Cross-Pollinating Flowers to Create Diversity

There can be no genetic improvement in crops without genetic diversity. In all crop species, plant breeders use cross-pollination to mate diverse parents and create novel progeny in segregating populations.

Making cross-pollinations requires the movement of pollen from a flower from the male plant to the stigma in the flower of a female parent plant. There are many different types of flowers. Flowers that are considered to be 'perfect' have petals, sepals, a stamen (male parts), and a pistil (female parts). Flowers that have both the stamen and pistil are referred to as 'complete'. Therefore, a perfect flower is always a complete flower, but a complete flower could be missing petals and/or sepals and therefore be an imperfect flower.

Flower morphology can promote or inhibit cross-pollination. Flower forms and functions promote cross-pollination include plants that have male flowers on one part of the plant and female flowers on another part of the same plant. These types of plants have a monoecious flowering habit. Corn is monoecious with the stamen (tassles) being at the top of the plant and the pistil (ears and silk) being in the middle of the plant. Other plants have a dioecious flowering habit in which a plant only has staminate flowers (male plant) or a pistillate flower (female plant). Examples of this type of flowering behavior are hops as well as hemp plants. Some crops have perfect flowers, but cannot self-pollinate due to genetically controlled systems that inhibit self-fertilization. Many of the clover species behave this way. All of these systems reduce or eliminate self-pollination in a natural setting.

Other crops have mechanisms by which self-pollination is almost guaranteed in a natural environment. Crops such as wheat, oats, soybean, and rice are usually self-pollinated due to the structures and timing of pollination in the flowers. Other crops such as cotton will only be cross-pollinated if an insect pollinator is actively moving pollen between flowers. Plant breeders must understand the flower behavior of their crop to effectively make cross-pollinations.

Let's focus on cotton as a model for a plant breeding program. Most cotton breeding programs use a pedigree breeding system. This process begins with a cross-pollination, also known as a hybridization. Seed from the cross-pollination are grown and the resulting offspring are self-pollinated when they begin to flower. The cotton breeder repeats this process for two to sometimes five generations. They want to develop a segregating population that is likely to have individual plants with a desirable combination of traits from both of the original parents. Because the plants have been self-pollinating, the resulting offspring are unlikely to segregate substantially in subsequent generations. The inability to further segregate due to self-pollination or inbreeding helps the crop to be predictable in its performance and appearance.

Cotton breeders will typically make an individual plant selection after 3-5 generations of self-pollination. Seed from a single plant will then be planted into a progeny row, which usually contain about 100 plants. The best of the progeny rows are then promoted into the next phase of the pedigree breeding system in which they are called strain lines. These strains are tested in multiple locations and years in replicated trials until the most elite strains are identified. These elite lines then become commercial varieties, which farmers grow. The process from the initial cross-pollination to a finished variety usually takes at least 10 years. Along the way an extensive record keeping is required of each line as it is promoted within the system. Important information includes the parents or pedigree, performance of yield components and quality traits under the various environments, and descriptions of the morphology of the plants within the line. Most cotton breeding programs track thousands of lines each year within this pedigree system. It is important to remember that a successful cotton variety depends largely upon that first cross-pollination between two unique parents.

Exercise:

1. **Understanding the behavior of a cotton flower**: the cotton flower is perfect and can readily self-pollinate. In order to control pollination in cotton, plant breeders will emasculate, or remove the anthers, to create a flower that exclusively be a female flower.
2. **Emasculation**: the day before dehiscence (release of pollen from the anthers) and petals open, the cotton flower will look like a 2-3 inch candle with a closed tip. In the afternoon of a candle flower, the plant breeder will emasculate the cotton flower and cover the stigma and style so no unwanted pollen can fertilize the flower.
3. **Transfer of pollen**: the next morning, flowers from the male parent with pollen that is now dehisced are plucked from plants. The male flower is then taken to the female plant where the male flower is brushed against the female flower in order to transfer the pollen and allow for cross-fertilization. The fertilized flower has a tag placed around the pedicel so it later can be found in about 6 weeks when the seed is fully mature.

Discussion Questions:

1. Why is genetic diversity important to crop improvement?
2. How does cross-pollination increase genetic diversity?
3. What types of flowers are most likely to cross-pollinate?
4. Why do cotton breeders self-pollinate lines for 2-5 generations before they begin testing for traits and performance?