erized, or planted out in the field. Another 2 years will give a 18 to 24 in., or 24 to 30 in. Alberta spruce, and a 12 to 15 in., or 15 to 18 in. nest spruce.

You will notice that this method took no flats or no small pots, as all plants were machine-planted in beds and in the field; no mist, no heat, no hormones, only time.

HENRY KOCK: What was your percent shade cloth?

DAVE BAKKER: I am not sure but we just buy bed sheeting by the yard and it will be the correct amount of shade.

PETER VERMEULEN: Could you give us some information on the age and size of your parent plants?

DAVE BAKKER: We learned that the hard way after setting up a stock block. The cuttings from the stock block did not root as well as when we take them from plants that are ready for sale that year.

Tuesday Evening, December 6, 1983

Mike Young moderated a group of presentations on grafting, including demonstrations. The following papers by Mike Young, Peter Vermeulen, Leonard Savella, and Tom McCloud were part of that session.

REVIEW OF GRAFTING

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Grafting is one of the oldest known forms of plant regeneration. References to it have appeared in writings for well over 2000 years. Over time it has become a valuable means of propagating many woody perennials as well as some herbaceous plants. Techniques in common use today are, in most respects, the same as those employed over the past several hundred years.

Grafting refers to the process of joining parts of two or more plants in such a way that they will unite and grow as one. The stock is the part of the new combination which will produce the root system and, occasionally with trees, the trunk as well. The scion is the part joined to the stock which will produce the top of the plant.

There are many reasons for propagating plants by grafting. From the standpoint of the nurseryman and ultimately his customers, three are of particular importance:

(1) Perpetuation of clones which cannot be easily or economically increased by cuttings or other vegetative methods.

(2) To obtain the benefits of certain stocks such as disease and nematode resistance, size control, and cold hardiness.

(3) To obtain special growth forms, as the "weeping" form of certain upright growing ornamentals.

With time, practice, and patience the various methods of grafting can be mastered by most persons. Regardless of the technique used, however, five basic requirements should be met to maximize success:

(1) The stock and scion must be compatible with one another, therefore capable of uniting as one. In general, the closer the botanical relationship between the two plants to be joined, the greater the probability of obtaining a successful union. However, it should be emphasized that botanical relationships are based primarily on reproductive (flower, fruit) and not on vegetative characteristics. The chances of successfully grafting two members of the same species is very high, between species good, and between genera rather low by comparison.

(2) The vascular cambia of the stock and scion must be brought into close proximity with one another, preferably making contact, and held tightly together. The existence of a continuous vascular cambium in dicots and conifers and its absence in monocots is a very important reason it is used commercially only with the first two groups of plants. The freshly cut surfaces of both stock and scion must be capable of producing the callus tissue necessary for formation of the union. When using stocks with an intact and functioning root system, most of the callus formed will originate from it and not the scion. Callus growth is followed by formation of a vascular bridge and reestablishment of vascular continuity between the two.

(3) Buds on the scion should be dormant and remain so until healing has occurred. Depending on the technique used, the rootstock may or may not be dormant.

(4) Exposed cut surfaces must be protected from drying out and entry of decay-causing microorganisms prevented. This is accomplished with soil, or various wraps or waxes depending on the technique.

(5) Grafted plants should be given special attention for up to one full growing season or more after scions begin to grow.

This includes cutting or removal of wrapping materials, removal of suckers on the stock as they appear, and staking or otherwise supporting the newly-developing scion shoot(s).

Many nursery plants are grafted by joining a scion to roots from plants which had been previously dug in the field. If the root system is large enough, then individual pieces of sufficient diameter can be cut up and used. Each root piece is then grafted individually to a scion of similar size and length (piece-root grafting). If not large enough to subdivide, then the entire root system can be grafted to a scion (whole-root grafting). Since root grafting usually takes place indoors on tables in the winter months, it is often called bench grafting. Established plants in the nursery row or in containers are commonly crown or top-grafted. In the latter case scions are usually inserted into the stock from 10 to 20 cm above the soil line.

The many techniques of grafting developed over the years can be grouped into two categories. The first is approach grafting whereby the parts which will become the scion and stock are not cut from the parent plants until a union has formed. True approach grafting is sometimes used by nurserymen for plants which form a union very slowly. The second category is detached scion grafting, techniques of which are commonly used by nurserymen. With apical grafting techniques such as the whip, cleft, and saddle, the stock and scion are joined end-to-end. In inlay (veneer) and side grafting the scion is inserted on the side of the stock.

Two types of rootstocks are used in the nursery industry. The first, *seedlings*, have several advantages. They are relatively simple and economical to grow, rarely retain pathogens — especially viruses — occurring in the parent plant, and usually develop a deeper and more firmly anchored root system. Unfortunately, from the standpoint of propagation, horticultural plants are mostly heterozygous and their seedlings, therefore, will not consistently perpetuate desirable characteristics of the cultivar. There are several ways this variation can be minimized, however, and often it does not represent a serious problem to overall growth and longevity of the grafted plant. The second type, *clonal rootstocks*, are vegetatively propagated by layering or rooting cuttings. Therefore, each rootstock plant is genetically the same as all others of the clone and desirable characteristics are perpetuated intact. Although more expensive to produce than seedlings, consistent performance with respect to size control and disease resistance usually justifies the extra cost. In propagating and utilizing clonal stocks, the importance of using disease-free plant material when available cannot be overemphasized. Diseases occur-

ring in a mother stock plant will unavoidably be spread to all its propagations.

If a suitable environment is provided, grafting can be done at any time of the year. However, limitations dictated by economics and normal plant growth cycles result in the use of particular techniques only during certain times of the year. Generally, scionwood consists of the previous seasons' growth with healthy axillary buds. Watersprouts, when available, provide an excellent source of scionwood for many plants. Regardless of the technique used and time of year performed, it is essential that scion buds remain dormant until healing occurs. Therefore, conditions favoring callusing and healing of the graft union should not result in rapid growth of these buds. This may necessitate collection and cold storage of scionwood for some time prior to its actual utilization. Under environmental conditions favorable for growth, non-dormant buds on scions will grow for some time, whether a union forms or not. Unable to continually extract enough water from the scion though, they will soon die if sufficient growth precedes formation of the union and reestablishment of vascular continuity between stock and scion. In addition, moisture removed from the scion by rapidly elongating buds would otherwise be available to aid callusing and healing of the graft union. Usually, sufficiently rapid callus formation can be attained at temperatures below that which stimulate rapid bud activity.

Relative growth activity of the stock dictates in part the technique that can be used. Whip and cleft grafting techniques are more easily performed when both stock and scion are dormant and the bark adheres tightly to the wood. When actively growing, the bark often pulls away from the wood during the cutting operation. In contrast, the bark graft can only be performed at times of the year when the stock plant is actively growing and the bark is "slipping". Bench grafting is done during the late fall-early winter period due to the availability of roots from recently dug plants. With the overall view of producing a saleable plant at the end of the growing season, most forms of nursery grafting are done during the winter months when other nursery activities are minimal. After grafting, callusing and, if necessary, artificial chilling, the new plants are lined out in the nursery row in early spring. Depending on the plant, sufficient growth usually occurs in one growing season so that they can be dug and sold in the fall. In some cases, it is necessary to carry them on through a second growing season in order to attain adequate size.

Scions used in grafting usually are long enough to include 2 to 4 buds. In contrast, techniques of grafting in which the scion has only one bud are called budding. In fact, most nursery plants, especially fruit trees, are produced by budding. Most techniques of budding depend on an actively growing stock plant with slipping bark. In shield (T) budding the bark of the stock is cut in such a way that a broad face of cambial and other vascular cells capable of callus formation are exposed. Callus formed from these cells and those on the underside of the scion merge and form a union. Therefore, shield and patch budding techniques can only be performed during the growing season. In the dormant season chip budding can be used. With this technique cuts are made sufficiently deep into the stock to expose two thin lines of cambia. Similar thin lines of cambia on the underside of the cut scion must be aligned with those on the stock for healing to occur.

The scion used in budding normally consists of a bud with varying amounts of bark tissue surrounding it, depending on the technique. In shield budding, the scion is prepared so that a thin sliver of wood remains on the underside. The scion with the "wood in" is inserted into the stock, the wood giving it a degree of rigidity. Alternatively, this sliver of wood can be removed ("wood out") so that the underside of the scion as well as the stock will have broad cambial faces exposed to one another. Although the rate of success of one compared to the other is debatable, a scion with the "wood out" is more pliable and often easier to insert into smaller diameter stocks.

Regardless of the technique employed, adequate knowledge of the plant materials to be used and conditions necessary for success are indispensable in insuring a high degree of proficiency in grafting. As has been the case for many years as a method of propagation, it remains a valuable means of producing many important horticultural plants.