

the successful grafting of guava (Nelson, 1954b) was entirely due to using scions of vigorous, more or less undifferentiated tissue. The scions having these qualities of cell activity could not be found on older trees unless drastic pruning was done by topping approximately 1/3 of the tree selected as a scion source. With adequate nutrition and water, vigorous shoots were produced that provided scions that gave a high percentage of success.

Lychee graftwood can be improved by a similar procedure as was done to guava. Vigorous growth produces stems that provide a larger diameter scion that is easier to cut to fit onto the rootstock, hopefully providing more meristematic tissues.

Rootstocks grown from seeds should not be used because of their variability. There is a good chance that many seedlings would not have tolerance to alkaline soil, or they might have other defects that could hinder the production of a uniform and productive grafted lychee tree. Only clonal rootstocks that have a known history of tolerance for calcareous soils should be used.

Venning (1949) did the first anatomical study of lychee. His research gave a rather discouraging picture of the potential for successfully grafting lychee. He found that lychee stems as small as 0.04 inches (1 mm) in diameter show all primary tissue around the entire stem. No secondary tissues are formed at this early growth period. However, when the stem enlarges to 0.16 to 0.2 inches (4 or 5 mm) in diameter, the cambium is activated and is producing secondary tissues, but only about half of the cambium is active around the stem at any one growth period. When the stem reaches a diameter of 0.4 inches (1 cm), about 1/3 of the cambium is active during a particular period of growth. This definitely presents a difficulty when a scion is placed on the rootstock, since there is no external clue as to where the cambium activity is occurring. Venning states that at certain growth periods, however, cambial activity resumes movement around the stem. He suggests that some grafting success is possible if the scion can be kept from drying out during a period of cambial inactivity in the area where the propagator may have placed the scion. The question would be whether the cambial activity would resume soon enough to reach the scion and provide cells that would unite with the scion before it dies. High humidity under a mist system could be used to keep the scion alive (Nelson, 1953a; 1954a).

Summary

We know that successful grafting has been accomplished on lychee for many years by one technique or another. To increase the chances for successful grafting, efforts should be made to obtain graftwood from trees that have been topped, fertilized heavily, and have received all minor elements required. Graftwood selection would most likely be available several weeks following the fruit harvest. Trees will have received their heaviest fertilization as well as pruning. The growth flushes will provide suitable scions on trees that have been topped and hedged. Rootstocks should also be in a stage of active growth.

The very active, recently organized lychee growers should request some additional anatomical research to learn more about cambial activity in the graftwood and rootstocks that have been grown under the conditions I described, i.e., high rates of fertilizer and forced growth flushes by severe pruning of the graftwood source, and the use of very vigorous rootstocks.

The skill required to become a good propagator begins to develop after grafting a few thousand trees and experiencing both failure and success, while learning the art of grafting.

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CONFRONTING PLANT DIVERSITY WHEN PROPAGATING *LITCHI CHINENSIS*

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Abstract. The Treehouse (Bokeelia, Fla.) has been involved in the production of lychee (*Litchi chinensis* Sonn.) trees in parallel with a wide range of citrus cultivars for over 18 years.

Many problems of the two bear a close resemblance. The effects of parentage, limb and bud sports, virus and other causes on diversity has been well researched in citrus because of its world-wide importance. The citrus investigations suggest the path future research must take to resolve the problems encountered in propagating the lychee. In addition, Groff's (1921) work is relevant to modern problems with lychee propagation. That we are dealing with a species of great genetic diversity, manifesting severe graft incompatibilities, is quite apparent. Having had to familiarize ourselves with many citrus disorders, we can only come to one conclusion—that these incompatibilities of lychee are also indicative of graft-transmissible pathogens. Thus, we view with alarm certain practices, used for

centuries, that are being used as the norm in lychee propagation.

When propagating lychee (*Litchi chinensis*) in small quantities, diversity within this species is not readily apparent. Increasing the numbers dramatically reveals this diversity.

Groff (1921) described what he encountered in China at that time. His work contains statements not fully understood unless one, in large scale propagation, recognizes certain recurring problems. When these appear, Groff's statements become clearer, making this "outdated" work a current source of information. Among other things, he reports:

- The Chinese used the "mountain"-type lychee.
- There was also a "water"-type lychee.
- A longan (*Euphoria longana*)-lychee cross existed, called the "lungly".
- Other members of the Sapindeceae grew in China.
- No air layers of the cultivar, Hanging Green, were like the parent tree.
- Seeds of the best varieties were not viable.
- Propagation was carried out without much regard for bud or limb variation.

The implications of these observations are pertinent to the present-day problems that propagators encounter. Some of these are:

- Under given conditions, a single plant does not appear, grow, or produce the same way as all others of the same cultivar in a single planting.
- Plants imported from one region to another do not respond in their new location, regardless of care.
- Seedlings seem to exhibit rejection of a particular cultivar's scions.
- When grafts do "take", incompatibilities manifest themselves in various forms.
- A particular cultivar exhibits distinctively different growth patterns when propagated by airlayering than it does as a grafted tree.

Consider, for a moment, citrus, a more widely propagated group and thereby more widely researched and understood. Citrus production in Florida, alone, has progressed from the planting of seedlings in the 1830s to the multitude of cultivars recognized today (Castle et al., 1989). Some of these cultivars originated as seedlings, bud-sports, or as limb-sports of other cultivars. When propagating the Rutaceae, a rather large family (203 species in 33 genera), complications arise which often require a review of the parentage of the cultivar in question. When no common parentage is found, one often finds answers to cross-pollination failures, graft incompatibilities, and other problems (Castle et al., 1989).

Much that is true of citrus may possibly be applied to lychee propagation. We have air-layered, rooted cuttings, and grown seedlings which were subsequently grafted. Results have not always been uniform. Airlayers rooted to varying degrees, the root systems of cuttings varied widely, and grafts were not always compatible (delayed and immediate rejection). Below we discuss, in more detail, our observations of diversity resulting from various propagation methods.

Cuttings

The survival rate of cuttings and other complications have caused us to limit our work in this area. Therefore, we will not discuss this method of propagation.

Airlayering

Grove owners and propagators often airlayer trees of a single cultivar, selecting trees that are not bearing at the same time that all others of like type are in fruit or flower, and avoiding those that have a record of good bearing. They are reluctant to airlayer the trees that bear heavily, because they do not want to lose the crop. In effect, they are cloning their most unproductive trees.

In addition to this problem, consider Groff's (1921) statements concerning 'Hanging Green'. The Chinese assumed that because no air-layered limb of this tree performed like its parent, the planting location was responsible ("unique") for the differences they observed. We think that a more likely explanation is that the root structure of an airlayer is different from that of the parent tree (parent seedling?) and response is therefore different from the parent and, potentially, every other airlayer. For example, at least 4 trees in our collection are airlayers of 'Brewster' but are not recognized as such by competent lychee propagators because of their different appearance.

Considering the possibility of limb-sporting in lychee, one can readily recognize the complications in tracing the origins of variants in 2,000 years of propagation using airlayering as the principle method. In addition, airlayering is an excellent method of spreading diseases caused by viruses, if the airlayer source trees are infected. Eventually, given current practice, we could end up eliminating pathogen-free scion sources. As in citrus, some infections could be passed from tree to tree, not only by insect vectors, but by the tools of propagators. We may also have to reconsider how we acquire and handle plants if pathogens can be spread through seed.

Seeds

Groff (1921) states that there were, at that time, recognized crosses of longan and lychee, intimating that they produced inferior fruit. We feel certain that some of these crosses may have persisted unrecognized. Assuming one encountered such a cross, we suppose it would exhibit some indication of parentage such as leaf shape, size, color, growth habit, bark texture, season of bearing, flower panicle and/or fruit shape, color, etc

In the case of our seedling, #88-1, some of these characteristics are evident. This plant came to our attention as a very young seedling in a tray with many other seedling lychees. The leaves were much larger than normal and of a dark purple color, much like a longan seedling. Still it is a "lychee". New flushes on this plant are of the diameter and color of longan, but the leaves are soft and drooping. Total weight is much greater than lychee or longan flushes. But the deciding factor indicating parentage, in our opinion, is fruit shape. It is round (Fig. 1). Moreover, the pericarp does not have the roughness of a typical lychee. It resembles 'Sweet Cliff' in texture, size, color, and flavor (Fig. 2). One should note, however, that none of the other conditions indicative of a suspected cross are visible in 'Sweet Cliff'. It is recognized as a lychee despite its round fruit.

If lychee and longan cross upon occasion, and have for centuries, what other members of the Sapindaceae may have crossed with lychee in ancient China? Have these "lychees" (through variants) lost all visible traces of parentage?

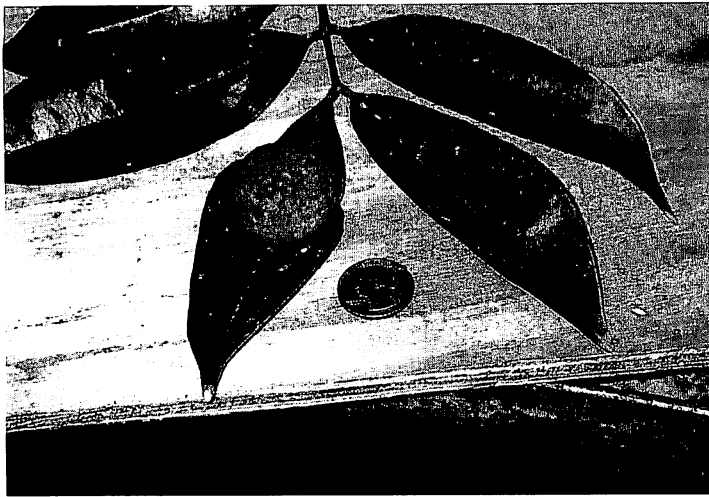


Figure 1. Seedling #88-1 with leaf.

We have observed that flower panicles vary in form, color, and flower-type dominance (Mustard, 1958). If plants cross readily, the fact that, among the cultivars, there is a range of flower-type dominance on any given day, makes cross-pollination easy to accomplish in multi-cultivar plantings. Stern et al. (1993) confirms this observation in the case of 'Floridian' and 'Mauritius' in Israel. Some cultivars bear early and some late. At the beginning of the bloom cycle we would expect this to be shown in the panicles with either "early" —Type II flowers dominating, or "late" —unopened, Type I or III dominating. This is exactly what we have observed and seems to confirm the ease with which these plants could diversify, as outcrossed hybrids.

During 1990, a year when 'Ohia' produced to the exclusion of almost all other cultivars in our plantings, the percentage of aborted seed was very high (80% - 90%), and this has also been observed with other isolated 'Ohia' trees (J. Blazer, personal communication). In subsequent years, when other cultivars bore heavily, the percentage of aborted seed fell dramatically in 'Ohia' (10% - 15%). We assume that if our observations are correct, 'Ohia' trees grown in any suitable location with no other cultivars in close proximity should produce a large percentage of aborted seed. This cultivar's reputation,



Figure 2. Left - Seedling 88-1, Right - 'Sweet Cliff'.

in Thailand, as a producer of aborted seed now becomes questionable (Anon., 1982).

Grafting

Perhaps the most indicative of plant diversity in Groff's (1921) work is the reference to the Chinese returning to a particular tree (they preferred the "Mountain"-type lychee) and airlayering limbs to serve as rootstocks for grafting. He does not say that the Chinese could explain the reason for undertaking this labor- and time-consuming procedure.

Our work indicates that cultivars previously rejected as being without potential in Florida may not have been properly evaluated, if trials consisted only of airlayers. Consider again 'Sweet Cliff', which as an airlayer planted in the calcareous soils of Dade County, presents a stunted, chlorotic, poorly producing specimen, while in the sandy loam of Lee County, grows into a vigorous, good producer. In Sarasota County, 3 trees of 'Sweet Cliff' were observed growing in close proximity in fine white sand—two airlayers doing poorly and a grafted tree doing very well.

In our experience, 'No Mai Tze' presents the most difficulty in grafting. Grafts which appear to be well-knit subsequently exhibit all forms of incompatibility described in this paper. Yet 3 grafted trees in our field plantings show no signs



Figure 3. Scion - 'No Mai Tze'. (3+ years old.) Proliferation of buds now dying. Note flower panicles. Diameter of rootstock 3/8 inch.



Figure 4. Scion - 'No Mai Tze'. Large pits are leaf scar. Note pitting at graft union and below leaf scar, disorganized tissue at top of cleft flap and thickness of bark.

of incompatibility and are performing well. It is interesting to speculate that we might be able to use these trees to obtain rootstock shoots that would be more compatible than most. Perhaps compatibility was the reason that the Chinese returned over and over to the same trees for rootstock material.

Much like citrus, we encounter diversity in grafting lychee, including complete incompatibility, scion overgrowing rootstock, delayed incompatibility (scion dies 1 or 2 years after grafting), and occasionally, a rust-like appearance of the bark across the graft union, extending several inches above and/or below it. To date we have not encountered any case of a "clean-break" of the graft union as is often found with some combinations.

When, in the hands of a competent propagator, we observe the continuous rejection of a particular cultivar's scions, regardless of technique, we assume complete incompatibility. The source of the scion now becomes "suspect" for reasons which will become apparent.

Several years after grafted trees are planted in the field, delayed incompatibilities manifest themselves in various ways. One may encounter the scion overgrowing the rootstock, with the development of the rootstock arrested. Often when this occurs, the bark darkens and a certain amount of roughness or corkiness of the bark appears, particularly on the sci-



Figure 5. Scion - 'Emperor'. (5 years old). Clean graft.

on, but sometimes on both scion and rootstock. After partially removing the bark, one can see a line where scion phloem tissue is overgrowing the graft union, and a constricted area of scion xylem that appears to have increased little, if at all, in diameter since the date of grafting (i. e., the growth in diameter of the scion is largely confined to the phloem).

Scion diameter increases two to three times that of the rootstock and appears stunted while producing a proliferation of buds (Fig. 3).

Should an adventitious shoot appear on the rootstock, the shoot exhibits normal color and growth. Rootstock diameter begins to increase in normal fashion from the point of shoot emergence and downward, while the scion, and in some cases the rootstock trunk, above this point dies. A check of the graft union by removal of a strip of bark discloses pitting of the wood of the rootstock, much like one would find in citrus rootstocks grafted to scions harboring certain pathogens (Fig. 4) (Castle et al., 1989). Just what pathogen of lychee, if any, may be involved is not known. Because all of our budwood trees exhibit no visible symptoms of disease, we assume that, much like citrus, these pathogens (if present) only manifest themselves when the infected scions are grafted on non-tolerant rootstocks (Castle et al., 1989). Further research on this problem is essential.



Figure 6. Row of 4 year old 'Emperor' trees.

Conclusions

Our observations have led us to conclude that until the genetics of lychee are better understood, until pathogens have been identified and indexing procedures developed, or until other factors involved have been identified, compatibility of rootstocks and scions will continue to be a "hit or miss" proposition. Therefore, to minimize and/or avoid these problems, our program of propagation includes the following:

- Sanitizing grafting areas, tools, and workers, particularly between scion sources.
- Planting seeds of various cultivars growing in close proximity to one another.
- Observing seedlings for uniformity and making selections for new cultivars and/or rootstocks.
- Grafting these seedlings to particular cultivars which they may resemble and/or scions of their parents.
- Planting out and monitoring grafts that "take".
- Decapitating trees that form the best unions and vegetatively propagating the shoots for future rootstocks.

- Distributing grafted trees to various regions to observe performance.

Using these procedures, we have successfully identified rootstocks for several lychee cultivars. Success with one in particular, 'Emperor', has been very good (Fig. 5, 6). A few 'Emperor'/rootstock combinations have exhibited the "rust-like" bark conditions across the graft union, but without any apparent effects on growth or production up to this time (5 years). Until compatible seed source trees are identified, we may have to content ourselves with returning to a singular, identified compatible tree as a source of rootstocks.

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THE LYCHEE'S HISTORY IN FLORIDA

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Abstract. The lychee (*Litchi chinensis* Sonn.) was introduced to Florida before 1880, but attracted little attention until the 1940s when its suitability for fruit production was noted by a small group who thereupon worked effectively to popularize this crop. The discovery of an improved method of propagation, marcottage using polyethylene plastic and sphagnum moss, made mass production of nursery stock practical. In the 10 years from 1948 to 1958, a center of production developed in Sarasota County on the west coast, but prolonged freezing weather in early 1958 killed or severely damaged the plantings there. Production moved southward, and before Hurricane Andrew, 150 acres were concentrated in southern Florida. Lychee trees showed earlier recovery from hurricane damage than many other important fruit crops, and one estimate of the area currently planted to this crop is 350 acres. The two cultivars on which the industry is presently based, 'Brewster' and 'Mauritius', both have production problems, and therefore improved cultivars are needed.

The first introduction of lychee plants to Florida took place before 1880, to a site in the vicinity of Sanford (Manville *et al.*, 1889; Singh & Singh, 1954). Little more was heard of this introduction, but the 'Brewster' or 'Chen Purple', brought from Fujien Province, China, late in 1903 (U.S. Dept. of Agriculture, 1908), had a greater impact on Florida's development of a lychee industry. Although its introduction was re-

corded by USDA without a cultivar name, as P.I. 21204, credit for 'Brewster's' introduction should go to an American missionary of the same name who collected and brought it from China. Many plants grown in Florida were brought from Reasoner's Nursery, in Manatee County. Their stock of lychee probably was propagated from the 1903 introduction, although the name 'Brewster' was not attached to it in their catalog (Royal Palm Nursery, 1937). A tree bought from them in 1919 and planted in south Dade County survived for 73 years, just west of U.S. 1 and north of S.W. 288 Street (Biscayne Drive), until it was destroyed in the aftermath of Hurricane Andrew in 1992 (Collins, 1935). 'Brewster' and a second cultivar, 'Mauritius', introduced by the University of Florida from Natal, South Africa (Ledin, 1957), have been the most important cultivars in Florida's lychee industry to date, although neither is ideally adapted to Florida conditions.

Lychee growing in Florida received substantial support in the 1940s from Col. William R. Grove, U.S. Army (Ret.), who lived at Laurel, in Sarasota County. Judge C. E. Ware, of Clearwater, also was an active enthusiast at that time who promoted lychee culture on the west coast. A ferment of research and development took place, powered by Col. Grove, Judge Ware, and a group of like-minded friends and associates. They founded the Florida Lychee Growers Association in 1951, and this organization made a valuable contribution to the young industry through the publication of their yearbooks from 1954 through 1963. The greatest of these associates was perhaps G. Weidman Groff, a horticulturist and authority on the lychee (Groff, 1921) who before World War II was Dean of the College of Agriculture at Lingnan University, Guangzhou (Canton), China. Returning to the United States after 1947 and settling at Laurel, he contributed substantially to the development of the growing industry until his death in 1954.

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