Australia with its fvf scheme, together with the Interregional Research Project (IR-2) scheme of USA, and the EMLA scheme of the United Kingdom, has been at the forefront in establishing germplasm banks of virus-tested, horticulturally important fruit cultivars. Interchange of material between these schemes allows for much faster introduction of new fruit cultivars through quarantine and speeds up their incorporation into virus-tested foundation plantings.

The benefits of the scheme are now becoming increasingly apparent in the Australian fruit industries. Continued close surveillance of all facets of the scheme should ensure that these Australian fruit industries have the benefits of virus-tested fvf propagating material.

AN HISTORICAL REVIEW OF GRAFTING TECHNIQUES

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Grafting is the implanting of a piece of tissue from one plant into another in such a manner that they will maintain a permanent bond. It is one of the oldest arts of plantcraft.

Natural grafting has been around at least as long as plants have had cambium layers to unite, and this natural grafting probably stimulated the early practitioners by way of approach grafting.

References are available to show that grafting techniques were used by the Chinese 3000 years ago (9). At approximately 2000 years ago Aristotle (9) (384 to 322 B.C.), Virgil (4) in his "Georgics" or "The Art of Husbandry" (30 B.C.) and Pliny the Elder (4), in his "Historia Naturalis Volume II" (77 A.D.) all discussed grafting with considerable understanding. Paul the Apostle (9), in his Epistle to the Romans (Chapter XI, Verses 17 to 24) "And if some of the branches be broken off, and thou, being a wild olive tree, wert graffed in among them, and with them partakest of the root . . .", appears to show that at that time the possibility of a reaction between stock and scion (cion, cyon, sion) was recognized.

Columella (2,6), who was regarded as one of the most learned writers on practical agriculture in Rome at the time of the birth of Christ, and who wrote 12 books on gardening (De Re Rustica) and related subjects, together with a supplementary treatise on trees, mentioned the bark and cleft grafts and the patch bud.

Furuta (7) quotes Theophrastus (370 to 286 B.C.) as writing in his "De Causis Planitarium" that the period of the Dog Star (autumn and spring) was the optimum for grafting. He also quotes Cato Major (about 160 B.C.), writing on the grafting of the olive using a bark graft with Greek willow ties and a sticky mass of clay with sand and cattle dung to seal the work.

While in these early times references are available discussing the aims of grafting and listing some types of grafting, the art was regarded as a professional secret by many over the ages. Indeed from time to time there has been agitation against grafting as being contrary to the nature of plants by being injurious and devitalising.

Some of the early writers, e.g. Virgil, seem to have had only the vaguest idea of the possibilities and limitations of the work, and even today it is not uncommon to hear reports of various rather unlikely combinations which, when followed up, are not true grafts.

Pliny, according to Bailey (4) describes a cleft graft. He gives several precautions: the stock must be that of a tree suitable for the purpose, and the graft must be taken from one that is proper for grafting; the incision or cleft must not be made in a knot; the graft must be from a tree that is a good bearer and from a young shoot; the graft must not be sharpened or pointed while the wind is blowing; a graft should not be used that is too full of sap, not more than one that is dry and parched, and finally it is a point most religiously observed to insert the graft during the moon's increase.

Many propagators today find more than a modicum of truth in some of the above statements and many of the small and maybe sometimes large losses which occur result from the neglect of basic rules elucidated some 2000 years ago.

Very little more appears to have been heard on the subject of grafting until the Renaissance (1300 to 1500 A.D.) when, as Hartmann and Kester (9) write, a resurgence of interest occurred as large numbers of new plants were imported into European gardens and were perpetuated by grafting.

During this period cleft and whip grafts were in wide use and it was realised that cambium layers must be matched, although the nature of the tissues was not understood. Most trees in English orchards were being grafted at this time. Leonard Mascall (12) in 1572 penned a delightful treatise on the joys of "planting and graffing, the which not only we may see with our eyes, but also feele with our handes in the secret workes of nature", and reviewed the English experience to that time.

In 1672 Drope (8) wrote in his book, "A Short and Sure

Guide in the Practice of Raising and Ordering of Fruit Trees", that oranges should be budded with an inverted "T" incision and discoursed on leaving the wood in the bud, using dormant scions for grafting, and on the mechanics of union.

Also in 1672 Sharrock (4) in his "History of the Propagation and Improvement of Vegetables" under the heading "Insitions" describes various types of grafts (and buds) with a rather interesting illustration of the various types of cuts. Sharrock also reiterates much of the early advice of Pliny.

Hartmann and Kester (9) write of the work of Stephen Hales who approach-grafted three plants and found that the centre one stayed alive when severed from its roots, and also of Duhamel who, at about the same time, studied wound healing and the graft union.

During the 19th century several writers discussed various aspects of the art. Thouin (9) described 119 kinds of grafts and classified grafting under three headings —

1. Bud grafting or budding (inoculation)
2. Scion grafting or what has been referred to as grafting proper
3. Grafting by approach, sometimes called inarching.

Thouin also discussed changes in growth habit due to grafting. The Gardeners' Chronicle (1) of 1851 showed woodcuts depicting details of various grafting cuts.

Burke (5) writing in "Australian Horticulture" of March, 1983, records the grafting of *Lechenaultia* in France in 1846 as the earliest known graft of an Australian native plant and states that more Australian native plants were grafted in Britain later in that Century. Hartmann and Kester (9) also note that Vochting in the late 19th century continued Duhamel's work on the anatomy of the graft union. Garner (8) quotes Knight's work on the use of raffia to temporarily cincture buds during the "taking" period.

With the coming of the 20th century, advancements in communication and research tools and the increase in the number of research workers, a great amount of information has become freely available. It would not be possible for me to completely detail the advances in this period, so I will confine my remarks to two areas of interest, i.e. tying and sealing, and mechanization.

The earliest tying materials appear to have been plant fibres, particularly the bast fibres of trees such as the bass wood (*Tilia* spp.), willow (*Salix*, spp.) and *Hibiscus tiliaceus* L. By the early 1900's other materials such as raffia and yarn were being used, followed by the use of waxed cloth, thread,

manila paper, and nursery tape. With the introduction of plastic (polyvinyl chloride [P.V.C.], etc.) ties in the 1950's some of the problems of both fixing and sealing were solved, although the new material was not without its problems, such as sunburn.

P.V.C. did not take over completely and we still see rubber strips in use in field grafting, and other materials such as crepe rubber, Parafilm®, florists tape, and plumber's tape being used in "bench" type situations. For top working and tree repair work it has been common for tacks (brads, bootmakers tingles, or flathead nails) to be used with or without other tying aids.

In some situations a special sealing material has not been necessary. Probably the first sealant was "pug", this being a mixture of clay, dung (horse or cow manure generally), chopped hay, or hair. With raffia, the common practice and the more hygienic one, was to cover the work with molten wax, but some workers heaped sandy soil up over the graft and this provided a good situation for callusing and, after two to three weeks, the raffia was decomposed sufficiently to avoid the need to cut it off.

Paraffin wax and other manufactured low melting point waxes (candle wax) have been used but grafting waxes (cold or hand) and brushing waxes (hard or hot) made to a range of formulae have been devised. Some of the materials used are listed: —

Basic wax: beeswax, resin, tallow.

Additives: raw linseed oil, mineral turpentine, alcohol, paraffin wax, lamp black, honey, talcum (chalk), fish glue, powdered charcoal (for visibility and heat absorption), venetian red, Kieselguhr (diatomaceous earth).

One pre-1900 French recipe contained black pitch, Burgundy pitch, yellow wax, tallow, and sifted ash (6).

Waxes are still used but the following is a list of some of the alternative materials that have been used to seal over the wound: —

Asphalt emulsion (Colgraft®)
Aerosol asphalt (wound dressing)
Petroleum jelly or mastics from similar sources
Petroleum jelly impregnated bandages (Densotape®)
Lanolin
Colloidal vulcanised rubber

Colas (cold bitumen) starch mixture
Wallpaper paste
Latex base pastes and paints (Goldseal®)
Plastic (P.V.A.) and acrylic paints
Wax impregnated plastic (Parafilm®)
Babies' bottle teats.

In Queensland, with deciduous fruit tree top working, waxed calico was used but did not encourage callus formation and encouraged ants to build under it. As a result of this, after the graft (strap or cleft) was completed and sealed with a minimum of mastic, a cylinder of paper was formed around the scion and filled with sand. This was successfully used until replaced by plastic (PVC) sheets. Plastic sheets may have to be shaded to prevent sunburn.

Various forms of hot callusing have recently been used over grafts without the need for a great deal of sealing, although as Hellriegel (10) says, Shippy used this technique over 50 years ago with apples. Plant growth substances, such as auxins (IBA, IAA, etc.) and gibberellins, anti-oxidants such as hydroquinone, and fungicides such as Mildothane® have been used mixed with the sealant to hopefully improve the results.

In the past, grafting was often just part of the general nursery and orchard practice and the proprietor did the carpentry part of the work with semi-skilled workers to tie and seal, etc. With the ever increasing need to produce much larger numbers of more specialised trees at a lower cost there has been, as one would expect, many changes. Most of the changes have taken place in the nursery as this has been the area of need.

We might start with the field grafting operation where probably the only changes are in the use of degradable ties, reusable budding clamps, and field transit machines.

In the grafting shed we have progressed from the original bench grafting for deciduous material to the use of containerised stock and to "cutting-grafts", and micro-grafting. With controlled conditions it has been possible in some situations to prepare the material mechanically using semi-skilled labour. Grafts, such as the chip bud, have been reintroduced to extend the grafting period. The plant growth cycles have been readjusted to facilitate these practices.

In 1957 Alley (3) introduced a modified version of Jacob's circular saw type grafting machine at the University of California, Davis. With Alley's machine it was claimed that three reasonably skilled persons could make 700 to 1000 grafts per hour with grapes. Alley also mentions a modified hand saw which could be used with his machine to cut the rootstocks

for top working grafts in the field. At this time (1957) grafting shears or secateurs were also available. Modern machines are based on the earlier ones.

In recent times budding guns capable of budding 500 plus stocks per hour have become available. However highly skilled manual budders are also capable of working large numbers of rootstocks under assembly line conditions. It must also be remembered that there has to be requirements for these enormous numbers of plants, a supply of suitable uniform rootstocks and scions, and that a high level of management skills in the nursery needs to be available.

As already stated, a tremendous fund of knowledge has been amassed over the centuries. It would be a great step forward if the Data Bases discussed by Wren (13) could be made more readily accessable to plant propagators, possibly through the auspices of the IPPS.

In conclusion, I can do no better than to follow R.J. Garner and others, and say that the modern grafter would do well to become imbued with some of the ancients' inquisitiveness, enthusiasm, and the observance of the IPPS motto, "To Seek and to Share".

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