Laboratory suggestions for introductory plant breeding courses

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ABSTRACT

This paper gives suggestions for laboratory procedures in eight different topic areas; crossing techniques, inheritance of qualitative and quantitative traits, quality factors, breeding methodology, breeding for disease and insect resistance, field screening and note taking, and special techniques. These suggestions are flexible enough that they can easily be tailored to different needs and facilities. The labs stress student participation, ease of preparation, and low cost.

Additional index words: Agronomy instruction, Course improvement.

Laboratory sections are becoming a more important part of agricultural curricula as colleges of agriculture see increasing enrollments of students from urban areas who have not had the experience of observing many of the techniques discussed in class. Little published information on suitable laboratory exercises for introductory plant breeding courses was found in the literature [two notable exceptions are Hawk and Crowder (2) and Marx (3)]. Eight laboratory exercises that have been of benefit to students in the undergraduate plant breeding course at the University of Florida are presented in this paper. The descriptions of these labs are not procedures, but general suggestions for labs. They are open-ended so they can be easily tailored to a department's own facilities and to the crops most important to an area. Low cost is stressed in these labs, although it is assumed that greenhouse space and student help are available to assist in the growing of plants and in lab preparation. Some field space is also helpful, although not essential.

Laboratory Suggestions

1. Crossing Techniques
   A. Students will need:
      1. flowering plants representing several different families

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2. Inheritance of Qualitative Traits

A. Students will need:
1. greenhouse flats with two lines of plants differing in qualitative, one or two gene, seedling traits.
2. flats with F2 plants from a cross of these lines.
B. In this lab the student will see how a plant breeder determines the dominant-recessive nature of the trait, as well as the number of genes controlling a trait. The students will also use a chi-square test on actual data they collect. Several biological supply houses carry parental and F2 seeds of such material, with easily identified traits such as cob, kernel color, albino seedlings of corn, sorghum and tobacco, and leaf shape in tomato.

3. Inheritance of Quantitative Traits

A. Students will need:
1. parental and F1 plants (or plant parts) segregating for easily measured quantitative traits.
2. measurement tools (balances or rulers).
B. Since yield and many other quantitative traits play such a large role in most plant breeding programs, an examination of the behavior of these traits is important for the students. Many traits suitable for this lab are available in mature plants, which can be harvested at the end of the growing season and stored until lab time. Seed from individual plants can be harvested, packaged, and stored until need. Five or six inexpensive triple beam balances can suffice for a class of twenty or more, especially if some students can be assigned a seed processing task while others weigh the seed. If an inadequate number of balances are available, traits such as pod length or plant height can be measured on stored material. After gathering the appropriate measurements, students can then graph the distributions of the traits in the population as well as determine broad sense heritability from these data.

4. Quality Factors

A. Students will need:
1. plant material from three to five genotypes differing in an easily measured factor
2. facilities for measurement of this factor.
B. Although there are staggering numbers of different quality factors, this lab can show the student that yield is not the only goal (in fact, often not even a major goal) of a plant breeding program. A popular way of showing genotypic differences for quality has been to examine the taste of different peanut genotypes when made into peanut butter. Simple taste tests can be run with different varieties of local fruits or vegetables. Scoring for flavor can be done on a one to six numerical scale, with six being an excellent taste. If differences do exist, this is an ideal time to introduce the students to analysis of variance, explaining that a statistical method for identification of real differences is important in plant breeding. Calculations can be made in class, or the process can be explained and the students can perform the calculations themselves.

5. Breeding Methodology

A. Students will need:
1. visits to on-going breeding programs
2. presentations by plant breeders.
B. When discussing pedigrees, recurrent selection, and other methods of plant breeding, it is beneficial if students can actually see some plant breeding operations. Most land grant institutions have on-going programs students can observe, and many commercial companies welcome class visits. Showing the students how plant materials are actually evaluated and handled makes explanations of breeding schemes much easier. These visits will be most helpful for students when taken at the end of a term after students have gained some background knowledge needed to understand the mechanics of a breeding program. Unfortunately, the weather in many parts of the country does not permit such visits at the appropriate time. A satisfactory alternative to such visits is for students to discuss their programs and show slides in the classroom.

At the Univ. of Florida, winter wheat has been used to simulate a small cereal breeding program to demonstrate many different plant breeding concepts. The original parents included short, tall, awned and awnless lines. In the field, rows of pure lines, F1, F2, and F3 seed are included. The segregating generations include both bulks and single plant selections to show students the differences between the pedigree and bulk, as well as selection effects on the heterozygosity of a population of self-pollinated plants. This breeding nursery is also used for source material in the student crossings and quantitative trait labs (see suggested labs 1 and 3).

6. Breeding for Disease and Insect Resistance

A. Students will need:
1. parents differing in resistance to a disease or insect which can be screened easily in the greenhouse.
2. the F₂ from crosses of these parents.

B. The development of plants resistant to insects or diseases is an important part of many breeding programs. Often plant pathology faculty have materials they are working with that show clearcut resistance and susceptibility in the seedling stage. Materials for this lab take up little room, since several flats can contain a large number of seedlings to be screened. Pathogens are often stored in refrigerators or maintained on isolated plants in greenhouses.

Several students from the class can inoculate plant material as a demonstration for the rest of the class. When plants develop symptoms or signs of the disease, the entire class can rate the plants for resistance or susceptibility. Discussions of how a breeder can use information on both the genetics of resistance and the resistant segregants can follow this lab.

Nematode resistance has been used to demonstrate pathogen resistance. A population of one race of Meloidogyne arenaria maintained on 'Rutgers' tomato plants served as a source of inoculum for segregating populations of tomato seedlings.

7. Field Screening and Note Taking
A. Students will need:
1. a cultivar trial in the field
2. plot plans.
B. Cultivar trials from active research programs can be used to illustrate several plant breeding techniques. Alfalfa trials have been used to give students first-hand experience at field note taking. Vigor and stand percentages were evaluated by students to give them a feel for the types of field notes a plant breeder takes. Although the subjective nature of these notes should be pointed out, it can be shown that, in a relative sense, a good degree of accuracy can be obtained even by novices such as the students. A comparison of notes between different class members usually gives only slight differences in rankings of cultivars. Analyses of variance can be performed to identify the superior genotypes.

This opportunity can be taken to show how much material can be eliminated from a breeding program with little hard data. While in the field, experimental design techniques such as border effects, replications, plot sizes and shapes, and arrangement of an experiment in the field can be pointed out to the students.

8. Special Techniques
A number of special techniques are used by plant breeders, depending on the crop in question. Some of these techniques can be used as effective laboratory exercises.

Example: Mutation effects
A. Students will need:
1. Original line and M₂ seed from a mutation study.
2. if no mutation work is being done at an institution, mutated material is available from biological supply houses.

B. Students can examine the effects of different levels of the mutagen on seed germination and gross morphology changes. The instructor must be careful to use M₂ seed since this is the first generation recessive traits will be expressed.

Example: Chromosome doubling
C. Students will need:
1. flowering plants of various ploidy levels
2. seeds and seedlings of small-seeded diploid plants
3. colchicine solution
4. microscopes.

D. Size and color differences between diploid and polyploid stocks can be shown with diploid, triploid, and tetraploid marigolds as well as diploid and tetraploid snapdragons. These can be obtained from some of the major flower seed companies in the United States. Pollen grain size or stomatal guard cell size can be compared to show cellular effects of polyploidy.

Actual chromosome doubling can be used as a lab exercise if a solution of colchicine (0.2% works well) is applied to the growing tips of plants once a day for 1, 2, 4, 7, or 10 days (tomatoes have been used successfully). Seeds can also be soaked in a colchicine solution and examined after treatment for various intervals. If adequate time is not available to allow plants to reach flowering, pollen grain size can not be used to indicate ploidy changes. However, examination of guard cells of the lower epidermal layer of leaves is a good screening method for changes in these plants. These cells can easily be pulled off and mounted on a microscope slide if clear fingernail polish is applied to the abaxial side of leaves, allowed to dry and then pulled off with clear tape.

CONCLUSION

These lab suggestions are designed as open-ended and general enough that plant breeding instructors can modify them to conform to their own budgets and facilities, and include local plant breeders and regionally important plants. Obviously, some of these labs are well suited for other courses, such as genetics, statistics, and plant protection. Some can be effectively used as demonstrations in classes with no scheduled lab periods.

LITERATURE CITED