Grape Breeding Procedures

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Even without an understanding of grapevine floral biology and genetics, early farmers had the ability to select the best vines and plant new vineyards with vines propagated from their best selections. Today, the science is much more precise, but grapevine breeding is still based on hybridization schemes designed to develop a single elite individual vine combining the best traits of both carefully-chosen parents. Because most grapes are propagated from cuttings, and not grown from seeds, a single vine with good characteristics can be readily turned into many more vines, all with the same genes and thus the same characteristics.

The earliest varieties were propagated from choice wild seedlings, the products of chance crosses between vines. The process of breeding, however, goes one step further, by controlling pollination and choosing which varieties will act as parents for seed production. Parents must be carefully chosen based on the traits desired in the progeny, and what might already be known about a parent's ability to impart those desired traits to its seedlings. The purpose of this web site is to explain the technology of grape hybridization once parental vines have been identified.

Basic Background on Grape Flowers

Making crosses is all about flowers. Like many other organisms, grapes reproduce sexually. In other words, each seedling is a unique combination of the genes from a female and the genes from a male. Pollen from a male fertilizes the female ovary, and a seed develops. Depending on the individual vine, flowers might be female, male, or hermaphroditic (also known as "perfect", which means that each flower contains both male and female structures).

By far, the majority of cultivated varieties are hermaphroditic. Because fruit does not result without fertilization, hermaphroditic vines are preferred because they are capable of fertilizing themselves, and every vine planted is capable of bearing fruit.

The male parts of the flower are the stamens, each consisting of a pollen-bearing anther supported by a filament. Generally there are five anthers arranged around the ovary, but some varieties may have more or less. Pollen are shed as the anther ripens and are primarily transported by wind, though rarely more than 20 feet (7 meters) from the source. Pollination occurs when pollen lands on the female parts of a flower. Each pollen grain grows a long tube towards the eggs within the ovary, and sperm cells move down this tube.
The female parts of the flower consist of the ovary, the stigma, and the style. The stigma and style provide the entrance to the ovary for pollen. When a sperm cell in the pollen tube unites with an egg cell in the ovary, an embryo (a new seedling plant) is produced. The embryo grows within the developing seed, while the entire ovary grows to become the grape berry itself with seeds contained within.

A few cultivated varieties, and many wild vines, are female. These plants have flowers which contain a well-formed ovary, stigma, and style, but have poorly formed male parts. The anthers produce pollen that are generally sterile, and the filaments supporting them are often short, and reflexed back away from the ovary. Such varieties require a male or hermaphroditic vine nearby to provide pollen in order to set fruit.

Since male vines are incapable of bearing fruit, they are not used in commercial agriculture, though a few are used as rootstocks. The flowers of these vines contain functional anthers, but the center of the flower has only a small, rudimentary ovary and no stigma or style. These vines reproduce through fertilization of other vines by wind-blown pollen. Many wild vines found throughout North America and Asia are male.

Making Crosses

**Step 1: Pollen Collection**

If the variety to be used as a male happens to be in flower at the same time as the female (in grape breeding lingo, they "nick"), then this step can be easily accomplished by collecting a few of the flowering clusters for pollen. However, differences in timing require other approaches. If the male is significantly earlier, it may become necessary to collect and store pollen. This can be done by drying the clusters (1-2 days) and shaking out the pollen onto a sheet of glass or other smooth surface, then collecting it into a vial by scraping the glass with a razor blade. If, however, the male flowers after the female, then the pollen must be collected, dried, and stored in the freezer (at -20 C / 0 F) and the cross made next year. Stored pollen usually remains viable, but it is often not as effective as fresh pollen. Another option where the male flowers before the female is to reverse the cross - use the male as a female and use the female as a male. This only works if both parents have perfect flowers.
**Step 2: Preparing the Female**

Each flower cluster on a grapevine may hold from dozens to hundreds of individual flowers. All steps described here must be applied to every flower on clusters chosen for pollination. The guiding principle in preparing female flowers is to prevent accidental pollination before the application of pollen from the selected male parent. Before the flowers open, each one is covered by a cap, short for calyptra. Though this cap eventually dries and comes off on its own, it must be removed a day or two before the cross is to be made to prevent self-pollination with perfect-flowered varieties. In most cases, the anthers can, with some care and practice, be removed at the same time as the calyptra, using forceps with very fine tips. This practice is called emasculation. After the cluster has been emasculated, you must wait one to four days before proceeding (more time in cool weather and less time in warm weather) so that the female parts of the flower mature further and attain peak receptivity. This is often indicated by the appearance of a bead of moisture on the stigma. During this time, the cluster is covered with a bag to prevent fertilization by external pollen sources. If the female variety produces female (imperfect) flowers, no emasculation is necessary. The flowers are covered with a paper bag until they are ready for pollen application.

**Step 3: Making the Cross**

Crossing is often simply a matter of brushing the pollen onto stigmas of the emasculated cluster. If both parents are flowering simultaneously, the pollen-bearing cluster can be gently brushed against the emasculated female. However, if pollen was collected earlier and stored, application with a soft paint brush is recommended. Care must be taken to sterilize the brush (and your hands) with 70% ethanol between pollinations.

After pollen has been thoroughly applied to a cluster, taking care to brush every flower, the paper bag is replaced over the cluster, both to prevent fertilization by other pollen sources, and to protect the developing fruit from birds and the elements. The bags also help to identify the cluster locations at harvest time, at which time the seeds are removed from the individual berries.
Planting the Seeds

Over the course of the season, berries on the cluster mature and ripen within the bags. The clusters are collected and the seeds extracted from within the berries. These seeds contain embryos of new plants with an equal amount of genetic material from each parent, and each is genetically distinct. In order to separate inviable seeds from the viable, the seeds are dropped into a small beaker of water. Inviable seeds tend to float, and are skimmed off and discarded. The remainder are cleaned of any remaining pulp, dried, and stored at -20 C / 0 F.

Grape seeds require stratification in order to germinate well. In our program, this stratification is provided by placing the seeds, along with a dilute solution of fungicide on filter paper, in plastic bags and placing them in the refrigerator (5 C / 40 F) for approximately three months. Without this chilling period, seed germination rates would be very low and uniformity in growth among those germinating would be poor. There are many variations on this stratification technique. Some researchers have utilized hydrogen peroxide and or gibberellic acid to reduce the time required for stratification or to increase germination percentage.

In March, the seeds are planted in small peat pots and germinated in the greenhouse. After danger of frost has passed, they are moved outdoors to a sheltered "cold frame" location, where they can be covered if sub-freezing temperatures are expected. In June, our seedlings are planted outdoors into an irrigated nursery site.

Making Selections

A long term commitment is necessary to find the best selections once you've successfully made crosses and produced seedlings. The more seedlings planted and the longer spent evaluating them, the better the chance of finding the exceedingly rare selection with potential. However, the reality is that there are always limits in terms of time, space, and manpower. In the past, our program has transplanted all of the seedlings grown in the nursery into the vineyard. In the last few years, however, many seedlings have been eliminated in the nursery, where they are grown without disease control. Only vines appearing to be disease resistant in the nursery are then transplanted to a permanent vineyard location for further evaluation.

It is more difficult to select for some other characteristics such as wine quality or cold hardiness, and several years of growth in the vineyard are required for proper evaluation. The criteria used depend on your goals. Persistence, creativity, knowledge of grape genetics, careful evaluation and some amount of luck are the keys to success.