First Place Student Essay

Soybean Development is Affected by Method and Timing of Rye Control in Cover Crop Systems

Leslie R. Westgate* and Jeremy W. Singer

ABSTRACT

Cover crops provide many environmental and soil quality benefits, yet their adoption into production agriculture has been limited by insufficient management information. This study was conducted to determine a combination of method and timing of rye (Secale cereale L.) control that would not hinder soybean (Glycine max (L.) Merr.) growth or result in resource competition. The effects of mechanical and chemical rye control at 2nd node, boot, and anthesis growth stages on soil water, light interception, soybean growth and maturity were investigated near Boone, IA, on Spillville loam (Fine-loamy, mixed, superactive, mesic Cumulic Hapludolls), and Clarion loam (Fine-loamy, mixed, superactive, mesic Typic Hapludolls) in 2002 and 2003 growing seasons. In 2002, untilly rainfall reduced soil water 0.0325 kg kg⁻¹ from 2nd node to anthesis in the 0–15 cm depth in chemical control. In mechanical control, rye depleted soil water until it matured, at which point larger plants in check subplots utilized soil water at a higher rate than soybean in treatments with rye. Soybean light interception was reduced by rye in mechanical treatments in both years. Anthesis and check plots in chemical control had similar values for light interception. Biomass accumulation was lower under mechanical control than chemical control. However, even the best treatment in chemical control, anthesis, accumulated 140 g m⁻² less biomass than check treatments in 2002. All treatments containing rye delayed maturity. Anthesis timing matured closest to check subplots at 6.5 and 3.8 days after the check in 2002 and 2003, respectively. The possibility of allelopathy delaying maturity is worthy of further investigation. Chemical control at anthesis was the most effective management system next to the check, differing significantly and 3.8 days after the check in 2002 and 2003, respectively. The chemical control was a glyphosate label rate 1.68 kg a.i. ha⁻¹ results in equal control (95%) at growth stages from flag leaf to soft dough. Nevertheless, timing of cover crop control must be balanced with main crop planting date to reach a reasonable balance.

Although numerous studies have examined the effects of method or timing of cover crop management on soybean (Creamer et al., 1995; Munawar et al., 1990; Hoffman et al., 1993), more information is required on the interaction between method and timing of rye control. It is necessary to identify systems that maintain adequate soybean growth and development while reducing resource competition from cover crops. The objectives of this study were to identify critical growth stages for mechanical and chemical rye control on soybean development and resource utilization and provide soybean producers with more management information.

MATERIALS AND METHODS

Field studies were conducted at the Agricultural Engineering Research Center in Boone County, Iowa (42°01′ N, 93°45′ W; 341 m asl), from October 2001–2003. In 2001–2002, the soil was a Spillville loam (Fine-loamy, mixed, superactive, mesic Cumulic Hapludoll), and in 2002–2003 a Clarion loam (Fine-loamy, mixed, superactive, mesic Typic Hapludoll). ‘Rymin’ rye was planted at 405 000 seeds ha⁻¹ with a Marliss (Marliss Division/Sukup Manufacturing Company, Jonesboro, AR) drill in late September or early October of each year following corn grain harvest.

The experimental design was a randomized complete block with treatments arranged in a split-plot with four replications. Main plots were mechanical or chemical rye control applied in the spring. Subplots were timing of rye control and were 5 rows (3.8 m) wide by 28.9 m and 12.2 m long in 2002 and 2003, respectively. The chemical control was a glyphosate
(Roundup UltraMax) application at a rate of 1.41 kg a.i. ha$^{-1}$. Mechanical control was achieved using a Buffalo (Fleischer Manufacturing Inc., Columbus, NE) stalk chopper with one pass in 2002 and two passes in 2003, which left approximately 15 cm of rye stubble. Timing of rye control occurred at one of three growth stages: 2nd node visible (7), boot (9.8), or flowering (10.5.1) corresponding to Feeke’s decimal code for cereals (Zadoks et al., 1974). Control was implemented, respectively, on 7, 14, and 23 May 2002 and 12, 20, and 30 May 2003. Check subplots containing no rye were established by killing rye with glyphosate (0.70 kg a.i. ha$^{-1}$ Roundup UltraMax) in the spring one week after green-up (16 April and 15 April, 2002 and 2003, respectively). Check subplots were maintained vegetation free for the entire growing season with additional glyphosate and hand weeding as necessary. All other subplots received no additional vegetation control until soybean reached approximately R4 (Ritchie et al., 1994); all subplots were then sprayed with glyphosate (0.70 kg a.i. ha$^{-1}$ Roundup UltraMax) to kill weeds and prevent seed development.

Pioneer Brand ‘92B84’ soybean was planted 28 May and 5 June in 2002 and 2003 at 445 000 seeds ha$^{-1}$ at 76 cm row spacing. Soybean plants were harvested for dry matter determination at the soil surface from 0.5 m of non-harvest row within each subplot every 10 and 15 d in 2002 and 2003, respectively. Samples were dried at 70°C in a forced-air oven until a constant weight was achieved. Prior to harvest, soybean maturity data were obtained as the date when 95% of pods reached their final color.

Interception of photosynthetically active radiation (PAR) was measured weekly from 24 June through 26 September (2002), and 2 July through 24 September (2003) between 1200 and 1500 h in full sun conditions (PAR > 1600 μmol m$^{-2}$ s$^{-1}$) using a 1-m Sunscan Probe (Delta-T Devices Cambridge, England). Measurements were collected diagonally across the three center rows of each subplot. Three were collected below the soybean canopy and three were observed at approximately the same location above the soybean canopy, but below any canopy of weeds or rye re-growth, depending on the treatment. Light interception by soybean was calculated as the difference between incident and transmitted light divided by incident light.

Soil water was collected every 7–10 d from the 0–15 and 15–30 cm soil depths using a soil core with a diameter of 18 mm. Five (2002) and three (2003) soil cores per subplot were combined, weighed wet, dried in an oven at 100°C until constant weight, weighed dry, and converted to gravimetric (kg kg$^{-1}$) water using the difference between the wet and dry weights.

Data were significant between years and analyzed separately. Each year was analyzed as a split-plot using PROC GLM in SAS (SAS Institute, 2001). Treatment means were separated using a protected LSD procedure (Little and Hills, 1978) when the F-test was significant ($P < 0.05$).

**RESULTS AND DISCUSSION**

Growing conditions were more favorable in 2003 than 2002 (Fig. 1). Rainfall during the growing season (May–September) was 623 mm in 2002 and 562 mm in 2003. Although total rainfall in 2002 exceeded that of 2003, the distribution of rainfall played a more influential role in soybean development and the accumulation of dry matter than total rainfall. Rainfall accumulation in June was 81 mm in 2002 and 150 mm in 2003. The effects of this early dry period and above average temperatures in 2002 are evident from V2 through R2, when water stress had the most adverse affects on the accumulation of soybean biomass in mechanical plots.

**Soil Water**

Soil water depletion and recharge followed rainfall events closely (Compare Fig. 1 and 2). The greatest differences occurred during periods of low rainfall. Data are presented only for 2002 (Fig. 2) because few differences were observed in 2003 as a result of more consistent and timely rainfall throughout the season and more effective mechanical rye control.

Mechanical control was not completely effective in 2002 and re-growth occurred in both years in earlier control dates: 2nd node and boot growth stages consequently produced substantial living residue during the beginning of the growing season. To increase effectiveness of the treatment, weights were added above the blades of the buffalo stalk chopper in 2003.

In 2002, soil water reached a high of 0.2302 kg kg$^{-1}$ on DOY (Day of year) 193 in chemical control at anthesis in the 0–15 cm depth. A low of 0.0910 kg kg$^{-1}$ was recorded on DOY 184 in mechanical control at the 2nd node timing in the 0–15 cm depth. Field capacity is referenced as 0.258 kg kg$^{-1}$.

In chemical control plots, rye residue increased with delayed control, therefore, 2nd node had the least quantity of residue covering the soil surface compared with control at anthesis, which had the greatest quantity of rye residue. Mechanical plots also experienced rapid soil water depletion in

---

**Fig. 1.** Daily air temperature and precipitation for the Agronomy Agricultural Engineering Research Center near Boone, IA, for 2002 and 2003, compared with the 50 yr average air temperature.
2nd node treatment during the first dry down period. However, check subplots, rather than subplots with rye removed at anthesis exhibited the greatest soil water content during the first dry down period. Soil water was utilized by rye in 2002 due to the ineffective mechanical control.

The second dry down period in 2002 was between DOY 189 and 216. In the mechanical control, rye regrowth matured and was no longer competing for water by DOY 189. The treatment with the lowest soil water content was the check. This result was observed at both soil depths and displayed a maximum difference in the 15–30 cm depth of 0.0152 kg kg$^{-1}$ between boot and check. The second node, boot, and anthesis treatments had more soil water because soybean were slower to develop than in check subplots; therefore, their de-

Fig. 2. Method and timing of rye control on soil water at 0–15 and 15–30 cm soil depths in 2002 and 2003, near Boone, IA.

Fig. 3. Method and timing of rye control on soybean light interception in 2002 and 2003, near Boone, IA.
layed water use only partially depleted the levels of soil water in the latter part of the season. Check subplots had a much higher soybean dry matter accumulation at this point and the larger plants utilized a greater amount of soil water.

In chemical control, the second dry down period was characterized differently from the 0–15 cm soil depth than the 15–30 cm depth. The 116 mm of rain received during this period was not sufficient to increase soil water content from the 15–30 cm soil depth. During this time, weed competition for 2nd node treatment hastened soil water depletion from the 15–30 cm soil depth.

**Light Interception**

Chemical and mechanical rye control affected light interception by soybean (Fig. 3). In chemical control plots, rye residue intercepted light until soybean reached a height of approximately 17 cm. The residue reduced weed establishment and by mid-season there was no canopy above the soybean in chemical plots. The thickness of this residue layer varied with time of control date. The residue from 2nd node and boot treatments was insufficient to control weed establishment, which then reduced light interception of soybean. The anthesis treatment provided sufficient surface residue to prevent weed establishment and had similar light interception as the check.

In mechanical control, the rye canopy reduced total light interception by soybean. This may be attributed to water stress, as a consequence of living rye in the mechanical treatments. No treatment effects were observed among timings; however, all three timings were lower than the check. These results were consistent in both years, but exacerbated in 2002 because of insufficient rye control and increased water stress.

**Dry Matter Accumulation and Maturity**

Treatments with higher light interception by soybean and higher soil water had higher amounts of biomass (Fig. 4 and 5). In 2002 significant differences were observed across both timing and method of rye control. In mechanical treatments, dry matter accumulated at the same rate for all timings, but was significantly lower than check subplot and all timings subjected to chemical control.

In chemical control, differences were observed among subplots. Timing of control at 2nd node and boot stages had a lower accumulation of dry matter than anthesis and check subplots. The separation among treatments in chemically controlled plots began at DOY 203 with trends and separation continuing throughout the season.

In 2002, maximum accumulation of dry matter in chemical treatments was 508, 526, 612, and 751 g m$^{-2}$ in 2nd node, boot, anthesis, and check, respectively. Maximum accumulation in mechanical treatments was 146, 176, 159, and 553 g m$^{-2}$ in 2nd node, boot, anthesis, and check, respectively. These differences can be attributed to ineffective control in mechanical plots resulting in increased resource competition.

In 2003, the accumulation of dry matter was not significantly different across method of rye control due to more effective mechanical management. Accumulation was affected by the presence of rye; all subplots containing rye were significantly lower than control subplots. Averaged across timing of control, 2nd node, boot, and anthesis accumulated 395, 443, and 380 g m$^{-2}$ dry matter compared with 637 g m$^{-2}$ accumulated in the check treatment.

The check subplots reached maturity on DOY 265 (2002) and 275 (2003) (Table 1). Anthesis was the first timing treatment to reach maturity at 6.5 and 9.3 d after check plots matured in 2002 and 2003, respectively. Boot treatments matured 9.2 (2002) and 5 (2003) d after check. Maturity in 2nd node was 7.3 (2002) and 5.3 (2003) d after check. One explanation for the observed difference in maturity is the possibility of al-

![Fig. 4. Method and timing of rye control on dry matter accumulation in 2002, near Boone, IA.](image1)

![Fig. 5. Timing of rye control on dry matter accumulation in 2003, near Boone, IA.](image2)
lelopathy. There are references to phytotoxic effects produced by decomposition of litter. Although exact mechanisms are not completely understood, allelopathic effects of residue have been found to decrease germination and vigor of soybean plants (Facelli and Picket, 1991).

**CONCLUSIONS**

Cover crops have the potential to provide environmental and soil quality benefits. However, management information that does not limit soybean growth must be available. Management systems practiced in this study reduced soybean development and dry matter accumulation. Periods of low rainfall, ineffective rye control, and possible allelopathy were critical limiting factors. Chemical control at anthesis was the most effective treatment but still delayed maturity. Producers who adopt this method must compensate for the possibility of soybean yield depression by identifying markets that offset losses with higher prices.

<table>
<thead>
<tr>
<th>Timing†</th>
<th>df</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd Node</td>
<td>8</td>
<td>7.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Boot</td>
<td>8</td>
<td>7.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Anthesis</td>
<td>8</td>
<td>6.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Check</td>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>LSD(0.05)§</td>
<td>0.7</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

**ANOVA**

Method (M) | 1 | 0.205 | 0.396 |
Timing (T) | 3 | 0.000 | 0.000 |
M × T      | 3 | 0.034 | 0.393 |

† 2nd node, boot, and anthesis correspond to Feeke’s growth stages 7, 9.8, and 10.5.1, respectively.
‡ Pod maturity reported as days after check-plots reached maturity on DOY 265 and 275 in 2002 and 2003, respectively.
§ LSD compares subplot means.

### REFERENCES


---

**Table 1. Timing of rye control effects on soybean pod maturity in 2002 and 2003, near Boone, IA.**

<table>
<thead>
<tr>
<th>Timing†</th>
<th>df</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd Node</td>
<td>8</td>
<td>7.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Boot</td>
<td>8</td>
<td>7.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Anthesis</td>
<td>8</td>
<td>6.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Check</td>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>LSD(0.05)§</td>
<td>0.7</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

**ANOVA**

Method (M) | 1 | 0.205 | 0.396 |
Timing (T) | 3 | 0.000 | 0.000 |
M × T      | 3 | 0.034 | 0.393 |

† 2nd node, boot, and anthesis correspond to Feeke’s growth stages 7, 9.8, and 10.5.1, respectively.
‡ Pod maturity reported as days after check-plots reached maturity on DOY 265 and 275 in 2002 and 2003, respectively.
§ LSD compares subplot means.