

accumulation of sugar could be beneficial to the raisin industry, because it would allow earlier harvesting and increase the possibility of avoiding fall rain on grapes or on drying clusters on picking trays.

Fruit-set

Plant growth retardants can markedly increase fruit-set and yield in grape cultivars with clusters that are too loose. For example, University of California researchers found that spraying Malvasia bianca grapes at prebloom with chlormequat more than doubled yield. The increase was largely due to improved berry set.

Emperor grapes sometimes are affected by a condition known as berry shrivel. Scattered grapes in the clusters begin to turn soft in August and attain only about half the normal size by harvest because of water loss. If more than about 12 berries per cluster are affected, the cluster must be discarded as a cull. Applications of GA₃ to Emperor at 20 ppm two weeks after the fruit-set stage were found to prevent berry shrivel.

Rot often occurs in seeded wine grapes that have very compact clusters. As the berries expand during growth, they may break near the area of attachment to the cap stem. The exposed berry flesh attracts insects, which may also introduce yeasts and other spoilage organisms. In 1959 we found that GA₃ sprays applied three weeks before bloom could markedly loosen the clusters, mainly as a result of decreased fruit-set and elongation of berry stems. Elongation of the main stem of the cluster may also be involved. Vines are sprayed when shoots are 14 to 16 inches long at concentrations ranging from 1 to 10 ppm, depending on the grape variety. Unfortunately, the practice of spraying tight-clustered wine varieties with GA₃ has been halted for the present because of some toxic effects observed on the Chenin blanc vines.

Second crop

In some years, one-third of the total yield of wine grapes is made up of a second crop. The second crop matures later than the first, so that it is not a good idea to pick it at the regular harvest season. However, much of the second crop is usually harvested along with the first crop, whether picked by hand or mechanically harvested. We have found that application of auxins such as naphthaleneacetic acid (NAA) applied just before the second crop is beginning to bloom will remove 70 to 100 percent of the second crop. At that time the first (primary) crop is not injured because the berries are larger and resist damage from the NAA.

Berry size and wine quality

One viticultural theory is that a struggling vine produces better wine than one that has better growing conditions. If this is true, the reason may be that the struggling vine has smaller berries than the vine growing under more favorable conditions. Thus there is more skin (which contains pigments and some flavor and tannins) per ton of grapes and per gallon of wine than when berries are larger. We have found that smaller berries may be obtained by spraying with growth retardants such as daminozide. However, this material is not cleared for use in California.

In 1949 there was only one known class of plant regulators—the auxins. Now there are five main classes—auxins, gibberellins, cytokinins, ethylene, and inhibitors. No doubt this list will lengthen as new hormones are discovered and new growth regulators synthesized. It is quite possible that, in time, all physiological processes in plants will be controlled by application of growth substances.

Propagation of grapevines

Curtis J. Alley

Grapevines are propagated primarily by cuttings just as they have been for years. The use of seeds for propagation is not satisfactory, because the seedling does not resemble the parent vine. Work by F. T. Bioletti in the 1920s indicated that production of new vineyards was the same whether or not the original cuttings arose from vines that bore heavy crops or light crops. The difference was caused by the environment and was not inherited.

The best length and diameter of cuttings for propagation were determined by research. At first, medium-size cuttings 10 to 12 inches long with four to five nodes were recommended, but later, it was found that short cuttings did not grow as well as longer cuttings in sandy areas. Cuttings should be at least $\frac{1}{3}$ to $\frac{1}{2}$ inch in diameter at the top. Length can vary from 14 to 18 inches, depending on location and soil type; the longer lengths are best for sandy areas.

A. J. Winkler found in 1927 that the earlier the planting, the more successful the rooting. Wood maturity was important: rooting improved with maturity of the cutting. Winkler also developed the iodine color test, which measured stored starch in grading cuttings for wood maturity.

In Fresno County studies, the best rooting resulted when cuttings that had been stored in a sand pit were planted in April and May. At planting time, the cuttings had roots out about $\frac{1}{6}$ to $\frac{1}{4}$ inch, and the top bud was pushing about $\frac{3}{4}$ to 1 inch. Cuttings may also be held in refrigeration but should be removed about two weeks before planting and allowed to warm and start growing. Removing cuttings from refrigeration late in the spring and planting directly into the nursery may be detrimental. In areas where strong winds prevail in the spring and early summer, cuttings root and grow better when the top bud is covered over with a layer of soil. Where there are no winds in the spring, cuttings root and grow better when the top one or two buds are left exposed.

Rootstocks

When first grape phylloxera and later root-knot nematode infections of grapevines were identified, growers in affected areas had to change their propagation methods. They had to borrow from the experience of French vineyardists and use phylloxera-resistant rootstocks. St. George, MdG 41B and 420A, and Couderc 3306 and 3309 were recommended in the 1920s. Some Lenoir (Jacques) was used, but later St. George became the most popular rootstock, followed by AxR #1. Researchers recently found AxR #1 to be the best for production among the several rootstocks tested.

Rootstocks resistant to root-knot nematodes became important in the sandy soils of California. Couderc 1613 has been the leading resistant rootstock for years. In sandy areas where this rootstock cannot grow satisfactorily, Salt Creek and Dog Ridge have been used. Two new rootstocks, Harmony and Freedom, are now becoming more important, replacing the earlier nematode-resistant rootstocks.

The need for resistant rootstocks has complicated the propaga-

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tion picture. In nonirrigated vineyards where phylloxera was first recognized, the common practice was to field-bud the fruiting cultivar onto a rootstock. The rootstock had to be rooted first in the nursery row from cuttings similar to own-rooted cuttings. Only now the cuttings had to be longer so that they could be planted as deeply as before but with the top high enough to permit insertion of a bud above the soil level. Also, all the buds on the rootstock cutting, except the top one or two, had to be removed (disbudded) before planting in the nursery to eliminate all future suckering of the rootstock.

Benchgrafting

The field-budding method was expensive and slow. Benchgrafting was developed, whereby a one-bud scion was hand-whip-grafted to the standard 10- to 12-inch dormant rootstock cutting that had been disbudded. This method with hot-room callusing before planting opened an entire industry for providing vines grafted on different types of resistant rootstocks.

The French have been very successful with the short whip-type benchgrafting machines. H. E. Jacob is credited with the first saw-type machine in California in 1936, patterned after a machine developed in Austria by Albert Hengel. This cuts a series of grooves similar to a mortise joint. More recently, the German Omega-cut grafting machine has been widely used in Europe, because it has the highest output of benchgrafted cuttings. The benchgrafting-greenhouse method, a detailed procedure requiring close care and handling, is used extensively in Europe. This industry has not developed to the same extent in California, because most grapevines are grown on their own roots.

With greenhouse benchgrafts, the growing vines are delivered directly to the grower in late spring or early summer, planted immediately in the vineyard, and kept growing during the season. For growers who prefer a dormant benchgraft, the nursery will keep the growing benchgrafts, planting them to finish out the growing season, then dig the following winter, and deliver the dormant bare-rooted benchgraft during the winter.

Field-grafting

Once a vine (own-rooted or on rootstock) has been growing for several years in the vineyard, the variety sometimes needs to be changed to a more desirable one, or an older rootstock that has failed to take when originally budded needs to be top-worked. The whip-graft has been used, but the two most common field-grafting methods are the split and the kerf. With both methods, vines are grafted at ground level, and loose, moist soil is placed over the graft to keep it from drying out. The split graft has been the most popular, because it requires less skill, and results have been good.

To change over varieties in a mature vineyard and retain the trunk, the common practice was to decapitate the vine just below the head or below the lower wire of the trellis and to use the saw-kerf or bark-graft method. The former required considerable skill; the latter could not be started in the early spring until the bark would "slip." The notch-graft, a modified type of saw-kerf that required less skill, was faster and gave as good results as the other types. However, all these high-level grafts required the use of grafting compounds, and there were inherent problems with the methods.

The dormant T-bud method, which was described in 1891 in France under the name of "Vouzou" graft, has been used recently in Argentina, Mexico, and California with very good results. It requires a minimum of skill, gives high takes, and needs only plastic tape to hold the bud in place and prevent drying. More recently, we have used the chip bud to change over varieties at high level and get

an earlier start in the spring (March instead of May). The take is as good as with T-budding, but more skill is needed.

Rooting with growth regulators

Ever since plant growth regulators (hormones) were synthesized, they have been used to improve rooting. Indolebutyric acid (IBA), both as a 24-hour soak and as a quick dip, improved rooting of Salt Creek and St. George in studies, although results were not consistent for each year. Later work indicated that a quick dip (3 to 5 seconds of 4,000 to 5,000 ppm IBA) and hot-room callusing were very effective in causing the bases of Salt Creek and Dog Ridge cuttings to callus profusely and root more quickly. IBA generally has not improved the rooting of cuttings of cultivars that root easily.

Green or soft-wood cuttings

Green or soft-wood cuttings are used for very rapid propagation of vines on their own roots. The method was first used in the certification program in California to rapidly increase small quantities of cultivars free of known virus diseases. Through the use of heated greenhouses, IBA, and intermittent mist, vines can be increased manifold from limited quantities of dormant cuttings and brush by using one-bud, green shoots with one attached leaf. The young, rapidly growing vines have to be observed very closely under greenhouse conditions to make certain light is sufficient, vines are misted and fertilized properly, drainage is adequate, root aeration is good, water quality is satisfactory, and no fungus or insect diseases get started. The system was used extensively 10 to 15 years ago during the upsurge of vineyard planting in California. The resulting potted vines were shallow-rooted and required careful handling in the vineyard. Some growers who were not equipped to handle them or were unfamiliar with the requirements of this type of plant material suffered losses. The method is still used, but more for new cultivars that are in short supply.

Greengrafting is used only on irrigated vines of California's lower San Joaquin Valley. It consists of making a short whip-graft (no tongue) of the herbaceous scion to the herbaceous shoot of the understock where both have similar diameters. It has been used when budding failed. Considerable skill and care of the vines are required. The method is more expensive than other more common types so it is not used extensively.

Layering

Layering is a specialized method to replant missing vines in an established vineyard. Competition from adjacent vines is generally so great that a replant is not successful unless the grower can devote extra care to frequently water the replant. It is necessary to use a cultivar that produces long canes (Thompson Seedless, Emperor). A long cane from the adjacent vine is extended to the old planting location, buried at the stake position with the top of the cane pruned to two to four buds above the ground, and tied to the stake. The new vine obtains nutrition from the parent vine, and roots develop on the lower part of the buried cane. After two to three years the new vine may be detached from the mother plant. This method of propagation has remained the same over the years.

Nursery practices have not changed much. Improvements have been made in some new benchgrafting machines, and greenhouses are being used for benchgrafting and rapid propagation. Indolebutyric has improved the successful take of some difficult-to-root cultivars.