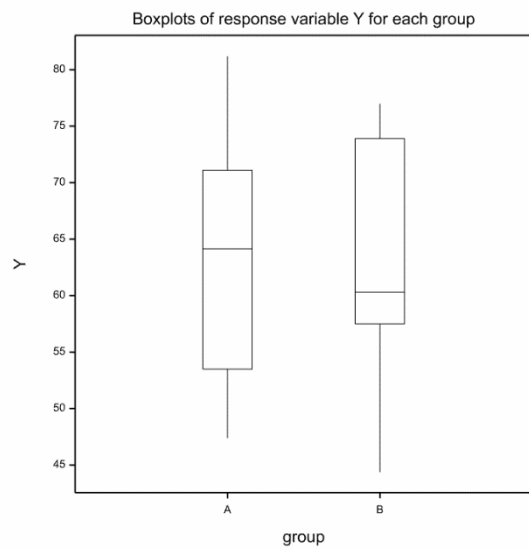


Analysis of Dataset Example_3

Mean and standard deviation of Y and X by group

	Mean	s.d.
grp		
A	63.06	10.88
B	63.18	10.40

	Mean	s.d.
grp		
A	9.71	3.490
B	17.58	3.063



ANOVA to compare mean of response variable Y across groups

Analysis of variance

Variate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	0.1	0.1	0.00	0.980
Residual	18	2038.5	113.3		
Total	19	2038.6			

Tables of means

Variate: y

Grand mean 63.1

grp	A	B
	63.1	63.2

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	18
l.s.d.	10.00

ANOVA to compare mean of covariate X across groups

Analysis of variance

Variate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	309.68	309.68	28.72	<.001
Residual	18	194.06	10.78		
Total	19	503.75			

ANCOVA to compare mean of response variable Y across groups, adjusting for covariate X - parallel slopes

Analysis of variance (adjusted for covariate)

Variate: y

Covariate: x

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
grp	1	1090.79	1090.79	75.30	0.39	<.001
Covariate	1	1792.27	1792.27	123.72		<.001
Residual	17	246.27	14.49		7.82	
Total	19	2038.61				

Tables of means (adjusted for covariate)

Variate: y

Covariate: x

Grand mean 63.12

grp	A	B
	75.02	51.22

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	17
l.s.d.	5.786

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	1792.3	896.17	61.86	<.001
Residual	17	246.3	14.49		
Total	19	2038.6	107.30		

Percentage variance accounted for 86.5
Standard error of observations is estimated to be 3.81.

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x	123.72	1	123.72	<0.001
grp	75.30	1	75.30	<0.001

Residual d.f. 17

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

Variate	Fixed value	Source of value
x	13.64	Mean of variate

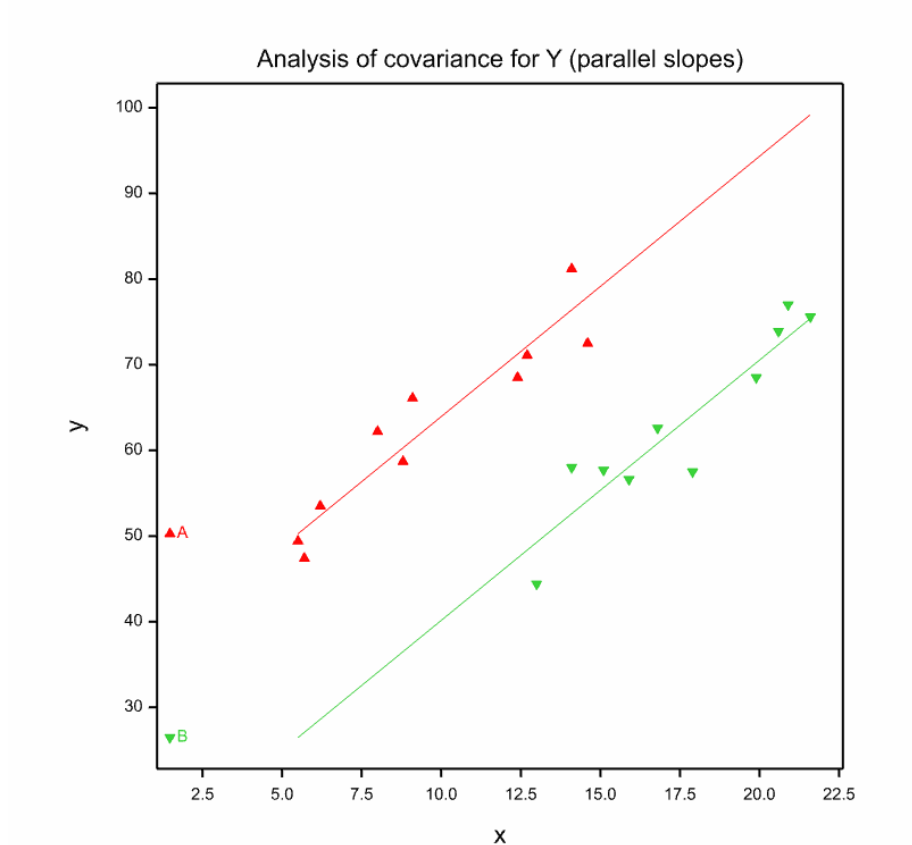
Response variate: y

	Prediction
grp	
A	75.02

B 51.22

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	5.786	*
	1		2



ANCOVA to compare mean of response variable y across groups, adjusting for covariate X - non-parallel slopes

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp + x.grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1795.0	598.32	39.29	<.001

Residual	16	243.6	15.23
Total	19	2038.6	107.30

Percentage variance accounted for 85.8
Standard error of observations is estimated to be 3.90.

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x.grp	0.1723	1	0.17	0.684

Residual d.f. 16

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

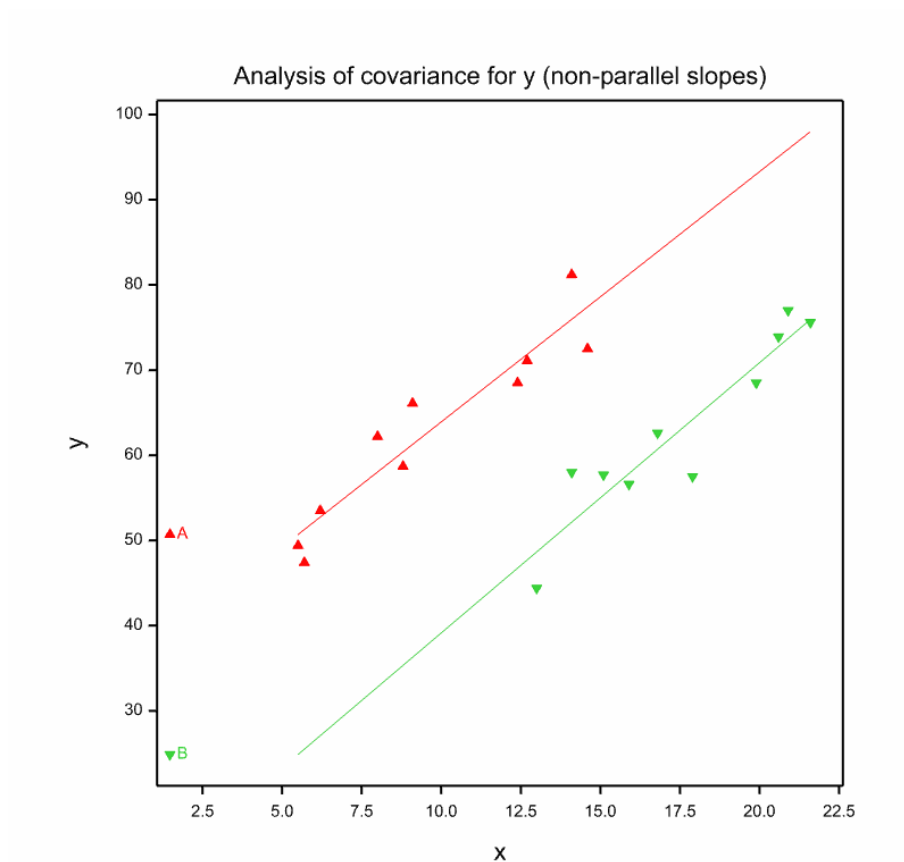
Variate	Fixed value	Source of value
x	13.64	Mean of variate

Response variate: y

	Prediction
grp	
A	74.62
B	50.70

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	5.992	*
		1	2

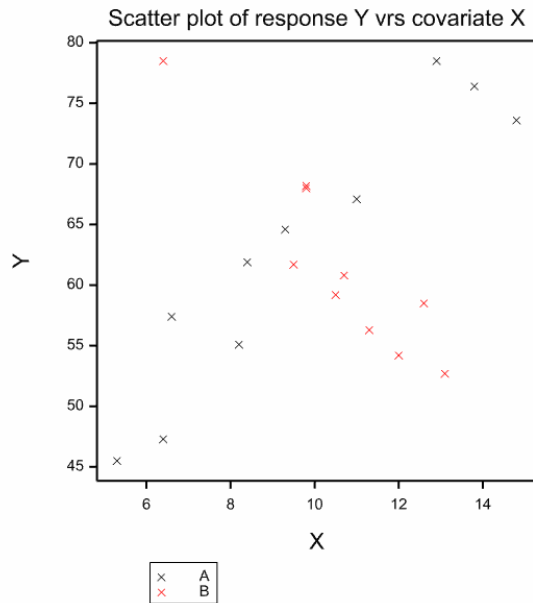
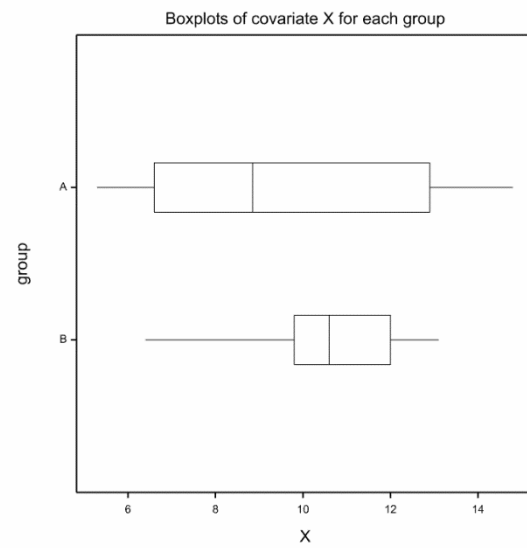
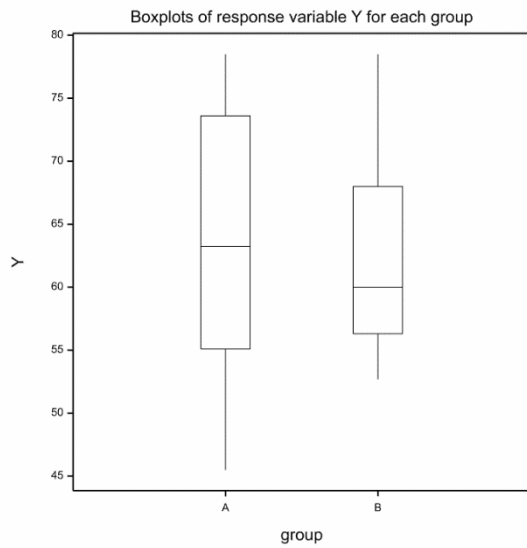


Analysis of Dataset Example_4

Mean and standard deviation of Y and X by group

	Mean	s.d.
grp		
A	62.74	11.540
B	61.81	7.801

	Mean	s.d.
grp		
A	9.67	3.312
B	10.57	1.910



ANOVA to compare mean of response variable Y across groups

Analysis of variance

Variate: y

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
grp	1	4.32	4.32	0.04	0.835
Residual	18	1746.35	97.02		
Total	19	1750.68			

Tables of means

Tables of means (adjusted for covariate)

Variate: y
Covariate: x

Grand mean 62.3

grp	A	B
	63.4	61.1

Least significant differences of means (5% level)

Table	grp
rep.	10
d.f.	17
l.s.d.	8.83

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	2	305.	152.50	1.79	0.196
Residual	17	1446.	85.04		
Total	19	1751.	92.14		

Percentage variance accounted for 7.7
Standard error of observations is estimated to be 9.22.

Message: the following units have large standardized residuals.

Unit	Response	Residual
20	78.50	2.85

Message: the following units have high leverage.

Unit	Response	Leverage
3	73.60	0.30

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x	3.536	1	3.54	0.077
grp	0.299	1	0.30	0.591

Residual d.f. 17

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

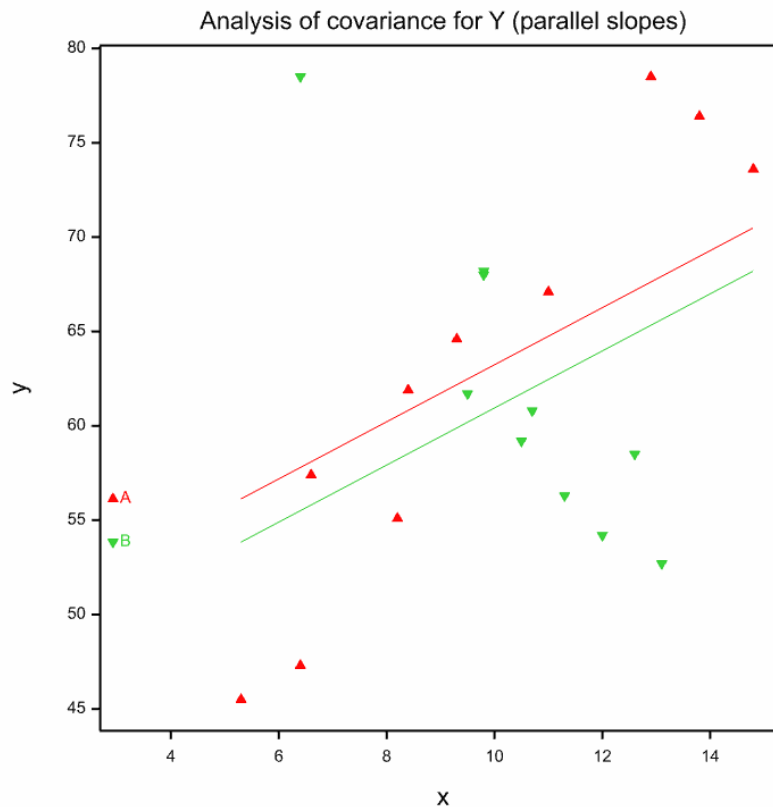
Variate	Fixed value	Source of value
x	10.12	Mean of variate

Response variate: y

	Prediction
grp	
A	63.42
B	61.13

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	8.834	*
		1	2



ANCOVA to compare mean of response variable y across groups, adjusting for covariate X - non-parallel slopes

Regression analysis

Response variate: y
Fitted terms: Constant + x + grp + x.grp

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1525.7	508.57	36.17	<.001
Residual	16	225.0	14.06		
Total	19	1750.7	92.14		

Percentage variance accounted for 84.7

Standard error of observations is estimated to be 3.75.

Message: the following units have high leverage.

Unit	Response	Leverage
20	78.50	0.63

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
x.grp	86.82	1	86.82	<0.001

Residual d.f. 16

Predictions from regression model

These predictions are estimated mean values.

The predictions have been formed only for those combinations of factor levels that are present in the data.

The predictions are based on fixed values of some variates:

Variate	Fixed value	Source of value
x	10.12	Mean of variate

Response variate: y

	Prediction
grp	
A	64.21
B	63.51

Least significant differences of predictions (5% level)

grp A	1	*	
grp B	2	3.627	*
		1	2

Predictions from regression model

These predictions are estimated mean values.

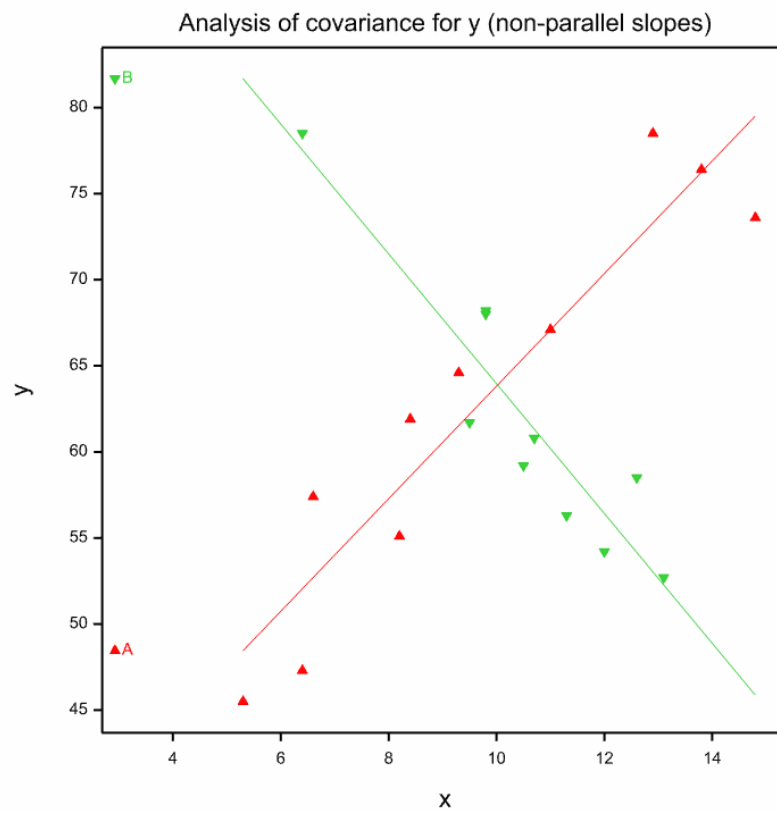
The predictions have been formed ignoring the presence of aliased parameters, effectively assuming such parameters to be zero.

Response variate: y

	Prediction	
grp	A	B
x		
8.0	57.28	71.50
8.5	58.92	69.61
9.0	60.55	67.73
9.5	62.18	65.84
10.0	63.82	63.96
10.5	65.45	62.07
11.0	67.09	60.19
11.5	68.72	58.30

Least significant differences of predictions (5% level)

x 8.0 grp A	1	*				
x 8.0 grp B	2	5.209	*			
x 8.5 grp A	3	0.400	5.121	*		
x 8.5 grp B	4	4.761	0.694	4.664	*	
x 9.0 grp A	5	0.800	5.063	0.400	4.601	*
x 9.0 grp B	6	4.378	1.387	4.273	0.694	4.203
x 9.5 grp A	7	1.200	5.036	0.800	4.572	0.400
x 9.5 grp B	8	4.077	2.081	3.964	1.387	3.889
x 10.0 grp A	9	1.600	5.041	1.200	4.577	0.800
x 10.0 grp B	10	3.879	2.774	3.760	2.081	3.681
x 10.5 grp A	11	2.000	5.078	1.600	4.618	1.200
x 10.5 grp B	12	3.799	3.468	3.677	2.774	3.596
x 11.0 grp A	13	2.400	5.146	2.000	4.692	1.600
x 11.0 grp B	14	3.844	4.161	3.724	3.468	3.644
x 11.5 grp A	15	2.800	5.243	2.400	4.798	2.000
x 11.5 grp B	16	4.011	4.855	3.896	4.161	3.819
		1	2	3	4	5
x 9.0 grp B	6	*				
x 9.5 grp A	7	4.171	*			
x 9.5 grp B	8	0.694	3.855	*		
x 10.0 grp A	9	4.177	0.400	3.861	*	
x 10.0 grp B	10	1.387	3.644	0.694	3.651	*
x 10.5 grp A	11	4.221	0.800	3.909	0.400	3.702
x 10.5 grp B	12	2.081	3.559	1.387	3.566	0.694
x 11.0 grp A	13	4.303	1.200	3.996	0.800	3.794
x 11.0 grp B	14	2.774	3.607	2.081	3.614	1.387
x 11.5 grp A	15	4.418	1.600	4.121	1.200	3.925
x 11.5 grp B	16	3.468	3.784	2.774	3.791	2.081
		6	7	8	9	10
x 10.5 grp A	11	*				
x 10.5 grp B	12	3.618	*			
x 11.0 grp A	13	0.400	3.712	*		
x 11.0 grp B	14	3.665	0.694	3.758	*	
x 11.5 grp A	15	0.800	3.846	0.400	3.891	*
x 11.5 grp B	16	3.840	1.387	3.929	0.694	4.055
		11	12	13	14	15
x 11.5 grp B	16	*				
		16				



195
196 ENDJOB

End of job.

Chapter 12. Spatial Analysis of Field Experiments by Juan Burgueño

Genstat code developed by Vanessa M. Cave and output are provided here for the two examples presented in Chapter 12.

Example 1: Row-column variety trial

Genstat Commands for Example 1

```
" ***** "  
"  Example 1:  Row-column variety trial (Burgueño et al., 2000)  "  
" ***** "  
  
" Expt design: 64 varieties planted in two contiguous replicates laid  
  out in 8 rows and 16 columns with two replicates for each variety "
```

JOB

```
" Load the data, where rep, row, col and entry are factors "
```

```
FACTOR rep, row, col, entry  
READ [SETLEVELS=yes] rep, row, col, entry, yld  
1 1 1 5 1.5318 2 5 1 58 3.7139  
1 1 2 19 2.2211 2 5 2 44 3.6386  
1 1 3 55 1.4589 2 5 3 15 2.8465  
1 1 4 23 1.2436 2 5 4 25 2.4823  
1 1 5 27 1.8989 2 5 5 18 2.6002  
1 1 6 38 1.3366 2 5 6 53 2.5417  
1 1 7 64 1.8966 2 5 7 5 1.6013  
1 1 8 44 1.4775 2 5 8 22 2.1818  
1 1 9 14 1.6483 2 5 9 55 3.5086  
1 1 10 13 1.5220 2 5 10 36 3.4147  
1 1 11 59 1.8581 2 5 11 33 3.1765  
1 1 12 25 1.9730 2 5 12 29 2.8818  
1 1 13 45 2.5290 2 5 13 12 3.1165  
1 1 14 49 2.3901 2 5 14 47 3.5868  
1 1 15 11 2.4703 2 5 15 8 3.5954  
1 1 16 43 3.5279 2 5 16 1 3.5711  
1 2 1 2 2.0066 2 6 1 41 2.7717  
1 2 2 36 1.4573 2 6 2 17 2.9044  
1 2 3 62 2.2574 2 6 3 63 3.0646  
1 2 4 29 1.4428 2 6 4 37 3.2219  
1 2 5 34 1.3521 2 6 5 38 2.4959  
1 2 6 40 1.8021 2 6 6 19 3.7729  
1 2 7 52 1.3945 2 6 7 26 2.7808  
1 2 8 54 1.5750 2 6 8 21 2.5957  
1 2 9 28 1.3825 2 6 9 28 2.3549  
1 2 10 26 1.6735 2 6 10 4 3.0692  
1 2 11 58 1.9658 2 6 11 6 3.2589  
1 2 12 42 2.1403 2 6 12 45 3.4685  
1 2 13 32 2.6153 2 6 13 56 2.9773  
1 2 14 6 2.8538 2 6 14 46 3.6739  
1 2 15 39 3.4978 2 6 15 59 4.4576  
1 2 16 53 2.4935 2 6 16 42 4.7826
```

```

1 3 1 37 1.8915 2 7 1 14 2.9164
1 3 2 3 1.9649 2 7 2 9 2.2630
1 3 3 17 1.5145 2 7 3 62 1.9820
1 3 4 24 1.3582 2 7 4 48 2.6628
1 3 5 15 1.8466 2 7 5 34 2.7700
1 3 6 50 1.7456 2 7 6 31 2.7649
1 3 7 47 1.3042 2 7 7 60 2.0307
1 3 8 56 1.7161 2 7 8 13 2.3102
1 3 9 16 1.1509 2 7 9 20 2.2525
1 3 10 30 1.4549 2 7 10 7 2.6594
1 3 11 31 1.6291 2 7 11 64 2.3498
1 3 12 60 1.4454 2 7 12 3 2.8951
1 3 13 7 2.0237 2 7 13 39 3.5951
1 3 14 18 2.8159 2 7 14 40 3.6799
1 3 15 8 3.2111 2 7 15 10 3.8023
1 3 16 21 3.2198 2 7 16 23 4.2910
1 4 1 20 3.3420 2 8 1 24 2.2748
1 4 2 35 2.6472 2 8 2 52 2.1081
1 4 3 57 1.9362 2 8 3 11 2.5377
1 4 4 63 3.1655 2 8 4 54 1.4670
1 4 5 46 2.2962 2 8 5 51 1.6475
1 4 6 12 2.7581 2 8 6 57 2.7363
1 4 7 41 2.4225 2 8 7 35 2.2646
1 4 8 10 2.6407 2 8 8 2 2.6282
1 4 9 22 2.8679 2 8 9 50 1.7699
1 4 10 1 2.8687 2 8 10 27 2.1685
1 4 11 51 3.1765 2 8 11 30 2.1797
1 4 12 61 2.5182 2 8 12 61 2.7998
1 4 13 33 2.7195 2 8 13 43 2.3903
1 4 14 48 3.4329 2 8 14 49 3.2857
1 4 15 4 3.8140 2 8 15 32 3.8995
1 4 16 9 4.1069 2 8 16 16 3.5976 :
SORT [INDEX=rep,row,col,entry] rep,row,col,entry,yld

```

```
" *** Analysis of variance (Table 1) *** "
```

```
" Notes:
```

- * The ANOVA model can be fitted using either the FIT directive (i.e. a linear regression) or the REML directive.
- * The AICs / BICs of REML (and PROC MIXED and PROC GLIMMIX) will not be the same as the regression AICs / BICs of FIT. This is because REML AIC / BIC uses the REML deviance to assess the random model rather than the fixed model. "

```
" Analysis of variance model fitted using the FIT directive "
```

```
MODEL yld
```

```
FIT [PRINT=model,summary; FPROB=yes; SELECTION=r2] row+col+entry
```

```
" SS3 "
```

```
CAPTION 'test of row'; STYLE=meta
```

```
TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \
    NOMESSAGE=residual] row
```

```
CAPTION 'test of col'; STYLE=meta
```

```
TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \
    NOMESSAGE=residual] col
```

```
CAPTION 'test of entry'; STYLE=meta
```

```
TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \
    NOMESSAGE=residual] entry
```

```

" Coefficient of variation "
RKEEP MEANDEVIANCE=rsme
PRINT 100*SQRT(rsme)/MEAN(yld); HEADING='C.V. (%)'; DEC=1
" Entry means and standard errors "
PREDICT [PRINT=predictions,se] entry
" Residual plots "
RCHECK

" Analysis of variance model fitted using the REML directive "
VCOMPONENTS [FIXED=row+col+entry]
REML [PRINT=model,components,deviance,waldTests;] yld
" Coefficient of variation "
VKEEP [SIGMA2=sigma2]
PRINT 100*SQRT(sigma2)/MEAN(yld); HEADING='C.V. (%)'; DEC=1
" AIC and BIC "
VAIC [PRINT=aic,bic]
" Entry means and standard errors "
VPREDICT [PRINT=predictions,se; PREDICTION=m_nonspatial; \
  SE=sem_nonspatial] entry
" Residual plots "
VPLOT

" *** Autoregressive model of order 1 (AR1) in the row and column
  directions (Tables 2-4) *** "

" Notes:
  * Initial values for the covariance parameters have been provided
    to help with convergence.
  * REML estimates the denominator degrees of freedom (ddf) using the
    the Kenward-Roger method, not the Satterthwaite method. "

" Initial values "
VCOMPONENTS [FIXED=row+col] RANDOM=row.col
VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1;
REML [PRINT=components] yld
VKEEP [VESTIMATES=initial]

" Fit Spatial AR1 (x) AR1 model "
VCOMPONENTS [FIXED=row+col+entry] RANDOM=row.col
VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1; \
  INITIAL=#initial$[-1]
REML [PRINT=model,components,deviance,waldTests] yld
" AIC and BIC "
VAIC [PRINT=aic,bic]
" Entry means and standard errors "
VPREDICT [PRINT=predictions,se,aves; PREDICTION=m_spatial; \
  SE=sem_spatial] CLASSIFY=entry
" Residual plots "
VPLOT
VDFIELDRESIDUALS [PLOT=contour,shade; RMETHOD=all] Y=row; X=col
" 2D variogram (i.e. semi-variance) "
VKEEP [RESIDUAL=residual]
F2DRESIDUALVARIOGRAM [ROW=row; COL=col] residual
" Note: Open the graph in editor mode to rotate the plot "

" *** Spatial model plus polynomial fixed row & col regression *** "

```

```

" Fit spatial AR1 (x) AR1 model + polynomial fixed regression "
VARIATE rowV; VALUES=row
VARIATE colV; VALUES=col
CALC quadrowV = rowV*rowV
CALC quadcolV = colV*colV
VCOMPONENTS [FIXED=rowV+colV+quadrowV+quadcolV+entry] \
  RANDOM=row.col
VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1; \
  INITIAL=#initial$[-1]
REML [PRINT=model,components,deviance,waldTests] yld
" AIC and BIC "
VAIC [PRINT=aic,bic]
" Entry means and standard errors "
VPREDICT [PRINT=predictions,se,aves; PREDICTION=m_spatialpoly; \
  SE=sem_spatialpoly] CLASSIFY=entry
" Residual plots "
VPLOT
VDFIELDRESIDUALS [PLOT=contour,shade] Y=row; X=col
" 2D variogram (i.e. semi-variance) "
VKEEP [RESIDUAL=residualpoly]
F2DRESIDUALVARIOGRAM [ROW=row; COL=col] residualpoly

" Average standard error of the entry means "
PRINT MEAN(sem_nonspatial,sem_spatial,sem_spatialpoly); DEC=4; \
  HEADING='avg sem non-spatial','avg sem spatial',\
    'avg sem spatial+poly'

" Correlation between predicted means from the non-spatial, spatial
  and spatial + polynomial models "
VTABLE m_nonspatial; m_nonspatialV
VTABLE m_spatial; m_spatialV
VTABLE m_spatialpoly; m_spatialpolyV
FCORRELATION [PRINT=correlations,test] m_nonspatialV,m_spatialV,\
  m_spatialpolyV

ENDJOB

```

Genstat Output from Example 1

```

2  " ***** "
3  "  Example 1:  Row-column variety trial (Burgueño et al., 2000)  "
4  " ***** "
5
6  " Expt design: 64 varieties planted in two contiguous replicates laid
-7  out in 8 rows and 16 columns with two replicates for each variety "
8
9  JOB

```

End of job.

```

10
11  " Load the data, where rep, row, col and entry are factors "
12  FACTOR rep, row, col, entry
13  READ [SETLEVELS=yes] rep, row, col, entry, yld

```

Identifier	Minimum	Mean	Maximum	Values	Missing

yld	1.151	2.539	4.783	128	0
Identifier	Values	Missing	Levels		
rep	128	0	2		
row	128	0	8		
col	128	0	16		
entry	128	0	64		

```

78 SORT [INDEX=rep,row,col,entry] rep,row,col,entry,yld
79
80 " *** Analysis of variance (Table 1) *** "
81
82 " Notes:
-83 * The ANOVA model can be fitted using either the FIT directive
-84   (i.e. a linear regression) or the REML directive.
-85 * The AICs / BICs of REML (and PROC MIXED and PROC GLIMMIX) will
-86   not be the same as the regression AICs / BICs of FIT. This is
-87   because REML AIC / BIC uses the REML deviance to assess the
-88   random model rather than the fixed model. "
89
90 " Analysis of variance model fitted using the FIT directive "
91 MODEL yld
92 FIT [PRINT=model,summary; FPROB=yes; SELECTION=r2] row+col+entry

```

Regression analysis

Response variate: yld
Fitted terms: Constant + row + col + entry

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	85	74.536	0.8769	6.16	<.001
Residual	42	5.980	0.1424		
Total	127	80.516	0.6340		

R-squared statistic 0.926

Message: the following units have large standardized residuals.

Unit	Response	Residual
19	2.257	2.29
99	1.982	-2.29

```

93 " SS3 "
94 CAPTION 'test of row'; STYLE=meta

```

test of row

```

95 TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \
96   NOMESSAGE=residual] row

```

Regression analysis

Response variate: yld
Fitted terms: Constant + col + entry

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	78	49.60	0.6360	1.01	0.495
Residual	49	30.91	0.6309		
Total	127	80.52	0.6340		
Change	7	24.93	3.5617	25.01	<.001

```
97  CAPTION 'test of col'; STYLE=meta
```

test of col

```
98  TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \  
99      NOMESSION=residual] col
```

Regression analysis

Response variate: yld
Fitted terms: Constant + row + entry

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	70	57.03	0.8147	1.98	0.004
Residual	57	23.49	0.4121		
Total	127	80.52	0.6340		
Change	15	17.51	1.1672	8.20	<.001

```
100  CAPTION 'test of entry'; STYLE=meta
```

test of entry

```
101  TRY [PRINT=model,summary; FPROB=yes; SELECTION=*; \  
102      NOMESSION=residual] entry
```

Regression analysis

Response variate: yld
Fitted terms: Constant + row + col

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	22	65.65	2.9843	21.08	<.001
Residual	105	14.86	0.1415		
Total	127	80.52	0.6340		
Change	63	8.88	0.1410	0.99	0.521

```

103 " Coefficient of variation "
104 RKEEP MEANDEVIANCE=rsme
105 PRINT 100*SQRT(rsme)/MEAN(yld); HEADING='C.V. (%)'; DEC=1

```

C.V. (%)
14.9

```

106 " Entry means and standard errors "
107 PREDICT [PRINT=predictions,se] entry

```

Predictions from regression model

The standard errors are appropriate for interpretation of the predictions as summaries of the data rather than as forecasts of new observations.

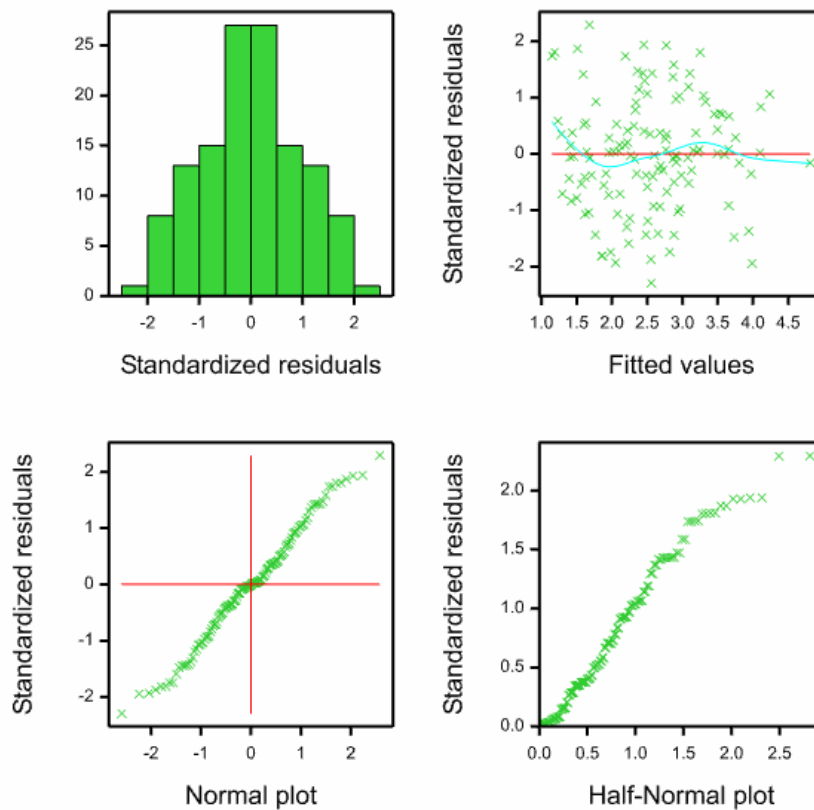
Response variate: yld

entry	Prediction	s.e.
1	2.083	0.3075
2	2.772	0.3099
3	2.741	0.3150
4	2.596	0.3155
5	1.719	0.3133
6	2.762	0.3163
7	2.574	0.3098
8	2.702	0.3550
9	2.279	0.3086
10	2.727	0.3148
11	2.810	0.3182
12	2.449	0.3075
13	2.390	0.3081
14	2.566	0.3204
15	2.874	0.3198
16	2.069	0.3139
17	2.606	0.3120
18	2.541	0.3301
19	3.124	0.3071
20	2.507	0.3204
21	2.382	0.3089
22	2.347	0.3146
23	2.509	0.3090
24	2.213	0.3139
25	2.539	0.3199
26	2.421	0.3082
27	2.627	0.3139
28	2.114	0.3541
29	2.451	0.3199

30	2.193	0.3084
31	2.389	0.3079
32	3.261	0.3210
33	2.561	0.3089
34	2.688	0.3573
35	2.482	0.3122
36	2.656	0.3081
37	2.649	0.3139
38	2.131	0.3164
39	3.440	0.3210
40	2.539	0.3154
41	2.134	0.3133
42	2.826	0.3152
43	2.652	0.3090
44	2.959	0.3077
45	3.109	0.3139
46	2.280	0.3301
47	2.206	0.3148
48	2.523	0.3137
49	2.423	0.3565
50	2.106	0.3133
51	2.459	0.3166
52	2.327	0.3122
53	1.857	0.3071
54	2.235	0.3087
55	2.995	0.3189
56	2.544	0.3093
57	2.388	0.3132
58	2.902	0.3080
59	2.913	0.3147
60	2.064	0.3150
61	2.499	0.3543
62	2.959	0.3504
63	3.091	0.3123
64	2.561	0.3086

```
108 " Residual plots "  
109 RCHECK
```

yld



```

110
111 " Analysis of variance model fitted using the REML directive "
112 VCOMPONENTS [FIXED=row+col+entry]
113 REML [PRINT=model,components,deviance,waldTests;] yld

```

REML variance components analysis

Response variate: yld
Fixed model: Constant + row + col + entry
Number of units: 128

Residual term has been added to model

Sparse algorithm with AI optimisation

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.142	0.0311

Deviance: -2*Log-Likelihood

Deviance	d.f.
34.19	41

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
row	227.19	7	32.46	42.0	<0.001
col	233.92	15	15.59	42.0	<0.001
entry	62.38	63	0.99	42.0	0.521

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
row	175.10	7	25.01	42.0	<0.001
col	122.96	15	8.20	42.0	<0.001
entry	62.38	63	0.99	42.0	0.521

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
114 " Coefficient of variation "
115 VKEEP [SIGMA2=sigma2]
116 PRINT 100*SQRT(sigma2)/MEAN(yld); HEADING='C.V. (%)'; DEC=1
```

C.V. (%)
14.9

```
117 " AIC and BIC "
118 VAIC [PRINT=aic,bic]
```

Akaike information coefficient	113.38
Schwarz Bayes information coefficient	115.12

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
119 " Entry means and standard errors "
120 VPREDICT [PRINT=predictions,se; PREDICTION=m_nonspatial; \
121 SE=sem_nonspatial] entry
```

Predictions from REML analysis

Response variate: yld

Predictions

entry	1	2	3	4	5	6	7	8
	2.083	2.772	2.741	2.596	1.719	2.762	2.574	2.702
entry	9	10	11	12	13	14	15	16

	2.279	2.727	2.810	2.449	2.390	2.566	2.874	2.069
entry	17 2.606	18 2.541	19 3.124	20 2.507	21 2.382	22 2.347	23 2.509	24 2.213
entry	25 2.539	26 2.421	27 2.627	28 2.114	29 2.451	30 2.193	31 2.389	32 3.261
entry	33 2.561	34 2.688	35 2.482	36 2.656	37 2.649	38 2.131	39 3.440	40 2.539
entry	41 2.134	42 2.826	43 2.652	44 2.959	45 3.109	46 2.280	47 2.206	48 2.523
entry	49 2.423	50 2.106	51 2.459	52 2.327	53 1.857	54 2.235	55 2.995	56 2.544
entry	57 2.388	58 2.902	59 2.913	60 2.064	61 2.499	62 2.959	63 3.091	64 2.561

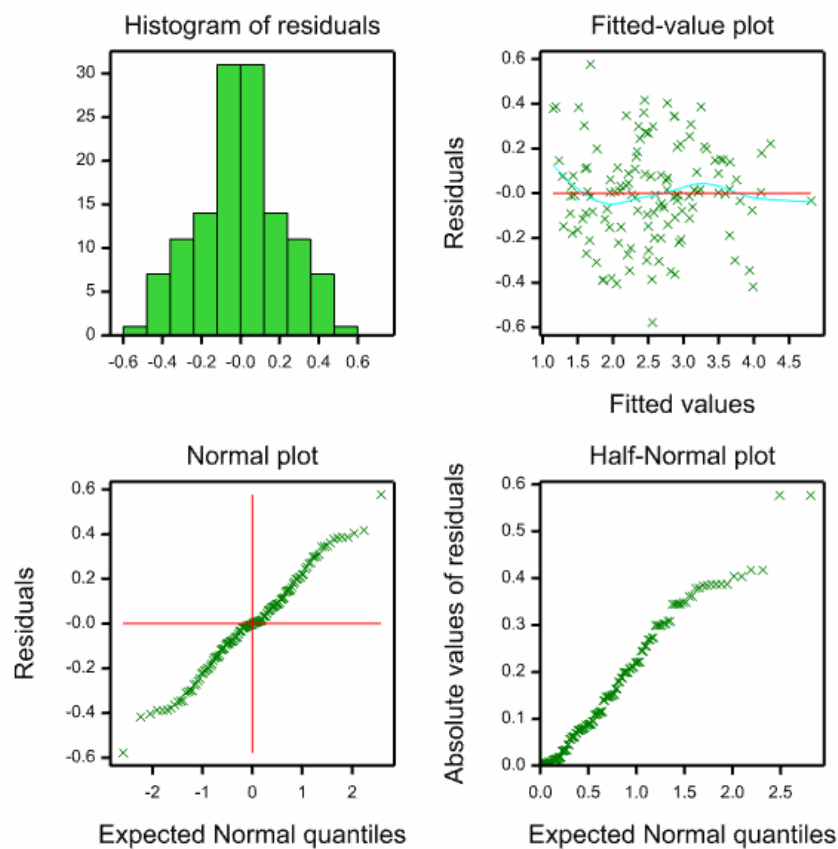
Standard errors

entry	1 0.3075	2 0.3099	3 0.3150	4 0.3155	5 0.3133	6 0.3163	7 0.3098	8 0.3550
entry	9 0.3086	10 0.3148	11 0.3182	12 0.3075	13 0.3081	14 0.3204	15 0.3198	16 0.3139
entry	17 0.3120	18 0.3301	19 0.3071	20 0.3204	21 0.3089	22 0.3146	23 0.3090	24 0.3139
entry	25 0.3199	26 0.3082	27 0.3139	28 0.3541	29 0.3199	30 0.3084	31 0.3079	32 0.3210
entry	33 0.3089	34 0.3573	35 0.3122	36 0.3081	37 0.3139	38 0.3164	39 0.3210	40 0.3154
entry	41 0.3133	42 0.3152	43 0.3090	44 0.3077	45 0.3139	46 0.3301	47 0.3148	48 0.3137
entry	49 0.3565	50 0.3133	51 0.3166	52 0.3122	53 0.3071	54 0.3087	55 0.3189	56 0.3093

entry	57	58	59	60	61	62	63	64
	0.3132	0.3080	0.3147	0.3150	0.3543	0.3504	0.3123	0.3086

```
122 " Residual plots "
123 VPLOT
```

yld



```
124
125 " *** Autoregressive model of order 1 (AR1) in the row and column
-126   directions (Tables 2-4) *** "
127
128 " Notes:
-129   * Initial values for the covariance parameters have been provided
-130     to help with convergence.
-131   * REML estimates the denominator degrees of freedom (ddf) using the
-132     the Kenward-Roger method, not the Satterthwaite method. "
133
134 " Initial values "
135 VCOMPONENTS [FIXED=row+col] RANDOM=row.col
136 VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1;
137 REML [PRINT=components] yld
```

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.

row.col			Sigma2	0.142	0.0206
	row	AR(1)	phi_1	-0.08637	0.11123
	col	AR(1)	phi_1	0.1357	0.1126

```

138 VKEEP [VESTIMATES=initial]
139
140 " Fit Spatial AR1 (x) AR1 model "
141 VCOMPONENTS [FIXED=row+col+entry] RANDOM=row.col
142 VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1; \
143   INITIAL=#initial$[-1]
144 REML [PRINT=model,components,deviance,waldTests] yld

```

REML variance components analysis

Response variate: yld
 Fixed model: Constant + row + col + entry
 Random model: row.col
 Number of units: 128

row.col used as residual term with covariance structure as below

Sparse algorithm with AI optimisation

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No. rows
row.col	row	Auto-regressive (+ scalar)	1	8
	col	Auto-regressive	1	16

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
row.col			Sigma2	0.144	0.0342
	row	AR(1)	phi_1	-0.05532	0.34487
	col	AR(1)	phi_1	0.1633	0.2918

Deviance: -2*Log-Likelihood

Deviance	d.f.
33.51	39

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr

row	178.40	7	24.63	6.9	<0.001
col	204.97	15	13.83	9.6	<0.001
entry	63.49	63	1.18	5.7	0.467

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
row	144.41	7	19.93	6.9	<0.001
col	119.14	15	8.04	9.6	0.001
entry	63.49	63	1.18	5.7	0.467

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
145 " AIC and BIC "
146 VAIC [PRINT=aic,bic]
```

Akaike information coefficient	116.70
Schwarz Bayes information coefficient	121.92

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
147 " Entry means and standard errors "
148 VPREDICT [PRINT=predictions,se,aves; PREDICTION=m_spatial; \
149   SE=sem_spatial] CLASSIFY=entry
```

Predictions from REML analysis

Response variate: yld

Predictions

entry	1	2	3	4	5	6	7	8
	2.061	2.804	2.773	2.646	1.724	2.790	2.624	2.728
entry	9	10	11	12	13	14	15	16
	2.312	2.667	2.822	2.438	2.434	2.617	2.816	2.109
entry	17	18	19	20	21	22	23	24
	2.634	2.516	3.069	2.518	2.351	2.325	2.473	2.215
entry	25	26	27	28	29	30	31	32
	2.512	2.394	2.631	2.081	2.338	2.240	2.412	3.266
entry	33	34	35	36	37	38	39	40
	2.618	2.640	2.461	2.593	2.639	2.037	3.441	2.551
entry	41	42	43	44	45	46	47	48
	2.166	2.791	2.651	2.901	3.111	2.291	2.216	2.575

entry	49	50	51	52	53	54	55	56
	2.484	2.124	2.476	2.284	1.880	2.208	3.016	2.601

entry	57	58	59	60	61	62	63	64
	2.434	2.864	2.906	2.053	2.477	2.971	3.077	2.624

Standard errors

entry	1	2	3	4	5	6	7	8
	0.3073	0.3048	0.3151	0.3089	0.3097	0.3108	0.3067	0.3594

entry	9	10	11	12	13	14	15	16
	0.3067	0.3159	0.3135	0.3018	0.3057	0.3184	0.3136	0.3126

entry	17	18	19	20	21	22	23	24
	0.3040	0.3273	0.3051	0.3191	0.3075	0.3114	0.3074	0.3129

entry	25	26	27	28	29	30	31	32
	0.3198	0.3050	0.3149	0.3542	0.3150	0.3029	0.3099	0.3176

entry	33	34	35	36	37	38	39	40
	0.3023	0.3630	0.3103	0.3044	0.3177	0.3072	0.3197	0.3111

entry	41	42	43	44	45	46	47	48
	0.3103	0.3126	0.3066	0.3018	0.3058	0.3272	0.3102	0.3112

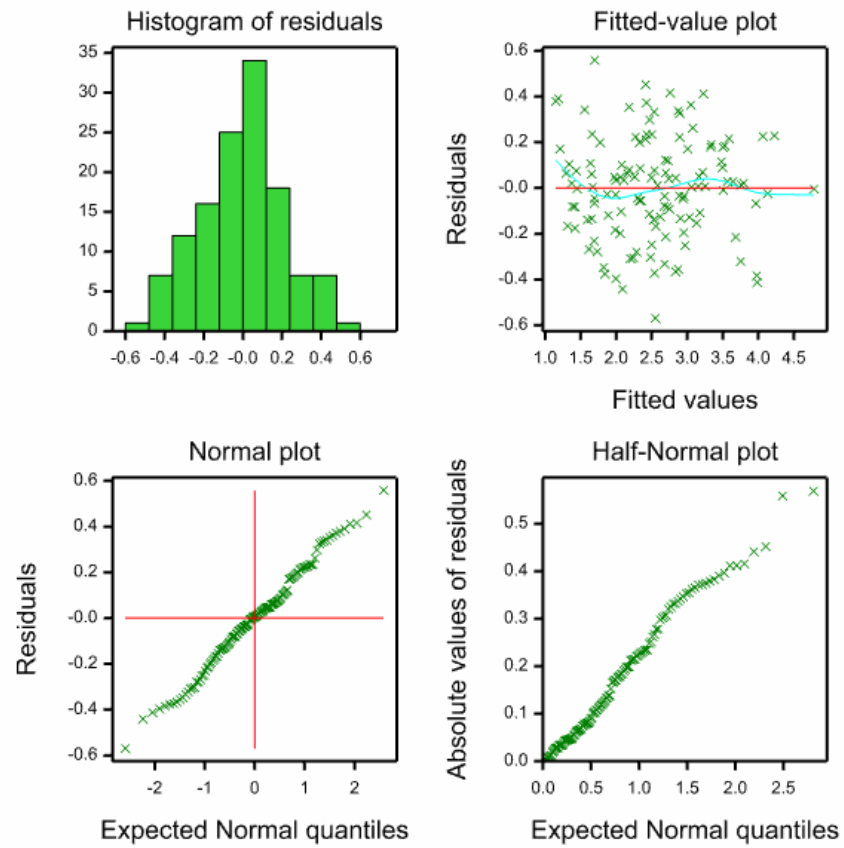
entry	49	50	51	52	53	54	55	56
	0.3537	0.3111	0.3116	0.3080	0.3052	0.3059	0.3167	0.3080

entry	57	58	59	60	61	62	63	64
	0.3180	0.3065	0.3087	0.3159	0.3506	0.3465	0.3096	0.3045

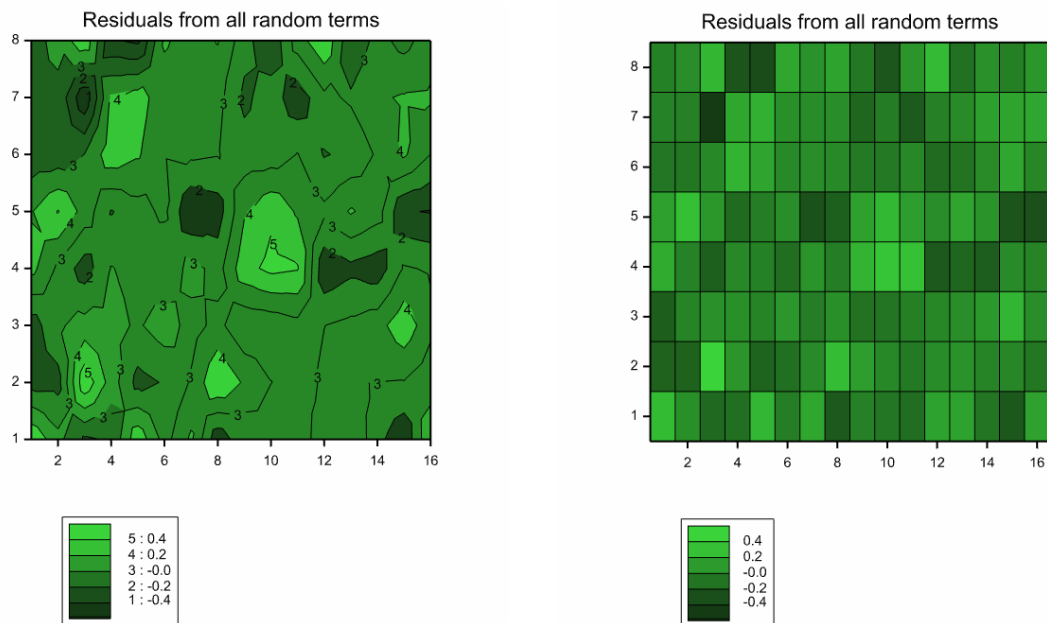
Approximate average standard error of difference: 0.4460 (calculated on variance scale)

```
150 " Residual plots "
151 VPLOT
```

yld



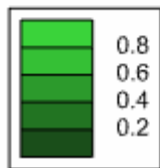
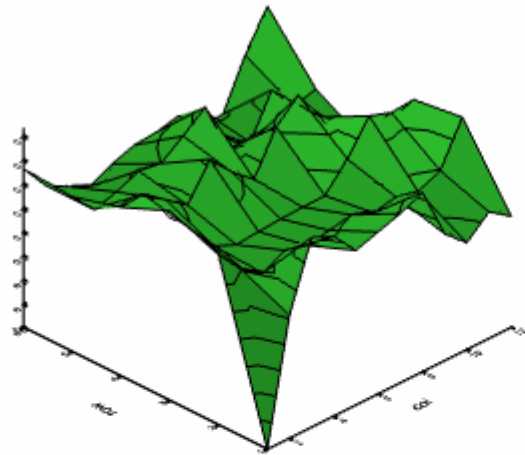
```
152  VDFIELDRESIDUALS [PLOT=contour,shade; RMETHOD=all] Y=row; X=col
```



```

153 " 2D variogram (i.e. semi-variance) "
154 VKEEP [RESIDUAL=residual]
155 F2DRESIDUALVARIOGRAM [ROW=row; COL=col] residual
156 " Note: Open the graph in editor mode to rotate the plot "

```



```

157
158 " *** Spatial model plus polynomial fixed row & col regression *** "
159
160 " Fit spatial AR1 (x) AR1 model + polynomial fixed regression "
161 VARIATE rowV; VALUES=row
162 VARIATE colV; VALUES=col
163 CALC quadrowV = rowV*rowV
164 CALC quadcolV = colV*colV
165 VCOMPONENTS [FIXED=rowV+colV+quadrowV+quadcolV+entry] \
166   RANDOM=row.col
167 VSTRUCTURE [TERMS=row.col] FACTOR=row,col; MODEL=ar,ar; ORDER=1,1; \
168   INITIAL=#initial$[-1]
169 REML [PRINT=model,components,deviance,waldTests] yld

```

REML variance components analysis

Response variate: yld
 Fixed model: Constant + rowV + colV + quadrowV + quadcolV + entry
 Random model: row.col
 Number of units: 128

row.col used as residual term with covariance structure as below

Sparse algorithm with AI optimisation
 All covariates centred

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No. rows
row.col	row	Auto-regressive (+ scalar)	1	8
	col	Auto-regressive	1	16

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
row.col			Sigma2	0.234	0.0494
	row	AR(1)	phi_1	0.1088	0.2072
	col	AR(1)	phi_1	0.4092	0.1461

Deviance: -2*Log-Likelihood

Deviance	d.f.
39.65	57

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
rowV	22.32	1	22.32	14.7	<0.001
colV	31.83	1	31.83	11.9	<0.001
quadrowV	15.00	1	15.00	15.1	0.001
quadcolV	31.18	1	31.18	11.5	<0.001
entry	59.50	63	0.99	14.3	0.546

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
rowV	19.83	1	19.83	14.7	<0.001
colV	11.23	1	11.23	11.9	0.006
quadrowV	12.40	1	12.40	15.1	0.003
quadcolV	23.25	1	23.25	11.5	<0.001
entry	59.50	63	0.99	14.3	0.546

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

```
170 " AIC and BIC "
171 VAIC [PRINT=aic,bic]
```

Akaike information coefficient 155.92

Schwarz Bayes information coefficient 162.20

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
172 " Entry means and standard errors "  
173 VPREDICT [PRINT=predictions,se,aves; PREDICTION=m_spatialpoly; \  
174 SE=sem_spatialpoly] CLASSIFY=entry
```

Predictions from REML analysis

Response variate: yld

Predictions

entry	1	2	3	4	5	6	7	8
	2.220	2.828	2.684	2.719	2.029	2.875	2.483	2.431
entry	9	10	11	12	13	14	15	16
	2.568	2.530	2.599	2.543	2.546	2.839	2.597	1.975
entry	17	18	19	20	21	22	23	24
	2.428	2.564	3.424	2.679	2.320	2.389	2.577	2.099
entry	25	26	27	28	29	30	31	32
	2.536	2.542	2.743	2.129	2.295	2.181	2.339	2.910
entry	33	34	35	36	37	38	39	40
	2.444	2.492	2.474	2.498	2.689	2.252	3.210	2.764
entry	41	42	43	44	45	46	47	48
	2.375	2.848	2.614	2.850	3.005	2.427	2.281	2.746
entry	49	50	51	52	53	54	55	56
	2.767	2.317	2.390	2.142	2.243	2.101	2.953	2.343
entry	57	58	59	60	61	62	63	64
	2.529	2.885	2.868	1.961	2.437	2.672	3.122	2.625

Standard errors

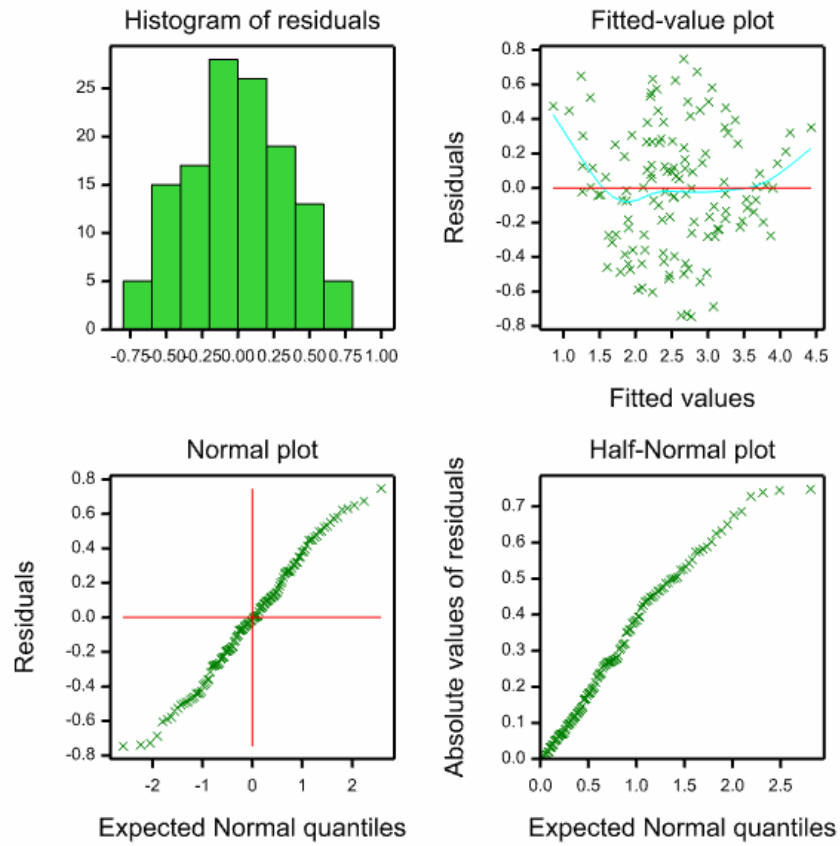
entry	1	2	3	4	5	6	7	8
	0.3234	0.3231	0.3123	0.3148	0.3248	0.3150	0.3119	0.3191
entry	9	10	11	12	13	14	15	16
	0.3235	0.3144	0.3263	0.3144	0.3127	0.3221	0.3129	0.3266

entry	17	18	19	20	21	22	23	24
	0.3186	0.3126	0.3151	0.3213	0.3248	0.3124	0.3215	0.3304
entry	25	26	27	28	29	30	31	32
	0.3120	0.3139	0.3160	0.3135	0.3121	0.3150	0.3236	0.3211
entry	33	34	35	36	37	38	39	40
	0.3125	0.3124	0.3272	0.3124	0.3262	0.3141	0.3128	0.3107
entry	41	42	43	44	45	46	47	48
	0.3248	0.3237	0.3408	0.3137	0.3158	0.3128	0.3127	0.3130
entry	49	50	51	52	53	54	55	56
	0.3289	0.3126	0.3130	0.3173	0.3225	0.3158	0.3159	0.3134
entry	57	58	59	60	61	62	63	64
	0.3276	0.3213	0.3128	0.3243	0.3140	0.3146	0.3172	0.3128

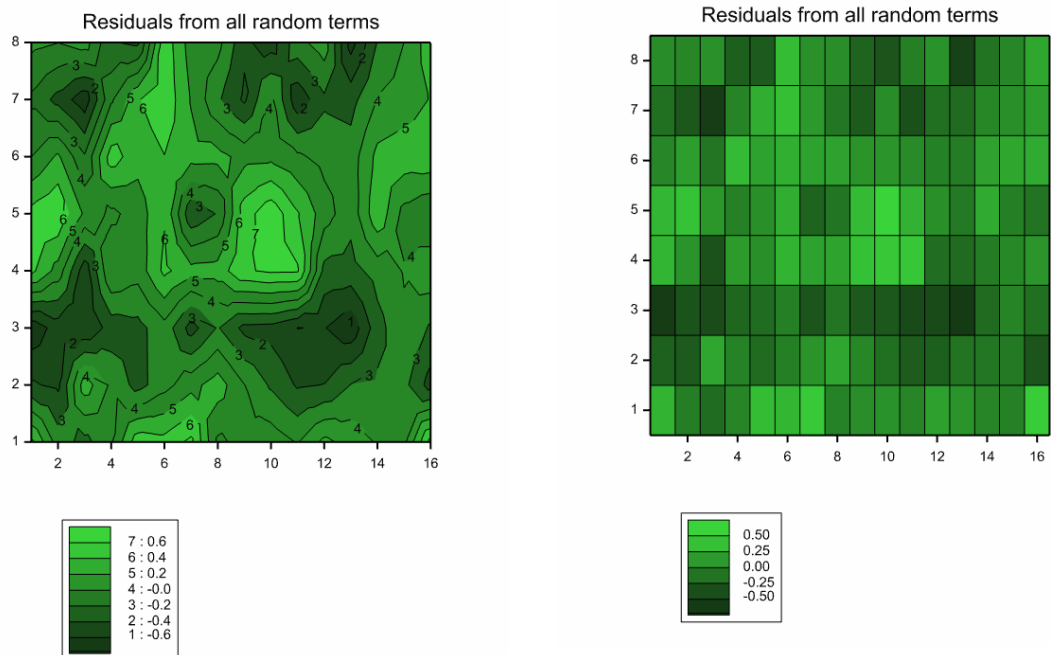
Approximate average standard error of difference: 0.4421 (calculated on variance scale)

```
175 " Residual plots "
176 VPLOT
```

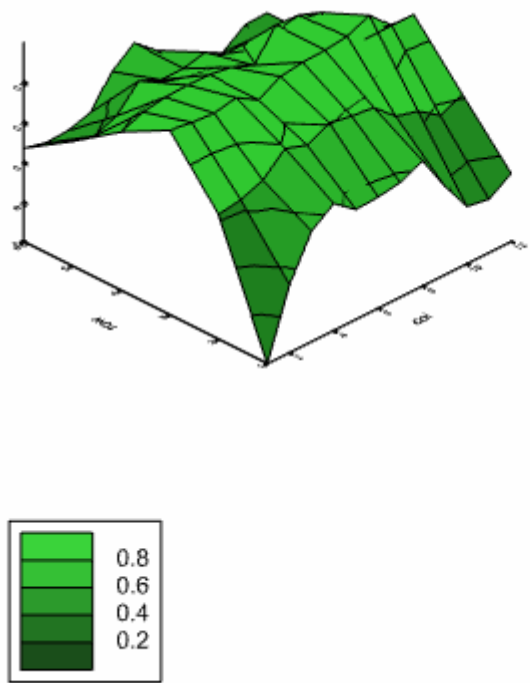

yld



```
177  VDFIELDRESIDUALS [PLOT=contour,shade] Y=row; X=col
```



```
178 " 2D variogram (i.e. semi-variance) "  
179 VKEEP [RESIDUAL=residualpoly]  
180 F2DRESIDUALVARIOGRAM [ROW=row; COL=col] residualpoly
```



```
181  
182 " Average standard error of the entry means "  
183 PRINT MEAN(sem_nonspatial,sem_spatial,sem_spatialpoly); DEC=4; \  
184   HEADING='avg sem non-spatial','avg sem spatial',\  
185           'avg sem spatial+poly'
```

avg sem non-spatial	avg sem spatial	avg sem spatial+poly
0.3174	0.3148	0.3180

```
186  
187 " Correlation between predicted means from the non-spatial, spatial  
-188   and spatial + polynomial models "  
189 VTABLE m_nonspatial; m_nonspatialV  
190 VTABLE m_spatial; m_spatialV  
191 VTABLE m_spatialpoly; m_spatialpolyV  
192 FCORRELATION [PRINT=correlations,test] m_nonspatialV,m_spatialV,\  
193   m_spatialpolyV
```

Correlations

m_nonspatialV	1	-		
m_spatialV	2	0.9931	-	
m_spatialpolyV	3	0.8594	0.8677	-
		1	2	3

Number of observations: 64

Two-sided test of correlations different from zero

m_nonspatialV	1	-			
m_spatialV	2	<0.001	-		
m_spatialpolyV	3	<0.001	<0.001	-	
		1	2	3	

```
194
195  ENDJOB
```

End of job.

Example 2: Un-replicated Maize trial

Genstat Commands for Example 2

```
" ***** "
"  Example 2:  Un-replicated Maize trial  "
" ***** "
```

```
" Expt design: Augmented design (see Example 2 in the Augmented
  Designs chapter)"
```

JOB

```
" Load the data, where Tester, Plot, Row, Col, Group and Acc
  are factors "
```

```
FACTOR Tester, Plot, Row, Col, Group, Acc
```

```
READ [SETLEVELS=yes; MISSING='.'] Tester, Plot, Row, Col, Group, \
  Acc, Plh, PGrhah; FREPRESENTATION=labels,levels,levels,\
  levels,*,*,*
```

```
Check1  10  1 10  1 1 273 3.44
```

```
Check3  1 1 1 1 1 268 2.105
```

```
. 2 1 2 1 . . .
```

```
Check1  22  2 15  1 1 256 3.539
```

```
Check3  31  2 6 1 1 254 2.813
```

```
CML269_CML264 36  2 1 2 241796 258 4.483
```

```
CML269_CML264 37  3 1 2 241071 250.4 2.38
```

```
CML269_CML264 72  4 1 2 241598 280 .
```

```
CML269_CML264 73  5 1 2 241654 297 .
```

```
CML269_CML264 109 7 1 2 242590 240.6 0.91
```

```
CML269_CML264 144 8 1 2 242078 264.4 1.437
```

```
CML269_CML264 181 11 1 2 241624 263 2.101
```

```
CML269_CML264 217 13 1 2 238769 261.2 1.955
```

```
CML269_CML264 252 14 1 2 241565 279 2.311
```

```
CML269_CML264 253 15 1 2 241854 273.4 1.95
```

```
CML269_CML264 288 16 1 2 241885 261 2.291
```

```
CML269_CML264 289 17 1 2 238761 277 2.677
```

```
CML269_CML264 324 18 1 2 241162 260 2.772
```

```
CML269_CML264 361 21 1 2 242365 225 1.254
```

CML269_CML264	396	22	1	2	240017	287	1.855
CML269_CML264	397	23	1	2	239999	256	1.71
CML269_CML264	432	24	1	2	239981	263	1.817
CML269_CML264	433	25	1	2	241939	245	2.556
CML269_CML264	468	26	1	2	238804	265	1.935
CML269_CML264	505	29	1	2	241506	285	2.468
CML269_CML264	540	30	1	2	239989	290	2.602
CML269_CML264	541	31	1	2	241536	278	2.022
CML269_CML264	576	32	1	2	238979	308.4	3.531
CML269_CML264	577	33	1	2	238637	296.6	3.575
CML269_CML264	612	34	1	2	241566	260.2	2.323
CML269_CML264	613	35	1	2	241986	276	0.946
CML269_CML264	648	36	1	2	241440	255	0.714
CML269_CML264	71	4	2	2	242029	289	2.97
CML269_CML264	74	5	2	2	242000	266	2.505
CML269_CML264	107	6	2	2	238953	291	2.603
CML269_CML264	110	7	2	2	240013	297	1.709
CML269_CML264	143	8	2	2	241166	264.4	3.016
CML269_CML264	182	11	2	2	241503	285	2.446
CML269_CML264	218	13	2	2	239013	271	2.909
CML269_CML264	251	14	2	2	241867	256.4	2.088
CML269_CML264	254	15	2	2	238867	297	4.334
CML269_CML264	290	17	2	2	241932	260	1.635
CML269_CML264	323	18	2	2	238774	262	2.289
CML269_CML264	326	19	2	2	241405	264	2.574
CML269_CML264	359	20	2	2	241130	280	0.805
CML269_CML264	395	22	2	2	241237	257	2.966
CML269_CML264	398	23	2	2	241498	243	1.535
CML269_CML264	431	24	2	2	241609	258	1.921
CML269_CML264	434	25	2	2	241622	259	3.801
CML269_CML264	467	26	2	2	238679	270	2.044
CML269_CML264	470	27	2	2	241429	281	1.994
CML269_CML264	503	28	2	2	240721	264.4	3.332
CML269_CML264	506	29	2	2	241240	264	2.609
CML269_CML264	542	31	2	2	239229	283	6.905
CML269_CML264	575	32	2	2	241202	299	2.354
CML269_CML264	578	33	2	2	241491	270.8	3.723
CML269_CML264	647	36	2	2	241263	293	1.643
CML269_CML264	3	1	3	2	240086	197.4	2.589
CML269_CML264	34	2	3	2	241487	257	2.519
CML269_CML264	39	3	3	2	241777	259	3.085
CML269_CML264	70	4	3	2	241765	300	1.577
CML269_CML264	106	6	3	2	241826	301	4.465
CML269_CML264	111	7	3	2	239986	297.4	2.436
CML269_CML264	142	8	3	2	241221	278.6	1.595
CML269_CML264	178	10	3	2	241361	260	1.618
CML269_CML264	183	11	3	2	238782	264.2	1.795
CML269_CML264	214	12	3	2	241634	280	2.426
CML269_CML264	255	15	3	2	241293	274.4	2.707
CML269_CML264	291	17	3	2	241893	270	2.342
CML269_CML264	322	18	3	2	238792	264	2.049
CML269_CML264	327	19	3	2	242250	205.4	2.205
CML269_CML264	358	20	3	2	241904	273.6	1.828
CML269_CML264	394	22	3	2	238990	249	1.788
CML269_CML264	466	26	3	2	241617	262.4	2.405
CML269_CML264	471	27	3	2	242032	282	5.716
CML269_CML264	502	28	3	2	242026	291.4	2.868

CML269_CML264	538	30	3	2	241212	297.6	5.093
CML269_CML264	543	31	3	2	241367	265	2.598
CML269_CML264	579	33	3	2	241469	284	1.66
CML269_CML264	610	34	3	2	242082	314	4.67
CML269_CML264	615	35	3	2	242044	297	2.659
CML269_CML264	40	3	4	2	242001	263.2	2.903
CML269_CML264	69	4	4	2	241420	302	2.306
CML269_CML264	105	6	4	2	241134	296	2.578
CML269_CML264	141	8	4	2	242024	278	2.75
CML269_CML264	148	9	4	2	238689	262	1.482
CML269_CML264	184	11	4	2	239075	283.8	2.989
CML269_CML264	213	12	4	2	241118	278	2.75
CML269_CML264	220	13	4	2	242056	294	1.992
CML269_CML264	249	14	4	2	241649	311	3.085
CML269_CML264	292	17	4	2	238956	277	2.627
CML269_CML264	328	19	4	2	241157	278	4.264
CML269_CML264	393	22	4	2	239049	240	1.508
CML269_CML264	400	23	4	2	242075	281	2.4
CML269_CML264	465	26	4	2	241787	247	2.12
CML269_CML264	472	27	4	2	238832	260	3.624
CML269_CML264	501	28	4	2	242149	280	4.311
CML269_CML264	508	29	4	2	239095	251	1.898
CML269_CML264	537	30	4	2	238730	279	3.451
CML269_CML264	544	31	4	2	241656	292	2.524
CML269_CML264	580	33	4	2	239053	281.6	2.276
CML269_CML264	616	35	4	2	238917	265.2	2.36
CML269_CML264	5	1	5	2	240000	236	1.796
CML269_CML264	32	2	5	2	242012	254	2.938
CML269_CML264	104	6	5	2	241280	282	1.322
CML269_CML264	176	10	5	2	241827	287.4	2.764
CML269_CML264	185	11	5	2	238754	245.6	1.405
CML269_CML264	212	12	5	2	241241	302.6	3.58
CML269_CML264	221	13	5	2	242592	237.8	1.09
CML269_CML264	257	15	5	2	241434	306	1.81
CML269_CML264	293	17	5	2	239091	283	1.659
CML269_CML264	329	19	5	2	239035	281	1.528
CML269_CML264	356	20	5	2	242046	272.8	2.319
CML269_CML264	392	22	5	2	241415	253	2.199
CML269_CML264	401	23	5	2	241080	273	1.28
CML269_CML264	428	24	5	2	240664	255	2.372
CML269_CML264	437	25	5	2	241284	238	2.098
CML269_CML264	500	28	5	2	238695	266	1.491
CML269_CML264	509	29	5	2	240047	290	1.697
CML269_CML264	536	30	5	2	242018	291	2.774
CML269_CML264	545	31	5	2	241203	276	3.475
CML269_CML264	572	32	5	2	241360	247	1.463
CML269_CML264	581	33	5	2	242757	228	1.409
CML269_CML264	608	34	5	2	238968	276	2.37
CML269_CML264	42	3	6	2	238860	276	1.729
CML269_CML264	67	4	6	2	241198	273.6	1.251
CML269_CML264	114	7	6	2	241192	301	2.87
CML269_CML264	150	9	6	2	241531	294	0.846
CML269_CML264	175	10	6	2	241285	265	3.115
CML269_CML264	211	12	6	2	241465	264	2.124
CML269_CML264	258	15	6	2	241652	318	2.708
CML269_CML264	294	17	6	2	241577	301	1.051
CML269_CML264	319	18	6	2	239229	270.6	4.895

CML269_CML264	330	19	6	2	241261	282	1.812
CML269_CML264	391	22	6	2	239062	245	1.227
CML269_CML264	438	25	6	2	241977	225	1.795
CML269_CML264	463	26	6	2	241127	279	1.955
CML269_CML264	535	30	6	2	241996	290.6	3.392
CML269_CML264	546	31	6	2	239084	250	3.005
CML269_CML264	571	32	6	2	240830	242.4	2.144
CML269_CML264	582	33	6	2	241990	283.4	2.171
CML269_CML264	607	34	6	2	240794	276	2.492
CML269_CML264	643	36	6	2	239050	289	1.164
CML269_CML264	7	1	7	2	241307	256	2.569
CML269_CML264	30	2	7	2	241595	258.4	2.965
CML269_CML264	43	3	7	2	242088	253	2.265
CML269_CML264	79	5	7	2	241929	253	2.789
CML269_CML264	102	6	7	2	241176	289	1.599
CML269_CML264	115	7	7	2	242027	300	3.952
CML269_CML264	138	8	7	2	242808	267.8	2.029
CML269_CML264	151	9	7	2	239034	276	2.542
CML269_CML264	187	11	7	2	241640	300	4.065
CML269_CML264	210	12	7	2	241918	271	2.045
CML269_CML264	246	14	7	2	239044	269.6	3.243
CML269_CML264	259	15	7	2	242007	295.8	4.36
CML269_CML264	282	16	7	2	239077	287	1.685
CML269_CML264	318	18	7	2	239045	238	2.099
CML269_CML264	331	19	7	2	241978	283	1.954
CML269_CML264	354	20	7	2	238998	274	1.748
CML269_CML264	403	23	7	2	241940	253	4.183
CML269_CML264	439	25	7	2	238750	253.4	2.183
CML269_CML264	462	26	7	2	241793	248	1.48
CML269_CML264	475	27	7	2	241174	296	4.074
CML269_CML264	570	32	7	2	241981	324.6	2.768
CML269_CML264	642	36	7	2	241775	264	2.275
CML269_CML264	29	2	8	2	241313	281.2	2.96
CML269_CML264	44	3	8	2	241209	276	2.343
CML269_CML264	65	4	8	2	241486	273.6	1.48
CML269_CML264	137	8	8	2	239043	276.6	2.983
CML269_CML264	152	9	8	2	242116	267	5.786
CML269_CML264	188	11	8	2	241969	258.4	1.626
CML269_CML264	224	13	8	2	241185	277	1.48
CML269_CML264	281	16	8	2	241500	259.6	1.819
CML269_CML264	296	17	8	2	241849	240	1.239
CML269_CML264	317	18	8	2	240792	230.6	2.044
CML269_CML264	332	19	8	2	242014	260	2.168
CML269_CML264	353	20	8	2	240615	274	1.59
CML269_CML264	368	21	8	2	241832	264	3.033
CML269_CML264	389	22	8	2	238707	287	2.245
CML269_CML264	404	23	8	2	241136	278.8	3.077
CML269_CML264	476	27	8	2	238738	258	1.976
CML269_CML264	497	28	8	2	242037	279.4	2.759
CML269_CML264	533	30	8	2	239994	291	3.001
CML269_CML264	548	31	8	2	241593	258	2.592
CML269_CML264	569	32	8	2	241561	267.4	1.336
CML269_CML264	605	34	8	2	241277	283	3.096
CML269_CML264	620	35	8	2	241871	268	2.608
CML269_CML264	641	36	8	2	238746	272	1.312
CML269_CML264	9	1	9	2	242103	281	3.152
CML269_CML264	28	2	9	2	241570	256.4	3.71

CML269_CML264	45	3	9	2	242125	283	3.501
CML269_CML264	64	4	9	2	238838	272	4.506
CML269_CML264	100	6	9	2	242100	259.6	1.401
CML269_CML264	117	7	9	2	240067	297	1.308
CML269_CML264	153	9	9	2	241905	290	1.81
CML269_CML264	208	12	9	2	242152	301	3.43
CML269_CML264	225	13	9	2	241133	270	2.807
CML269_CML264	261	15	9	2	241159	243.2	3.215
CML269_CML264	280	16	9	2	241959	264	2.342
CML269_CML264	333	19	9	2	238783	242	2.008
CML269_CML264	369	21	9	2	241643	296	3.806
CML269_CML264	388	22	9	2	241214	277	2.643
CML269_CML264	405	23	9	2	241365	263	1.437
CML269_CML264	424	24	9	2	241569	275.2	2.923
CML269_CML264	441	25	9	2	238969	263	2.611
CML269_CML264	496	28	9	2	241597	289	5.738
CML269_CML264	513	29	9	2	241985	271	3.833
CML269_CML264	532	30	9	2	238988	260	1.942
CML269_CML264	549	31	9	2	241386	273	2.47
CML269_CML264	568	32	9	2	241800	291	3.472
CML269_CML264	585	33	9	2	241352	294.4	4.309
CML269_CML264	640	36	9	2	241523	255	2.419
CML269_CML264	27	2	10	2	241915	231.8	3.926
CML269_CML264	46	3	10	2	241350	245	2.342
CML269_CML264	63	4	10	2	238991	247	2.858
CML269_CML264	135	8	10	2	242011	275	1.205
CML269_CML264	154	9	10	2	239404	295	2.639
CML269_CML264	190	11	10	2	242419	260	1.445
CML269_CML264	207	12	10	2	241297	279	2.473
CML269_CML264	226	13	10	2	238907	282	3.438
CML269_CML264	243	14	10	2	242013	246	1.643
CML269_CML264	262	15	10	2	242411	263.6	2.505
CML269_CML264	279	16	10	2	241311	299	1.735
CML269_CML264	298	17	10	2	242703	245	2.875
CML269_CML264	315	18	10	2	241496	286	2.986
CML269_CML264	351	20	10	2	241252	271	3.296
CML269_CML264	370	21	10	2	241346	267	2.207
CML269_CML264	406	23	10	2	241369	263	2.325
CML269_CML264	423	24	10	2	241594	231	1.526
CML269_CML264	459	26	10	2	241395	295	1.728
CML269_CML264	478	27	10	2	241774	271	3.187
CML269_CML264	514	29	10	2	242788	255.6	1.919
CML269_CML264	531	30	10	2	242537	259	2.537
CML269_CML264	550	31	10	2	241238	299	5.404
CML269_CML264	567	32	10	2	241396	282.4	1.735
CML269_CML264	586	33	10	2	241529	261	2.264
CML269_CML264	603	34	10	2	241612	266	1.779
CML269_CML264	639	36	10	2	241147	260.4	3.607
CML269_CML264	26	2	11	2	239001	237	1.927
CML269_CML264	83	5	11	2	238862	257.8	2.303
CML269_CML264	98	6	11	2	241887	267	2.294
CML269_CML264	119	7	11	2	239088	263	3.547
CML269_CML264	134	8	11	2	241384	265	2.063
CML269_CML264	155	9	11	2	241485	270.6	2.625
CML269_CML264	170	10	11	2	239010	296.4	3.696
CML269_CML264	191	11	11	2	242115	300	4.398
CML269_CML264	242	14	11	2	241183	293.6	3.358

CML269_CML264	263	15	11	2	241242	275.6	2.17
CML269_CML264	278	16	11	2	241537	286	3.043
CML269_CML264	299	17	11	2	241552	271.8	4.27
CML269_CML264	314	18	11	2	242034	294.2	2.941
CML269_CML264	335	19	11	2	242783	211.4	1.572
CML269_CML264	350	20	11	2	241924	233	2.118
CML269_CML264	386	22	11	2	241400	266.8	2.698
CML269_CML264	407	23	11	2	242113	228	2.09
CML269_CML264	458	26	11	2	238778	270	1.855
CML269_CML264	479	27	11	2	241255	290	2.562
CML269_CML264	494	28	11	2	241477	262	1.212
CML269_CML264	566	32	11	2	241914	283	4.153
CML269_CML264	623	35	11	2	238726	257	1.953
CML269_CML264	638	36	11	2	241910	300	3.037
CML269_CML264	48	3	12	2	241142	268	2.363
CML269_CML264	61	4	12	2	241993	268	2.396
CML269_CML264	97	6	12	2	240142	273	1.67
CML269_CML264	133	8	12	2	241201	254.4	2.305
CML269_CML264	156	9	12	2	242730	303.4	2.153
CML269_CML264	169	10	12	2	241956	266.4	3.227
CML269_CML264	228	13	12	2	241907	284	2.163
CML269_CML264	264	15	12	2	241922	257	1.606
CML269_CML264	277	16	12	2	241355	289	3.922
CML269_CML264	300	17	12	2	242775	240.8	2.444
CML269_CML264	313	18	12	2	241511	295	2.28
CML269_CML264	349	20	12	2	241564	242	5.417
CML269_CML264	372	21	12	2	238955	249	3.067
CML269_CML264	385	22	12	2	242127	273	7.115
CML269_CML264	444	25	12	2	241495	264.4	3.223
CML269_CML264	480	27	12	2	239229	289	5.642
CML269_CML264	493	28	12	2	239027	271	2.928
CML269_CML264	529	30	12	2	238767	273	2.218
CML269_CML264	552	31	12	2	241890	274	3.099
CML269_CML264	588	33	12	2	241559	255	1.754
CML269_CML264	601	34	12	2	238927	295.6	1.593
CML269_CML264	624	35	12	2	241751	285	1.866
CML269_CML264	637	36	12	2	239059	244.6	2.71
CML269_CML264	13	1	13	2	238673	300	4.195
CML269_CML264	49	3	13	2	242275	244	2.74
CML269_CML264	60	4	13	2	241200	244.6	1.99
CML269_CML264	85	5	13	2	238882	228.2	1.543
CML269_CML264	132	8	13	2	241784	256.4	1.874
CML269_CML264	193	11	13	2	241208	290	3.004
CML269_CML264	204	12	13	2	241103	281	2.567
CML269_CML264	229	13	13	2	241554	274	1.202
CML269_CML264	240	14	13	2	238716	303	2.183
CML269_CML264	265	15	13	2	241101	305	3.557
CML269_CML264	301	17	13	2	239082	250	3.157
CML269_CML264	312	18	13	2	238823	276	2.406
CML269_CML264	348	20	13	2	239998	242	1.589
CML269_CML264	373	21	13	2	238659	274.6	3.125
CML269_CML264	384	22	13	2	241567	258	2.837
CML269_CML264	409	23	13	2	241984	216	0.889
CML269_CML264	420	24	13	2	238776	254	2.239
CML269_CML264	456	26	13	2	241463	285	1.666
CML269_CML264	481	27	13	2	241866	275	4.314
CML269_CML264	492	28	13	2	241630	250	2.093

CML269_CML264	517	29	13	2	241651	316	4.613
CML269_CML264	528	30	13	2	242407	262	2.841
CML269_CML264	553	31	13	2	242248	275	3.949
CML269_CML264	564	32	13	2	241958	294	3.44
CML269_CML264	636	36	13	2	239064	244.6	1.172
CML269_CML264	14	1	14	2	241288	292	2.732
CML269_CML264	23	2	14	2	239052	252.8	2.35
CML269_CML264	59	4	14	2	241340	302	3.563
CML269_CML264	86	5	14	2	241979	270	0.909
CML269_CML264	95	6	14	2	238930	268	0.891
CML269_CML264	122	7	14	2	241425	295	2.09
CML269_CML264	131	8	14	2	241457	269	3.652
CML269_CML264	167	10	14	2	241982	263.4	3.414
CML269_CML264	203	12	14	2	241309	292	3.151
CML269_CML264	230	13	14	2	241481	266	2.64
CML269_CML264	239	14	14	2	241576	270	1.384
CML269_CML264	266	15	14	2	241923	271.6	2.522
CML269_CML264	275	16	14	2	241150	283	4.046
CML269_CML264	302	17	14	2	241447	276	3.016
CML269_CML264	338	19	14	2	241484	283	7.744
CML269_CML264	347	20	14	2	241756	269	2.129
CML269_CML264	374	21	14	2	242776	236	2.417
CML269_CML264	383	22	14	2	241965	287	3.068
CML269_CML264	419	24	14	2	240688	254	3.575
CML269_CML264	446	25	14	2	238845	290	2.845
CML269_CML264	455	26	14	2	239229	282	8.662
CML269_CML264	491	28	14	2	239976	261	3.51
CML269_CML264	554	31	14	2	239081	256	3.941
CML269_CML264	563	32	14	2	241799	262	2.032
CML269_CML264	590	33	14	2	238942	287.6	2.752
CML269_CML264	599	34	14	2	241266	296.6	4.429
CML269_CML264	15	1	15	2	241086	271	4.963
CML269_CML264	51	3	15	2	241618	247.6	1.111
CML269_CML264	58	4	15	2	241545	255	2.524
CML269_CML264	87	5	15	2	241336	260	2.948
CML269_CML264	123	7	15	2	241449	256.2	2.329
CML269_CML264	159	9	15	2	239079	254.6	3.87
CML269_CML264	166	10	15	2	241895	279.8	2.543
CML269_CML264	202	12	15	2	241431	289	2.336
CML269_CML264	238	14	15	2	238796	309	2.662
CML269_CML264	267	15	15	2	241382	275.4	4.182
CML269_CML264	274	16	15	2	240135	243	2.525
CML269_CML264	303	17	15	2	239002	283	1.09
CML269_CML264	310	18	15	2	242787	229.6	2.466
CML269_CML264	339	19	15	2	241472	248	1.205
CML269_CML264	375	21	15	2	241342	277.6	3.728
CML269_CML264	382	22	15	2	241319	279	1.67
CML269_CML264	411	23	15	2	241951	274	2.546
CML269_CML264	418	24	15	2	241507	252	2.247
CML269_CML264	447	25	15	2	238798	266	2.258
CML269_CML264	483	27	15	2	238657	282	2.116
CML269_CML264	490	28	15	2	241353	256.6	2.872
CML269_CML264	526	30	15	2	240887	255	1.702
CML269_CML264	555	31	15	2	241625	240	2.896
CML269_CML264	562	32	15	2	238745	289	2.688
CML269_CML264	598	34	15	2	238715	279	2.49
CML269_CML264	627	35	15	2	238975	286	3.97

CML269_CML264	21	2	16	2	241181	248.2	3.647
CML269_CML264	52	3	16	2	241946	266	1.535
CML269_CML264	93	6	16	2	242535	243	2.817
CML269_CML264	129	8	16	2	242273	240	2.779
CML269_CML264	165	10	16	2	241938	282	3.461
CML269_CML264	196	11	16	2	241792	281.6	3.555
CML269_CML264	201	12	16	2	241988	293	2.036
CML269_CML264	237	14	16	2	241151	269	1.687
CML269_CML264	304	17	16	2	238852	274	2.111
CML269_CML264	309	18	16	2	241872	244.6	1.791
CML269_CML264	345	20	16	2	238830	268	2.914
CML269_CML264	376	21	16	2	238700	252	2.019
CML269_CML264	417	24	16	2	241541	262	2.259
CML269_CML264	448	25	16	2	241562	258	1.677
CML269_CML264	453	26	16	2	241300	293	2.363
CML269_CML264	484	27	16	2	241626	241	3.948
CML269_CML264	520	29	16	2	241129	282	3.769
CML269_CML264	525	30	16	2	241257	272	2.816
CML269_CML264	561	32	16	2	241419	274.8	3.14
CML269_CML264	592	33	16	2	239090	246	4.759
CML269_CML264	597	34	16	2	238923	280.4	2.292
CML269_CML264	628	35	16	2	241399	279	3.195
CML269_CML264	633	36	16	2	241184	300	8.845
CML269_CML264	20	2	17	2	240329	271.6	3.525
CML269_CML264	56	4	17	2	242269	234	1.749
CML269_CML264	89	5	17	2	242023	264	1.304
CML269_CML264	125	7	17	2	238638	258	1.078
CML269_CML264	161	9	17	2	241957	241.4	1.792
CML269_CML264	197	11	17	2	238779	245	1.098
CML269_CML264	200	12	17	2	241306	297	2.032
CML269_CML264	236	14	17	2	238964	270.4	3.405
CML269_CML264	341	19	17	2	241548	255.6	2.212
CML269_CML264	344	20	17	2	239969	254	2.275
CML269_CML264	377	21	17	2	241422	280	2.843
CML269_CML264	413	23	17	2	241433	292	4.161
CML269_CML264	449	25	17	2	239983	280	2.316
CML269_CML264	485	27	17	2	239087	246	2.81
CML269_CML264	488	28	17	2	241582	268	3.932
CML269_CML264	521	29	17	2	242020	262	2.729
CML269_CML264	524	30	17	2	241456	284	4.222
CML269_CML264	557	31	17	2	241471	286	3.751
CML269_CML264	560	32	17	2	242413	268	2.308
CML269_CML264	596	34	17	2	242009	286.4	2.874
CML269_CML264	629	35	17	2	238989	272	2.579
CML269_CML264	632	36	17	2	238877	267	3.552
CML269_CML264	54	3	18	2	238683	211.4	1.392
CML269_CML264	55	4	18	2	239083	243	2.172
CML269_CML264	90	5	18	2	238938	277	1.944
CML269_CML264	91	6	18	2	241539	284	3.015
CML269_CML264	162	9	18	2	239061	222.6	1.921
CML269_CML264	234	13	18	2	241249	258	2.717
CML269_CML264	271	16	18	2	239078	222.6	1.813
CML269_CML264	307	18	18	2	238786	223	2.16
CML269_CML264	343	20	18	2	241155	270	3.149
CML269_CML264	378	21	18	2	241811	274	4.052
CML269_CML264	379	22	18	2	241119	258	2.223
CML269_CML264	414	23	18	2	241451	235	2.446

CML269_CML264	415	24	18	2	242251	213	3.075
CML269_CML264	450	25	18	2	241490	286	2.1
CML269_CML264	486	27	18	2	241835	248	2.985
CML269_CML264	558	31	18	2	238828	271	3.41
CML269_CML264	559	32	18	2	239016	273.6	4.366
CML269_CML264	594	33	18	2	238722	290.2	4.735
CML269_CML264	595	34	18	2	241343	261.6	2.724
CML269_CML264	631	36	18	2	241611	250	3.059
CML373_CML311	145	9	1	2	242227	261	2.312
CML373_CML311	611	34	2	2	242227	260	5.586
CML373_CML311	147	9	3	2	242227	270.4	4.404
CML373_CML311	430	24	3	2	242095	277	2.826
CML373_CML311	573	32	4	2	242631	253	2.476
CML373_CML311	6	1	6	2	242838	201	2.667
CML373_CML311	516	29	12	2	242712	259	2.1
CML373_CML311	589	33	13	2	239410	238	1.205
CML373_CML311	626	35	14	2	242528	288	2.328
CML373_CML311	231	13	15	2	242797	272.4	1.465
CML373_CML311	160	9	16	2	238704	264	1.49
CML373_CML311	164	10	17	2	242142	248.2	1.312
CML373_CML311	380	22	17	2	242786	240	3.126
CML373_CML311	19	2	18	2	242146	248	4.454
CML451_CML486	108	6	1	2	242483	297	1.161
CML451_CML486	469	27	1	2	241843	256	1.232
CML451_CML486	35	2	2	2	241851	268.6	1.681
CML451_CML486	179	10	2	2	242104	273	6.663
CML451_CML486	363	21	3	2	242053	267.4	2.057
CML451_CML486	177	10	4	2	242104	261.6	7.97
CML451_CML486	256	15	4	2	242488	275	0.831
CML451_CML486	321	18	4	2	241767	237.8	0.997
CML451_CML486	645	36	4	2	241845	270	1.535
CML451_CML486	68	4	5	2	241795	270	2.405
CML451_CML486	248	14	5	2	241769	288	1.131
CML451_CML486	284	16	5	2	241820	264	3.356
CML451_CML486	464	26	5	2	241861	255	3.034
CML451_CML486	617	35	5	2	241974	275	1.676
CML451_CML486	222	13	6	2	241891	264	1.375
CML451_CML486	247	14	6	2	241842	260	1.232
CML451_CML486	427	24	6	2	241855	268	1.809
CML451_CML486	474	27	6	2	241805	241	1.104
CML451_CML486	618	35	6	2	242083	302	2.412
CML451_CML486	606	34	7	2	242104	292	6.008
CML451_CML486	80	5	8	2	241770	272	1.209
CML451_CML486	461	26	8	2	241763	252	1.921
CML451_CML486	316	18	9	2	241945	224	1.28
CML451_CML486	118	7	10	2	242126	296	1.848
CML451_CML486	622	35	10	2	241829	252.6	2.262
CML451_CML486	227	13	11	2	241875	281	2.033
CML451_CML486	422	24	11	2	241886	269	3.133
CML451_CML486	443	25	11	2	241881	237.6	1.683
CML451_CML486	551	31	11	2	242104	269	2.751
CML451_CML486	587	33	11	2	241896	276	3.245
CML451_CML486	602	34	11	2	241925	265	1.384
CML451_CML486	12	1	12	2	242057	236	3.532
CML451_CML486	25	2	12	2	241937	282	1.852
CML451_CML486	337	19	13	2	242104	246	2.991
CML451_CML486	194	11	14	2	241916	297	2.326

CML451_CML486	340	19	16	2	241768	273	1.202
CML451_CML486	412	23	16	2	242147	277	3.368
CML451_CML486	233	13	17	2	242058	285	3.468
CML451_CML486	163	10	18	2	242105	325	4.3
CML451_CML486	198	11	18	2	242137	265	3.073
CML451_CML486	199	12	18	2	241898	238.4	2.379
CML451_CML486	487	28	18	2	242130	260	4.674
CML451_CML486	522	29	18	2	242114	268	5.159
CML495_CML494	216	12	1	2	238697	288	1.499
CML495_CML494	360	20	1	2	238667	281	5.77
CML495_CML494	146	9	2	2	242259	262	1.178
CML495_CML494	287	16	2	2	241308	283	1.733
CML495_CML494	219	13	3	2	241321	280	1.779
CML495_CML494	286	16	3	2	241528	282	1.314
CML495_CML494	435	25	3	2	238684	286	2.471
CML495_CML494	507	29	3	2	238672	300	3.202
CML495_CML494	646	36	3	2	238667	291	5.73
CML495_CML494	4	1	4	2	238797	248	4.016
CML495_CML494	33	2	4	2	242804	251	1.632
CML495_CML494	357	20	4	2	240319	265	1.13
CML495_CML494	41	3	5	2	241188	289	2.041
CML495_CML494	77	5	5	2	241646	280	4.34
CML495_CML494	113	7	5	2	238719	293	1.272
CML495_CML494	140	8	5	2	241165	276.2	4.013
CML495_CML494	78	5	6	2	238667	290	7.113
CML495_CML494	103	6	6	2	241310	267	0.83
CML495_CML494	139	8	6	2	241190	300	1.187
CML495_CML494	283	16	6	2	238639	305	2.625
CML495_CML494	402	23	6	2	241073	282	1.599
CML495_CML494	499	28	6	2	242739	267	1.67
CML495_CML494	174	10	7	2	241233	279	2.811
CML495_CML494	295	17	7	2	241370	302	4.963
CML495_CML494	426	24	7	2	238748	279.4	1.923
CML495_CML494	498	28	7	2	241392	264	1.198
CML495_CML494	534	30	7	2	241557	303	3.59
CML495_CML494	583	33	7	2	238650	303	5.695
CML495_CML494	619	35	7	2	241397	278	2.579
CML495_CML494	173	10	8	2	241334	270	2.092
CML495_CML494	209	12	8	2	241076	290	4.933
CML495_CML494	245	14	8	2	238751	256	1.65
CML495_CML494	440	25	8	2	238962	269	3.196
CML495_CML494	81	5	9	2	241122	263.6	2.124
CML495_CML494	172	10	9	2	238787	286.6	2.218
CML495_CML494	352	20	9	2	242287	247	2.636
CML495_CML494	477	27	9	2	238721	232	1.293
CML495_CML494	82	5	10	2	241234	244	1.563
CML495_CML494	99	6	10	2	241638	300	3.295
CML495_CML494	387	22	10	2	241633	238	2.419
CML495_CML494	442	25	10	2	241572	292	1.428
CML495_CML494	515	29	11	2	238667	284	6.381
CML495_CML494	120	7	12	2	238667	287	4.499
CML495_CML494	192	11	12	2	242466	297	3.674
CML495_CML494	205	12	12	2	242801	259	1.131
CML495_CML494	336	19	12	2	241169	256	3.594
CML495_CML494	421	24	12	2	241260	288	3.549
CML495_CML494	457	26	12	2	238676	268	3.771
CML495_CML494	24	2	13	2	241430	294	3.058

CML495_CML494 96 6 13 2 241090 296 6.741
 CML495_CML494 157 9 13 2 241272 276 1.734
 CML495_CML494 168 10 13 2 241470 300 1.43
 CML495_CML494 625 35 13 2 238694 287 1.873
 CML495_CML494 50 3 14 2 241462 269 5.409
 CML495_CML494 410 23 14 2 241501 293 5.04
 CML495_CML494 527 30 14 2 241458 279 3.375
 CML495_CML494 94 6 15 2 242456 271 4.715
 CML495_CML494 454 26 15 2 239419 294 1.324
 CML495_CML494 591 33 15 2 241647 288 5.649
 CML495_CML494 634 36 15 2 241364 298 3.453
 CML495_CML494 124 7 16 2 241428 272 2.473
 CML495_CML494 489 28 16 2 241207 299 4.598
 CML495_CML494 53 3 17 2 241381 242 2.286
 CML495_CML494 128 8 17 2 241657 271 2.925
 CML495_CML494 272 16 17 2 238690 268.6 1.095
 CML495_CML494 308 18 17 2 241072 282 4.06
 CML495_CML494 452 26 17 2 238785 253 1.798
 CML495_CML494 235 14 18 2 240827 254 2.734
 CML495_CML494 342 19 18 2 238677 285 1.581
 CML495_CML494 523 30 18 2 242800 246 2.107
 Check1 38 3 2 1 1 268.6 2.221
 Check2 47 3 11 1 1 266 3.458
 Check2 66 4 7 1 1 277.4 4.238
 Check4 57 4 16 1 1 249.2 3.28
 Check3 84 5 12 1 1 258.2 2.423
 Check4 75 5 3 1 1 277.4 2.1
 Check2 101 6 8 1 1 269 4.084
 Check4 92 6 17 1 1 260 2.249
 Check3 121 7 13 1 1 265.4 1.97
 Check4 112 7 4 1 1 262.8 1.39
 CHIS474 116 7 8 3 28862 301 1.172
 . 8 1 8 1 . . .
 Check1 127 8 18 1 1 263.4 3.272
 Check3 136 8 9 1 1 253 2.326
 Check1 149 9 5 1 1 264 2.351
 Check2 158 9 14 1 1 270 4.248
 Check3 171 10 10 1 1 272.2 3.008
 Check4 180 10 1 1 1 246 1.996
 . 11 1 11 1 . . .
 Check2 195 11 15 1 1 272 3.236
 Check3 186 11 6 1 1 253.8 2.041
 Check1 206 12 11 1 1 249 3.946
 Check2 215 12 2 1 1 283 3.377
 Check1 232 13 16 1 1 266 2.88
 Check4 223 13 7 1 1 274 1.953
 Check3 241 14 12 1 1 271.6 2.191
 Check4 250 14 3 1 1 283 2.398
 Check1 260 15 8 1 1 273 3.213
 Check2 269 15 17 1 1 274 3.962
 . 16 1 16 1 . . .
 Check2 276 16 13 1 1 276 4.653
 Check3 285 16 4 1 1 259.6 1.655
 . 17 1 17 1 . . .
 Check3 306 17 18 1 1 251.6 2.566
 Check4 297 17 9 1 1 259 2.305
 CHIS474 305 17 17 3 28862 312 3.356

```

. 18 1 18 1 . . .
Check1 311 18 14 1 1 267 3.424
Check4 320 18 5 1 1 248 1.719
Check2 325 19 1 1 1 262.8 2.276
Check4 334 19 10 1 1 267 3.337
Check1 346 20 15 1 1 259.4 2.428
Check4 355 20 6 1 1 255 1.131
Check1 362 21 2 1 1 271 3.115
Check3 371 21 11 1 1 261 2.871
Check2 390 22 7 1 1 279 4.06
Check3 381 22 16 1 1 266 3.234
Check2 399 23 3 1 1 273.4 4.425
Check4 408 23 12 1 1 260 2.49
. 429 24 4 1 . . .
Check1 416 24 17 1 1 251 3.763
Check3 425 24 8 1 1 263 3.701
Check1 445 25 13 1 1 283 4.19
Check4 436 25 4 1 1 263 2.626
Check2 460 26 9 1 1 273.4 4.859
Check4 451 26 18 1 1 251 2.633
Check2 473 27 5 1 1 268.4 3.822
Check3 482 27 14 1 1 258 2.736
Check1 504 28 1 1 1 274.8 2.261
Check2 495 28 10 1 1 266.4 4.136
Check2 510 29 6 1 1 274 3.871
Check3 519 29 15 1 1 266 2.665
CHIS474 511 29 7 3 28862 287 2.137
Check3 539 30 2 1 1 262 1.982
Check4 530 30 11 1 1 273 2.904
Check1 547 31 7 1 1 288 3.022
Check4 556 31 16 1 1 272 3.13
Check1 574 32 3 1 1 280 3.435
Check2 565 32 12 1 1 286 3.963
Check3 593 33 17 1 1 268 3.576
Check4 584 33 8 1 1 283.6 2.496
Check2 609 34 4 1 1 285.4 4.265
Check3 600 34 13 1 1 272.8 2.325
Check1 621 35 9 1 1 275.6 2.557
Check2 630 35 18 1 1 255 4.281
CHIS474 614 35 2 3 28862 272.2 1.955
Check1 644 36 5 1 1 276.2 2.841
Check4 635 36 14 1 1 272 3.397
. 62 4 11 1 . . .
GUAT153 76 5 4 3 8345 332 2.362
GUER208 88 5 16 3 28897 302 1.446
. 126 7 18 1 . . .
OAXA280 130 8 15 3 17602 312 1.114
GUER208 189 11 9 3 28897 297 2.631
GUAT153 244 14 9 3 8345 307 1.819
. 268 15 16 1 . . .
GUER208 270 15 18 3 28897 300 2.601
. 273 16 16 1 . . .
. 364 21 4 1 . . .
. 365 21 5 1 . . .
. 366 21 6 1 . . .
. 367 21 7 1 . . .
GUAT153 512 29 8 3 8345 294.6 3.3

```

```
OAXA280 518 29 14 3 17602 279 1.139
GUER208 604 34 9 3 28897 255 0.256 :
```

```
" *** Analysis of plant height: AR1 (x) AR1 (Table 6) ***"
VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
  Row.Col
VSTRUCTURE [TERMS=Row.Col] FACTOR=Row,Col; MODEL=ar,ar; ORDER=1,1
REML [PRINT=model,components,deviance,waldTests; \
  MVINCLUDE=explanatory,yvariate] Plh
" Note: Option MVINCLUDE is used to retain the balanced structure of
  the data, thereby ensuring an extra error term isn't unintentionally
  fitted. "
" AIC and BIC "
VAIC [PRINT=aic,bic]
" 2D variogram (i.e. semi-variance) "
VKEEP [RESIDUAL=residualPlh]
F2DRESIDUALVARIOGRAM [ROW=Row; COL=Col] residualPlh

" *** Analysis of grain yield: AR1 (x) AR1 (Table 7) *** "
VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
  Row.Col
VSTRUCTURE [TERMS=Row.Col] FACTOR=Row,Col; MODEL=ar,ar; ORDER=1,1
REML [PRINT=model,components,deviance,waldTests; \
  MVINCLUDE=explanatory,yvariate] PGrhah
" AIC and BIC "
VAIC [PRINT=aic,bic]

" *** Analysis of grain yield: linear random effects in row and
  column directions (Table 8) *** "
VARIATE RowV; VALUES=Row
VARIATE ColV; VALUES=Col
VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
  RowV+ColV
REML [PRINT=model,components,deviance,waldTests] PGrhah
" AIC and BIC "
VAIC [PRINT=aic,bic]

" *** Analysis of grain yield: row and column random effects
  (Table 9) *** "
VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
  Row+Col
REML [PRINT=model,components,deviance,waldTests] PGrhah
" AIC and BIC "
VAIC [PRINT=aic,bic]

ENDJOB
```

Genstat Output from Example 2

```

2  " ***** "
3  "   Example 2:  Un-replicated Maize trial   "
4  " ***** "
5
6  " Expt design: Augmented design (see Example 2 in the Augmented
-7    Designs chapter)"
8
9  JOB

```

End of job.

```

10
11  " Load the data, where Tester, Plot, Row, Col, Group and Acc
-12    are factors "
13  FACTOR Tester, Plot, Row, Col, Group, Acc
14  READ [SETLEVELS=yes; MISSING='.'] Tester, Plot, Row, Col, Group, \
15    Acc, Plh, PGrhah; FREPRESENTATION=labels,levels,levels,levels,\
16    levels,*,*,*

```

Identifier	Minimum	Mean	Maximum	Values	Missing
Plh	197.4	270.3	332.0	648	15
PGrhah	0.2560	2.701	8.845	648	17

Identifier	Values	Missing	Levels
Tester	648	15	12
Plot	648	0	648
Row	648	0	36
Col	648	0	18
Group	648	0	3
Acc	648	15	540

```

665
666  " *** Analysis of plant height: AR1 (x) AR1 (Table 6) ***"
667  VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
668    Row.Col
669  VSTRUCTURE [TERMS=Row.Col] FACTOR=Row,Col; MODEL=ar,ar; ORDER=1,1
670  REML [PRINT=model,components,deviance,waldTests; \
671    MVINCLUDE=explanatory,yvariate] Plh

```

REML variance components analysis

Response variate: Plh
 Fixed model: Constant + Group + Group.Tester
 Random model: Acc.Group.Tester + Row.Col
 Number of units: 648

Row.Col used as residual term with covariance structure as below

Sparse algorithm with AI optimisation

Units with missing factor/covariate values included

- specific effect for term(s) omitted for units with missing values in Acc, Tester

Units with missing data values included

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No. rows
Row.Col	Row	Auto-regressive (+ scalar)	1	36
	Col	Auto-regressive	1	18

Estimated variance components

Random term	component	s.e.
Acc.Group.Tester	248.9	28.6

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
Row.Col			Sigma2	146.3	20.6
	Row	AR(1)	phi_1	0.2039	0.0851
	Col	AR(1)	phi_1	0.3999	0.0768

Deviance: -2*Log-Likelihood

Deviance	d.f.
4255.64	617

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group	9.68	2	4.84	204.2	0.009
Group.Tester	19.52	9	2.17	270.5	0.025

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group.Tester	19.52	9	2.17	270.5	0.025

Message: denominator degrees of freedom for approximate F-tests are calculated using numerical derivatives ignoring fixed/boundary/singular variance parameters.

```

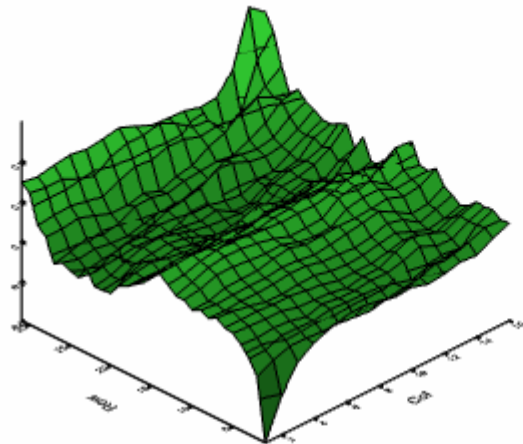
672 " Note: Option MVINCLUDE is used to retain the balanced structure of
-673 the data, thereby ensuring an extra error term isn't unintentionally
-674 fitted. "
675 " AIC and BIC "
676 VAIC [PRINT=aic,bic]

```

Akaike information coefficient	5404.96
Schwarz Bayes information coefficient	5422.69

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
677 " 2D variogram (i.e. semi-variance) "  
678 VKEEP [RESIDUAL=residualPlh]  
679 F2DRESIDUALVARIOGRAM [ROW=Row; COL=Col] residualPlh
```



```
680  
681 " *** Analysis of grain yield: AR1 (x) AR1 (Table 7) *** "  
682 VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\  
683   Row.Col  
684 VSTRUCTURE [TERMS=Row.Col] FACTOR=Row,Col; MODEL=ar,ar; ORDER=1,1  
685 REML [PRINT=model,components,deviance,waldTests; \  
686   MVINCLUDE=explanatory,yvariate] PGrhah
```

REML variance components analysis

Response variate:	PGrhah
Fixed model:	Constant + Group + Group.Tester
Random model:	Acc.Group.Tester + Row.Col
Number of units:	648

Row.Col used as residual term with covariance structure as below

Sparse algorithm with AI optimisation

Units with missing factor/covariate values included

- specific effect for term(s) omitted for units with missing values in Acc, Tester

Units with missing data values included

Covariance structures defined for random model

Covariance structures defined within terms:

Term	Factor	Model	Order	No. rows
Row.Col	Row	Auto-regressive (+ scalar)	1	36
	Col	Auto-regressive	1	18

Estimated variance components

Random term	component	s.e.
Acc.Group.Tester	0.7063	0.1040

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
Row.Col			Sigma2	0.628	0.0795
	Row	AR(1)	phi_1	0.07481	0.07378
	Col	AR(1)	phi_1	-0.04489	0.07387

Deviance: -2*Log-Likelihood

Deviance	d.f.
764.64	615

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group	3.28	2	1.64	145.0	0.198
Group.Tester	6.53	9	0.72	214.5	0.687

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group.Tester	6.53	9	0.72	214.5	0.687

Message: denominator degrees of freedom for approximate F-tests are calculated using numerical derivatives ignoring fixed/boundary/singular variance parameters.

```
687 " AIC and BIC "
688 VAIC [PRINT=aic,bic]
```

Akaike information coefficient	1910.29
Schwarz Bayes information coefficient	1928.00

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```

689
690 " *** Analysis of grain yield: linear random effects in row and
-691      column directions (Table 8) *** "
692 VARIATE RowV; VALUES=Row
693 VARIATE ColV; VALUES=Col
694 VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
695      RowV+ColV
696 REML [PRINT=model,components,deviance,waldTests] PGrhah

```

REML variance components analysis

Response variate: PGrhah
 Fixed model: Constant + Group + Group.Tester
 Random model: Acc.Group.Tester + RowV + ColV
 Number of units: 631 (17 units excluded due to zero weights or missing values)

Residual term has been added to model

Sparse algorithm with AI optimisation
 All covariates centred

Estimated variance components

Random term	component	s.e.
Acc.Group.Tester	0.6957	0.1001
RowV	0.0001	0.0001
ColV	0.0013	0.0019

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.593	0.0756

Deviance: $-2 \times \text{Log-Likelihood}$

Deviance	d.f.
747.30	615

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group	3.42	2	1.71	150.6	0.184
Group.Tester	7.68	9	0.85	220.6	0.568

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group.Tester	7.68	9	0.85	220.6	0.568

Message: denominator degrees of freedom for approximate F-tests are calculated using numerical derivatives ignoring fixed/boundary/singular variance parameters.

```
697 " AIC and BIC "
698 VAIC [PRINT=aic,bic]
```

Akaike information coefficient	1892.94
Schwarz Bayes information coefficient	1910.65

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
699
700 " *** Analysis of grain yield: row and column random effects
-701 (Table 9) *** "
702 VCOMPONENTS [FIXED=Group+Group.Tester] RANDOM=Acc.Group.Tester+\
703 Row+Col
704 REML [PRINT=model,components,deviance,waldTests] PGrhah
```

REML variance components analysis

Response variate: PGrhah
Fixed model: Constant + Group + Group.Tester
Random model: Acc.Group.Tester + Row + Col
Number of units: 631 (17 units excluded due to zero weights or missing values)

Residual term has been added to model

Sparse algorithm with AI optimisation

Estimated variance components

Random term	component	s.e.
Acc.Group.Tester	0.7125	0.0998
Row	0.0325	0.0226
Col	0.0598	0.0311

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	0.535	0.0752

Deviance: -2*Log-Likelihood

Deviance	d.f.
750.16	615

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group	3.70	2	1.85	156.1	0.161
Group.Tester	7.26	9	0.81	226.4	0.612

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Group.Tester	7.26	9	0.81	226.4	0.612

Message: denominator degrees of freedom for approximate F-tests are calculated using numerical derivatives ignoring fixed/boundary/singular variance parameters.

```
705 " AIC and BIC "  
706 VAIC [PRINT=aic,bic]
```

Akaike information coefficient	1895.81
Schwarz Bayes information coefficient	1913.52

Note: omits constant, $-\log(\det(X'X))$, that depends only on the fixed model.

```
707  
708 ENDJOB
```

End of job.

Chapter 13. Augmented Designs - Experimental Designs in which All Treatments are not Replicated by Juan Burgueño, José Crossa, Francisco Rodríguez, and Kathleen M. Yeater

Genstat code developed by Vanessa M. Cave and output are provided here for the five different analyses of the completely randomized design with un-replicated treatments example presented in Chapter 13.

Note: Augmented designs can be formed in Genstat using the AFAUGMENTED procedure.

Completely randomized design with un-replicated treatments

Genstat Commands

```
" ***** "  
"    Completely randomized design with un-replicated treatments    "  
" ***** "
```

JOB

```
" Load the data, where t, d1 and d2 are factors "  
FACTOR t, d1, d2  
READ [SETLEVELS=yes] t, d1, d2, y ; FREPRESENTATION=labels  
C1 1 1 22  
C1 1 1 21  
C1 1 1 24  
C2 2 1 29  
C2 2 1 26  
C2 2 1 28  
G3 3 2 28  
G4 3 2 32  
G5 3 2 27  
G6 3 2 38  
G7 3 2 35  
G8 3 2 28 :  
  
"*** Model P1-f ***"  
CAPTION 'P1-f'; STYLE=meta  
VCOMPONENTS [FIXED=t]  
REML [PRINT=model,components,means,waldTests,deviance,effects; \  
      PSE=allemimates] y  
" Comparison between two replicated treatments (checks): C1 vs C2 "  
TABLE [CLASSIFICATION=t] Ch; VALUES=!(1,-1,0,0,0,0,0,0)  
VTCOMPARISON Ch  
" Comparison between two un-replicated treatments: G3 vs G4 "  
TABLE [CLASSIFICATION=t] UnT; VALUES=!(0,0,1,-1,0,0,0,0)  
VTCOMPARISON UnT  
" Comparison between a replicated and an un-replicated treatment:  
  C1 vs G3 "  
TABLE [CLASSIFICATION=t] Ch_UnT; VALUES=!(1,0,-1,0,0,0,0,0)  
VTCOMPARISON Ch_UnT
```

```

DELETE [REDEFINE=y] Ch, UnT, Ch_UnT

"*** Model P2-f ***"
CAPTION 'P2-f'; STYLE=meta
VCOMPONENTS [FIXED=d1/t]
REML [PRINT=model,components,means,waldTests,deviance,effects; \
      PSE=allestimates] y
" d1 means (averaged over present combinations of d1.t) "
VPREDICT [PRESENT=d1,t] d1
" Comparison between two replicated treatments (checks): C1 vs C2 "
TABLE [CLASSIFICATION=d1,t] Ch; VALUES=!(1,0,0,0,0,0,0,0,\
                                           0,-1,0,0,0,0,0,0,\
                                           0,0,0,0,0,0,0,0)

VTCOMPARISON Ch
" Comparison between two un-replicated treatments: G3 vs G4 "
TABLE [CLASSIFICATION=d1,t] UnT; VALUES=!(0,0,0,0,0,0,0,0,\
                                           0,0,0,0,0,0,0,0,\
                                           0,0,1,-1,0,0,0,0)

VTCOMPARISON UnT
" Comparison between a replicated and an un-replicated treatment:
  C1 vs G3 "
TABLE [CLASSIFICATION=d1,t] Ch_UnT; VALUES=!(1,0,0,0,0,0,0,0,\
                                           0,0,0,0,0,0,0,0,\
                                           0,0,-1,0,0,0,0,0)

VTCOMPARISON Ch_UnT
DELETE [REDEFINE=y] Ch, UnT, Ch_UnT

"*** Model P3-f ***"
CAPTION 'P3-f'; STYLE=meta
VCOMPONENTS [FIXED=d2/t]
REML [PRINT=model,components,means,waldTests,deviance,effects; \
      PSE=allestimates] y
" d2 means (averaged over present combinations of d2.t) "
VPREDICT [PRESENT=d2,t] d2
" Comparison between two replicated treatments (checks): C1 vs C2 "
TABLE [CLASSIFICATION=d2,t] Ch; VALUES=!(1,-1,0,0,0,0,0,0,\
                                           0,0,0,0,0,0,0,0)

VTCOMPARISON Ch
" Comparison between two un-replicated treatments: G3 vs G4 "
TABLE [CLASSIFICATION=d2,t] UnT; VALUES=!(0,0,0,0,0,0,0,0,\
                                           0,0,1,-1,0,0,0,0)

VTCOMPARISON UnT
" Comparison between a replicated and an un-replicated treatment:
  C1 vs G3 "
TABLE [CLASSIFICATION=d2,t] Ch_UnT; VALUES=!(1,0,0,0,0,0,0,0,\
                                           0,0,-1,0,0,0,0,0)

VTCOMPARISON Ch_UnT
DELETE [REDEFINE=y] Ch, UnT, Ch_UnT

"*** Model P2-r ***"
CAPTION 'P2-r'; STYLE=meta
VCOMPONENTS [FIXED=d1] RANDOM=d1.t
REML [PRINT=model,components,means,waldTests,deviance,effects; \
      PSE=allestimates; PTERMS=d1+d1.t; METHOD=Fisher] y
" Comparison between two replicated treatments (checks): C1 vs C2 "
TABLE [CLASSIFICATION=d1,t] Ch; VALUES=!(1,0,0,0,0,0,0,0,\
                                           0,-1,0,0,0,0,0,0,\
                                           0,0,0,0,0,0,0,0)

```



```

0,0,0,0,0,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch
" Comparison between two un-replicated treatments: G3 vs G4 "
TABLE [CLASSIFICATION=d1,t] UnT; VALUES=(0,0,0,0,0,0,0,0,\
0,0,0,0,0,0,0,0,\
0,0,1,-1,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] UnT
" Comparison between a replicated and an un-replicated treatment:
  C1 vs G3 "
TABLE [CLASSIFICATION=d1,t] Ch_UnT; VALUES=(1,0,0,0,0,0,0,0,\
0,0,0,0,0,0,0,0,\
0,0,-1,0,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch_UnT
DELETE [REDEFINE=y] Ch, UnT, Ch_UnT

"*** Model P3-r ***"
CAPTION 'P3-r'; STYLE=meta
VCOMPONENTS [FIXED=d2] RANDOM=d2.t
REML [PRINT=model,components,means,waldTests,deviance,effects; \
PSE=allestimates; PTERMS=d2+d2.t; METHOD=Fisher] y
" Comparison between two replicated treatments (checks): C1 vs C2 "
TABLE [CLASSIFICATION=d2,t] Ch; VALUES=(1,-1,0,0,0,0,0,0,\
0,0,0,0,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch
" Comparison between two un-replicated treatments: G3 vs G4 "
TABLE [CLASSIFICATION=d2,t] UnT; VALUES=(0,0,0,0,0,0,0,0,\
0,0,1,-1,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] UnT
" Comparison between a replicated and an un-replicated treatment:
  C1 vs G3 "
TABLE [CLASSIFICATION=d2,t] Ch_UnT; VALUES=(1,0,0,0,0,0,0,0,\
0,0,-1,0,0,0,0,0)
VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch_UnT
DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
"Note: Genstat does not have the limitation of SAS with regards to
the estimation of standard errors for BLUP contrasts from
models with nested random effects. Therefore, the use of the
switch variable method is not required."

ENDJOB

```

Genstat Output

```

2 " ***** "
3 "    Completely randomized design with un-replicated treatments    "
4 " ***** "
5
6 JOB
7
8 " Load the data, where t, d1 and d2 are factors "
9 FACTOR t, d1, d2
10 READ [SETLEVELS=yes] t, d1, d2, y ; FREPRESENTATION=labels

```

Identifier	Minimum	Mean	Maximum	Values	Missing
y	21.00	28.17	38.00	12	0

Identifier	Values	Missing	Levels
t	12	0	8
d1	12	0	3
d2	12	0	2

```

23
24  """ Model P1-f """
25  CAPTION 'P1-f'; STYLE=meta

```

P1-f

```

26  VCOMPONENTS [FIXED=t]
27  REML [PRINT=model,components,means,waldTests,deviance,effects; \
28      PSE=allemimates] y

```

REML variance components analysis

Response variate: y
Fixed model: Constant + t
Number of units: 12

Residual term has been added to model

Sparse algorithm with AI optimisation

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.333	1.650

Deviance: -2*Log-Likelihood

Deviance	d.f.
9.59	3

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
t	112.43	7	16.06	4.0	0.009

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
t	112.43	7	16.06	4.0	0.009

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

22.33 Standard error: 0.882

Table of effects for t

t	C1	C2	G3	G4	G5	G6	G7	G8
	0.000	5.333	5.667	9.667	4.667	15.667	12.667	5.667

Standard errors

t	C1	C2	G3	G4	G5	G6	G7	G8
	0.000	1.247	1.764	1.764	1.764	1.764	1.764	1.764

Standard errors

Average:	1.690
Maximum:	1.764
Minimum:	1.247

Table of predicted means for Constant

29.75 Standard error: 0.493

Table of predicted means for t

t	C1	C2	G3	G4	G5	G6	G7	G8
	22.33	27.67	28.00	32.00	27.00	38.00	35.00	28.00

Standard errors

t	C1	C2	G3	G4	G5	G6	G7	G8
	0.88	0.88	1.53	1.53	1.53	1.53	1.53	1.53

Standard errors

Average:	1.366
Maximum:	1.528
Minimum:	0.8819

```

29 " Comparison between two replicated treatments (checks): C1 vs C2 "
30 TABLE [CLASSIFICATION=t] Ch; VALUES=(1,-1,0,0,0,0,0,0)
31 VTCOMPARISON Ch

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch	-5.333	1.247	-4.28	4.00	0.013

```

32 " Comparison between two un-replicated treatments: G3 vs G4 "
33 TABLE [CLASSIFICATION=t] UnT; VALUES=(0,0,1,-1,0,0,0,0)
34 VTCOMPARISON UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
UnT	-4.000	2.160	-1.85	4.00	0.138

```

35 " Comparison between a replicated and an un-replicated treatment:
-36 C1 vs G3 "
37 TABLE [CLASSIFICATION=t] Ch_UnT; VALUES=(1,0,-1,0,0,0,0,0)
38 VTCOMPARISON Ch_UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch_UnT	-5.667	1.764	-3.21	4.00	0.033

```

39 DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
40
41 "*** Model P2-f ***"
42 CAPTION 'P2-f'; STYLE=meta

```

P2-f

```

43 VCOMPONENTS [FIXED=d1/t]
44 REML [PRINT=model,components,means,waldTests,deviance,effects; \
45     PSE=alallestimates] y

```

REML variance components analysis

Response variate: y
Fixed model: Constant + d1 + d1.t
Number of units: 12

Residual term has been added to model

Sparse algorithm with AI optimisation

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.333	1.650

Deviance: -2*Log-Likelihood

Deviance	d.f.
9.59	3

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d1	69.86	2	34.93	4.0	0.003
d1.t	42.57	5	8.51	4.0	0.030

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d1.t	42.57	5	8.51	4.0	0.030

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

22.33 Standard error: 0.882

Table of effects for d1

d1	1	2	3
	0.000	5.333	5.667

Standard errors

d1	1	2	3
	0.000	1.247	1.764

Standard errors

Average: 1.506
Maximum: 1.764
Minimum: 1.247

Table of effects for d1.t

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	0.000	*	*	*	*	*	*
2	*	0.000	*	*	*	*	*
3	*	*	0.000	4.000	-1.000	10.000	7.000

t	G8
d1	
1	*
2	*
3	0.000

Standard errors

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	0.000	*	*	*	*	*	*
2	*	0.000	*	*	*	*	*
3	*	*	0.000	2.160	2.160	2.160	2.160

t	G8
d1	
1	*
2	*
3	2.160

Table of predicted means for Constant

28.50 Standard error: 0.744

Table of predicted means for d1

d1	1	2	3
	*	*	*

All values in table missing: due to missing factor combinations in higher order interactions.

Table of predicted means for d1.t

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	22.33	*	*	*	*	*	*
2	*	27.67	*	*	*	*	*
3	*	*	28.00	32.00	27.00	38.00	35.00

t	G8
d1	
1	*
2	*
3	28.00

Standard errors

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	0.88	*	*	*	*	*	*
2	*	0.88	*	*	*	*	*
3	*	*	1.53	1.53	1.53	1.53	1.53

t	G8
d1	
1	*
2	*
3	1.53

Standard errors

Average: 1.366
Maximum: 1.528
Minimum: 0.8819

```
46 " d1 means (averaged over present combinations of d1.t) "  
47 VPREDICT [PRESENT=d1,t] d1
```

Predictions from REML analysis

Model terms included for prediction: Constant + d1 + d1.t

Status of model variables in prediction:

Variable	Type	Status
t	factor	Averaged over combinations present d1.t
d1	factor	Classifies predictions
Constant	factor	Included in prediction

Response variate: y

Predictions

d1	1	2	3
	22.33	27.67	31.33

Standard errors

d1	1	2	3
	0.8819	0.8819	0.6236

Approximate average standard error of difference: 1.139 (calculated on variance scale)

```

48  " Comparison between two replicated treatments (checks): C1 vs C2 "
49  TABLE [CLASSIFICATION=d1,t] Ch; VALUES=(1,0,0,0,0,0,0,0,\
50                                           0,-1,0,0,0,0,0,0,\
51                                           0,0,0,0,0,0,0,0)
52  VTCOMPARISON Ch

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch	-5.333	1.247	-4.28	4.00	0.013

```

53  " Comparison between two un-replicated treatments: G3 vs G4 "
54  TABLE [CLASSIFICATION=d1,t] UnT; VALUES=(0,0,0,0,0,0,0,0,\
55                                           0,0,0,0,0,0,0,0,\
56                                           0,0,1,-1,0,0,0,0)
57  VTCOMPARISON UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
UnT	-4.000	2.160	-1.85	4.00	0.138

```

58  " Comparison between a replicated and an un-replicated treatment:
-59  C1 vs G3 "
60  TABLE [CLASSIFICATION=d1,t] Ch_UnT; VALUES=(1,0,0,0,0,0,0,0,\
61                                           0,0,0,0,0,0,0,0,\
62                                           0,0,-1,0,0,0,0,0)
63  VTCOMPARISON Ch_UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch_UnT	-5.667	1.764	-3.21	4.00	0.033


```

64 DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
65
66 "*** Model P3-f ***"
67 CAPTION 'P3-f'; STYLE=meta

```

P3-f

```

68 VCOMPONENTS [FIXED=d2/t]
69 REML [PRINT=model,components,means,waldTests,deviance,effects; \
70      PSE=alallestimates] y

```

REML variance components analysis

Response variate: y
 Fixed model: Constant + d2 + d2.t
 Number of units: 12

Residual term has been added to model

Sparse algorithm with AI optimisation

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.333	1.650

Deviance: -2*Log-Likelihood

Deviance	d.f.
9.59	3

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d2	51.57	1	51.57	4.0	0.002
d2.t	60.86	6	10.14	4.0	0.021

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d2.t	60.86	6	10.14	4.0	0.021

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for Constant

22.33 Standard error: 0.882

Table of effects for d2

d2	1	2
	0.000	5.667

Standard errors

d2	1	2
	0.000	1.764

Table of effects for d2.t

t	C1	C2	G3	G4	G5	G6	G7
d2							
1	0.000	5.333	*	*	*	*	*
2	*	*	0.000	4.000	-1.000	10.000	7.000

t	G8
d2	
1	*
2	0.000

Standard errors

t	C1	C2	G3	G4	G5	G6	G7
d2							
1	0.000	1.247	*	*	*	*	*
2	*	*	0.000	2.160	2.160	2.160	2.160

t	G8
d2	
1	*
2	2.160

Standard errors

Average:	2.008
Maximum:	2.160
Minimum:	1.247

Table of predicted means for Constant

28.33 Standard error: 0.583

Table of predicted means for d2

d2	1	2
	*	*

All values in table missing: due to missing factor combinations in higher order interactions.

Table of predicted means for d2.t

	t	C1	C2	G3	G4	G5	G6	G7
d2								
	1	22.33	27.67	*	*	*	*	*
	2	*	*	28.00	32.00	27.00	38.00	35.00

	t	G8
d2		
	1	*
	2	28.00

Standard errors

	t	C1	C2	G3	G4	G5	G6	G7
d2								
	1	0.88	0.88	*	*	*	*	*
	2	*	*	1.53	1.53	1.53	1.53	1.53

	t	G8
d2		
	1	*
	2	1.53

Standard errors

Average: 1.366
Maximum: 1.528
Minimum: 0.8819

```
71 " d2 means (averaged over present combinations of d2.t) "  
72 VPREDICT [PRESENT=d2,t] d2
```

Predictions from REML analysis

Model terms included for prediction: Constant + d2 + d2.t

Status of model variables in prediction:

Variable	Type	Status
t	factor	Averaged over combinations present d2.t
d2	factor	Classifies predictions
Constant	factor	Included in prediction

Response variate: y

Predictions

d2	1	2
	25.00	31.33

Standard errors

d2	1	2
	0.6236	0.6236

Approximate average standard error of difference: 0.8819 (calculated on variance scale)

```
73 " Comparison between two replicated treatments (checks): C1 vs C2 "  
74 TABLE [CLASSIFICATION=d2,t] Ch; VALUES=!(1,-1,0,0,0,0,0,0,\  
75                                         0,0,0,0,0,0,0,0)  
76 VTCOMPARISON Ch
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch	-5.333	1.247	-4.28	4.00	0.013

```
77 " Comparison between two un-replicated treatments: G3 vs G4 "  
78 TABLE [CLASSIFICATION=d2,t] UnT; VALUES=!(0,0,0,0,0,0,0,0,\  
79                                         0,0,1,-1,0,0,0,0)  
80 VTCOMPARISON UnT
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
UnT	-4.000	2.160	-1.85	4.00	0.138

```
81 " Comparison between a replicated and an un-replicated treatment:  
-82 C1 vs G3 "  
83 TABLE [CLASSIFICATION=d2,t] Ch_UnT; VALUES=!(1,0,0,0,0,0,0,0,\  
84                                         0,0,-1,0,0,0,0,0)  
85 VTCOMPARISON Ch_UnT
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch_UnT	-5.667	1.764	-3.21	4.00	0.033

```
86 DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
87
88 "*** Model P2-r ***"
89 CAPTION 'P2-r'; STYLE=meta
```

P2-r

```
90 VCOMPONENTS [FIXED=d1] RANDOM=d1.t
91 REML [PRINT=model,components,means,waldTests,deviance,effects; \
92     PSE=allemimates; PTERMS=d1+d1.t; METHOD=Fisher] y
```

REML variance components analysis

Response variate: y
Fixed model: Constant + d1
Random model: d1.t
Number of units: 12

Residual term has been added to model

Non-sparse algorithm with Fisher scoring

Estimated variance components

Random term	component	s.e.
d1.t	17.533	12.673

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.333	1.650

Deviance: -2*Log-Likelihood

Deviance	d.f.
31.32	7

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d1	3.99	2	2.00	4.3	0.243

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d1	3.99	2	2.00	4.3	0.243

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for d1

d1	1	2	3
	0.000	5.333	9.000

Standard errors

d1	1	2	3
	0.000	6.052	4.650

Standard errors

Average:	5.351
Maximum:	6.052
Minimum:	4.650

Table of effects for d1.t

t	C1	C2	G3	G4	G5
d1					
1	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	-2.9418	0.5884	-3.8244

t	G6	G7	G8
d1			
1	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000
3	5.8837	3.2360	-2.9418

Standard errors

t	C1	C2	G3	G4	G5
d1					
1	4.1873	0.0000	0.0000	0.0000	0.0000

2	0.0000	4.1873	0.0000	0.0000	0.0000
3	0.0000	0.0000	2.1537	2.1537	2.1537

t	G6	G7	G8
d1			
1	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000
3	2.1537	2.1537	2.1537

Standard errors

Average: 2.662
Maximum: 4.187
Minimum: 2.154

Table of predicted means for d1

d1	1	2	3
	22.33	27.67	31.33

Standard errors

d1	1	2	3
	4.28	4.28	1.82

Standard errors

Average: 3.459
Maximum: 4.279
Minimum: 1.820

Table of predicted means for d1.t

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	22.33	22.33	22.33	22.33	22.33	22.33	22.33
2	27.67	27.67	27.67	27.67	27.67	27.67	27.67
3	31.33	31.33	28.39	31.92	27.51	37.22	34.57

t	G8
d1	
1	22.33
2	27.67
3	28.39

Standard errors

t	C1	C2	G3	G4	G5	G6	G7
d1							
1	0.88	4.28	4.28	4.28	4.28	4.28	4.28
2	4.28	0.88	4.28	4.28	4.28	4.28	4.28
3	1.82	1.82	1.45	1.45	1.45	1.45	1.45

t	G8
d1	
1	4.28
2	4.28
3	1.45

Standard errors

Average: 3.084
Maximum: 4.279
Minimum: 0.8819

```

93  " Comparison between two replicated treatments (checks): C1 vs C2 "
94  TABLE [CLASSIFICATION=d1,t] Ch; VALUES=(1,0,0,0,0,0,0,0,\
95                                         0,-1,0,0,0,0,0,0,\
96                                         0,0,0,0,0,0,0,0)
97  VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch	-5.333	1.247	-4.28	4.00	0.013

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.

```

98  " Comparison between two un-replicated treatments: G3 vs G4 "
99  TABLE [CLASSIFICATION=d1,t] UnT; VALUES=(0,0,0,0,0,0,0,0,\
100                                         0,0,0,0,0,0,0,0,\
101                                         0,0,1,-1,0,0,0,0)
102  VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
UnT	-3.530	2.029	-1.74	4.00	0.157

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.


```

103 " Comparison between a replicated and an un-replicated treatment:
-104 C1 vs G3 "
105 TABLE [CLASSIFICATION=d1,t] Ch_UnT; VALUES=(1,0,0,0,0,0,0,0,\
106                                           0,0,0,0,0,0,0,0,\
107                                           0,0,-1,0,0,0,0,0)
108 VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch_UnT

```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch_UnT	-6.058	1.698	-3.57	4.00	0.023

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.

```

109 DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
110
111 "*** Model P3-r ***"
112 CAPTION 'P3-r'; STYLE=meta

```

P3-r

```

113 VCOMPONENTS [FIXED=d2] RANDOM=d2.t
114 REML [PRINT=model,components,means,waldTests,deviance,effects; \
115      PSE=allemimates; PTERMS=d2+d2.t; METHOD=Fisher] y

```

REML variance components analysis

Response variate: y
Fixed model: Constant + d2
Random model: d2.t
Number of units: 12

Residual term has been added to model

Non-sparse algorithm with Fisher scoring

Estimated variance components

Random term	component	s.e.
d2.t	16.740	10.946

Residual variance model

Term	Model(order)	Parameter	Estimate	s.e.
Residual	Identity	Sigma2	2.343	1.656

Deviance: -2*Log-Likelihood

Deviance	d.f.
35.70	8

Note: deviance omits constants which depend on fixed model fitted.

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d2	3.36	1	3.36	5.4	0.122

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
d2	3.36	1	3.36	5.4	0.122

Message: denominator degrees of freedom for approximate F-tests are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters.

Table of effects for d2

d2	1	2
	0.000	6.333

Standard errors

d2	1	2
	0.000	3.456

Table of effects for d2.t

t	C1	C2	G3	G4	G5	G6	G7
d2							
1	-2.548	2.548	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	-2.924	0.585	-3.801	5.848	3.216

t	G8
d2	
1	0.000
2	-2.924

Standard errors

t	C1	C2	G3	G4	G5	G6	G7

d2								
1	2.957	2.957	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	2.122	2.122	2.122	2.122	2.122	2.122

t	G8
d2	
1	0.000
2	2.122

Standard errors

Average: 2.331
Maximum: 2.957
Minimum: 2.122

Table of predicted means for d2

d2	1	2
	25.00	31.33

Standard errors

d2	1	2
	2.96	1.78

Standard errors

Average: 2.372
Maximum: 2.960
Minimum: 1.783

Table of predicted means for d2.t

t	C1	C2	G3	G4	G5	G6	G7
d2							
1	22.45	27.55	25.00	25.00	25.00	25.00	25.00
2	31.33	31.33	28.41	31.92	27.53	37.18	34.55

t	G8
d2	
1	25.00
2	28.41

Standard errors

t	C1	C2	G3	G4	G5	G6	G7
d2							
1	0.87	0.87	2.96	2.96	2.96	2.96	2.96
2	1.78	1.78	1.45	1.45	1.45	1.45	1.45

t	G8
d2	
1	2.96
2	1.45

Standard errors

Average: 1.986
Maximum: 2.960
Minimum: 0.8739

```
116 " Comparison between two replicated treatments (checks): C1 vs C2 "
117 TABLE [CLASSIFICATION=d2,t] Ch; VALUES=!(1,-1,0,0,0,0,0,0,\
118           0,0,0,0,0,0,0,0)
119 VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch	-5.096	1.222	-4.17	4.00	0.014

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.

```
120 " Comparison between two un-replicated treatments: G3 vs G4 "
121 TABLE [CLASSIFICATION=d2,t] UnT; VALUES=!(0,0,0,0,0,0,0,0,\
122           0,0,1,-1,0,0,0,0)
123 VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] UnT
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
UnT	-3.509	2.028	-1.73	4.00	0.159

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.

```
124 " Comparison between a replicated and an un-replicated treatment:
-125 C1 vs G3 "
126 TABLE [CLASSIFICATION=d2,t] Ch_UnT; VALUES=!(1,0,0,0,0,0,0,0,\
127           0,0,-1,0,0,0,0,0)
128 VTCOMPARISON [DFMETHOD=given; DFGIVEN=4] Ch_UnT
```

Comparisons between REML means

Response variate: y

Contrast	estimate	s.e.	t	d.f.	pr.
Ch_UnT	-5.957	1.693	-3.52	4.00	0.024

Message: the supplied residual d.f. may not be accurate, so the probabilities should be used with care.

```
129  DELETE [REDEFINE=y] Ch, UnT, Ch_UnT
130  "Note: Genstat does not have the limitation of SAS with regards to
-131      the estimation of standard errors for BLUP contrasts from
-132      models with nested random effects. Therefore, the use of the
-133      switch variable method is not required."
134
135  ENDJOB
```

End of job.

Chapter 14. Multivariate Methods for Agricultural Research by Kathleen M. Yeater and María B. Villamil

Genstat code developed by Vanessa M. Cave and output are provided here for the analysis of the Yield Challenge data presented in Chapter 14.

Yield Challenge Example

Genstat Commands

```
" *****  
"                               Yield Challenge Data                               "  
" *****  
  
JOB  
  
" ***** Data Exploration ***** "  
  
" Import data, where missing values are coded as dots "  
IMPORT [MISSING='.'] 'mvYCdata.csv'  
POINTER [VALUE=Region,Yield,pH,SOM,P_,K,Ca,Mg,CEC,SCN] YC  
  
" Convert Region from a text structure to a factor "  
GROUP [REDEFINE=yes] Region; Region  
  
" Print summary statistics "  
DESCRIBE [SELECTION=nmv,mean,median,min,max,q1,q3,sd,skew,kurtosis] \  
  YC[2...10]  
TABULATE [PRINT=counts; CLASSIFICATION=Region]  
  
" Print observations with missing SCN values "  
RESTRICT #YC; CONDITION=SCN == !s(*)  
PRINT #YC  
RESTRICT #YC  
  
" Remove observations with missing SCN values "  
SUBSET [CONDITION=SCN <> !s(*)] Region,Yield,pH,SOM,P_,K,Ca,Mg,CEC,\  
  SCN; Region_new,Yield_new,pH_new,SOM_new,P__new,K_new,Ca_new,\  
  Mg_new,CEC_new,SCN_new;  
  
" Create a pointer to the soil variables "  
POINTER [VALUE=pH_new,SOM_new,P__new,K_new,Ca_new,Mg_new,CEC_new,\  
  SCN_new] soil  
  
" ***** Visualization ***** "  
  
" Scatterplot matrix of soil variables with histogram down the main  
  diagonal "  
DMSCATTER [PLOT=histogram] soil; YTITLE=!t (pH,SOM,P,K,Ca,Mg,CEC,SCN)  
  
" Correlations between soil variables "  
FCORRELATION [PRINT=correlations] #soil
```

```

" Boxplot of the soil variables "
BOXPLOT [WINDOW=3; METHOD=Schematic; ORIENTATION=down] #soil; \
UNITLABELS=*

" Shapiro-Wilks test of univariate normality "
WSTATISTIC #soil

" Tests of multivariate normality "
NORMTEST [PRINT=radius,critical,stars] soil

" ***** Principal Components Analysis ***** "

" Print the latent roots (i.e. eigenvalues), percentage of variation
  explained by each principal component, trace (i.e. total variance),
  and loadings of the principal components. Loadings, roots and trace
  saved in soil_pc, and the scores in score_pc. "
PCP [PRINT=roots,loadings; METHOD=correlation] soil; LRV=soil_pc; \
SCORES=scores_pc

" Scree plot "
LRVSCREE [PRINT=*; PLOT=scree; WINDOW=3; TITLE='Scree Plot'] soil_pc

" Create variates of the scores for the first three PCs "
VARIATE comp1,comp2,comp3; VALUES=scores_pc$[*;1],scores_pc$[*;2],\
scores_pc$[*;3]

" ***** Multiple Linear Regression ***** "

" How do these soil properties at planting impact the seed yield
  response? "
MODEL Yield_new
FIT [PRINT=model,summary,estimates; FPROB=yes; TPROB=yes] \
comp1+comp2+comp3
RCHECK

" ***** Discriminant Analysis ***** "

" Remove observations with missing Region values from the PC scores "
SUBSET [CONDITION=Region_new .NI. !t('')] Region_new,comp1,comp2,\
comp3; Region_nmd,comp1_nmd,comp2_nmd,comp3_nmd

" Re-order the levels of the Region variable "
TABULATE [PRINT=counts; CLASSIFICATION=Region_nmd]
FACSort Region_nmd; INDEX=!(2,1,3)

" Linear Discriminant Analysis, with scatterplot of the scores
  coloured by Region. Leave-one-out cross-validation (i.e. jackknife)
  used to estimate error rates. Note cross-validation results will
  differ from R as here the prior probabilities of group membership
  are equal, whereas by default R uses the group proportions. This
  option is not present in Genstat. "
PEN 1,2,3; COLOUR='black','red','blue'
DISCRIMINATE [PRINT=lr,table; VALIDATIONMETHOD=jackknife] \
!p(comp1_nmd,comp2_nmd,comp3_nmd); GROUPS=Region_nmd

ENDJOB

```

Genstat Output

```
4  " ***** Data Exploration ***** "  
5  
6  " Import data, where missing values are coded as dots "  
7  IMPORT [MISSING='.'] 'mvYCdata.csv'
```

Loading Spreadsheet File

Catalogue of file mvYCdata.csv

Sheet Title: Sheet1

Description: <none>

Sheet Type: vector

Index	Type	Nval	Name
1	variate	477	Yield
2	text	477	Region
3	variate	477	pH
4	variate	477	SOM
5	variate	477	P_
6	variate	477	K
7	variate	477	Ca
8	variate	477	Mg
9	variate	477	CEC
10	variate	477	SCN

```
8  POINTER [VALUE=Region,Yield,pH,SOM,P_,K,Ca,Mg,CEC,SCN] YC  
9  
10 " Convert Region from a text structure to a factor "  
11 GROUP [REDEFINE=yes] Region; Region  
12  
13 " Print summary statistics "  
14 DESCRIBE [SELECTION=nmv,mean,median,min,max,q1,q3,sd,skew,kurtosis] \  
15     YC[2...10]
```

Summary statistics for Yield

Number of missing values = 74
Mean = 4477
Median = 4499
Minimum = 2091
Maximum = 5945
Lower quartile = 4082
Upper quartile = 4921
Standard deviation = 629.0
Skewness = -0.517
Kurtosis = 0.970

Summary statistics for pH

Number of missing values = 0
Mean = 6.442
Median = 6.4
Minimum = 5.1
Maximum = 7.9
Lower quartile = 6.1
Upper quartile = 6.7
Standard deviation = 0.454
Skewness = 0.444
Kurtosis = 0.470

Summary statistics for SOM

Number of missing values = 0
Mean = 3.236
Median = 3.3
Minimum = 1
Maximum = 4.9
Lower quartile = 3
Upper quartile = 3.8
Standard deviation = 0.812
Skewness = -0.959
Kurtosis = 0.821

Summary statistics for P_

Number of missing values = 0
Mean = 65.86
Median = 47.6
Minimum = 8.5
Maximum = 475.7
Lower quartile = 33.5
Upper quartile = 81.38
Standard deviation = 53.53
Skewness = 2.933
Kurtosis = 13.21

Summary statistics for K

Number of missing values = 0
Mean = 256.3
Median = 201.5
Minimum = 56
Maximum = 1465
Lower quartile = 141.4
Upper quartile = 307.2
Standard deviation = 180.2
Skewness = 2.512
Kurtosis = 9.114

Summary statistics for Ca

Number of missing values = 0
Mean = 3421
Median = 2707
Minimum = 794.5
Maximum = 13346
Lower quartile = 1895
Upper quartile = 4572
Standard deviation = 2076
Skewness = 1.450
Kurtosis = 2.250

Summary statistics for Mg

Number of missing values = 0
Mean = 475.7
Median = 409
Minimum = 72
Maximum = 1605
Lower quartile = 247.6
Upper quartile = 640.6
Standard deviation = 289.5
Skewness = 1.154
Kurtosis = 1.188

Summary statistics for CEC

Number of missing values = 0
Mean = 16.87
Median = 16.4
Minimum = 6.3
Maximum = 40
Lower quartile = 13.17
Upper quartile = 20
Standard deviation = 5.352
Skewness = 0.654
Kurtosis = 0.691

Summary statistics for SCN

Number of missing values = 6
Mean = 180.4
Median = 80
Minimum = 0
Maximum = 3000
Lower quartile = 40
Upper quartile = 200
Standard deviation = 321.0
Skewness = 5.015

Kurtosis = 33.47

```
16 TABULATE [PRINT=counts; CLASSIFICATION=Region]
```

	Count
Region	
Central	288
North	87
South	92

Unknown cell

Count 10

```
17
```

```
18 " Print observations with missing SCN values "
```

```
19 RESTRICT #YC; CONDITION=SCN == !s(*)
```

```
20 PRINT #YC
```

Region	Yield	pH	SOM	P _u	K
North	5118	6.800	4.400	67.60	311.2
Central	5158	6.700	3.100	187.70	927.0
Central	4291	5.900	3.600	53.30	382.1
North	4775	7.700	3.500	54.20	231.2
Central	5501	6.600	3.200	101.90	301.1
Central	3914	5.900	3.800	47.60	328.5

Ca	Mg	CEC	SCN
8712	1604.7	29.90	*
3174	825.7	13.50	*
5220	855.4	22.00	*
13346	809.6	37.10	*
5765	637.5	19.00	*
5036	663.1	20.20	*

```
21 RESTRICT #YC
```

```
22
```

```
23 " Remove observations with missing SCN values "
```

```
24 SUBSET [CONDITION=SCN <> !s(*)] Region,Yield,pH,SOM,P_,K,Ca,Mg,CEC,\
```

```
25 SCN; Region_new,Yield_new,pH_new,SOM_new,P__new,K_new,Ca_new,\
```

```
26 Mg_new,CEC_new,SCN_new;
```

```
27
```

```
28 " Create a pointer to the soil variables "
```

```
29 POINTER [VALUE=pH_new,SOM_new,P__new,K_new,Ca_new,Mg_new,CEC_new,\
```

```
30 SCN_new] soil
```

```
31
```

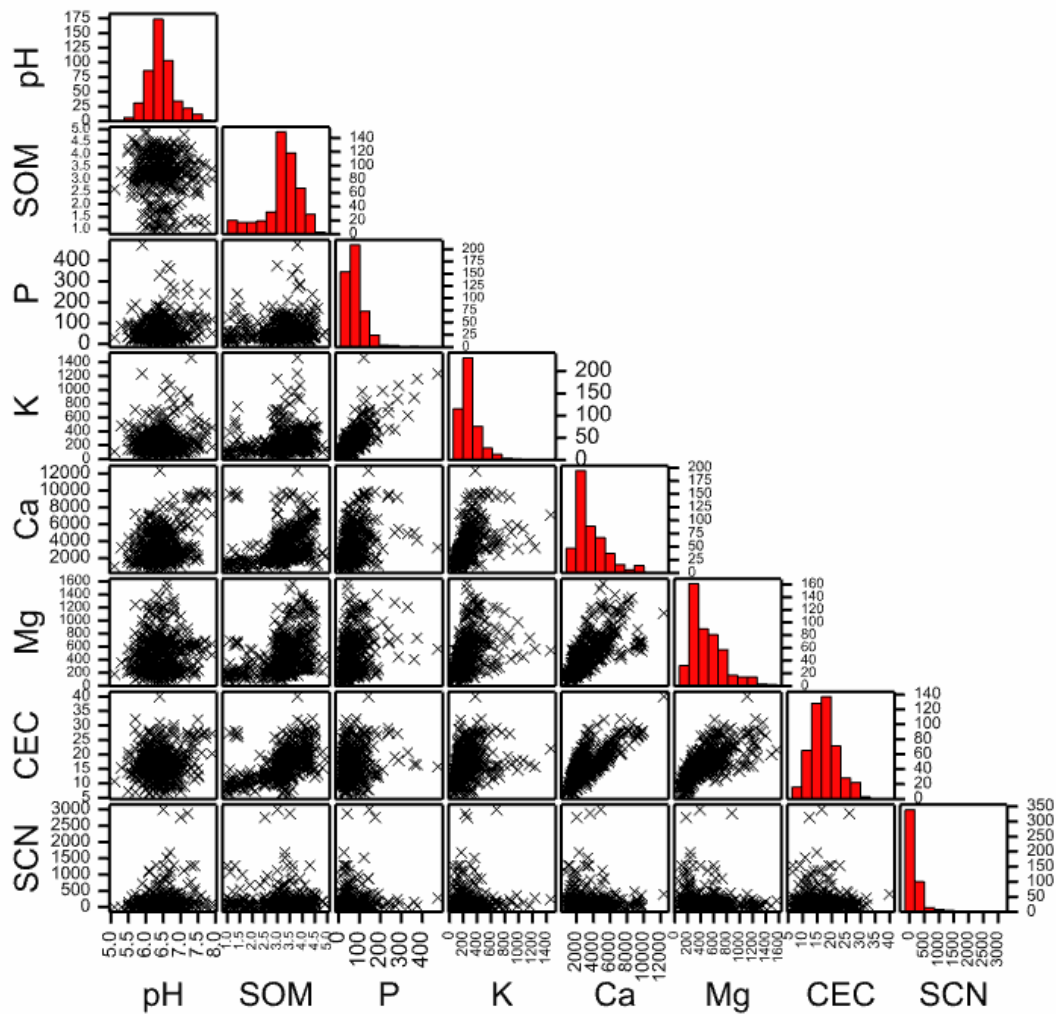
```
32 " ***** Visualization ***** "
```

```
33
```

```
34 " Scatterplot matrix of soil variables with histogram down the main
```

```
-35 diagonal "
```

```
36 DMSCATTER [PLOT=histogram] soil; YTITLE=!t (pH,SOM,P,K,Ca,Mg,CEC,SCN)
```



```

37
38 " Correlations between soil variables "
39 FCORRELATION [PRINT=correlations] #soil

```

Correlations

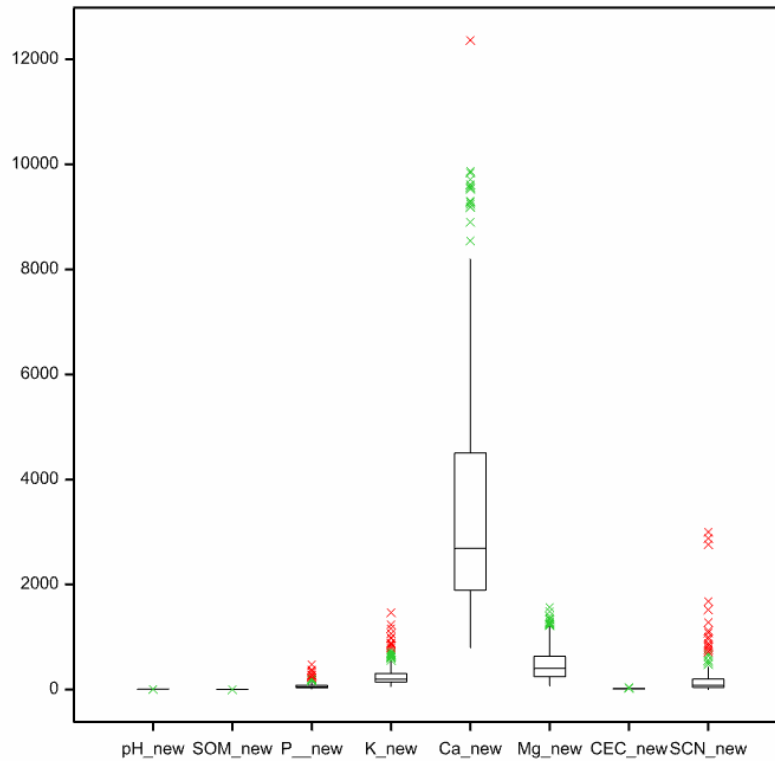
pH_new	1	-						
SOM_new	2	-0.0935	-					
P_new	3	0.1261	0.0896	-				
K_new	4	0.0877	0.2098	0.7764	-			
Ca_new	5	0.3155	0.3100	0.3931	0.5169	-		
Mg_new	6	0.0475	0.4052	0.2774	0.3922	0.6919	-	
CEC_new	7	0.1657	0.5158	0.1588	0.2496	0.7540	0.6870	-
SCN_new	8	0.1498	-0.0638	0.0279	0.0095	-0.0605	-0.1227	-0.0805
		1	2	3	4	5	6	7
SCN_new	8	-						
			8					

Number of observations: 471

```

40
41 " Boxplot of the soil variables "
42 BOXPLOT [WINDOW=3; METHOD=Schematic; ORIENTATION=down] #soil; \
43     UNITLABELS=*

```



```

44
45 " Shapiro-Wilks test of univariate normality "
46 WSTATISTIC #soil

```

Shapiro-Wilk test for Normality

Data variate: pH_new
 Test statistic W: 0.9814
 Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: SOM_new
 Test statistic W: 0.9187
 Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: P_new
 Test statistic W: 0.7305
 Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: K_new
Test statistic W: 0.7705
Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: Ca_new
Test statistic W: 0.8696
Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: Mg_new
Test statistic W: 0.9053
Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: CEC_new
Test statistic W: 0.9766
Probability: <0.001

Shapiro-Wilk test for Normality

Data variate: SCN_new
Test statistic W: 0.5045
Probability: <0.001

```
47
48 " Tests of multivariate normality "
49 NORMTEST [PRINT=radius,critical,stars] soil
```

Critical values of test statistics (bivariate angle and radius tests)

Test statistic	15%	10%	5%	2.5%	1%
Anderson-Darling	1.610	1.933	2.492	3.070	3.857
Cramer-von Mises	0.284	0.347	0.461	0.581	0.743
Watson	0.131	0.152	0.187	0.221	0.267

Radius test

Anderson-Darling	Cramer-von Mises	Watson
91.0247 **	13.4287 **	4.7718 **

?, *, ** indicate significance at 10%, 5% and 1% levels respectively

```

50
51 " ***** Principal Components Analysis ***** "
52
53 " Print the latent roots (i.e. eigenvalues), percentage of variation
-54 explained by each principal component, trace (i.e. total variance),
-55 and loadings of the principal components. Loadings, roots and trace
-56 saved in soil_pc, and the scores in score_pc. "
57 PCP [PRINT=roots,loadings; METHOD=correlation] soil; LRV=soil_pc; \
58 SCORES=scores_pc

```

Principal components analysis

Latent roots

1	2	3	4	5	6
3.255	1.434	1.155	0.904	0.585	0.293
7	8				
0.229	0.143				

Percentage variation

1	2	3	4	5	6
40.69	17.93	14.44	11.30	7.32	3.66
7	8				
2.87	1.79				

Trace

8.000

Latent vectors (loadings)

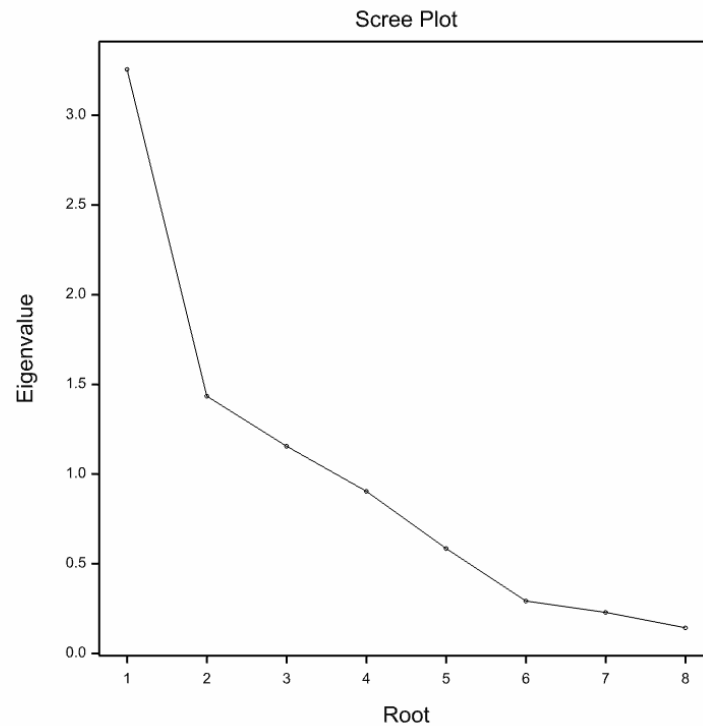
	1	2	3	4	5
pH_new	0.12847	0.28425	0.69879	-0.37719	0.45068
SOM_new	0.29488	-0.39027	-0.11631	0.45252	0.70195
P_new	0.32278	0.54827	-0.31624	0.00509	0.11007
K_new	0.38359	0.44818	-0.32222	0.05794	0.07521
Ca_new	0.49117	-0.01530	0.19365	-0.15504	-0.21784
Mg_new	0.45098	-0.22016	-0.00070	-0.01144	-0.41313
CEC_new	0.44530	-0.33220	0.21843	0.02300	-0.10635
SCN_new	-0.04780	0.32614	0.45729	0.79049	-0.23862
	6	7	8		
pH_new	0.24306	0.01217	0.09887		

SOM_new	0.11357	-0.04841	-0.18562
P_new	-0.04520	0.66005	-0.21296
K_new	-0.00207	-0.58361	0.44559
Ca_new	-0.35698	-0.32916	-0.64324
Mg_new	0.75384	0.09130	0.02698
CEC_new	-0.47982	0.32336	0.54498
SCN_new	0.00626	-0.00060	-0.01948

```

59
60 " Scree plot "
61 LRVSCREE [PRINT=*; PLOT=scree; WINDOW=3; TITLE='Scree Plot'] soil_pc

```



```

62
63 " Create variates of the scores for the first three PCs "
64 VARIATE comp1,comp2,comp3; VALUES=scores_pc$[*;1],scores_pc$[*;2],\
65     scores_pc$[*;3]
66
67 " ***** Multiple Linear Regression ***** "
68
69 " How do these soil properties at planting impact the seed yield
-70 response? "
71 MODEL Yield_new
72 FIT [PRINT=model,summary,estimates; FPROB=yes; TPROB=yes] \
73     comp1+comp2+comp3

```

Regression analysis

Response variate: Yield_new
 Fitted terms: Constant + comp1 + comp2 + comp3

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3719830.	1239943.	3.19	0.024
Residual	393	152936005.	389150.		
Total	396	156655835.	395596.		

Percentage variance accounted for 1.6

Standard error of observations is estimated to be 624.

Message: the following units have large standardized residuals.

Unit	Response	Residual
227	2239.	-3.48
228	2455.	-3.12
292	2643.	-3.31
325	2327.	-3.30
346	2562.	-3.10
418	2091.	-3.57
439	2347.	-3.42

Message: the following units have high leverage.

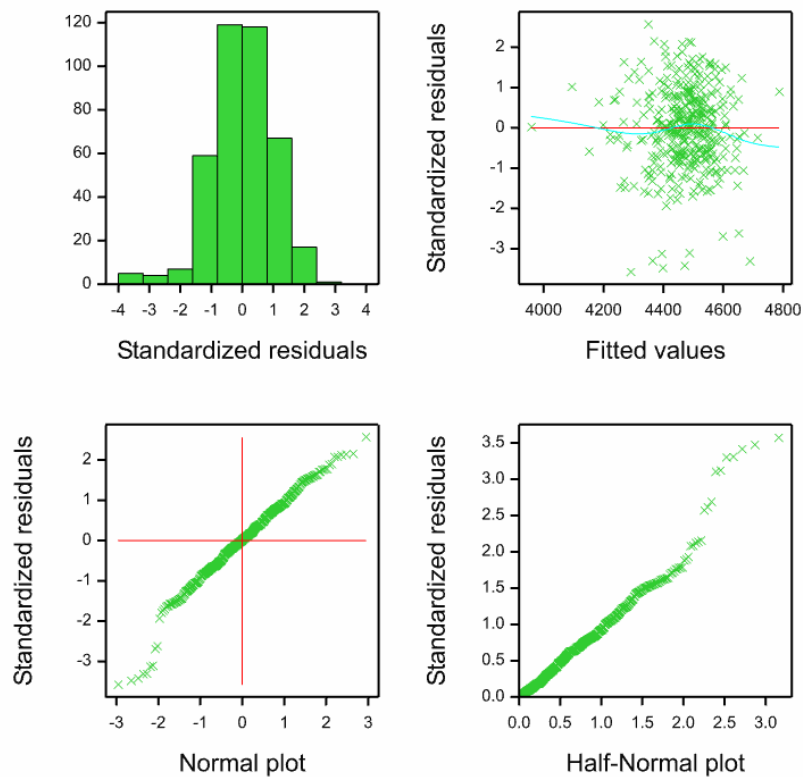
Unit	Response	Leverage
25	3974.	0.079
26	3793.	0.032
315	4788.	0.048
324	3800.	0.036
331	5084.	0.035
381	4708.	0.072
388	4916.	0.034
396	4963.	0.032
398	5400.	0.080
408	4950.	0.055
417	3416.	0.033
445	5313.	0.123
452	3739.	0.041
453	4223.	0.039

Estimates of parameters

Parameter	estimate	s.e.	t(393)	t pr.
Constant	4466.9	31.6	141.19	<.001
comp1	11.6	17.3	0.67	0.502
comp2	-25.9	26.1	-0.99	0.322
comp3	-84.7	28.7	-2.95	0.003

74 RCHECK

Yield_new



```

75
76 " ***** Discriminant Analysis ***** "
77
78 " Remove observations with missing Region values from the PC scores "
79 SUBSET [CONDITION=Region_new .NI. !t('')] Region_new,comp1,comp2,\
80     comp3; Region_nmd,comp1_nmd,comp2_nmd,comp3_nmd
81
82 " Re-order the levels of the Region variable "
83 TABULATE [PRINT=counts; CLASSIFICATION=Region_nmd]

```

	Count
Region_nmd	
Central	284
North	85
South	92

```

84 FACSORT Region_nmd; INDEX=!(2,1,3)
85
86 " Linear Discriminant Analysis, with scatterplot of the scores
87   coloured by Region. Leave-one-out cross-validation (i.e. jackknife)
88   used to estimate error rates. Note cross-validation results will
89   differ from R as here the prior probabilities of group membership
90   are equal, whereas by default R uses the group proportions. This
91   option is not present in Genstat. "
92 PEN 1,2,3; COLOUR='black','red','blue'

```

```

93 DISCRIMINATE [PRINT=lr,table; VALIDATIONMETHOD=jackknife] \
94      !p(comp1_nmd,comp2_nmd,comp3_nmd); GROUPS=Region_nmd

```

Discriminant analysis

Latent vectors, roots, and trace from CVA

Vectors:

Scores	Scores[1]	Scores[2]
comp1_nmd	-0.5752	0.0606
comp2_nmd	0.3919	0.4676
comp3_nmd	0.1751	-0.7596

Roots:

Scores
Scores[1] 0.3407
Scores[2] 0.0109

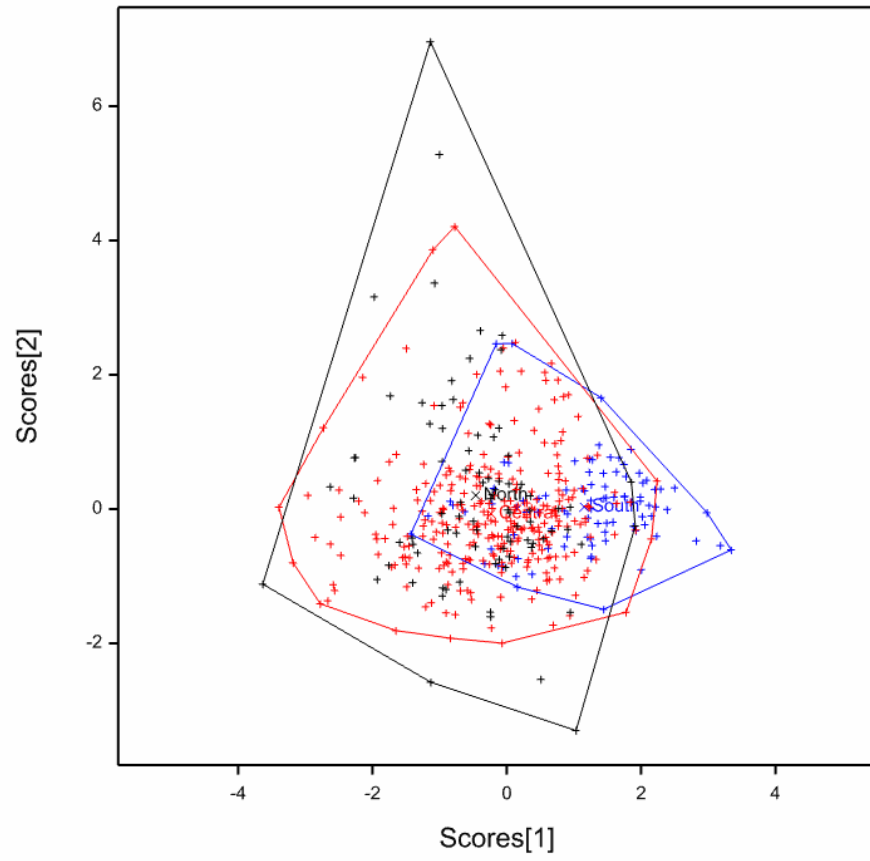
Trace: 0.3516

No	Root	%%	Cum	%	Scree Diagram (* represents 3%)
1	0.3407	969	969	97	*****
2	0.0109	31	1000	3	*

Scale: 1 asterisk represents 3 units.

Table of counts for allocation of training units

Region_nmd	Counts			Total
	North	Central	South	
Tallocate				
North	43	105	10	158
Central	32	104	13	149
South	10	75	69	154
Total	85	284	92	461



95

96 ENDJOB

End of job.

Chapter 15. Nonlinear Regression Models and Applications by Fernando Miguez, Sotirios Archontoulis, and Hamze Dokoohaki

Genstat code developed by Vanessa M. Cave and output are provided here for most of the analyses presented in Chapter 15. The extended application (example 2) is only partially translated as the final model is not readily fitted using Genstat.

Analysis of the Biomass Accumulation Data

Genstat Commands

JOB

```
" Load the data, where Block, Input and Crop are factors "
```

```
FACTOR Block, Input, Crop
```

```
READ [SETLEVELS=yes] Obs,DOY,Block,Input,Crop,Yield; \
```

```
  FREPRESENTATION=labels
```

1	141	1	2	M	0.00000	119	211	3	2	S	8.94119
2	141	2	2	M	0.00000	120	211	4	2	S	12.54775
3	141	3	2	M	0.00000	121	211	1	1	S	7.42333
4	141	4	2	M	0.00000	122	211	2	1	S	11.65094
5	141	1	1	M	0.00000	123	211	3	1	S	7.39926
6	141	2	1	M	0.00000	124	211	4	1	S	10.99033
7	141	3	1	M	0.00000	125	211	1	2	F	16.07903
8	141	4	1	M	0.00000	126	211	2	2	F	9.97832
9	141	1	2	S	0.00000	127	211	3	2	F	13.92924
10	141	2	2	S	0.00000	128	211	4	2	F	11.63735
11	141	3	2	S	0.00000	129	211	1	1	F	15.29955
12	141	4	2	S	0.00000	130	211	2	1	F	11.07560
13	141	1	1	S	0.00000	131	211	3	1	F	13.02743
14	141	2	1	S	0.00000	132	211	4	1	F	12.99200
15	141	3	1	S	0.00000	133	225	1	2	M	18.97108
16	141	4	1	S	0.00000	134	225	2	2	M	13.97785
17	141	1	2	F	0.00000	135	225	3	2	M	20.12643
18	141	2	2	F	0.00000	136	225	4	2	M	12.92471
19	141	3	2	F	0.00000	137	225	1	1	M	11.86006
20	141	4	2	F	0.00000	138	225	2	1	M	9.25771
21	141	1	1	F	0.00000	139	225	3	1	M	8.91000
22	141	2	1	F	0.00000	140	225	4	1	M	11.47636
23	141	3	1	F	0.00000	141	225	1	2	S	20.81630
24	141	4	1	F	0.00000	142	225	2	2	S	22.62614
25	168	1	2	M	0.42636	143	225	3	2	S	26.43625
26	168	2	2	M	0.47368	144	225	4	2	S	19.31603
27	168	3	2	M	0.44427	145	225	1	1	S	16.46884
28	168	4	2	M	0.44810	146	225	2	1	S	16.73960
29	168	1	1	M	0.42636	147	225	3	1	S	17.17676
30	168	2	1	M	0.47368	148	225	4	1	S	14.98377
31	168	3	1	M	0.44427	149	225	1	2	F	21.22479
32	168	4	1	M	0.44810	150	225	2	2	F	18.95059
33	168	1	2	S	0.55333	151	225	3	2	F	18.06756
34	168	2	2	S	0.56757	152	225	4	2	F	22.89504
35	168	3	2	S	0.56206	153	225	1	1	F	17.94640

36	168	4	2	S	0.56099	154	225	2	1	F	13.67034
37	168	1	1	S	0.55333	155	225	3	1	F	16.94531
38	168	2	1	S	0.56757	156	225	4	1	F	13.95996
39	168	3	1	S	0.56206	157	243	1	2	M	22.25491
40	168	4	1	S	0.56099	158	243	2	2	M	16.61565
41	168	1	2	F	0.45810	159	243	3	2	M	21.82077
42	168	2	2	F	0.48466	160	243	4	2	M	17.30287
43	168	3	2	F	0.47124	161	243	1	1	M	12.59370
44	168	4	2	F	0.47133	162	243	2	1	M	16.81818
45	168	1	1	F	0.47133	163	243	3	1	M	15.77413
46	168	2	1	F	0.48466	164	243	4	1	M	12.55910
47	168	3	1	F	0.47124	165	243	1	2	S	27.04360
48	168	4	1	F	0.47575	166	243	2	2	S	32.68473
49	176	1	2	M	2.37325	167	243	3	2	S	24.24132
50	176	2	2	M	2.00316	168	243	4	2	S	36.84177
51	176	3	2	M	2.19912	169	243	1	1	S	22.58049
52	176	4	2	M	2.19184	170	243	2	1	S	17.55427
53	176	1	2	S	1.10432	171	243	3	1	S	24.20756
54	176	2	2	S	1.38752	172	243	4	1	S	16.09398
55	176	3	2	S	1.25095	173	243	1	2	F	36.68057
56	176	4	2	S	1.24760	174	243	2	2	F	26.18346
57	176	1	2	F	1.21923	175	243	3	2	F	31.59453
58	176	2	2	F	1.84674	176	243	4	2	F	30.76946
59	176	3	2	F	1.67250	177	243	1	1	F	22.20426
60	176	4	2	F	1.57949	178	243	2	1	F	15.96902
61	185	1	2	M	3.38732	179	243	3	1	F	24.52840
62	185	2	2	M	3.49804	180	243	4	1	F	13.69994
63	185	3	2	M	3.38732	181	263	1	2	M	21.43922
64	185	4	2	M	3.49804	182	263	2	2	M	14.30769
65	185	1	1	M	1.93068	183	263	3	2	M	18.69361
66	185	2	1	M	1.90740	184	263	4	2	M	17.16525
67	185	3	1	M	1.93068	185	263	1	1	M	12.24700
68	185	4	1	M	1.90740	186	263	2	1	M	14.33091
69	185	1	2	S	1.41657	187	263	3	1	M	14.93738
70	185	2	2	S	1.37778	188	263	4	1	M	11.31081
71	185	3	2	S	1.41657	189	263	1	2	S	46.63989
72	185	4	2	S	1.37778	190	263	2	2	S	27.34436
73	185	1	1	S	1.05171	191	263	3	2	S	21.64182
74	185	2	1	S	1.02630	192	263	4	2	S	51.73975
75	185	3	1	S	1.05171	193	263	1	1	S	36.63405
76	185	4	1	S	1.02630	194	263	2	1	S	30.26200
77	185	1	2	F	3.78025	195	263	3	1	S	45.29689
78	185	2	2	F	3.95644	196	263	4	1	S	20.60917
79	185	3	2	F	3.78025	197	263	1	2	F	36.54930
80	185	4	2	F	3.95644	198	263	2	2	F	22.16076
81	185	1	1	F	1.54376	199	263	3	2	F	30.65052
82	185	2	1	F	1.67455	200	263	4	2	F	26.84545
83	185	3	1	F	1.54376	201	263	1	1	F	26.59299
84	185	4	1	F	1.67455	202	263	2	1	F	28.40977
85	196	1	2	M	6.59763	203	263	3	1	F	24.73412
86	196	2	2	M	4.48241	204	263	4	1	F	29.27921
87	196	3	2	M	5.95156	205	283	1	2	S	40.03468
88	196	4	2	M	5.21500	206	283	2	2	S	30.09828
89	196	1	1	M	5.05497	207	283	3	2	S	28.16290
90	196	2	1	M	3.82129	208	283	4	2	S	42.52825
91	196	3	1	M	2.32475	209	283	1	1	S	30.06088
92	196	4	1	M	6.85365	210	283	2	1	S	29.76598

```

93 196 1 2 S 9.63448 211 283 3 1 S 38.43803
94 196 2 2 S 4.92300 212 283 4 1 S 31.47936
95 196 3 2 S 6.65467 213 283 1 2 F 38.22111
96 196 4 2 S 7.49728 214 283 2 2 F 26.58728
97 196 1 1 S 4.63590 215 283 3 2 F 38.43949
98 196 2 1 S 2.54400 216 283 4 2 F 27.33577
99 196 3 1 S 2.42181 217 283 1 1 F 27.03488
100 196 4 1 S 5.05650 218 283 2 1 F 28.09636
101 196 1 2 F 4.82335 219 283 3 1 F 29.34588
102 196 2 2 F 9.16699 220 283 4 1 F 24.41846
103 196 3 2 F 7.51804 221 303 1 2 S 34.43455
104 196 4 2 F 6.29618 222 303 2 2 S 22.76971
105 196 1 1 F 5.74248 223 303 3 2 S 26.45379
106 196 2 1 F 7.65420 224 303 4 2 S 39.05722
107 196 3 1 F 9.30576 225 303 1 1 S 23.20726
108 196 4 1 F 4.34633 226 303 2 1 S 16.03402
109 211 1 2 M 12.39712 227 303 3 1 S 29.30742
110 211 2 2 M 11.90800 228 303 4 1 S 23.34675
111 211 3 2 M 13.41000 229 303 1 2 F 37.65097
112 211 4 2 M 10.85442 230 303 2 2 F 22.11074
113 211 1 1 M 9.95378 231 303 3 2 F 29.16811
114 211 2 1 M 8.26690 232 303 4 2 F 25.61200
115 211 3 1 M 10.37958 233 303 1 1 F 26.22214
116 211 4 1 M 8.49705 234 303 2 1 F 19.60814
117 211 1 2 S 12.27200 235 303 3 1 F 30.39771
118 211 2 2 S 9.01893 236 303 4 1 F 27.88253 :

```

```

" Note: A variety of standard non-linear regression models can be
  fitted using the FITCURVE directive. Other models can be fitted
  using the FIT or FITNONLINEAR directives. "

```

```

" ***** "
" Example 1: Maize Biomass Accumulation "
" ***** "

```

```

" Figure 4A: Observed yield during the growth season (Block 1,
  Crop M (Maize)) "

```

```

RESTRICT Yield; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M'
XAXIS [RESET=yes] WINDOW=1; TITLE='Day of the Year'
YAXIS [RESET=yes] WINDOW=1; TITLE='Yield (Mg/ha)'
PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='circle','diamond'; \
  SIZE=1.5,1.6
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=Yield; X=DOY; PEN=Input
DKEY !T(Low,High) "Input factor: 1st level = Low, 2nd level = High"
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1
PEN [RESET=yes] 1,2
RESTRICT Yield

```

```

" *** Non-linear regression: Beta growth function *** "

```

```

" Define the beta growth model "

```

```

EXPRESSION [VALUE=fitBG=Ymax*(1+(te-DOY)/(te-tm))*\
  (DOY/te)**(te/(te-tm))] BetaGrowth

```

```

" Non-linear regression for the low input maize data in Block 1 "

```

```

RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \

```

```

.AND. Input .IN. 1
MODEL Yield; FITTED=fitBG
RCYCLE [MAXCYCLE=30] Ymax,te,tm; INITIAL=13,240,180
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
  CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations]
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Low input'] INDEX=DOY
" Save parameter estimates (for creating Figure 4B) "
RKEEP ESTIMATES=e_low
" Residuals (raw) "
RKEEP [RMETHOD=simple] RESIDUALS=r_low
PRINT MEAN(r_low); HEADING='Mean of residuals (bias): low input'
" Residual diagnostic plots (cf Figures 5 and 6) "
RCHECK [TITLE='Low input']
RESTRICT Yield,DOY

" Non-linear regression for the high input maize data in Block 1 "
RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
.AND. Input .IN. 2
MODEL Yield; FITTED=fitBG
RCYCLE Ymax,te,tm; INITIAL=25,240,210
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
  CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations]
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='High input'] INDEX=DOY
" Save parameter estimates (for creating Figure 4B) "
RKEEP ESTIMATES=e_high
" Residuals (raw) "
RKEEP [RMETHOD=simple] RESIDUALS=r_high
PRINT MEAN(r_high); HEADING='Mean of residuals (bias): High input'
" Residual diagnostic plots (cf Figures 5 and 6) "
RCHECK [TITLE='High input']
RESTRICT Yield,DOY

" Figure 4B: Observed and predicted yield during the growth season
(Block 1, Crop M (Maize)) "
VARIATE [VALUES=141...263] d
" Predicted values for low input "
CALC Ymax = e_low$['Ymax']
CALC te = e_low$['te']
CALC tm = e_low$['tm']
CALC pred_low = Ymax*(1+(te-d)/(te-tm))*(d/te)**(te/(te-tm))
" Predicted values for high input "
CALC Ymax = e_high$['Ymax']
CALC te = e_high$['te']
CALC tm = e_high$['tm']
CALC pred_high = Ymax*(1+(te-d)/(te-tm))*(d/te)**(te/(te-tm))
" Plot "
XAXIS [RESET=yes] WINDOW=1; TITLE='Day of the Year'
YAXIS [RESET=yes] WINDOW=1; TITLE='Yield (Mg/ha)'
" Observed "
RESTRICT Yield; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M'
PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='circle','diamond'
DGRAPH [WINDOW=1; KEYWINDOW=0] Y=Yield; X=DOY; PEN=Input
RESTRICT Yield
" Plot fitted "
PEN [RESET=yes] 1,2; METHOD=line; SYMBOL=0; LINESTYLE=1,2

```



```

DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=resize] Y=pred_low,pred_high; \
  X=d,d; PEN=1,2
" Add key "
PEN [RESET=yes] 1,2; METHOD=line; SYMBOL='circle','diamond'; \
  LINESTYLE=1,2
DKEY !T(Low,High) "Input factor: 1st level = Low, 2nd level = High"
XAXIS [RESET=yes] WINDOW=1
YAXIS [RESET=yes] WINDOW=1
PEN [RESET=yes] 1,2

" *** Comparing alternative models: Block 1, Crop M (Maize),
  Input 2 (High) *** "
" Note: The Gompertz, Logistic and Richards (also known as the
  Generalized Logistic) models are available as 'standard curves' in
  Genstat, and therefore can be fitted using the FITCURVE directive.
  FITCURVE is more efficient than a FITNONLINEAR. "

RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
  .AND. Input .IN. 2

" Plot (Figure 7) "
XAXIS [RESET=yes] WINDOW=3; TITLE='Day of the Year'
YAXIS [RESET=yes] WINDOW=3; TITLE='Yield (Mg/ha)'
DGRAPH [WINDOW=3; KEYWINDOW=0] Y=Yield; X=DOY
RESTRICT Yield

" Gompertz "
MODEL [SAVE=s_Gompertz] Yield
TERMS DOY
FITCURVE [PRINT=model,summary,estimates; CURVE=gompertz; \
  SENSE=right; CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,\
  seobservations,aic,bic] DOY
"B == k; M == t.m; C == Y.asim"
" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Gompertz']
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Gompertz']

" Logistic "
MODEL [SAVE=s_Logistic] Yield
TERMS DOY
FITCURVE [PRINT=model,summary,estimates; CURVE=logistic; \
  CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,seobservations,\
  aic,bic] DOY
"B == k; M == t.m; C == Y.asim"
" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Logistic']
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Logistic']

" Richards (also known as the Generalized Logistic) "
MODEL [SAVE=s_Richards] Yield
TERMS DOY
FITCURVE [PRINT=model,summary,estimates; CURVE=glogistic; \
  CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,seobservations,\
  aic,bic] DOY
"B == k; M == t.m; C == Y.asim; T == v"

```

```

" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Richards']
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Richards']

" Beta "
RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
.AND. Input .IN. 2
DELETE [REDEFINE=yes] fitBG
MODEL [SAVE=s_Beta] Yield; FITTED=fitBG
RCYCLE [MAXCYCLE=30; METHOD=GaussNewton] Ymax,te,tm; \
INITIAL=10.1,250,220.1
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations,\
aic,bic]
"Ymax == Y.asim; te == t.e; tm == t.m"
" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Beta']
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Beta'] INDEX=DOY

" Modified Beta "
EXPRESSION ModifiedBeta[1,2]; VALUE=!e(X = MVINSERT(DOY; DOY<tb)),\
!e(fitMBG = MVREPLACE(Yb+(Ymax-Yb)*(1+(te-X)/(te-tm))\
*((X-tb)/(te-tb))*((te-tb)/(te-tm)))));0)
DELETE [REDEFINE=yes] fitMBG
MODEL [SAVE=s_ModBeta] Yield; FITTED=fitMBG
RCYCLE [MAXCYCLE=30] Ymax,te,tm,Yb,tb; \
INITIAL=24,250,215,0,141; LOWER=0; STEP=0.5
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
CALC=ModifiedBeta[]; FPROB=yes; SELECTION=r2,%variance,\
seobservations,aic,bic]
"Ymax == w.max; te == t.e; tm == t.m; Yb == wb; tb == t.b "
" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Modified Beta']
" Plot the fitted model "
RGRAPH [WINDOW=3; TITLE='Modified Beta'] INDEX=DOY

" Weibull "
EXPRESSION [VALUE=fitW=Yasim*(1-EXP(-a*(DOY-140)**b))] Weibull
MODEL [SAVE=s_Weibull] Yield; FITTED=fitW
RCYCLE [MAXCYCLE=300; METHOD=NewtonRaphson] Yasim,a,b; \
INITIAL=22,0.0000009,3.3; LOWER=*,0,*
FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
CALC=Weibull; FPROB=yes; SELECTION=r2,%variance,seobservations,\
aic,bic]
" Residual diagnostic plots (cf Figures 9 and 10) "
RCHECK [TITLE='Weibull']
" Plot the fitted model (cf Figure 8) "
RGRAPH [WINDOW=3; TITLE='Weibull'] INDEX=DOY

" Mean of residuals (bias) "
RKEEP [RMETHOD=simple; SAVE=s_Gompertz] RESIDUALS=r_Gompertz
CALC mr_Gompertz = MEAN(r_Gompertz)
RKEEP [RMETHOD=simple; SAVE=s_Logistic] RESIDUALS=r_Logistic
CALC mr_Logistic = MEAN(r_Logistic)
RKEEP [RMETHOD=simple; SAVE=s_Richards] RESIDUALS=r_Richards

```

```

CALC mr_Richards = MEAN(r_Richards)
RKEEP [RMETHOD=simple; SAVE=s_Beta] RESIDUALS=r_Beta
CALC mr_Beta = MEAN(r_Beta)
RKEEP [RMETHOD=simple; SAVE=s_ModBeta] RESIDUALS=r_ModBeta
CALC mr_ModBeta = MEAN(r_ModBeta)
RKEEP [RMETHOD=simple; SAVE=s_Weibull] RESIDUALS=r_Weibull
CALC mr_Weibull = MEAN(r_Weibull)
CAPTION STYLE=meta; TEXT='Mean of residuals'
PRINT mr_Gompertz,mr_Logistic,mr_Richards,mr_Beta,mr_ModBeta,\
      mr_Weibull; HEADING='Gompertz','Logistic','Richards','Beta',\
      'Modified Beta2','Weibull'

" Plot of predicted yield for the different models (Figure 8) "
YAXIS [RESET=no] WINDOW=3; UPPER=25
PEN [RESET=yes] 3; SYMBOL='circle'; COLOUR='black'; CFILL='gray';\
    SIZE=2
PEN [RESET=yes] 2; COLOUR='black'
RGRAPH [WINDOW=3; SAVE=s_Gompertz]
PEN [RESET=yes] 2; COLOUR='red'
RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Logistic]
PEN [RESET=yes] 2; COLOUR='green'
RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Richards]
PEN [RESET=yes] 2; COLOUR='blue'
RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Beta] INDEX=DOY
PEN [RESET=yes] 2; COLOUR='hotpink'
RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_ModBeta] INDEX=DOY
PEN [RESET=yes] 2; COLOUR='gold'
RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Weibull] INDEX=DOY
PEN [RESET=yes] 1...6; METHOD=line; SYMBOL=0; COLOUR='black',\
    'red','green','blue','hotpink','gold'
FRAME WINDOW=2; YLOWER=0.5; YUPPER=1
DKEY [WINDOW=2; BORDER=none] !T(Gompertz,Logistic,Richards,Beta,\
    ModifiedBeta,Weibull)
PEN [RESET=yes] 1...6
FRAME [RESET=yes] WINDOW=2
XAXIS [RESET=yes] WINDOW=3
YAXIS [RESET=yes] WINDOW=3

RESTRICT Yield,DOY

```

Genstat Output

2 JOB

End of job.

```

3
4 " Load the data, where Block, Input and Crop are factors "
5 FACTOR Block, Input, Crop
6 READ [SETLEVELS=yes] Obs,DOY,Block,Input,Crop,Yield; \
7   FREPRESENTATION=labels

```

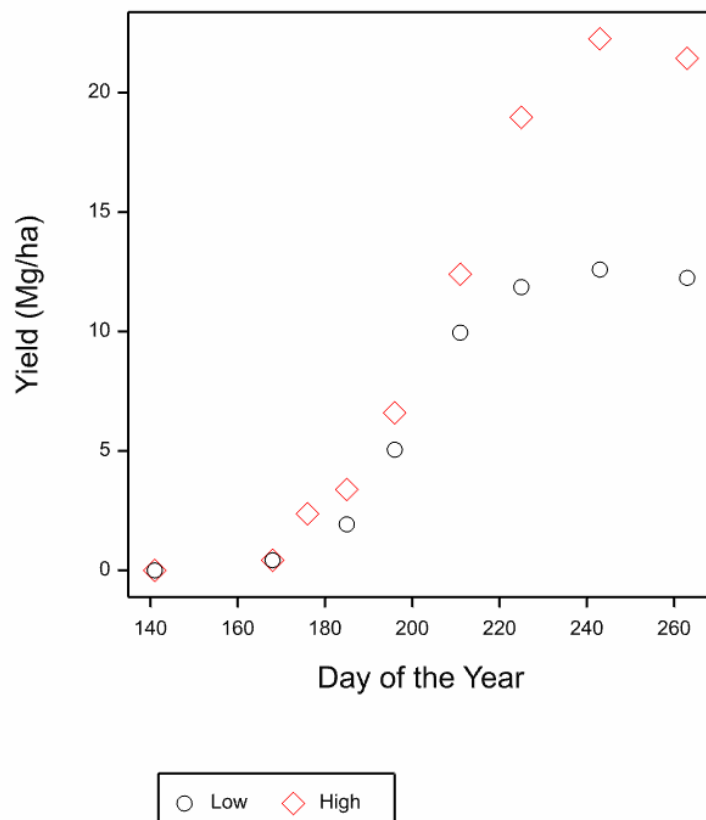
Identifier	Minimum	Mean	Maximum	Values	Missing
Obs	1.000	118.5	236.0	236	0
DOY	141.0	214.6	303.0	236	0

Yield	0.0000	12.76	51.74	236	0	Skew
Identifier	Values	Missing	Levels			
Block	236	0	4			
Input	236	0	2			
Crop	236	0	3			

```

126
127 " Note: A variety of standard non-linear regression models can be
-128 fitted using the FITCURVE directive. Other models can be fitted
-129 using the FIT or FITNONLINEAR directives. "
130
131 " ***** "
132 " Example 1: Maize Biomass Accumulation "
133 " ***** "
134
135 " Figure 4A: Observed yield during the growth season (Block 1,
-136 Crop M (Maize)) "
137 RESTRICT Yield; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M'
138 XAXIS [RESET=yes] WINDOW=1; TITLE='Day of the Year'
139 YAXIS [RESET=yes] WINDOW=1; TITLE='Yield (Mg/ha)'
140 PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='circle','diamond'; \
141 SIZE=1.5,1.6
142 DGRAPH [WINDOW=1; KEYWINDOW=0] Y=Yield; X=DOY; PEN=Input
143 DKEY !T(Low,High) "Input factor: 1st level = Low, 2nd level = High"
144 XAXIS [RESET=yes] WINDOW=1
145 YAXIS [RESET=yes] WINDOW=1
146 PEN [RESET=yes] 1,2
147 RESTRICT Yield

```



```

148
149 " *** Non-linear regression: Beta growth function *** "
150
151 " Define the beta growth model "
152 EXPRESSION [VALUE=fitBG=Ymax*(1+(te-DOY)/(te-tm))*\
153             (DOY/te)**(te/(te-tm))] BetaGrowth
154
155 " Non-linear regression for the low input maize data in Block 1 "
156 RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
157 .AND. Input .IN. 1
158 MODEL Yield; FITTED=fitBG
159 RCYCLE [MAXCYCLE=30] Ymax,te,tm; INITIAL=13,240,180
160 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
161 CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations]

```

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	565.89	188.630	79.24	<.001
Residual	5	11.90	2.380		
Total	8	577.79	72.224		

Percentage variance accounted for 92.2

R-squared statistic 0.944

Standard error of observations is estimated to be 1.54.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	14.41	1.32
te	249.10	2.92
tm	220.40	4.45

```

162 " Plot the fitted model "
163 RGRAPH [WINDOW=3; TITLE='Low input'] INDEX=DOY
164 " Save parameter estimates (for creating Figure 4B) "
165 RKEEP ESTIMATES=e_low
166 " Residuals (raw) "
167 RKEEP [RMETHOD=simple] RESIDUALS=r_low
168 PRINT MEAN(r_low); HEADING='Mean of residuals (bias): low input'

```

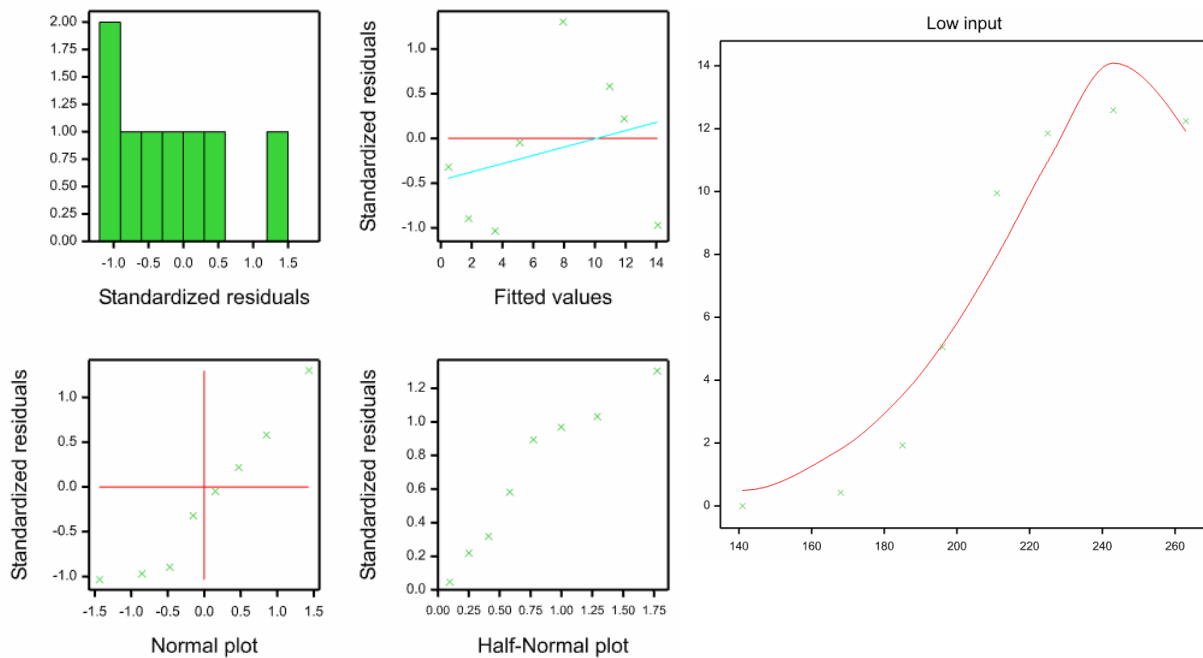
Mean of residuals (bias): low input
 -0.2232

```

169 " Residual diagnostic plots (cf Figures 5 and 6) "
170 RCHECK [TITLE='Low input']
171 RESTRICT Yield,DOY

```

Low input



```

172
173 " Non-linear regression for the high input maize data in Block 1 "
174 RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
175   .AND. Input .IN. 2
176 MODEL Yield; FITTED=fitBG
177 RCYCLE Ymax,te,tm; INITIAL=25,240,210
178 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
179   CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations]

```

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1518.40	506.135	278.00	<.001
Residual	6	10.92	1.821		
Total	9	1529.33	169.925		

Percentage variance accounted for 97.8

R-squared statistic 0.984

Standard error of observations is estimated to be 1.35.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	24.99	1.21
te	251.28	1.43
tm	225.77	1.93

```

180 " Plot the fitted model "
181 RGRAPH [WINDOW=3; TITLE='High input'] INDEX=DOY
182 " Save parameter estimates (for creating Figure 4B) "
183 RKEEP ESTIMATES=e_high
184 " Residuals (raw) "
185 RKEEP [RMETHOD=simple] RESIDUALS=r_high
186 PRINT MEAN(r_high); HEADING='Mean of residuals (bias): High input'

```

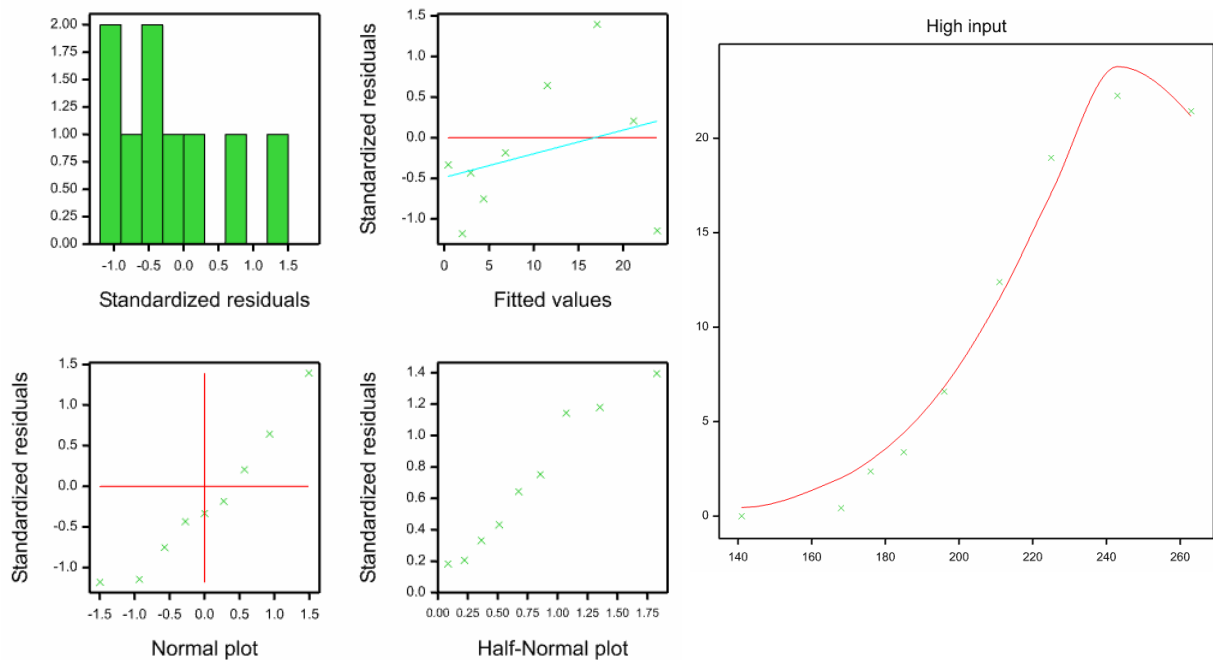
Mean of residuals (bias): High input
-0.2667

```

187 " Residual diagnostic plots (cf Figures 5 and 6) "
188 RCHECK [TITLE='High input']
189 RESTRICT Yield,DOY

```

High input



```

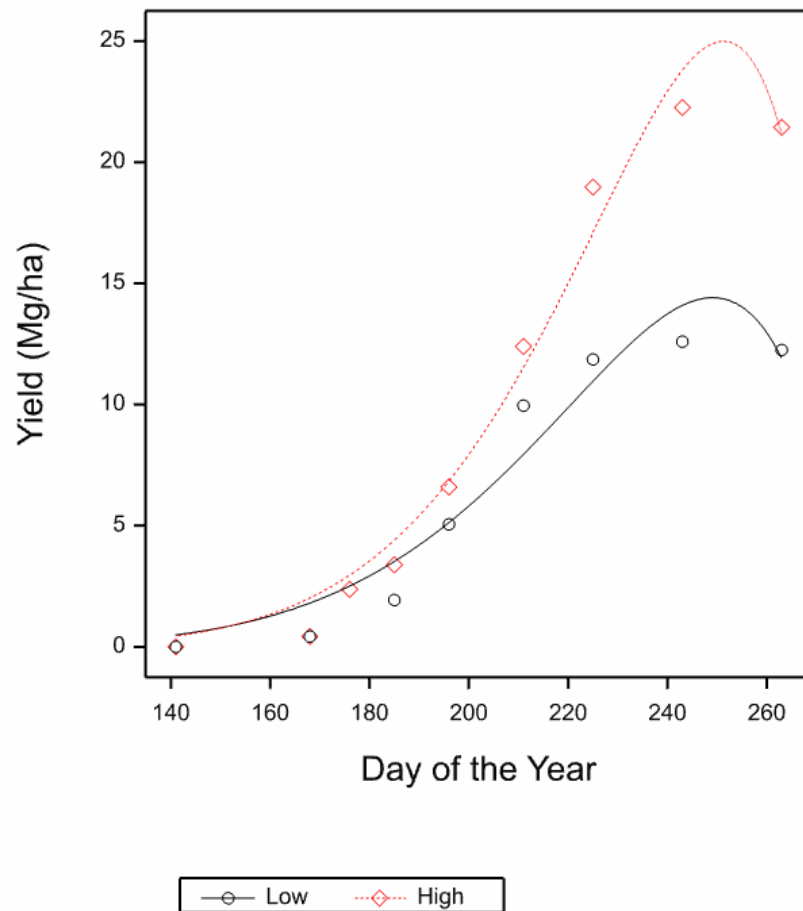
190
191 " Figure 4B: Observed and predicted yield during the growth season
-192 (Block 1, Crop M (Maize)) "
193 VARIATE [VALUES=141...263] d
194 " Predicted values for low input "
195 CALC Ymax = e_low$['Ymax']
196 CALC te = e_low$['te']
197 CALC tm = e_low$['tm']
198 CALC pred_low = Ymax*(1+(te-d)/(te-tm))*(d/te)**(te/(te-tm))

```

```

199 " Predicted values for high input "
200 CALC Ymax = e_high$['Ymax']
201 CALC te = e_high$['te']
202 CALC tm = e_high$['tm']
203 CALC pred_high = Ymax*(1+(te-d)/(te-tm))*(d/te)**(te/(te-tm))
204 " Plot "
205 XAXIS [RESET=yes] WINDOW=1; TITLE='Day of the Year'
206 YAXIS [RESET=yes] WINDOW=1; TITLE='Yield (Mg/ha)'
207 " Observed "
208 RESTRICT Yield; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M'
209 PEN [RESET=yes] 1,2; METHOD=point; SYMBOL='circle','diamond'
210 DGRAPH [WINDOW=1; KEYWINDOW=0] Y=Yield; X=DOY; PEN=Input
211 RESTRICT Yield
212 " Plot fitted "
213 PEN [RESET=yes] 1,2; METHOD=line; SYMBOL=0; LINESTYLE=1,2
214 DGRAPH [WINDOW=1; KEYWINDOW=0; SCREEN=resize] Y=pred_low,pred_high; \
215   X=d,d; PEN=1,2
216 " Add key "
217 PEN [RESET=yes] 1,2; METHOD=line; SYMBOL='circle','diamond'; \
218   LINESTYLE=1,2
219 DKEY !T(Low,High) "Input factor: 1st level = Low, 2nd level = High"
220 XAXIS [RESET=yes] WINDOW=1
221 YAXIS [RESET=yes] WINDOW=1
222 PEN [RESET=yes] 1,2

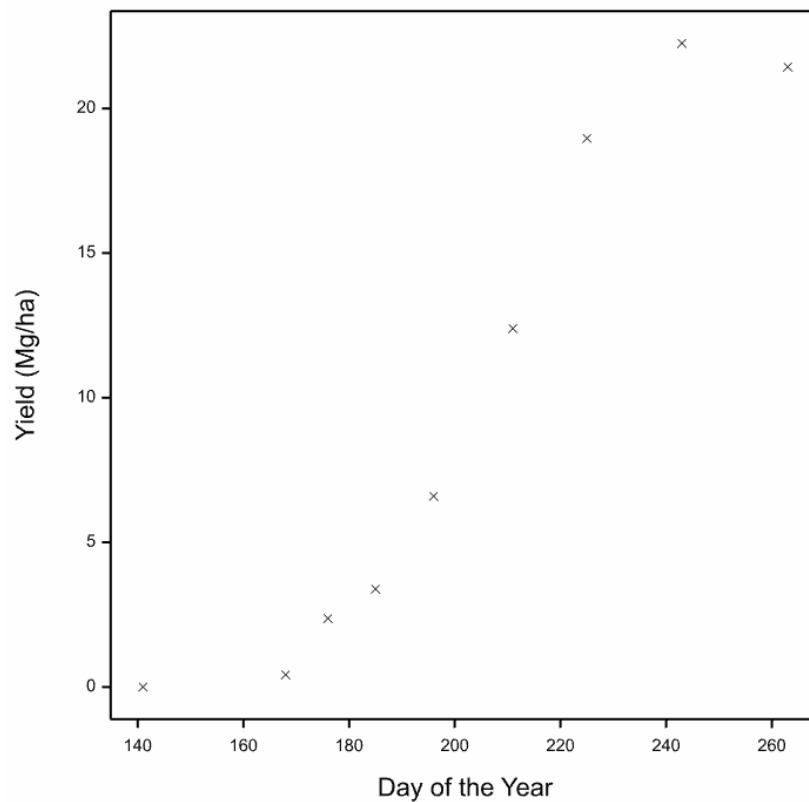
```




```

223
224 " *** Comparing alternative models: Block 1, Crop M (Maize),
-225     Input 2 (High) *** "
226 " Note: The Gompertz, Logistic and Richards (also known as the
-227     Generalized Logistic) models are available as 'standard curves' in
-228     Genstat, and therefore can be fitted using the FITCURVE directive.
-229     FITCURVE is more efficient than a FITNONLINEAR. "
230
231 RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
232     .AND. Input .IN. 2
233
234 " Plot (Figure 7) "
235 XAXIS [RESET=yes] WINDOW=3; TITLE='Day of the Year'
236 YAXIS [RESET=yes] WINDOW=3; TITLE='Yield (Mg/ha)'
237 DGRAPH [WINDOW=3; KEYWINDOW=0] Y=Yield; X=DOY
238 RESTRICT Yield

```



```

239
240 " Gompertz "
241 MODEL [SAVE=s_Gompertz] Yield
242 TERMS DOY
243 FITCURVE [PRINT=model,summary,estimates; CURVE=gompertz; \
244     SENSE=right; CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,\
245     seobservations,aic,bic] DOY

```

Nonlinear regression analysis

Response variate: Yield
 Explanatory: DOY
 Fitted Curve: $A + C \cdot \exp(-\exp(-B \cdot (X - M)))$

Constraints: $C > 0$; $A = 0.0$

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1521.546	507.182	391.04	<.001
Residual	6	7.782	1.297		
Total	9	1529.328	169.925		

Percentage variance accounted for 98.5

R-squared statistic 0.988

Standard error of observations is estimated to be 1.14.

Akaike information criterion is estimated to be 24.5.

Schwarz Bayes information criterion is estimated to be 25.1.

Message: the following units have large standardized residuals.

Unit	Response	Residual
126	21.44	-2.06

Message: the following units have high leverage.

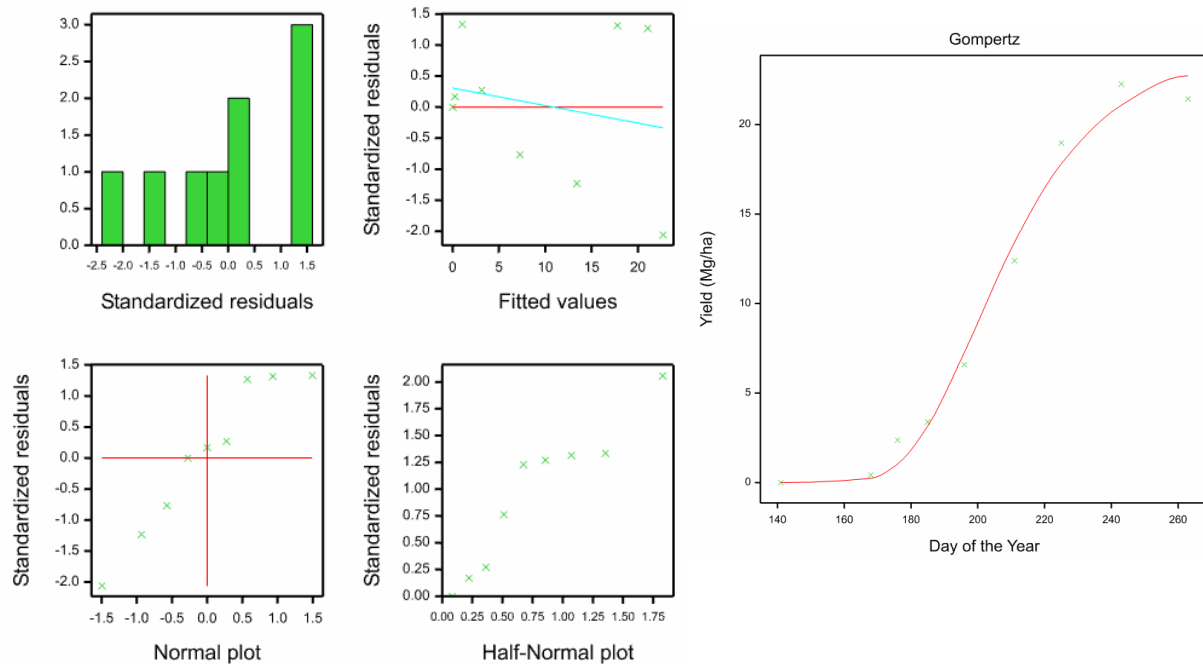
Unit	Response	Leverage
126	21.44	0.70

Estimates of parameters

Parameter	estimate	s.e.
B	0.04853	0.00797
M	199.49	2.37
C	23.79	1.48

```
246 "B == k; M == t.m; C == Y.asim"
247 " Residual diagnostic plots (cf Figures 9 and 10) "
248 RCHECK [TITLE='Gompertz']
249 " Plot the fitted model "
250 RGRAPH [WINDOW=3; TITLE='Gompertz']
```

Gompertz



```

251
252 " Logistic "
253 MODEL [SAVE=s_Logistic] Yield
254 TERMS DOY
255 FITCURVE [PRINT=model,summary,estimates; CURVE=logistic; \
256   CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,seobservations,\
257   aic,bic] DOY

```

Nonlinear regression analysis

Response variate: Yield
 Explanatory: DOY
 Fitted Curve: $A + C/(1 + \text{EXP}(-B*(X - M)))$
 Constraints: $A = 0.0$

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1526.193	508.7310	973.53	<.001
Residual	6	3.135	0.5226		
Total	9	1529.328	169.9254		

Percentage variance accounted for 99.4
 R-squared statistic 0.995
 Standard error of observations is estimated to be 0.723.
 Akaike information criterion is estimated to be 16.3.
 Schwarz Bayes information criterion is estimated to be 16.9.

Estimates of parameters

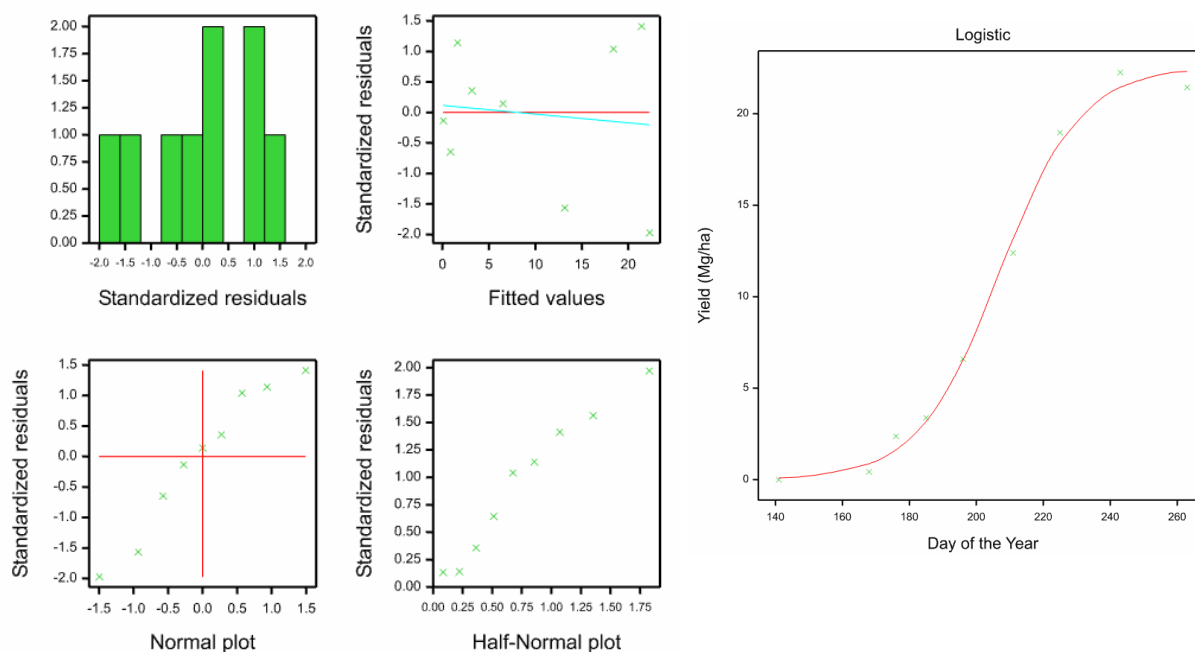
Parameter	estimate	s.e.
B	0.08265	0.00726
M	206.87	1.45
C	22.528	0.641

```

258 "B == k; M == t.m; C == Y.asim"
259 " Residual diagnostic plots (cf Figures 9 and 10) "
260 RCHECK [TITLE='Logistic']
261 " Plot the fitted model "
262 RGRAPH [WINDOW=3; TITLE='Logistic']

```

Logistic



```

263
264 " Richards (also known as the Generalized Logistic) "
265 MODEL [SAVE=s_Richards] Yield
266 TERMS DOY
267 FITCURVE [PRINT=model,summary,estimates; CURVE=glogistic; \
268   CONSTANT=omit; FPROB=yes; SELECTION=r2,%variance,seobservations,\
269   aic,bic] DOY

```

Nonlinear regression analysis

Response variate: Yield
 Explanatory: DOY
 Fitted Curve: $A + C / ((1 + T \cdot \exp(-B \cdot (X - M)))^{1/T})$
 Constraints: $A = 0.0$

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	4	1527.412	381.8530	996.32	<.001
Residual	5	1.916	0.3833		
Total	9	1529.328	169.9254		

Percentage variance accounted for 99.5

R-squared statistic 0.997

Standard error of observations is estimated to be 0.619.

Akaike information criterion is estimated to be 13.9.

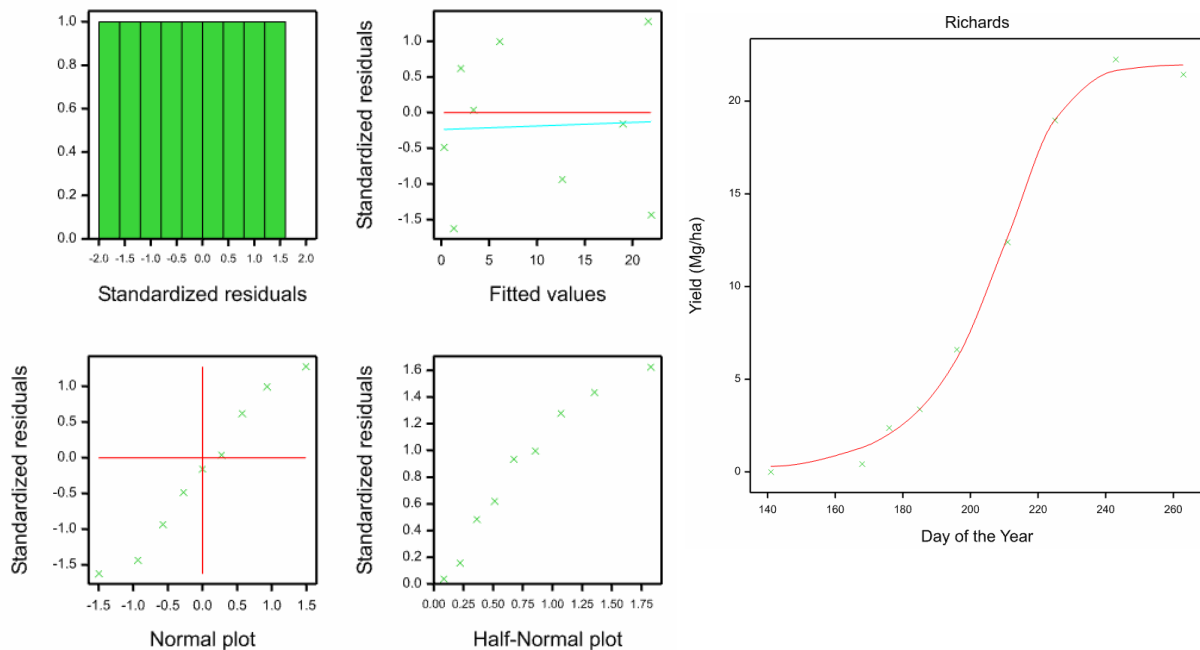
Schwarz Bayes information criterion is estimated to be 14.6.

Estimates of parameters

Parameter	estimate	s.e.
B	0.1354	0.0407
M	212.10	2.76
T	2.44	1.03
C	21.980	0.526

```
270 "B == k; M == t.m; C == Y.asim; T == v"  
271 " Residual diagnostic plots (cf Figures 9 and 10) "  
272 RCHECK [TITLE='Richards']  
273 " Plot the fitted model "  
274 RGRAPH [WINDOW=3; TITLE='Richards']
```

Richards



```

275
276 " Beta "
277 RESTRICT Yield,DOY; CONDITION = Block .IN. 1 .AND. Crop .IN. 'M' \
278 .AND. Input .IN. 2
279 DELETE [REDEFINE=yes] fitBG
280 MODEL [SAVE=s_Beta] Yield; FITTED=fitBG
281 RCYCLE [MAXCYCLE=30; METHOD=GaussNewton] Ymax,te,tm; \
282 INITIAL=10.1,250,220.1
283 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
284 CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,seobservations,\
285 aic,bic]

```

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1518.40	506.135	278.00	<.001
Residual	6	10.92	1.821		
Total	9	1529.33	169.925		

Percentage variance accounted for 97.8
 R-squared statistic 0.984
 Standard error of observations is estimated to be 1.35.
 Akaike information criterion is estimated to be 27.5.
 Schwarz Bayes information criterion is estimated to be 28.1.

Estimates of parameters

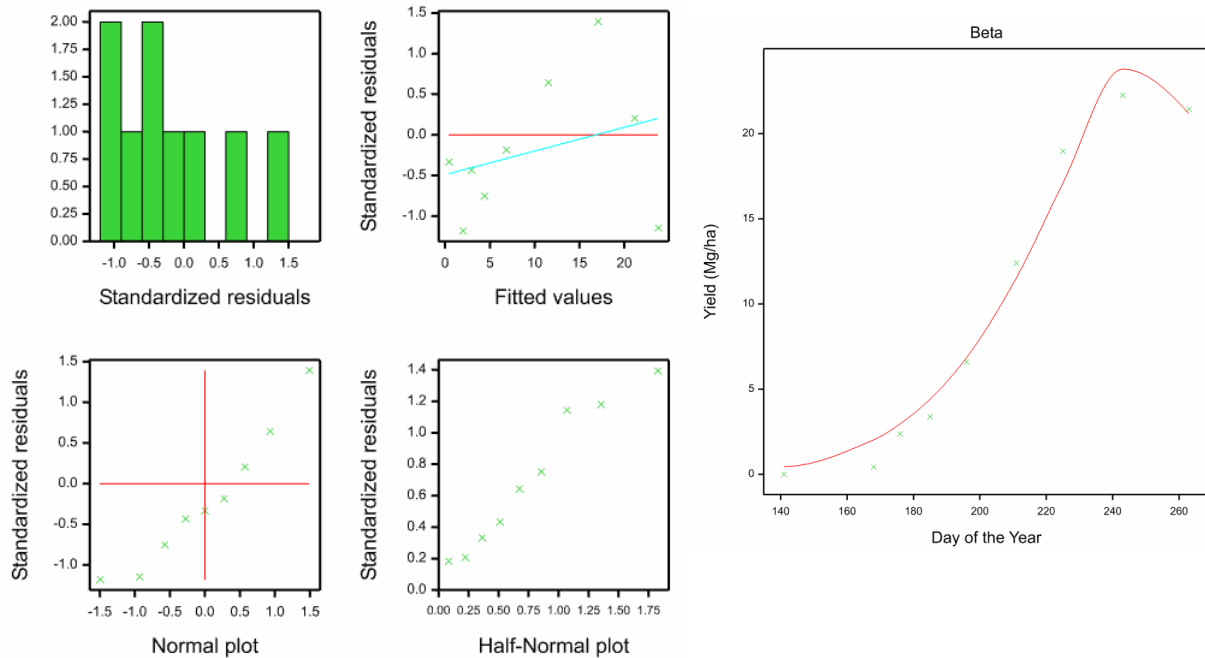
Parameter	estimate	s.e.
Ymax	24.99	1.21
te	251.27	1.43
tm	225.77	1.93

```

286 "Ymax == Y.asim; te == t.e; tm == t.m"
287 " Residual diagnostic plots (cf Figures 9 and 10) "
288 RCHECK [TITLE='Beta']
289 " Plot the fitted model "
290 RGRAPH [WINDOW=3; TITLE='Beta'] INDEX=DOY

```

Beta



```

291
292 " Modified Beta "
293 EXPRESSION ModifiedBeta[1,2]; VALUE=!e(X = MVINSERT(DOY; DOY<tb)),\
294      !e(fitMBG = MVREPLACE(Yb+(Ymax-Yb)*(1+(te-X)/(te-tm))\
295      *((X-tb)/(te-tb))*((te-tb)/(te-tm)))));0)
296 DELETE [REDEFINE=yes] fitMBG
297 MODEL [SAVE=s_ModBeta] Yield; FITTED=fitMBG
298 RCYCLE [MAXCYCLE=30] Ymax,te,tm,Yb,tb; \
299     INITIAL=24,250,215,0,141; LOWER=0; STEP=0.5
300 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
301     CALC=ModifiedBeta[]; FPROB=yes; SELECTION=r2,%variance,\
302     seobservations,aic,bic]

```

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm, Yb, tb
 Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	5	1527.395	305.4790	631.98	<.001
Residual	4	1.933	0.4834		
Total	9	1529.328	169.9254		

Percentage variance accounted for 99.4
 R-squared statistic 0.997

Standard error of observations is estimated to be 0.695.
 Akaike information criterion is estimated to be 15.9.
 Schwarz Bayes information criterion is estimated to be 16.9.

Estimates of parameters

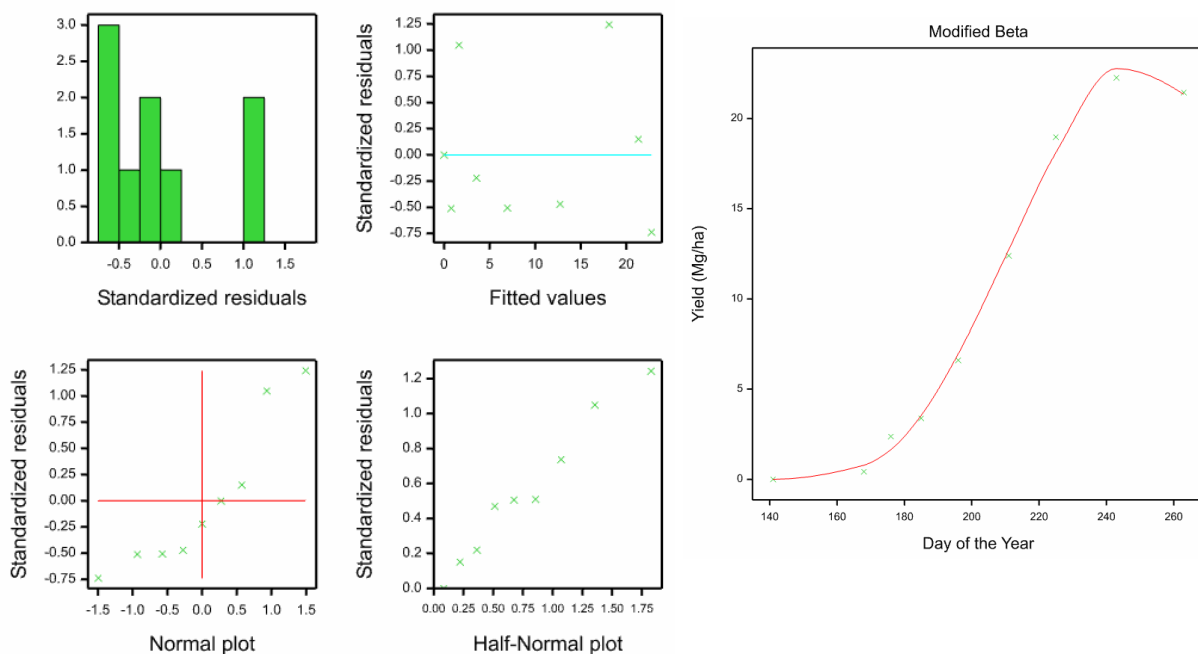
Parameter	estimate	s.e.
Ymax	23.277	0.668
te	250.19	1.51
tm	210.76	5.17
Yb	0.64	1.25
tb	162.6	17.6

```

303 "Ymax == w.max; te == t.e; tm == t.m; Yb == wb; tb == t.b "
304 " Residual diagnostic plots (cf Figures 9 and 10) "
305 RCHECK [TITLE='Modified Beta']
306 " Plot the fitted model "
307 RGRAPH [WINDOW=3; TITLE='Modified Beta'] INDEX=DOY

```

Modified Beta



```

308
309 " Weibull "
310 EXPRESSION [VALUE=fitW=Yasim*(1-EXP(-a*(DOY-140)**b))] Weibull
311 MODEL [SAVE=s_Weibull] Yield; FITTED=fitW
312 RCYCLE [MAXCYCLE=300; METHOD=NewtonRaphson] Yasim,a,b; \
313   INITIAL=22,0.0000009,3.3; LOWER=*,0,*
314 FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
315   CALC=Weibull; FPROB=yes; SELECTION=r2,%variance,seobservations,\
316   aic,bic]

```

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Yasim, a, b
 Model calculations: Weibull

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1526.617	508.8724	1126.15	<.001
Residual	6	2.711	0.4519		
Total	9	1529.328	169.9254		

Percentage variance accounted for 99.5

R-squared statistic 0.996

Standard error of observations is estimated to be 0.672.

Akaike information criterion is estimated to be 15.0.

Schwarz Bayes information criterion is estimated to be 15.6.

Estimates of parameters

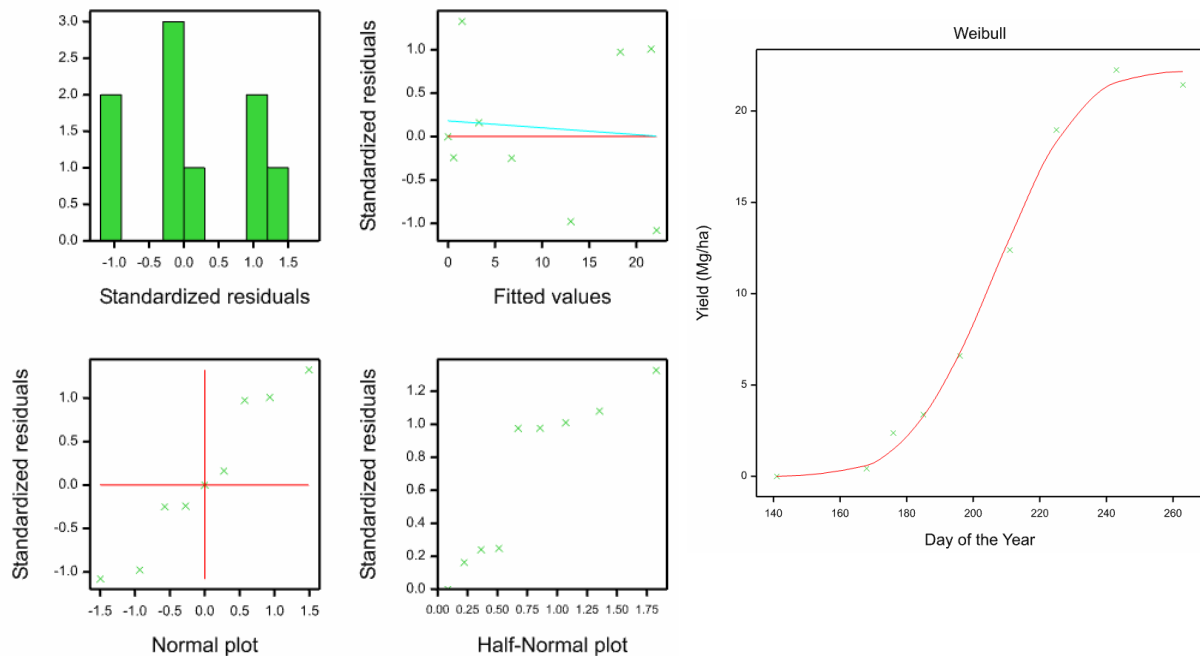
Parameter	estimate	s.e.
Yasim	22.185	0.517
a	9.75E-08	4.39E-08
b	3.759	0.108

```

317 " Residual diagnostic plots (cf Figures 9 and 10) "
318 RCHECK [TITLE='Weibull']
319 " Plot the fitted model (cf Figure 8) "
320 RGRAPH [WINDOW=3; TITLE='Weibull'] INDEX=DOY

```

Weibull



```

321
322 " Mean of residuals (bias) "
323 RKEEP [RMETHOD=simple; SAVE=s_Gompertz] RESIDUALS=r_Gompertz
324 CALC mr_Gompertz = MEAN(r_Gompertz)
325 RKEEP [RMETHOD=simple; SAVE=s_Logistic] RESIDUALS=r_Logistic
326 CALC mr_Logistic = MEAN(r_Logistic)
327 RKEEP [RMETHOD=simple; SAVE=s_Richards] RESIDUALS=r_Richards
328 CALC mr_Richards = MEAN(r_Richards)
329 RKEEP [RMETHOD=simple; SAVE=s_Beta] RESIDUALS=r_Beta
330 CALC mr_Beta = MEAN(r_Beta)
331 RKEEP [RMETHOD=simple; SAVE=s_ModBeta] RESIDUALS=r_ModBeta
332 CALC mr_ModBeta = MEAN(r_ModBeta)
333 RKEEP [RMETHOD=simple; SAVE=s_Weibull] RESIDUALS=r_Weibull
334 CALC mr_Weibull = MEAN(r_Weibull)
335 CAPTION STYLE=meta; TEXT='Mean of residuals'

```

Mean of residuals

```

336 PRINT mr_Gompertz,mr_Logistic,mr_Richards,mr_Beta,mr_ModBeta,\
337     mr_Weibull; HEADING='Gompertz','Logistic','Richards','Beta',\
338     'Modified Beta2','Weibull'

```

Gompertz	Logistic	Richards	Beta	Modified Beta2	Weibull
0.1237	0.02416	-0.06421	-0.2671	0.00001155	0.06946

```

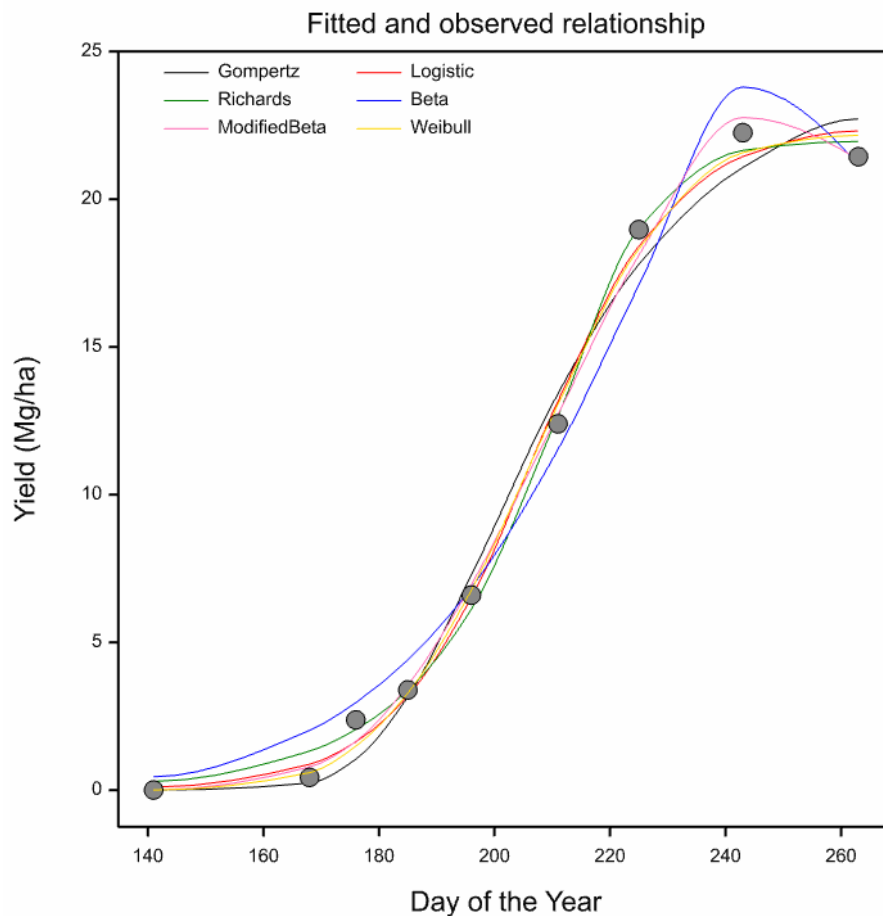
339
340 " Plot of predicted yield for the different models (Figure 8) "
341 YAXIS [RESET=no] WINDOW=3; UPPER=25
342 PEN [RESET=yes] 3; SYMBOL='circle'; COLOUR='black'; CFILL='gray';\
343     SIZE=2

```

```

344 PEN [RESET=yes] 2; COLOUR='black'
345 RGRAPH [WINDOW=3; SAVE=s_Gompertz]
346 PEN [RESET=yes] 2; COLOUR='red'
347 RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Logistic]
348 PEN [RESET=yes] 2; COLOUR='green'
349 RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Richards]
350 PEN [RESET=yes] 2; COLOUR='blue'
351 RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Beta] INDEX=DOY
352 PEN [RESET=yes] 2; COLOUR='hotpink'
353 RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_ModBeta] INDEX=DOY
354 PEN [RESET=yes] 2; COLOUR='gold'
355 RGRAPH [WINDOW=3; SCREEN=keep; SAVE=s_Weibull] INDEX=DOY
356 PEN [RESET=yes] 1...6; METHOD=line; SYMBOL=0; COLOUR='black',\
357   'red','green','blue','hotpink','gold'
358 FRAME WINDOW=2; YLOWER=0.5; YUPPER=1
359 DKEY [WINDOW=2; BORDER=none] !T(Gompertz,Logistic,Richards,Beta,\
360   ModifiedBeta,Weibull)
361 PEN [RESET=yes] 1...6
362 FRAME [RESET=yes] WINDOW=2
363 XAXIS [RESET=yes] WINDOW=3
364 YAXIS [RESET=yes] WINDOW=3

```



```

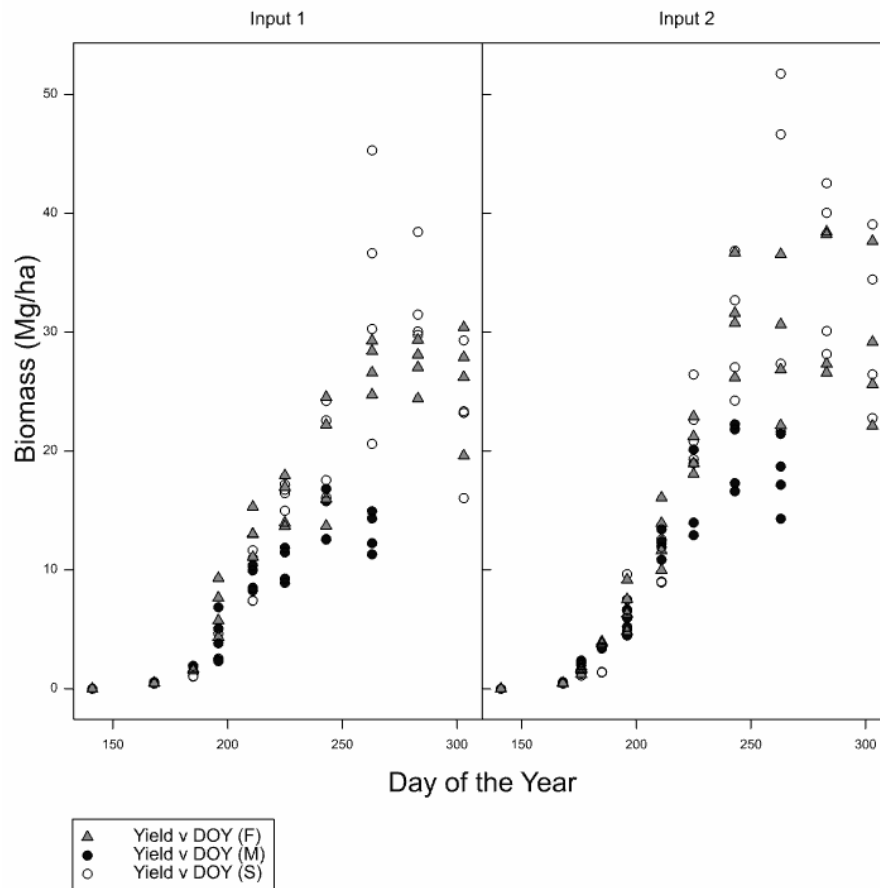
365
366 RESTRICT Yield,DOY
367

```

```

368 " ***** "
369 "   Example 2:  Extended Application "
370 " ***** "
371
372 " Note: As the final model of this example (which includes the
-373 effects of Crop, Input and their interaction for each parameter
-374 and also models the residual variance using a power function)
-375 is not readily fitted in Genstat, Example 2 is only partially
-376 reproduced. "
377
378 " Plot of Biomass accumulation over time for three crops: maize (M),
-379 fiber sorghum (F), and sweet sorghum (S). The two panels represent
-380 the level of agricultural input: high (2) and low (1) (Figure 11) "
381 PEN [RESET=yes] 1...3; COLOUR='black'; SYMBOLS='triangle','circle',\
382 'circle'; CFILL='grey','black',*
383 TRELLIS [GROUPS=Input; PENGROUP=Crop; XTITLE='Day of the Year';\
384 YTITLE='Biomass (Mg/ha)'; NROWS=1; USEPENS=yes] Y=Yield; \
385 X=DOY; METHOD=Point
386 PEN [RESET=yes] 1...3

```



```

387
388 " *** Fitting the beta growth model to each experimental unit *** "
389
390 " Creating an index (eu) which describes the experimental unit "
391 FACPROD !P(Block,Input,Crop); eu
392

```

```

393 " Define the beta growth model (table 1, equation 2.5) "
394 EXPRESSION [VALUE=fitBG=Ymax*(1+(te-DOY)/(te-tm))*\
395             (DOY/te)**(te/(te-tm))] BetaGrowth
396
397 " Note: Genstat doesn't offer a pre-specified algorithm that chooses
-398   initial values, hence values are supplied following visual
-399   inspection of the data (Ymax_i ~ maximum yield, te_i ~ time to
-400   maximum yield, tm_i ~ time to half maximum yield "
401 GETATTRIBUTE [ATTRIBUTE=labels] eu; labels_eu
402 VARIATE [VALUES=27,13,37,38,22,47,28,17,30,27,17,33,30,16,45,38,22,\
403         28,29,13,31,31,17,52] Ymax_i
404 VARIATE [VALUES=283,243,263,283,243,263,263,243,263,283,243,243,303,\
405         243,263,283,243,283,263,243,283,243,243,263] te_i
406 VARIATE [VALUES=211,196,225,225,211,225,225,211,250,211,211,225,225,\
407         225,243,225,211,211,225,196,243,211,211,225] tm_i
408 FFRAME [ROWS=5; COLUMNS=5; STARTWINDOW=1; YMUPPER=0.05]
409 DCLEAR
410 XAXIS WINDOW=1...24; MARKS=50
411 FOR [INDEX=i] unit = 1...24
412   RESTRICT Yield,DOY; CONDITION = eu.IN.unit
413   PRINT #labels_eu[1]${i}
414   DELETE [REDEFINE=yes] fitBG
415   MODEL Yield; FITTED=fitBG
416   RCYCLE [MAXCYCLE=30; METHOD=GaussNewton] Ymax,te,tm; \
417     INITIAL=Ymax_i${i},te_i${i},tm_i${i}; LOWER=0,140,140; STEP=1
418   FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
419     CALC=BetaGrowth; FPROB=yes; SELECTION=r2,%variance,\
420     seobservations]
421   RKEEP RESIDUALS=residuals[i]; FITTED=fittedvalues[i]
422   RGRAPH [WINDOW=i; TITLE=#labels_eu[1]${i}; SCREEN=keep] INDEX=DOY
423   RESTRICT Yield,DOY
424 ENDFOR

```

11 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3143.98	1047.994	110.40	<.001
Residual	7	66.45	9.493		
Total	10	3210.43	321.043		

Percentage variance accounted for 92.7

R-squared statistic 0.943

Standard error of observations is estimated to be 3.08.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	29.69	2.15
te	283.39	4.38
tm	240.33	5.46

1 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	565.89	188.630	79.25	<.001
Residual	5	11.90	2.380		
Total	8	577.79	72.224		

Percentage variance accounted for 92.2

R-squared statistic 0.944

Standard error of observations is estimated to be 1.54.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	14.40	1.32
te	249.12	2.94
tm	220.34	4.46

1 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3563.75	1187.92	104.40	<.001
Residual	7	79.65	11.38		

Total	10	3643.40	364.34

Percentage variance accounted for 93.6
R-squared statistic 0.951
Standard error of observations is estimated to be 3.37.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	35.26	2.63
te	280.54	2.16
tm	247.26	4.37

1 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	6147.7	2049.23	102.24	<.001
Residual	8	160.4	20.04		
Total	11	6308.0	573.46		

Percentage variance accounted for 92.8
R-squared statistic 0.943
Standard error of observations is estimated to be 4.48.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	43.09	3.22
te	284.30	3.85
tm	245.04	4.94

1 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1518.40	506.135	278.00	<.001
Residual	6	10.92	1.821		
Total	9	1529.33	169.925		

Percentage variance accounted for 97.8

R-squared statistic 0.984

Standard error of observations is estimated to be 1.35.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	25.00	1.21
te	251.27	1.43
tm	225.78	1.93

1 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	6256.1	2085.38	139.84	<.001
Residual	8	119.3	14.91		
Total	11	6375.4	579.58		

Percentage variance accounted for 95.0

R-squared statistic 0.960

Standard error of observations is estimated to be 3.86.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	45.78	2.97
te	282.46	2.17
tm	247.84	3.81

2 1 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2573.99	857.997	180.95	<.001
Residual	7	33.19	4.742		
Total	10	2607.18	260.718		

Percentage variance accounted for 95.7
R-squared statistic 0.967
Standard error of observations is estimated to be 2.18.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	29.06	1.66
te	280.43	1.84
tm	245.00	3.54

2 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	655.457	218.486	206.87	<.001
Residual	5	5.281	1.056		
Total	8	660.738	82.592		

Percentage variance accounted for 97.4
R-squared statistic 0.981
Standard error of observations is estimated to be 1.03.

Estimates of parameters

Parameter	estimate	s.e.

Ymax	17.51	1.04
te	251.93	1.29
tm	229.47	2.09

2 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2741.54	913.847	129.73	<.001
Residual	7	49.31	7.044		
Total	10	2790.85	279.085		

Percentage variance accounted for 94.7
R-squared statistic 0.959
Standard error of observations is estimated to be 2.65.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	31.35	2.05
te	278.35	1.82
tm	245.77	3.82

2 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2847.81	949.27	87.64	<.001
Residual	8	86.66	10.83		
Total	11	2934.47	266.77		

Percentage variance accounted for 90.3

R-squared statistic 0.922
Standard error of observations is estimated to be 3.29.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	27.99	2.29
te	279.33	3.78
tm	236.76	5.88

2 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	842.28	280.760	137.44	<.001
Residual	6	12.26	2.043		
Total	9	854.54	94.948		

Percentage variance accounted for 95.4
R-squared statistic 0.965
Standard error of observations is estimated to be 1.43.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	18.18	1.26
te	248.62	1.73
tm	222.19	2.93

2 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3672.4	1224.12	51.63	<.001
Residual	8	189.7	23.71		
Total	11	3862.0	351.09		

Percentage variance accounted for 86.4

R-squared statistic 0.891

Standard error of observations is estimated to be 4.87.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	33.57	3.55
te	277.98	3.55
tm	240.28	6.80

3 1 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3483.84	1161.280	133.61	<.001
Residual	7	60.84	8.691		
Total	10	3544.68	354.468		

Percentage variance accounted for 93.9

R-squared statistic 0.953

Standard error of observations is estimated to be 2.95.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	31.34	1.96
te	289.44	6.78
tm	243.61	5.20

3 1 M

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	650.04	216.681	59.01	<.001
Residual	5	18.36	3.672		
Total	8	668.40	83.550		

Percentage variance accounted for 91.3
 R-squared statistic 0.938
 Standard error of observations is estimated to be 1.92.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	16.87	1.80
te	253.14	3.43
tm	228.89	4.10

3 1 S

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	5203.5	1734.51	95.03	<.001
Residual	7	127.8	18.25		
Total	10	5331.3	533.13		

Percentage variance accounted for 93.6
 R-squared statistic 0.950
 Standard error of observations is estimated to be 4.27.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	44.45	3.49
te	282.51	2.07
tm	251.97	4.23

3 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	4790.19	1596.730	182.11	<.001
Residual	8	70.14	8.768		
Total	11	4860.33	441.848		

Percentage variance accounted for 95.8
R-squared statistic 0.966
Standard error of observations is estimated to be 2.96.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	38.66	2.19
te	281.68	2.17
tm	244.36	3.57

3 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1443.18	481.061	149.98	<.001
Residual	6	19.25	3.208		
Total	9	1462.43	162.492		

Percentage variance accounted for 96.0
R-squared statistic 0.970
Standard error of observations is estimated to be 1.79.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	24.51	1.64
te	248.75	1.46
tm	223.80	2.66

3 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3162.3	1054.10	39.47	<.001
Residual	8	213.6	26.71		
Total	11	3376.0	306.90		

Percentage variance accounted for 81.5
R-squared statistic 0.852
Standard error of observations is estimated to be 5.17.

Message: the following units have large standardized residuals.

Unit	Response	Residual
50	26.44	2.15

Estimates of parameters

Parameter	estimate	s.e.
Ymax	29.60	3.54
te	283.65	7.62
tm	240.20	8.78

4 1 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2709.95	903.32	67.06	<.001
Residual	7	94.30	13.47		
Total	10	2804.25	280.43		

Percentage variance accounted for 89.4

R-squared statistic 0.918

Standard error of observations is estimated to be 3.67.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	28.78	2.54
te	290.15	8.07
tm	248.82	6.55

4 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	530.449	176.816	88.99	<.001
Residual	5	9.935	1.987		
Total	8	540.384	67.548		

Percentage variance accounted for 92.6

R-squared statistic 0.947

Standard error of observations is estimated to be 1.41.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	13.80	1.19
te	248.04	2.63
tm	218.82	4.34

4 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2540.41	846.805	114.88	<.001
Residual	7	51.60	7.371		
Total	10	2592.01	259.201		

Percentage variance accounted for 93.7
R-squared statistic 0.951
Standard error of observations is estimated to be 2.71.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	28.66	2.04
te	285.77	3.39
tm	249.12	4.49

4 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3631.8	1210.60	61.89	<.001
Residual	8	156.5	19.56		
Total	11	3788.3	344.39		

Percentage variance accounted for 87.3
R-squared statistic 0.898
Standard error of observations is estimated to be 4.42.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	31.81	3.10

te	279.16	4.30
tm	237.24	6.90

4 2 M

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	917.425	305.8082	310.23	<.001
Residual	6	5.915	0.9858		
Total	9	923.339	102.5932		

Percentage variance accounted for 98.0
 R-squared statistic 0.985
 Standard error of observations is estimated to be 0.993.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	18.931	0.840
te	252.58	1.87
tm	225.23	1.93

4 2 S

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: BetaGrowth

Summary of analysis

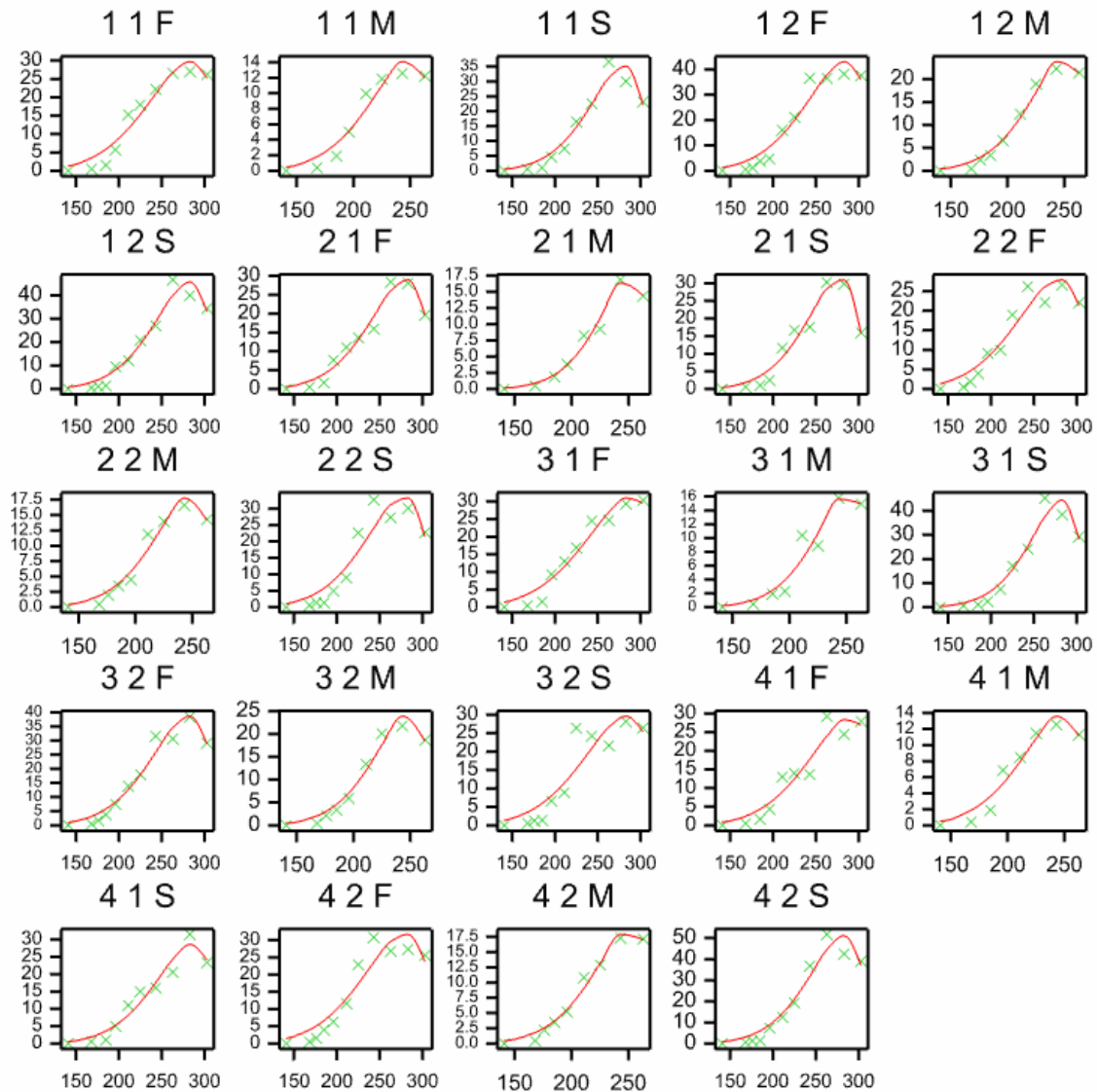
Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	7756.3	2585.44	102.06	<.001
Residual	8	202.7	25.33		
Total	11	7959.0	723.54		

Percentage variance accounted for 93.4
 R-squared statistic 0.947

Standard error of observations is estimated to be 5.03.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	51.19	3.88
te	282.56	2.50
tm	248.24	4.42



```

425 XAXIS [RESET=yes] WINDOW=1...24
426 " Apparent convergence for all experimental units "
427
428 " *** Fitting the modified beta growth model to each experimental
-429 unit *** "

```

```

430
431 " Define the modified beta growth model (table 3, equation 3.11) "
432 EXPRESSION ModifiedBeta[1,2]; VALUE=!e(X = MVINSERT(DOY; DOY<tb)),\
433      !e(fitMBG = MVREPLACE(Yb+(Ymax-Yb)*(1+(te-X)/(te-tm))\
434      *(((X-tb)/(te-tb))*((te-tb)/(te-tm)))));0))
435 " Model fitted with parameters tb and Yb fixed, where tb is the
-436 sowing date (141) and Yb is the biomass weight at sowing (0)"
437 SCALAR Yb; 0
438 SCALAR tb; 141
439 FFRAME [ROWS=5; COLUMNS=5; STARTWINDOW=1; YMUPPER=0.05]
440 DCLEAR
441 XAXIS WINDOW=1...24; MARKS=50
442 FOR [INDEX=i] unit = 1...24
443   RESTRICT Yield,DOY,X; CONDITION = eu.IN.unit
444   PRINT #labels_eu[1]$[i]
445   DELETE [REDEFINE=yes] fitMBG
446   MODEL Yield; FITTED=fitMBG
447   RCYCLE [MAXCYCLE=30; METHOD=GaussNewton] Ymax,te,tm; \
448     INITIAL=Ymax_i$[i],te_i$[i],tm_i$[i]; LOWER=0,140,140; STEP=1
449   FITNONLINEAR [PRINT=model,summary,estimates; CONSTANT=omit; \
450     CALC=ModifiedBeta[]; FPROB=yes; SELECTION=r2,\
451     %variance,seobservations]
452   RKEEP RESIDUALS=mod_residuals[i]; FITTED=mod_fittedvalues[i]
453   RGRAPH [WINDOW=i; TITLE=#labels_eu[1]$[i]; SCREEN=keep] INDEX=DOY
454   RESTRICT Yield,DOY,X
455 ENDFOR

```

1 1 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3179.29	1059.762	238.18	<.001
Residual	7	31.15	4.449		
Total	10	3210.43	321.043		

Percentage variance accounted for 96.6

R-squared statistic 0.973

Standard error of observations is estimated to be 2.11.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	28.57	1.36
te	281.12	4.59

tm 221.88 5.87

1 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	572.223	190.741	171.29	<.001
Residual	5	5.568	1.114		
Total	8	577.791	72.224		

Percentage variance accounted for 96.3
R-squared statistic 0.974
Standard error of observations is estimated to be 1.06.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	13.808	0.819
te	247.11	2.90
tm	208.49	4.58

1 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3597.17	1199.055	181.55	<.001
Residual	7	46.23	6.605		
Total	10	3643.40	364.340		

Percentage variance accounted for 96.3
R-squared statistic 0.971
Standard error of observations is estimated to be 2.57.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	34.46	1.92
te	277.25	1.95
tm	237.22	4.23

1 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	6228.47	2076.158	208.74	<.001
Residual	8	79.57	9.946		
Total	11	6308.04	573.458		

Percentage variance accounted for 96.4
R-squared statistic 0.971
Standard error of observations is estimated to be 3.15.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	41.53	2.11
te	281.77	3.91
tm	229.34	5.20

1 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.

Regression	3	1526.632	508.8775	1132.53	<.001
Residual	6	2.696	0.4493		
Total	9	1529.328	169.9254		

Percentage variance accounted for 99.5

R-squared statistic 0.996

Standard error of observations is estimated to be 0.670.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	23.721	0.535
te	250.32	1.15
tm	215.70	1.44

1 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	6295.91	2098.637	211.15	<.001
Residual	8	79.51	9.939		
Total	11	6375.43	579.584		

Percentage variance accounted for 96.6

R-squared statistic 0.973

Standard error of observations is estimated to be 3.15.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	44.13	2.29
te	279.51	2.30
tm	235.84	4.29

2 1 F

Nonlinear regression analysis

Response variate: Yield

Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2570.22	856.740	162.26	<.001
Residual	7	36.96	5.280		
Total	10	2607.18	260.718		

Percentage variance accounted for 95.3
R-squared statistic 0.963
Standard error of observations is estimated to be 2.30.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	27.82	1.65
te	277.23	2.53
tm	232.32	5.11

2 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	654.134	218.045	165.10	<.001
Residual	5	6.604	1.321		
Total	8	660.738	82.592		

Percentage variance accounted for 96.7
R-squared statistic 0.977
Standard error of observations is estimated to be 1.15.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	16.51	1.02
te	251.26	2.30
tm	221.78	3.31

2 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2750.27	916.755	158.12	<.001
Residual	7	40.58	5.798		
Total	10	2790.85	279.085		

Percentage variance accounted for 95.7
R-squared statistic 0.966
Standard error of observations is estimated to be 2.41.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	30.41	1.77
te	274.61	1.95
tm	235.34	4.35

2 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2885.28	961.760	156.43	<.001
Residual	8	49.18	6.148		
Total	11	2934.47	266.770		

Percentage variance accounted for 94.5
R-squared statistic 0.956
Standard error of observations is estimated to be 2.48.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	26.89	1.61
te	275.19	4.00
tm	217.56	6.74

2 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	848.673	282.8909	289.49	<.001
Residual	6	5.863	0.9772		
Total	9	854.536	94.9484		

Percentage variance accounted for 97.8
R-squared statistic 0.983
Standard error of observations is estimated to be 0.989.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	17.260	0.787
te	246.41	1.73
tm	211.15	2.96

2 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3745.7	1248.57	85.86	<.001
Residual	8	116.3	14.54		
Total	11	3862.0	351.09		

Percentage variance accounted for 91.6
R-squared statistic 0.933
Standard error of observations is estimated to be 3.81.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	32.73	2.64
te	273.32	3.40
tm	225.87	7.21

3 1 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3513.98	1171.326	267.04	<.001
Residual	7	30.70	4.386		
Total	10	3544.68	354.468		

Percentage variance accounted for 96.9
R-squared statistic 0.976
Standard error of observations is estimated to be 2.09.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	30.33	1.33
te	291.76	9.46
tm	223.14	6.23

3 1 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	651.56	217.187	64.48	<.001
Residual	5	16.84	3.368		
Total	8	668.40	83.550		

Percentage variance accounted for 92.0

R-squared statistic 0.943

Standard error of observations is estimated to be 1.84.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	16.04	1.50
te	253.28	5.76
tm	220.27	5.81

3 1 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	5249.33	1749.78	149.42	<.001
Residual	7	81.97	11.71		
Total	10	5331.30	533.13		

Percentage variance accounted for 95.9

R-squared statistic 0.968

Standard error of observations is estimated to be 3.42.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	43.44	2.68
te	279.75	1.94
tm	243.54	4.22

3 2 F

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	4820.33	1606.776	321.31	<.001
Residual	8	40.01	5.001		
Total	11	4860.33	441.848		

Percentage variance accounted for 97.6
R-squared statistic 0.981
Standard error of observations is estimated to be 2.24.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	36.95	1.55
te	278.60	2.32
tm	229.39	3.93

3 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	1455.498	485.166	420.12	<.001
Residual	6	6.929	1.155		
Total	9	1462.427	162.492		

Percentage variance accounted for 98.6
R-squared statistic 0.989
Standard error of observations is estimated to be 1.07.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	23.353	0.896

te	246.50	1.20
tm	214.09	2.26

3 2 S

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3219.4	1073.15	54.85	<.001
Residual	8	156.5	19.56		
Total	11	3376.0	306.90		

Percentage variance accounted for 86.5
 R-squared statistic 0.892
 Standard error of observations is estimated to be 4.42.

Message: the following units have large standardized residuals.

Unit	Response	Residual
50	26.44	2.16

Estimates of parameters

Parameter	estimate	s.e.
Ymax	28.52	2.79
te	280.76	9.71
tm	220.5	11.9

4 1 F

Nonlinear regression analysis

Response variate: Yield
 Nonlinear parameters: Ymax, te, tm
 Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2723.64	907.88	78.83	<.001
Residual	7	80.61	11.52		

Total	10	2804.25	280.43

Percentage variance accounted for 91.0

R-squared statistic 0.930

Standard error of observations is estimated to be 3.39.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	27.84	2.21
te	292.4	14.4
tm	232.67	9.46

4 1 M

Nonlinear regression analysis

Response variate: Yield

Nonlinear parameters: Ymax, te, tm

Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	535.326	178.442	176.40	<.001
Residual	5	5.058	1.012		
Total	8	540.384	67.548		

Percentage variance accounted for 96.2

R-squared statistic 0.973

Standard error of observations is estimated to be 1.01.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	13.161	0.771
te	245.79	2.76
tm	206.12	4.71

4 1 S

Nonlinear regression analysis

Response variate: Yield

Nonlinear parameters: Ymax, te, tm

Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	2538.15	846.051	109.96	<.001
Residual	7	53.86	7.694		
Total	10	2592.01	259.201		

Percentage variance accounted for 93.4

R-squared statistic 0.949

Standard error of observations is estimated to be 2.77.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	27.09	1.87
te	285.62	6.44
tm	234.26	7.08

4 2 F

Nonlinear regression analysis

Response variate: Yield

Nonlinear parameters: Ymax, te, tm

Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	3702.82	1234.27	115.55	<.001
Residual	8	85.46	10.68		
Total	11	3788.28	344.39		

Percentage variance accounted for 93.0

R-squared statistic 0.944

Standard error of observations is estimated to be 3.27.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	30.88	2.16
te	274.53	4.10
tm	219.50	7.42

4 2 M

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	920.991	306.9971	784.54	<.001
Residual	6	2.348	0.3913		
Total	9	923.339	102.5932		

Percentage variance accounted for 99.2
R-squared statistic 0.994
Standard error of observations is estimated to be 0.626.

Estimates of parameters

Parameter	estimate	s.e.
Ymax	17.968	0.459
te	253.21	2.30
tm	213.58	1.93

4 2 S

Nonlinear regression analysis

Response variate: Yield
Nonlinear parameters: Ymax, te, tm
Model calculations: ModifiedBeta[1], ModifiedBeta[2]

Summary of analysis

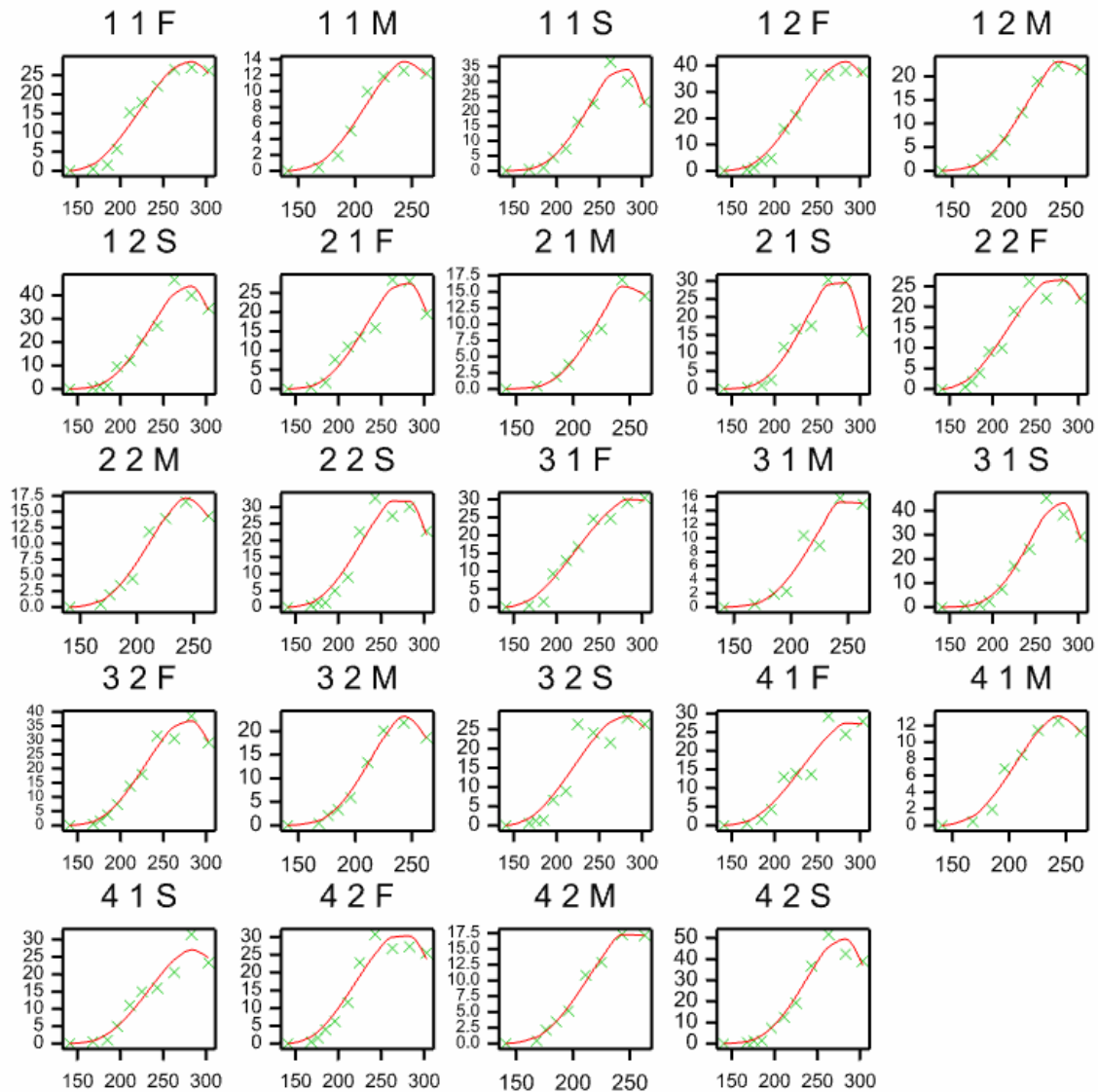
Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	3	7844.5	2614.83	182.75	<.001
Residual	8	114.5	14.31		
Total	11	7959.0	723.54		

Percentage variance accounted for 96.3
R-squared statistic 0.970
Standard error of observations is estimated to be 3.78.

Estimates of parameters

Parameter	estimate	s.e.

Ymax	49.74	2.78
te	279.46	2.34
tm	236.92	4.48



```

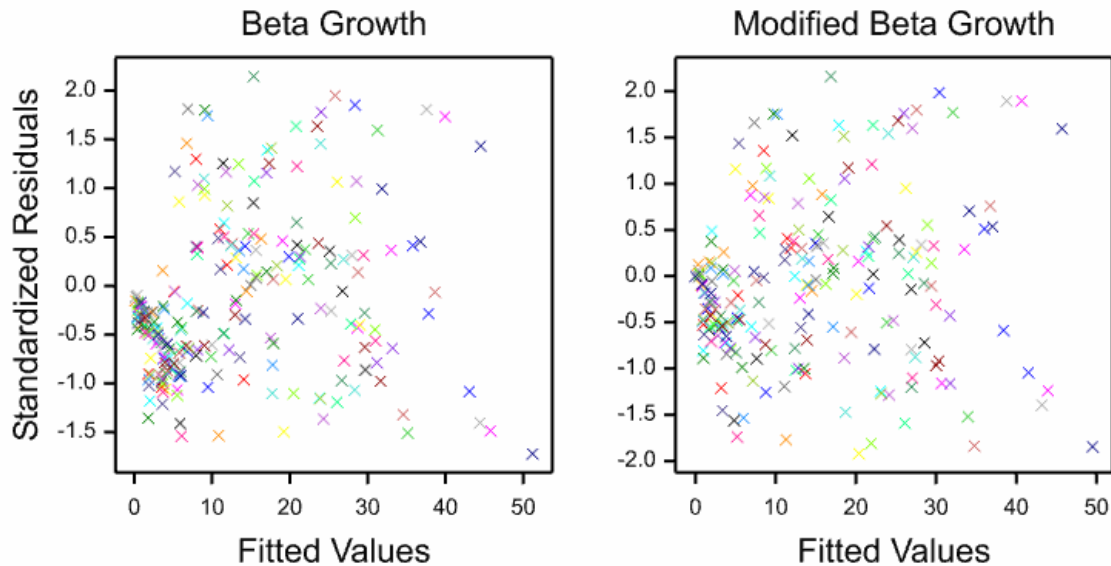
456 XAXIS [RESET=yes] WINDOW=1...24
457 " Apparent convergence for all experimental units "
458
459 " Residual plots (cf Figure 12) "
460 FFRAME [ROWS=1; COLUMNS=2; STARTWINDOW=1; RLOWER=0.5; \
461   MARGIN=ytitle,xtitle]
462 YAXIS [RESET=yes] WINDOW=1; TITLE='Standardized Residuals'
463 XAXIS [RESET=yes] WINDOW=1,2; TITLE='Fitted Values'
464 DGRAPH [WINDOW=1; KEY=0; TITLE='Beta Growth'] Y=#residuals; \
465   X=#fittedvalues
466 DGRAPH [WINDOW=2; KEY=0; TITLE='Modified Beta Growth'; SCREEN=keep] \
467   Y=#mod_residuals; X=#mod_fittedvalues

```

```

468 YAXIS [RESET=yes] WINDOW=1
469 XAXIS [RESET=yes] WINDOW=1

```



```

470
471 " *** Fitting the modified beta growth model to the full data *** "
472
473 " Notes:
-474 * Testing for group differences:
-475   For models that are linear in some parameters, Genstat offers a
-476   parallel curve analysis. Here, the curves can be constrained to be
-477   similar to each other to some degree, governed by restricting some
-478   of the parameters to be common to all groups. Genstat provides
-479   four levels of similarity for a single grouping factor: i) common
-480   curve, ii) separate constants for each group (i.e. parallel
-481   curves), iii) common non-linear parameters but with different
-482   linear parameters for each group, iv) separate curves for each
-483   group.
-484   Non-linear regression models with some linear parameters can be
-485   written as:  $Y = A + B.f(X;?)$ , where Y is the response variable,
-486   X is the explanatory variable, and A, B and ? are the constant,
-487   slope, and non-linear parameters, respectively.
-488 * Non-linear mixed models:
-489   Genstat's HGNONLINEAR procedure can be used to extend conjugate
-490   hierarchical generalized linear models to hierarchical generalized
-491   non-linear models by including non-linear parameters in the fixed
-492   model. "
493
494 " Parallel curve analysis (cf Table 9) "
495 " Non-linear component,  $f(X;?)$ , of the modified beta growth model "
496 " Note: as Yb is fixed at 0, the constant (A) is 0 and the slope (B)
-497   is Ymax "
498 EXPRESSION [VALUE=fitlin=(1+(te-DOY)/(te-tm)) * \
499             ((DOY-141)/(te-141))**((te-141)/(te-tm)) ] \
500             ModifiedBetaLin
501 MODEL Yield
502 RCYCLE [MAXCYCLE=30] te,tm; INITIAL=280,240; LOWER=140,140; STEP=1
503 " Parallel curve analysis for Crop "

```

```

504 RPARALLEL [PRINT=model,summary,accumulated,estimates; \
505     CALCULATION=ModifiedBetaLin; CONSTANT=omit] DOY; GROUPS=Crop

```

Nonlinear regression analysis

Response variate:
 Explanatory:
 Grouping factor:
 Fitted Curve:
 Nonlinear Parameters(theta):
 Calculations, f[]:
 Yield
 DOY
 Crop
 Slope*f(DOY; theta)
 te, tm.

$$\text{fitlin} = (1 + (te - DOY)/(te - tm)) * ((DOY - 141)/(te - 141))^{((te - 141)/(te - tm))}$$

Common curve for all levels of Crop

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	67234.	22411.39	874.62
Residual	233	5970.	25.62	
Total	236	73205.	310.19	

Percentage variance accounted for 82.7
 Standard error of observations is estimated to be 5.06.

Message: the following units have large standardized residuals.

Unit	Response	Residual
100	36.84	2.93
110	36.68	2.90
134	12.25	-3.12
140	11.31	-3.30
142	46.64	3.68
148	51.74	4.69
154	45.30	3.41

Message: the residuals do not appear to be random; for example, fitted values in the range 1.10 to 1.10 are consistently larger than observed values and fitted values in the range 10.71 to 10.71 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	283.26	2.22
tm	230.57	2.43
* Linear		
Slope[1]	30.637	0.766

Common non-linear, separate linear parameters

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	5	69020.	13803.98	762.00
Residual	231	4185.	18.12	
Total	236	73205.	310.19	

Percentage variance accounted for 87.8

Standard error of observations is estimated to be 4.26.

Message: the following units have large standardized residuals.

Unit	Response	Residual
110	36.68	3.01
142	46.64	3.38
148	51.74	4.58
154	45.30	3.06

Message: the residuals do not appear to be random; for example, fitted values in the range 0.77 to 1.28 are consistently larger than observed values and fitted values in the range 7.62 to 11.05 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	278.59	1.29
tm	228.21	2.03
* Linear		
slope[1]['F']	31.700	0.900
slope[1]['M']	20.61	1.15
slope[1]['S']	34.215	0.916

Note: slope[i][j] is slope parameter for calculation i, factor level j.

Residual SS for each level of Crop

ResSS['F']	1234
ResSS['M']	599.4
ResSS['S']	2351

Separate curve for each level of Crop

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	9	69422	7714	462.91
Residual	227	3783	17	
Total	236	73205	310	

Percentage variance accounted for 94.6

Residual SS for each level ofCrop

ResSS['F']	1200
ResSS['M']	351.1
ResSS['S']	2231

Estimates of parameters

te	. Crop	F	280.4	2.434
tm	. Crop	F	225.3	3.380
slope[1]	. Crop	F	30.99	0.9528
te	. Crop	M	249.2	3.156
tm	. Crop	M	213.8	4.393
slope[1]	. Crop	M	17.56	1.152
te	. Crop	S	278.1	1.227
tm	. Crop	S	234.2	2.425
slope[1]	. Crop	S	35.96	1.048

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.
+ DOY	3	67234	22411	1344.97
+ DOY.Crop	2	1786	893	53.58
+ Separate Nonlinear	4	402	101	6.03
Residual	227	3783	17	
Total	236	73205	310	

506 " Parallel curve analysis for Input "

```

507 RPARALLEL [PRINT=model,summary,accumulated,estimates;\
508     CALCULATION=ModifiedBetaLin; CONSTANT=omit] DOY; GROUPS=Input

```

Nonlinear regression analysis

Response variate:
 Explanatory:
 Grouping factor:
 Fitted Curve:
 Nonlinear Parameters(theta):
 Calculations, f[]:
 Yield
 DOY
 Input
 Slope*f(DOY; theta)
 te, tm.

$$\text{fitlin} = (1 + (te - DOY)/(te - tm)) * ((DOY - 141)/(te - 141))^{((te - 141)/(te - tm))}$$

Common curve for all levels of Input

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	67234.	22411.39	874.62
Residual	233	5970.	25.62	
Total	236	73205.	310.19	

Percentage variance accounted for 82.7
 Standard error of observations is estimated to be 5.06.

Message: the following units have large standardized residuals.

Unit	Response	Residual
100	36.84	2.93
110	36.68	2.90
134	12.25	-3.12
140	11.31	-3.30
142	46.64	3.68
148	51.74	4.69
154	45.30	3.41

Message: the residuals do not appear to be random; for example, fitted values in the range 1.10 to 1.10 are consistently larger than observed values and fitted values in the range 10.71 to 10.71 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	283.26	2.22
tm	230.57	2.43
* Linear		
Slope[1]	30.637	0.766

Common non-linear, separate linear parameters

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	4	67974.	16993.58	753.79
Residual	232	5230.	22.54	
Total	236	73205.	310.19	

Percentage variance accounted for 84.8

Standard error of observations is estimated to be 4.75.

Message: the following units have large standardized residuals.

Unit	Response	Residual
128	14.31	-3.51
132	17.17	-2.90
140	11.31	-2.90
142	46.64	3.30
148	51.74	4.38
154	45.30	4.26

Message: the residuals do not appear to be random; for example, fitted values in the range 2.35 to 5.63 are consistently larger than observed values and fitted values in the range 17.24 to 17.24 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	283.11	2.06
tm	230.33	2.27
* Linear		
slope[1]['1']	27.380	0.886
slope[1]['2']	33.801	0.934

Note: slope[i][j] is slope parameter for calculation i, factor level j.

Residual SS for each level of Input

ResSS['1']	2067
ResSS['2']	3163

Separate curve for each level of Input

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	6	68019	11337	502.85
Residual	230	5185	23	
Total	236	73205	310	

Percentage variance accounted for 92.7

Residual SS for each level of Input

ResSS['1']	2039
ResSS['2']	3146

Estimates of parameters

te	. Input	1	284.5	3.191
tm	. Input	1	234.1	3.449
slope[1]	. Input	1	28.05	1.044
te	. Input	2	282.0	2.610
tm	. Input	2	228.1	2.960
slope[1]	. Input	2	33.36	0.9988

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.
+ DOY	3	67234	22411	994.09
+ DOY.Input	1	740	740	32.83
+ Separate Nonlinear	2	45	22	1.00
Residual	230	5185	23	
Total	236	73205	310	

```

509 " Parallel curve analysis for Input by Crop (cf table 8) "
510 FACPRODUCT !P(Input,Crop); InputCrop
511 RPARALLEL [PRINT=model,summary,accumulated,estimates; \
512     CALCULATION=ModifiedBetaLin; CONSTANT=omit] DOY; GROUPS=InputCrop

```

Nonlinear regression analysis

Response variate:
 Explanatory:
 Grouping factor:
 Fitted Curve:
 Nonlinear Parameters(theta):
 Calculations, f[]:
 Yield
 DOY
 InputCrop
 Slope*f(DOY; theta)
 te, tm.

$$\text{fitlin} = (1 + (te - DOY)/(te - tm)) * ((DOY - 141)/(te - 141))^{((te - 141)/(te - tm))}$$

Common curve for all levels of InputCrop

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	3	67234.	22411.39	874.62
Residual	233	5970.	25.62	
Total	236	73205.	310.19	

Percentage variance accounted for 82.7
 Standard error of observations is estimated to be 5.06.

Message: the following units have large standardized residuals.

Unit	Response	Residual
100	36.84	2.93
110	36.68	2.90
134	12.25	-3.12
140	11.31	-3.30
142	46.64	3.68
148	51.74	4.69
154	45.30	3.41

Message: the residuals do not appear to be random; for example, fitted values in the range 1.10 to 1.10 are consistently larger than observed values and fitted values in the range 10.71 to 10.71 are consistently smaller than observed values.

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	283.26	2.22
tm	230.57	2.43
* Linear		

Slope[1]	30.637	0.766

Common non-linear, separate linear parameters

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	8	69775.	8721.90	579.88
Residual	228	3429.	15.04	
Total	236	73205.	310.19	

Percentage variance accounted for 89.8
Standard error of observations is estimated to be 3.88.

Message: the following units have large standardized residuals.

Unit	Response	Residual
142	46.64	2.88
146	21.64	-3.56
148	51.74	4.20
154	45.30	4.19

Message: the error variance does not appear to be constant; large responses are more variable than small responses.

Estimates of parameters

Parameter	estimate	s.e.
te	278.52	1.17
tm	228.01	1.84
* Linear		
slope[1]['1 F']	28.73	1.08
slope[1]['1 M']	17.22	1.42
slope[1]['1 S']	30.78	1.09
slope[1]['2 F']	34.60	1.10
slope[1]['2 M']	23.91	1.45
slope[1]['2 S']	37.58	1.12

Note: slope[i][j] is slope parameter for calculation i, factor level j.

Residual SS for each level of InputCrop

ResSS['1 F']	315.3
ResSS['1 M']	130.4
ResSS['1 S']	756.8
ResSS['2 F']	669.6
ResSS['2 M']	290.2
ResSS['2 S']	1267

Separate curve for each level of InputCrop

Nonlinear regression analysis

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.
Regression	18	70252	3903	288.13
Residual	218	2953	14	
Total	236	73205	310	

Percentage variance accounted for 95.6

Residual SS for each level of InputCrop

ResSS['1 F']	276.4
ResSS['1 M']	56.64
ResSS['1 S']	607.5
ResSS['2 F']	655.2
ResSS['2 M']	107.6
ResSS['2 S']	1250

Estimates of parameters

te	. InputCrop	1 F	283.9	4.504
tm	. InputCrop	1 F	226.5	5.012
slope[1]	. InputCrop	1 F	28.18	1.189
te	. InputCrop	1 M	250.1	5.339
tm	. InputCrop	1 M	214.2	6.966
slope[1]	. InputCrop	1 M	14.67	1.468
te	. InputCrop	1 S	278.4	1.454
tm	. InputCrop	1 S	238.6	3.094
slope[1]	. InputCrop	1 S	33.77	1.386
te	. InputCrop	2 F	278.0	2.349
tm	. InputCrop	2 F	224.5	3.749
slope[1]	. InputCrop	2 F	33.93	1.229
te	. InputCrop	2 M	248.6	3.175
tm	. InputCrop	2 M	213.7	4.614
slope[1]	. InputCrop	2 M	20.49	1.472
te	. InputCrop	2 S	278.1	1.659
tm	. InputCrop	2 S	230.9	3.017
slope[1]	. InputCrop	2 S	38.44	1.295

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.
+ DOY	3	67234	22411	1654.54
+ DOY.InputCrop	5	2541	508	37.52
+ Separate Nonlinear	10	476	48	3.52
Residual	218	2953	14	
Total	236	73205	310	

513

514 ENDJOB

End of job