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EVALUATION OF NURSERY PROCEDURES TO ELIMINATE GRAFT-TAKE PROBLEMS

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ABSTRACT

Successful grafting is a vital step in the production of clonal avocado trees. Various types of graft failure occur, ranging from early scion death to scion buds that break, and then cease growing. Failure tends to be seasonal, but varies between nurseries. Statistically valid trials, testing numerous grafting treatments are difficult, but necessary. The main factors affecting graft-take are graft partner compatibility, the grafting environment, grafting technique, pests and diseases, and the physiological condition of the rootstock and graftwood. These factors interact and can be likened to a chain, where each factor is both a chain link and a tension on the chain. Failure of a single link results in graft failure. Critical factors appear to be the grafting environment, and the rootstock and graftwood condition. Graftwood status should be afforded the most attention in order to alleviate graft-take problems.

INTRODUCTION

Clonal avocado propagation is a long involved technique, consisting of one or two grafting procedures. Graft failure is a big set-back for the nursery-man. Reasons for such failures are largely unclear, and major losses (up to 100 per cent) have been sustained in South Africa and around the world. Every time failure occurs, the rootstock is cut back causing reduced vigour, crooked stems and the resultant loss of a proportion of rootstocks.

A request by the Avocado Nurseryman's Association (ANA), led to an investigation into this problem. This paper covers the thinking behind the project, and proposes a new concept for the solution of graft-take problems in all plants, using the clonal avocado as a case study. Research on the subject is not yet complete, and trial results are only mentioned in order to obtain a general overview.

THE GRAFTING PROBLEM:

NURSERY SURVEY

Initially the nurserymen described graft failure as being erratic and unexplained, despite their own efforts to solve the problem. Nine of the ten nurseries registered with ANA in 1986, responded to a comprehensive questionnaire. All nursery procedures, techniques and grafting results were queried in order to:

(a) classify graft failure according to type and occurrence, and

(b) attempt to find out whether any common factors were linked to graft failure.

The questionnaire did not reveal any single factor responsible for graft failure. This was because the nurserymen were unable to provide reasonable assessments of graft failure with respect to failure type, occurrence, cultivar or species specificity, or to any other factors. However, as a result of the questionnaire, visits to the nurseries and the authors' own observations, the following general classifications were established.

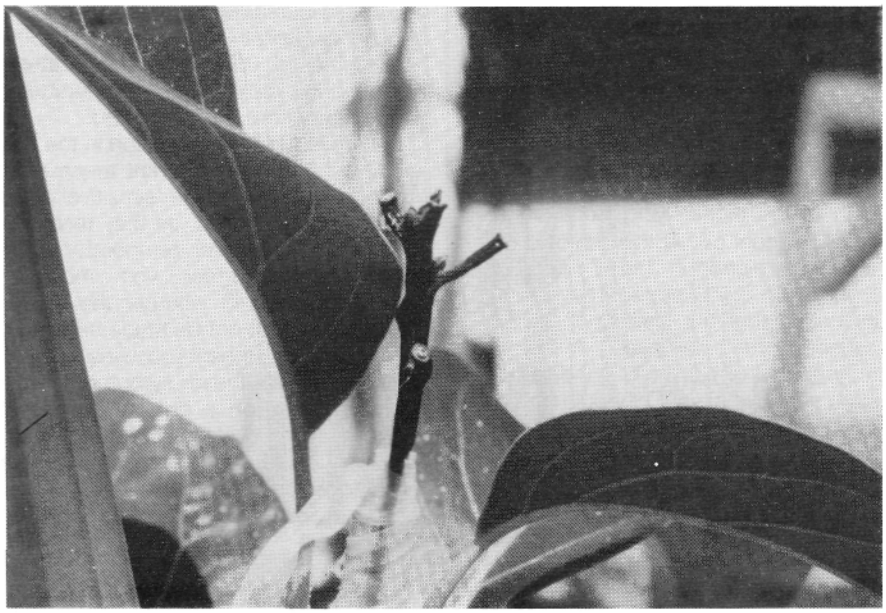

Fig 1 Avocado graft failure resulting from scion death before petiole stub abscission.

Types of graft failure

Graft-take could be classified into various groups:

1 The development of a successful graft union and the desired composite plant.

2 Early death of the scion; the scionwood shrivels, dies and turns black before the petiole stubs have abscised, i.e. within the first two weeks (Figure 1),

3 Death at a later stage after petiole abscission; again the scionwood shrivels and dies, often turning brown or grey (Figure 2).

4 The scionwood remains alive for between six weeks and four months, but the buds do not grow out. The outer bud scales either shrivel or abscise, leaving the thin undeveloped leaf primordia visible (Figure 3). After a variable period the graft reverts to type three above.

5 The most common form of graft failure is somewhat affectionately known as a 'moemparra' graft or bud amongst the Transvaal nurserymen. The bud actually breaks and the tip can grow to about five cm before all growth ceases. The leaves

are generally thin and elongated, usually lacking the characteristic pink tinge of young growth (Figure 4). This graft will survive for many months with no further development. Occasionally recovery occurs, but more often than not a stunted tree results.

6 Bud abscissions on graftwood or bud shields are rare and sporadic.

7 Abnormal scion development very rarely occurs, and is possibly the result of a poor graft union.

The nurserymen noted that Hass scions were more difficult to graft successfully. Various overseas studies (Chalker and Robinson, 1969; Gregoriou, Papademetriou and Christofides, 1984) have confirmed this. Almost invariably clonal rootstocks had lower success rates than seedling rootstocks, although at least once an entire batch on seedling rootstocks had failed. Failures also tended to be linked more to the late summer months, usually the peak grafting period. Nurserymen generally avoided grafting in winter when temperatures were too low. It has been assumed that the lack of secondary development in the scion was due to a lack of development of vascular connections across the graft interface (Hartmann and Kester, 1983),

Graft-take percentages varied remarkably between nurseries, including those in close proximity to each other, While no single factor could be implicated, it seems likely that various factors may be linked in causing graft failure.

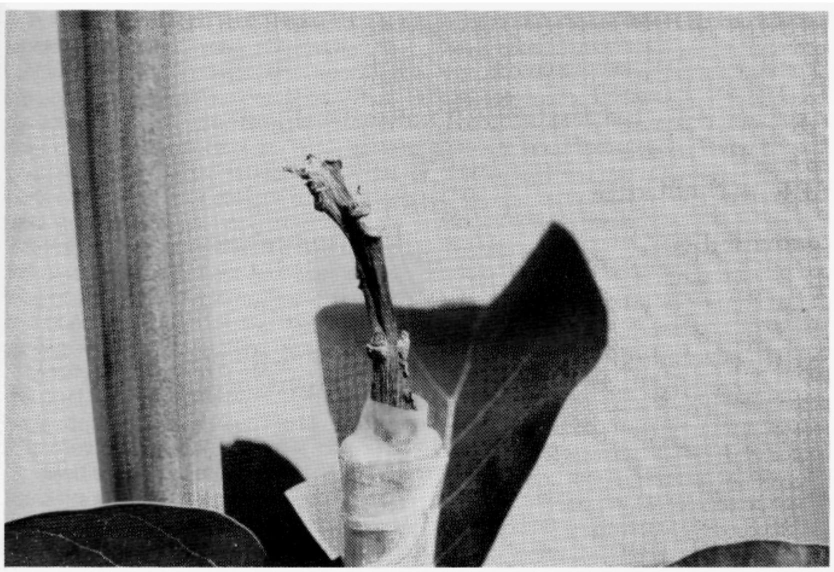

Fig 2 Avocado scion death after petiole stub abscission.

Fig 3 Avocado graft failure resulting from a total lack of bud development.

Fig 4 Avocado graft failure; scion buds break, showing abnormal leaf growths and then fail to develop any further.

Nursery procedures

A classification of certain nursery procedures may be useful in helping to solve the problem:

(a) Scion mother trees

1 Mother trees in full fruit production in a commercial orchard; graft failure is more likely to be seasonal in this case, generally limited to late summer,

2 Trees cut back severly in order to promote strong vegetative growth, or those cut severely for graftwood; failure is far more sporadic, occurring all year round.

3 Trees given special treatment; these techniques are not generally used locally, eg girdling and flower and fruit removal.

(b) Clonal rootstock propagation

1 The nurse seedling is still relatively young, vigorous and attached to the clonal rootstock at the time of grafting to the scion cultivar; graft success appears on average to be higher in this category.

2 Either

(i) the nurse seedling has been excised before scion grafting, or has become old due to regrafting or

(ii) rooted cuttings are employed; graft failure appears to be higher in this category.

(c) Rootstock quality

1 Strong, vigorous and healthy rootstocks are utilised; graft-take should be better than in 2 below.

2 Rootstocks are of poor quality.

These categories will be discussed later with respect to providing the means for finding solutions to graft-take problems.

EXPERIMENTAL APPROACH

A comprehensive review of numerous experiments on grafting and budding, and reasons for graft failure has highlighted two important aspects:

(a) Usually only one or two factors are tested at a time. The most successful treatments may result in much less than 100 per cent success. When grafting trials on the same cultivars are examined, conflicting results are found. This means that other untested factors are involved, and it seems highly likely that these factors interact to a greater or lesser extent. Thus a wide range of treatments need to be tested to obtain valid results.

(b) The yields of a single plant can only be a success or a failure, resulting in a binomial distribution. Therefore, a large number of plants per plot is required in order to satisfy the demands for a normal distribution and a valid statistical analysis of variance (Rayner, 1967).

Experiments must, therefore, be carefully designed and most results viewed with some caution.

THE GRAFTING CHAIN

A model is proposed for use in solving grafting problems. This will need to be adapted for each species/cultivar and situation. Consider the analogy of a chain which is only as strong as its weakest link. Each factor that affects the development of a successful graft union may be thought of as a link in the chain. Each link is different, and varies in strength. For grafting to be successful the chain must remain intact. A single break in any link will result in graft failure or poor scion growth, regardless of the relative strengths of the other links. In addition, various forces are applied to this chain. These forces are again the factors that affect graft-take, but in this instance are factorial interactions.

In general the main factors that affect graft-take are:

1 The compatibility of the graft partners.

2 The environment under which grafting occurs, and under which the composite plant subsequently grows. This includes the storage and transit period.

3 Grafting technique and the physical or mechanical matching of the graft partners (including graft polarity).

4 The effect of any pests or diseases.

5 The physiological condition of the rootstock.

6 The physiological condition of the mother plant and hence the graftwood.

Various other factors have been cited, but they could probably be placed in one of the above categories. A problem in any of these areas may result in the breaking of the chain at the respective link, or it may cause stress resulting in the breakdown of other links. Most of these factors have been listed in major reviews (De Waard and Zaubin, 1983; Hartmann and Kester, 1983) but little, if anything, has been reported on their interaction. Figure 5 shows this concept as applied to clonal avocado propagation.

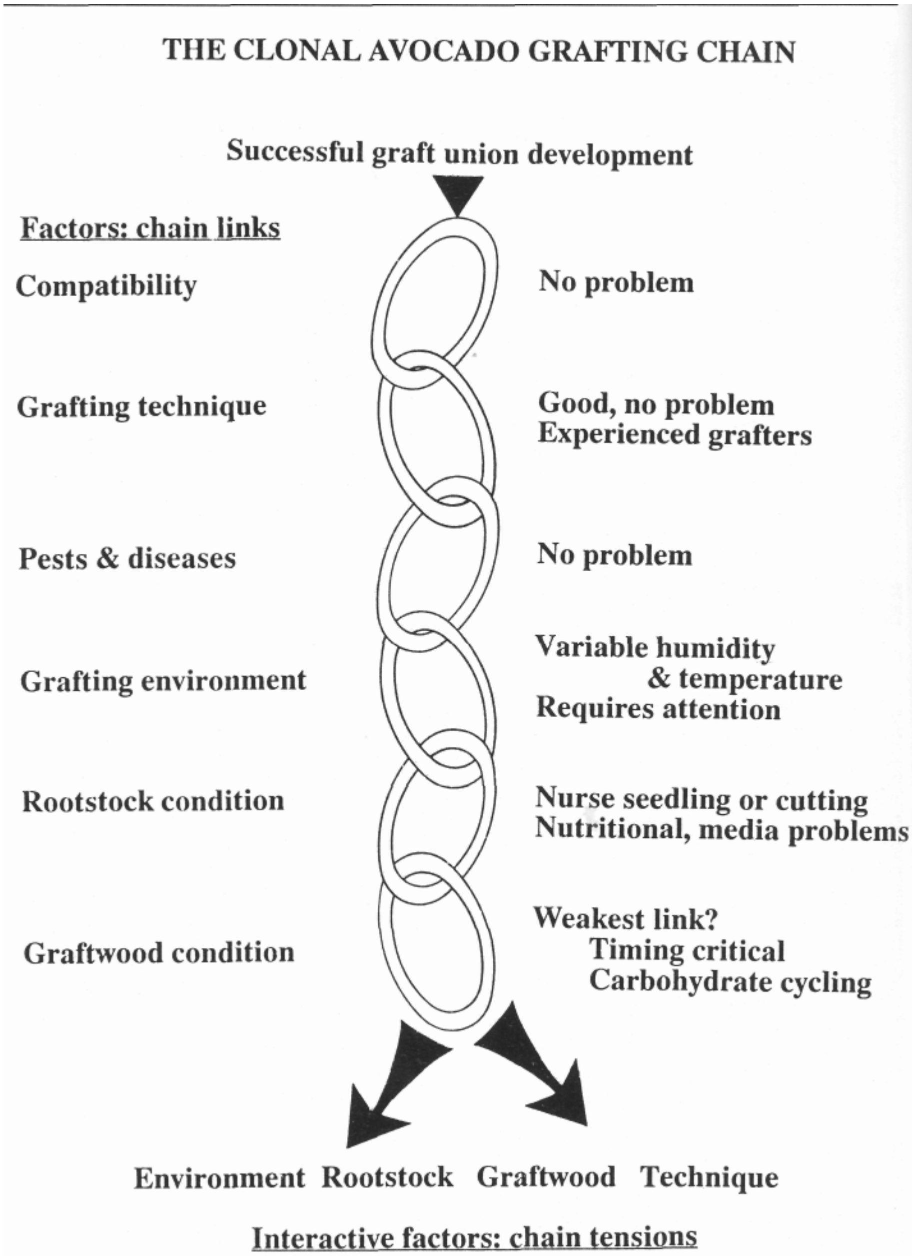

Fig 5 The factors affecting the development of the graft union presented as the 'grafting chain'. The various strengths and weaknesses of the clonal avocado grafting situation are shown.

Incompatibility

Incompatibility is a much misused term, often used to describe graft failure (Moore and Walker, 1981; De Waard and Zaubin, 1983). Although avocado orchard trees often show signs of uncongeniality between the stock and scion, which results in weak trees, no evidence exists that true incompatibility is related to present grafting problems. Failure is generally sporadic, seasonal and unpredictable not the signs of an incompatible situation. This is further supported by the failure of some Hass and Fuerte autografts. Although there are large genetic effects, these must not be confused with incompatibility, For example, Hass is usually more difficult to successfully graft onto currently used rootstocks than any of the other commonly grown cultivars. It is, therefore, assumed that cultivar compatibility is a strong link and no interactions cause any grafting problems.

Grafting environment

The environment under which the plant is grafted and subsequently grows, was initially thought to be one of the major causes of graft failure. The fact that failure is more common in mid to late summer (the hottest period) is not sufficient evidence to indicate that high temperatures alone are to blame.

Trials by the authors in controlled environments have indicated that constant high day temperatures of up to 30°C, were not prohibitive to good graft-take on clonal rootstocks when the graftwood was reasonably mature, Alternatively, cool day/night constant temperatures of 22/12°C gave poor graft-take with the same graftwood and rootstocks. However, when soft immature graftwood was used on seedling stocks, better results were obtained at the lower temperature. An intermediate controlled temperature of 26/16°C, gave best results in both situations, Under certain extreme temperature conditions, total graft failure has occurred despite various other treatments. In these cases the environmental effect has overridden that of the other factors. These results are good examples of the interactions as explained by the grafting chain.

Modifying the microclimate around the graft may be done with polyethylene bags and shading (Alexander, 1986). This method, tested under five different modified environmental conditions using seedling stocks, was of no benefit although graft-take was relatively low. Variable results have been obtained by local nurserymen using similar techniques. A second modification such as that used in mango, where the whole scion is wrapped with polythene grafting tape, may also aid in certain situations. These procedures may be of greater importance during periods of high temperatures and evaporative demand soon after grafting. Moderately heated greenhouses should enable nurserymen to extend the grafting period into the winter months.

This interactive situation is further highlighted by the differences obtained in grafting success rates by nurseries in close proximity, where only minor climatic differences exist. Therefore, as long as temperatures remain within reasonable limits, this link should remain intact during summer. Its interactive effect is assumed to be a marked one. Nurserymen should therefore take the necessary steps to overcome this problem,

Grafting technique

This subject has been well reviewed (Garner, 1979; Hartmann and Kester, 1983) and there seem to be no problems in this regard, provided that the grafters have the necessary skills. Various types of grafts and even chip budding have recently been used by the nurserymen, with no apparent differences emerging. Poor graft technique is likely to be associated with early death of the scion (graft-take classification 2). Grafters are generally skilled and there is no reason why their ability should vary so markedly between seasons and batches of plants. Thus, the grafting technique of experienced grafters appears to be a rather strong link with little interactive effect.

Pests and diseases

Limited graft failure has occurred in the nurseries due to pest or disease attack. Avocado pests are minor problems in shadehouses and are relatively easy to control in greenhouses. Fungal attacks have caused a few losses, but usually this affects the whole plant rather than just the scion. This link is a strong one with little interactive effect, due to the general absence of harmful pests and diseases.

Rootstock condition

The physiological condition of the rootstock would seem to have a major effect on graft-take. The most obvious difference is that seedling rootstocks generally graft more successfully than clonal rootstocks. This fact is supported by local nurserymen. In addition, young seedlings result in higher success rates than old seedlings. It has been suggested that the large seed cotyledons provide necessary substances (nutrients, plant growth substances [PGS] and/or carbohydrates), and that these are at lower levels in old seedlings or clonal rootstocks. Another explanation may involve the whole juvenility concept, which enables non-etiolated avocado seedling material to root relatively easily (Kadman, 1975), while physiologically older material is extremely difficult to root. Work on juvenility should be extended to grafting.

Some nurserymen feel that the numbers of leaves and roots on the rootstock has a marked effect on graft-take. This is well supported by Stoddard and McCully (1980). However, the authors' attempts to show this have not met with success. It would appear from various observations that there is a minimum root quantity standard required for good graft-take. Once this minimum has been achieved, larger root and leaf masses have no effect on improving the percentage of successful grafts (Figure 6).

Fig 6 Above a minimum standard it appears that avocado rootstock leaf and root numbers have little effect on graft-take.

A trial in which Duke 7 rootstocks were grown in three controlled day/night constant temperature glasshouses, and subsequently factorially grafted in each of the three, showed some interesting results. Plants either grown and/or grafted in the cool environment (22/12°C), would not graft successfully. However, plants grown and grafted in the two warmer environments were most successful. Rootstock stem, leaf or root masses did not appear to have any effect, so an unseen physiological balance was assumed to play a role in affecting graft-take.

Experiments involving dilute feed fertilisation and the effect of the physical properties of the growing medium, have indicated that much can be done to improve the conditions for the rootstock plants. It would appear that the air-filled-porosities (AFP's) of the growing media, used by South African nurserymen, are too low. Common practices of adding sand and other media thought to improve the physical properties of coarse, milled pine bark usually, but unwittingly led to poorer growing media, Optimal AFP's are in the region of 20-40 per cent depending on management practices (Smith and Church, 1987),

Many nurserymen tend to favour high nitrogen fertilisation, which may be detrimental. One N trial has shown that 160 mg $^{-1}$ N was significantly better for avocado plant growth than 220 or 280 mg 1^{-1} when used as a dilute feed in milled pine bark. Adequate nutrition of the rootstocks is essential and special emphasis should be placed on trace element nutrition. Visual 'analysis', a technique used by most local nurserymen, has been shown to be an unreliable method. The use of leaf analysis could be useful in determining future fertilisation requirements.

Graftwood condition

The condition of the mother tree when graftwood is collected appears to be the most critical link in the chain. If graft failure is largely seasonal, the environment must play the major role. The environment affects:

(a) the physiological condition of the mother tree;

(b) the physiological condition of the rootstock at grafting time, and

(c) the conditions under which grafting occurs and the composite plant grows.

The last two factors, while shown to have an effect, do not appear to account for all the problems which have arisen. The classification of mother trees becomes important here. Hass in particular, appears to be susceptible to the period of poor take in late summer. This may be associated with a period of low carbohydrate reserves in the mother tree (Cameron and Borst, 1938; Scholefield, Sedgley and Alexander, 1985). Nurserymen who cut back their mother trees, either deliberately or while collecting large amounts of graftwood from a single tree, usually obtain strong, vigorous and healthy looking graftwood. Strong, swollen buds are preferred by grafters, but it seems that these appearances are deceptive, and failure with such scionwood is not uncommon at any time of the year.

Recent cuttings back of the mother stock plant, and/or allowing the tree to continue in full production, drain its energy reserves. Much evidence exists (De Waard and Zaubin, 1983) that this results in poor development of the graft union. If the energy drains, i.e. the flowers and fruit (Wolstenholme, 1981; 1986) are removed and the balance swung in favour of strong, but not excessive vegetative growth, then the graftwood could well be in a superior physiological condition. It must be remembered that January and February coincide with a period of rapid fruit growth, the summer growth flush, and environmental stress all conducive to carbohydrate utilisation.

Another possibly useful technique involves the girdling of the mother plant some time before grafting, as utilised in macadamia grafting (Leigh, Trochoulias and Austen, 1971). Timing rootstock growth to allow the plants to be grafted during periods of optimum scionwood condition, will probably prove to be the most simple method of overcoming graft-take problems. Grafting at different times of the year in controlled environments and nurseries, has shown that timing is crucial. This is attributed to mother plant variation. Storage of graftwood from favourable to unfavourable periods is not practical at present, but requires investigation.

Scionwood pieces cut as for grafting, with the leaves trimmed to leave the petiole stubs were placed in a mistbed. This was done in an attempt to simulate a graft union situation where callus development was keeping the graft alive, but no vascular connections had developed to supply the scion with the necessary nutrients and PGS for secondary growth. The buds on the graftwood (even from the same tree) responded in different ways. The graftwood either:

(a) died within the first two weeks (as in type 2) in the graft-take classification, or

(b) remained alive for up to four months.

These buds either temporarily grew out as they would be in a normal successful graft, or they showed symptoms of graft failure as in types (3), (4) and (5) in the graft-take classification.

While successful scion growth is a result of the development of vascular connections across the graft interface, it would also appear that initial physiological activity in the bud and developing leaf primordia results in the development of secondary vascular connections. These events are not mutually exclusive (Sachs, 1981).

CONCLUSIONS

Numerous factors are involved in the successful production of a grafted avocado tree. In order to solve grafting problems, nurserymen should examine each 'chain link' in the production of their nursery trees. The grafting environments, and the physiological conditions of the rootstock especially that of the graftwood appear to be the most important factors. Since graft-take is so variable between nurseries, the weakest links in the grafting chain may vary in each situation. As new information is uncovered, it can be used to improve the model. Therefore, it is imperative that nurserymen keep records of production techniques and grafting results, which must then be closely examined in order to alleviate the persistent grafting problems.

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