TECHNIQUES IN BREEDING NEW VARIETIES OF ORCHARD TREES

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Introduction

The methods used in developing new varieties of orchard trees are perhaps similar in general to those used in forest-tree breeding. Differences in flower and fruit morphology in species in the fruit- and nut-tree groups make it necessary to vary the technique to obtain specific objectives, and this is undoubtedly true in the forest-tree groups. The objective of the fruit-tree breeder is usually new and superior varieties suited to specific areas or for special purposes. In many fruit- and nut-tree species this procedure is complicated by the fact that many varieties are already available, and it is frequently difficult to obtain new varieties sufficiently different from existing ones to merit testing and introduction. Only a few, like the Chinese chestnut, are relatively new to agriculture and have few varieties to complicate the breeding picture.

Progeny-Test Method

A procedure used in some orchard-tree breeding is to plant seed from a known tree or variety and grow these seedlings to maturity to determine the performance of the group as a whole. The seedlings can be evaluated as a group or compared with other groups of seedlings from other parents. In Chinese chestnut it has been found that the seedlings from one selected tree may be much more uniform and vigorous than those from another tree. This is also true in tung, pecan, and black walnut and may be characteristic of most other fruit and nut trees. In tung, 600 seedling trees were tested by the progeny-test method and 5 were selected as producing outstanding, vigorous, uniform, productive seedlings. The 5 selected were named and propagated asexually as horticultural varieties largely for the purpose of producing seed for the industry rather than for oil production. In selecting understock for grafting and budding operations in most of these groups it is thus important to know the best source of seed in order to grow uniform and vigorous material.

Hybridization Studies

Frequently, the objective in orchard-tree breeding is obtaining specific fruit and tree characteristics. Productiveness, time of maturity, and disease resistance are characters frequently sought, but such traits as size, quality and appearance of fruit and vigor of tree are also important. In appraisal of large numbers of peach seedlings as many as 10 fruit characteristics may be listed on a card, and each seedling is given a rating for each characteristic. This score-card procedure is helpful in eliminating seedlings that do not have the desired combination of characteristics and enables the worker to focus his attention on the few individuals likely to meet his objectives. In chestnut breeding work large numbers of seedlings of certain progenies, and even whole progenies, are eliminated on the basis of unsatisfactory yield alone, whereas all seedlings of certain other progenies are fairly productive. Since the chestnut orchard industry is largely based upon the planting of seedlings rather than horticultural varieties, it is important that a source of seed that gives seedlings of high productivity be used.

The effect of the pollen parent on the development of seed and fruit of many kinds of orchard trees is important. McKay and Crane (1939) found that certain pollinations of chestnuts gave heavier seeds than others. In pears, according to Tufts and Philip (1923), the time of maturity and even the flavor of the fruit differ according to whether self- or cross-pollination occurred. Heterosis is frequently discussed in connection with the effect of the male parent on the seed or the fruit and the term xenia is also used in describing some of these effects. According to many authors these two phenomena often overlap. For example, Nebel and Kertesz (1934) obtained greater seed length in some apple crosses than in others. They concluded that choice in the use of the terms heterosis and xenia in this case is a matter of definition or interpretation. Increased yield and added vigor as a result of heterosis are being put to good use in a wide range of crop plants at present. As stated by Jones (1956): "Hort culturists have long recognized that vegetatively propagated fruits, nuts, flowers, and other plants, are dependent upon a high degree of heterosis for their superior performance." In some instances the crop may be adversely affected, as when the sweet almond becomes bitter when pollinated with the bitter almond.

Pollination technique for orchard trees varies with flower morphology and the agency of pollination. Peach breeders in the U. S. Department of Agriculture enclose entire trees in cheesecloth tents to increase fruit set and also control pollination. The blossoms of the tree within the tent are emasculated and hand-pollinated with pollen of the desired male parent. The pistillate, or female, flowers of some species like filbert, pecan, and walnut that are wind-pollinated and monoecious are protected by sausage casing bags and later pollinated by a syringe gun, thus eliminating the need for removing the bags.

Breeding work with many kinds of fruit trees must take into account differences in chromosome number in different species and varieties and also sterilities that occur between many different types within each group. For example, in pollinations between diploid and polyploid species of plums, fruits with viable seeds are rarely formed. Several of the leading varieties of apples are triploid, and interest has recently centered around growing more triploid seedlings to fruiting in order to develop new and superior varieties. In one such project many thousands of seedlings were examined to determine chromosome numbers. Only the triploid seedlings were saved for growing to fruiting. This handling reduced the number of trees carried in the breeding plots. Tetraploids of some varieties are now available, and crossing these with diploids gives mostly triploids. In view of this interest in triploids, efforts are being made to produce tetraploid forms of additional leading varieties for use in crossing with diploids. In the pomiferous fruits seed fertility is not necessarily related to fruit production, and triploid varieties frequently give satisfactory yields; of fruit even though sterile. Often the tree will produce so many flowers that if only 5 percent set fruit, the crop will be sufficient.

Certain other kinds of orchard trees, notably almond, chestnut, and filbert, are largely self-sterile and must be cross-pollinated to set a crop of nuts. In chestnut, the production of large crops of hybrid nuts has been simplified by the establishment of isolation plots consisting of two varieties planted together some distance from other chestnuts. In these plantings, each variety pollinates the other without the laborious application of bags and other devices.

At Beltsville, a project to develop a new walnut by hybridizing the Persian walnut (Juglans regia) with the eastern black walnut (Juglans nigra) has been under way for many years. The objective is to combine the productivity and thin-shelled nut of the Persian walnut with the hardiness and kernel quality of the eastern black walnut. Seedlings from nuts produced by the first-generation hybrids of these two species are being fruited as fast as possible by grafting into large black walnut trees for the purpose of producing the second-generation. Among these second generation seedlings great variability in the characters has been observed. Because the first-generation hybrids are largely sterile and so much time is required to bring the second generation seedlings to fruiting progress on this project has been disappointingly slow. However a few seedlings which show a desirable recombination of some characters of the two parents have been fruited. These desirable characters indicate that the fruiting of large numbers of these seedlings would eventually produce the tree with the desired combination of characters of the two parents.

Genetic Studies

Considerable information is available about the mode of inheritance of various characteristics of many kinds of the tree fruits. For example, a surprisingly large number of important fruit characteristics of peach are determined by a single Mendelian gene. Among these are white versus yellow flesh, free versus clingstone pit, and soft versus firm flesh. Many of the characteristics which separate peach from nectarine are also determined by a single gene difference. Several important correlations of practical im portance in peach breeding technique are listed by Crane and Lawrence (1952). For example, when the calyx cup of the flower is green the color of the flesh is white, and when the calyx cup is orange the flesh is yellow. Such information is of value to the plant breeder seeking specific characters since he can then use short cuts and less material.

In apple, most nut tree species and many other kinds of orchard trees, the variation in most characters is exceptionally wide. In these forms the inheritance of most characteristics appears to be controlled by a number of genes. Dominance of many characteristics frequently can be determined in the first-generation hybrids, but behavior in later generations is unknown. In the Chinese chestnut, several seed and seedling characteristics which may throw more light on the mode of inheritance of certain characters in this species have recently been observed. Nuts of these known as "orange kernel" contain 5 times as much vitamin A as the normal chestnut. Another known as "snow kernel" is lethal since the nut develops to only one-fourth normal size and is incapable of producing a seedling. Information as to the mode of inheritance of these characters can be accumulated rapidly since the results from current crosses are available as soon as the crop is harvested.

Handling Seeds and Seedlings

The proper handling of seeds to insure good germination is an important aspect of breeding tree fruits. Seeds of apple, pear, most, if not all, Prunus species, and most oily nuts, require an after-ripening treatment which usually consists of a period in a cool, moist medium. Stratification in moist sand, peat or a mixture of the two for 30 to 90 days at 32 to 50 degrees F. will usually overcome dormancy in most species. In certain species of oil nuts, notably pecan (Carya illinoensis) and Persian walnut (Juglans regia), dormancy is not so pronounced as in others, and dry nuts of these species can usually be germinated under optimum conditions without previous stratification for as long as the nuts are viable. Care should be used in handling these seeds since unfavorable environmental conditions, such as a short period of exposure to excess hear, cause rancidity of the oil and thus destroy viability. For additional information the reader is referred to the "Woody Plant Seed Manual," Miscellaneous Publication 654, U. S. Dept. of Agriculture.

Tree seedlings used in breeding work are grown 1 or 2 years in the nursery and then transplanted to rows 20 to 25 feet apart and 3 to 5 feet apart in the row. This arrangement allows the individual tree space for fruiting but permits fairly large numbers to be grown on a given amount of land. It is usually possible to remove many trees the first year fruiting occurs, thus giving added space to those remaining. Peach seedlings usually fruit at four to five years of age, Chinese chestnut, filbert and plum at 5 to 6 years, and apple, pecan and walnut at 8 to 10 years. In view of the long period required to produce a generation as compared with many other crop plants, it is important to make selections promptly and propagate the best trees asexually for further testing thus permitting removal of all trees in the breeding plots and release of the land.

Discussion

Perhaps the most important single consideration in orchard-tree breeding is the use of superior parents that furnish the best germ plasm available for obtaining desired objectives. In many cases the desired characteristics must be obtained from different species. Hence, interspecific crosses are necessary and F_1 sterility is frequently encountered. One example is walnut, in which it is desired to combine the easily cracked, thin-shelled nut and heavy bearing characters of the English, or Persian walnut (J. regia) with high kernel quality and hardiness of the eastern black species (J. nigra). The cross is difficult to make, and most known hybrids of these 2 species are almost 100 percent sterile. Moreover, heterosis is so pronounced that the trees remain vegetative for many years. The plum species offer an example of many interspecific crosses that either fail or give sterile hybrids because of involved polyploidy. In other cases all desired characteristics are to be found in a single species and intraspecific crosses between existing horticultural varieties provide the plant breeder with sufficient material for appraisal and selection of new types.

The tree fruits as a group do not provide especially favorable material for genetic studies. The length of time required from seed to tree maturity is a deterrent to many working with this group. For example., in the nut spe cies a number of first-generation hybrids have been produced and grown to fruiting, but very few second-generation seedlings have been grown to maturity because of the long period required. Recombination of parental characters is much more likely to occur in the latter group, but since very few of these seedlings have ever been grown improvement has been slow in some of the nut-tree species.

Self-sterility is pronounced in many F_1 interspecific hybrids of nut species because of poor pollen, and seeds produced under conditions of open pollination usually represent backcrosses to one or to the other parent. Variability in the backcrossed seedlings is reduced as compared with that expected from self pollination, and the chances of finding seedlings with the desired combination of characters are thus less.

The space the trees occupy and the cost of maintenance are factors that often tend to restrict work with this group. A further limitation in genetical analysis is the large populations of individuals necessary because of the complex heterozygous constitution and involved polyploidy of some species. From a practical standpoint breeding work with edible fruits has been directed mainly toward search for new forms of commercial value rather than towards genetic analysis. An advantage not to be overlooked is the fact that once a superior plant has been developed it can be perpetuated without limit by asexual reproduction.

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