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Graft Union Behavior of Certain Species of *Malus* and *Prunus*[1]

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Abstract. Five apple species were grafted onto East Malling VII, IX and 26 and Malling Merton 104, 106 and 111 and 3 cherry species were grafted onto Mazzard F12/1 rootstock (a virus indexed clone) and grown in the field for one season. Determinations were made on graft success and plant response in the field. In October, representative graft unions of the 33 combinations were prepared, sectioned, and examined microscopically in an effort to find a rapid test for compatibility. The results of these microscopic examinations were correlated with the field results to see if one or more abnormalities could be found consistently in a significant number of grafts. Only a few grafts showed incompatibility characteristics which could be correlated to the field tests thus eliminating a quick microscope test. Anatomical abnormalities appeared to be the result of secondary influences suggesting that the biochemical factors probably control the compatibility or incompatibility of graft unions.

Problems of scion/rootstock incompatibility in fruit trees have become more apparent with the increased use of dwarfing clones to reduce the tree size. The causes and effects of incompatibility are not fully understood. Graft union incompatibilities are observed in varieties of both *Malus* and *Prunus* species.

Mosse (5) has compiled much of the past research on incompatibility problems. However, relatively little has been done in correlating field results with laboratory observations in an attempt to find a key to forecasting the success of a given graft union. Herrero (2) made extensive studies of the size and areas occupied by fibers, vessels, parenchyma and rays in the xylem. The width, distance between, and relative numbers of uniseriate and multiseriate rays in the cambium were also determined in both plum and pear. He could not correlate any of these anatomical characteristics with incompatibility. Lapins (4) compared 5 characteristics as possible indices of graft union failure in 2-year old apricot trees, but no correlation of anatomical structure to compatibility was found.

The main purpose of this research was to determine the anatomical differences at the graft union of several stock-scion combinations and investigate the feasibility of developing a quick test for incompatibility.[4]

Materials and Methods

In March 1966, five apples species: *Malus sylvestris* Mill. cv. 'Golden Delicious', *M. floribunda* Sieb., *M. baccata* Desf., *M. sargenti* Rehd., and *M. purpurea* Rehd. cv. 'Lemoinei', were whip and tongue grafted onto 6 clonal rootstocks: East Malling (EM) VII, IX and 26, Malling Merton (MM) 104, 106 and 111. Three cherry species *Prunus avium* Linn. cv. 'Hedelfingen', *P. cerasus* Linn. cv. 'Montmorency' and *P. serrulata* Lindley cv. 'Kwanzan', were similarly grafted onto Mazzard F12/1 rootstock. The 30 apple combinations were replicated 10 times, and the 3 cherry combinations were replicated 12 times. The grafted trees were stored until May, at which time they were planted in the field, where mulch and irrigation were provided as required for normal growth.

At the end of September 1966, the number of successful grafts in each combination was recorded. At this time the trees were either dead or healthy so the determination of a successful graft was, in general, no problem. Judgement was withheld on borderline trees until the following spring (Table 1).

Two samples of each combination containing the graft union were selected randomly, and fixed in FAA prior to sectioning. Where only 1 or 2 of the grafts were successful, selection was, by necessity, not random. In certain cases, although none of the grafts were successful, 1 or 2 trees had made some growth and their unions were sufficiently intact at time of sampling to be utilized.

In sectioning the unions, neither the freezing technique (8) nor the use of water soluble waxes (polyethylene glycols) (9) proved as successful as the celloidin method (7). The celloidin method allowed weak tissues to be sectioned successfully.

The embedding procedure followed was that of Sass (7). Although the ether extracted large amounts of tannin from the samples causing darkening of the celloidin solution, this had no adverse effect on the cutting or staining properties of the tissue. Sections were cut with a sliding microtome at 12 microns, with a blade angle of 30°. Of the 2 graft unions selected from each combination, one was sectioned transversely and the second tangentially and radially. Sections were floated onto glass slides, and covered with ordinary greenhouse saran shade cloth which provided an excellent method of both supporting delicate sections and holding them against the

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[3]The authors acknowledge suggestions on anatomical procedure by Dr. Roy Simons, University of Illinois.
[4]Incompatibility in this paper refers only to graft take for one year and does not refer to delayed or long-term graft or bud incompatibilities found in some cultivar/rootstock combinations.

Table 1. Field results of *Malus* and *Prunus* scion/rootstock grafts planted in the spring and examined in the fall. Each combination was replicated 10 times. Eleven classes from 0 to 10 were used in grading graft take.

Scion varieties	Rootstock clones						
	EM VII	EM IX	EM 26	MM 104	MM 106	MM 111	Maz. F12/1
	Class rating[a]						
Golden Delicious	9	9	7	9	10	10	—
M. floribunda	7	1	0	2	1	7	—
M. sargenti	0	1	2	1	3	2	—
M. purpurea Lemoinei	4	3	0	0	7	5	—
M. baccata	1	0	3	0	6	7	—
Hedelfingen	—	—	—	—	—	—	4
Montmorency	—	—	—	—	—	—	4
Kwanzan	—	—	—	—	—	—	7

[a] 0 = No grafts united or grew in the field.
10 = All grafts united and grew in the field.

slide during staining procedures. The saran cloth was affixed with a stainless steel hairclip at either end of the slide. These sections were then stained with safranin O and fast green or aniline blue following the standard procedure of Johansen (3).

An intensive microscopic examination was made of each combination, both tranversely and longitudinally, in an attempt to find anatomical characteristics which deviated from normal. All such characteristics were noted. Characteristics common to a number of unions were chosen for possible correlation with field performance data. These characteristics were:

A. Quality of grafting technique.
B. Normal circumferential growth attained.
C. Horizontal tissue orientation.
D. Critical distance of graft components required for successful healing.
E. Location of new circumferential growth.
F. Extent of callus formation.
G. Callus condition.
H. Width of xylem rays.
I. Degree of xylem ray blackening.
J. Difference in vessel density between stock and scion.
K. Diameter differences in tracheids and vessels between stock and scion.
L. Degree of cambial continuity.
M. Width of cambial zone.
N. Condition of cambial zone.
O. Distortion of phloem rays.
P. Degree of phloem ray blackening.
Q. Condition of the sieve tubes.
R. Degree of phloem and cambial degeneration.
S. Severity of "Wedging".
T. Width of periderm.

Graft combinations were divided into 11 classes according to graft take and growth in the field. Trees in class 0 did not take, or were dead or dying at the end of the first growing season; trees in class 10 were all alive and normal after one year's growth (Table 1).

Each graft combination was examined and rated for each of the 20 characteristics listed above. Ratings 0 and 5 represented extreme positions under each characteristic with ratings of 1 through 4 as intermediates. It was then determined how each of the 11 classes performed under each of the 20 characteristics. For example, under characteristic A, class 5 had a rating of 2. This was interpreted to mean that fairly poor technique was used in grafting those combinations in which 50% of the grafts were successful.

A histogram was drawn for each characteristic (Fig. 1), with classes arranged along the abscissa and ratings

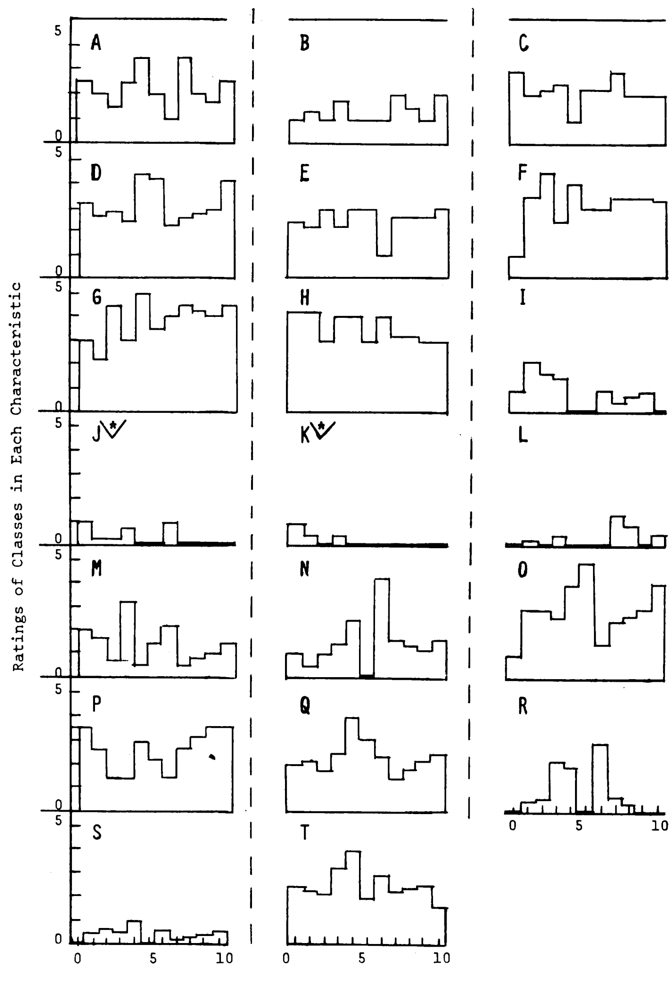

Fig. 1. Histograms illustrating the relative ratings of the anatomical graft union characteristics (ordinate) with the field results of the graft combinations (abscissa). *Indicates significance at 5% level.

along the ordinate. Hence the 11 classes were rated according to their performance under each characteristic.

Results and Discussion

No significant correlation was found between anatomical characteristics and graft take. However, when we compared the area under the histograms occupied by the poorer (0–5) classes with that occupied by the better (5–10) classes, characteristics J and K were judged significant. This result contradicts Herrero's (2) conclusion, and can

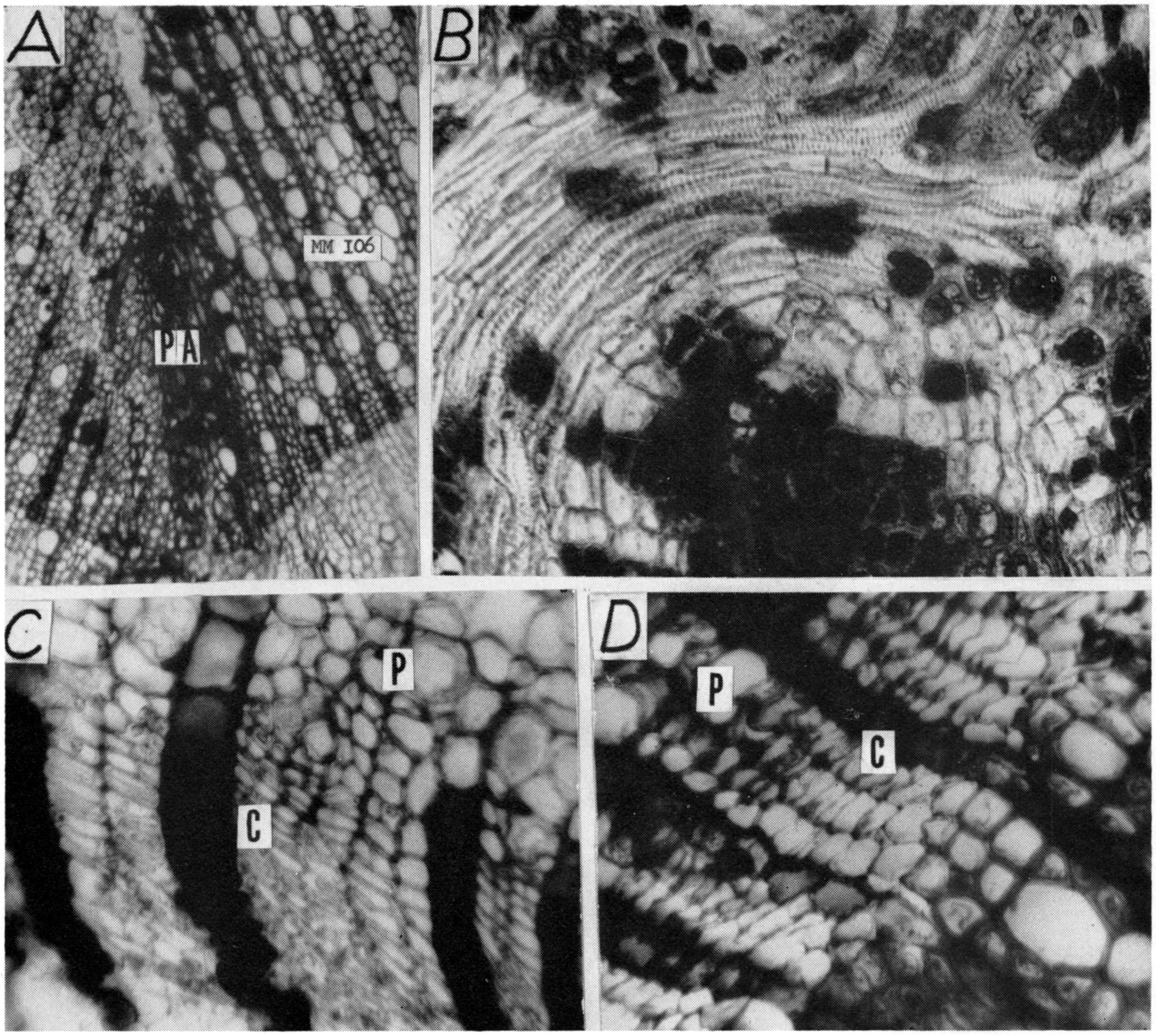

Fig. 2. A. Transverse section (×125) of *M. baccata*/MM 106 at the graft union showing variation in tracheid and vessel cell number and size. Note also parenchyma (PA) tissue development between the two constituents. B. Tangential section (×200) of Kwanzan/F12/1 showing some distortion of vascular tissue in the process of new tissue orientation at the graft union. C. Transverse section (×500) of Montmorency/F12/1 showing blackening and distortion of the ray initials and phloem rays (C = cambium and P = phloem). D. Transverse section (×500) of *M. sargenti*/MM 106 showing more normal phloem (P) and cambial (C) development and slight abnormal ray distortions at the graft union.

be interpreted to mean that when the xylem structure of 2 species is sufficiently different these 2 species will not intergraft with much success. The other characteristics failed to show a significant trend, except in the case of Hedelfingen/F12/1, where the cambium was wider in the scion than in the stock.

Results from this research indicated that: Graft success was not dependent on the distance between the component parts, since compatible tissues apparently have the ability to unite and heal even though not in direct contact (Fig. 2B). For example, poorly matched grafts of 'Golden Delicious'/EM VII were successful, whereas, perfectly matched *M. sargenti*/EM VII failed.

The condition of phloem, xylem and cambium was not related to graft take (Fig. 2, C and D), nor was the extent and condition of callus formation between the component parts.

New lateral growth was thicker at the 2 sides opposite the original cuts of the graft (area A vs. B, Fig. 3) in compatible as well as incompatible combinations.

A wedging condition of the phloem extending into the xylem cylinder (characteristics C and F) evident in many combinations, could not be correlated with the field data (Fig. 3).

Compatibility was predictable neither by the completeness of secondary growth nor by the continuity of the cambium after the first season.

Graft union compatibility was dependent on the similarity of the xylem structure of the 2 plants.

And, width of xylem rays, combial zone and periderm, although often abnormal, was not an indication of incompatibility.

It can further be concluded that anatomical investigations reveal mostly the secondary effects of incompatibility, and therefore cannot be used as a quick microscopic test for graft compatibility. According to Roberts (6), "Studies of the nature of the union are generally of more interest to students of anatomy than as contributions to the theories regarding graftage." However, it should be recognized that many factors are involved in successful grafting, among which are similarities in tissue condition, possible effects of latent viruses and morphological types. Factors such as alignment and distance between component parts, often considered to be im-

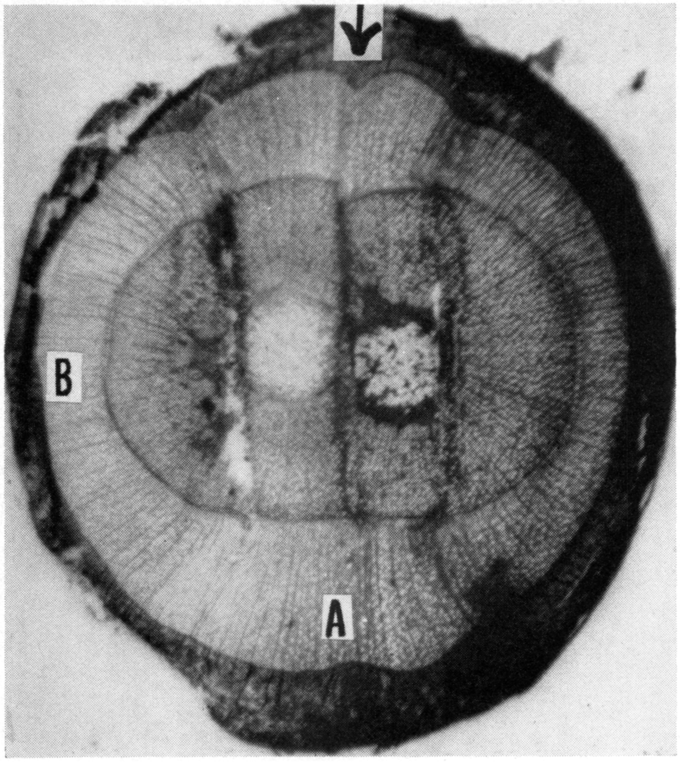

Fig. 3. A transverse section (×10) of *M. baccata*/EM VII showing healing of the graft, and phloem indentation (arrow) into the xylem. Note also positional differences in new lateral growth thickness (A vs. B) after one year of growth.

portant in graft success, were shown to be of little or no actual importance.

Some of the abnormal anatomical characteristics found in this study could have been the influence of latent viruses such as stem pitting and chlorotic leaf spot (1); however, none of the external symptoms were observed.

This study supports the premise that a successful graft union is dependent on biochemical factors associated with tissue growth and development.

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Effects of 2-Chloroethylphosphonic Acid on Ripening of Cantaloupes[1,2]

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Abstract. Applications of 2-chloroethylphosphonic acid to field grown cantaloupes resulted in yellowing of leaves, early abscission, apparent ripening of immature melons and increased total and marketable yields of full-slip melons. The percentage of soluble solids was slightly lower in treated melons.

Cantaloupes in California's San Joaquin Valley are commonly harvested 10 to 20 times during a season to obtain maximum yields. Frequent harvests are necessary because of the variability in time of fruit set and rate of fruit maturation. Treatments that might promote uniform ripening and thereby reduce the number of harvests could substantially lower harvesting costs.

The importance of ethylene as a ripening hormone has been known for some time. Recently it has been recognized as a key factor in regulating abscission and other processes often associated with ripening (3). The availability of 2-chloroethylphosphonic acid (CEPA), which on degradation yields ethylene (1, 6, 7), has made it possible to study the action of this hormone on fruit ripening in the field.

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[2]Amchem Inc., Ambler, Pa., is acknowledged for the generous supply of Ethrel, the commercial name for 2-chloroethylphosphonic acid. Drs. Kent Tyler and R. M. Davis, Jr. measured the percentage of soluble solids, and Mrs. Ann Francis analyzed the data presented in Tables 7 and 8 from the second Firebaugh study.

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Materials and Methods

The effects of CEPA on maturation and ripening of 'Powdery Mildew Resistant No. 45' cantaloupes were investigated in tests run in 1968 at the University of California at Davis and in commercial melon fields near Firebaugh, California.

The effects of submerging melons in solutions of CEPA and of spraying plants in the field prior to normal harvest were studied at Davis. For the submersion tests, 2 lots of fully netted but immature melons were harvested on July 11, one about 14 days prior to anticipated full-slip stage, and the other on July 18, about 7 days before anticipated full slip. Three comparable lots, each containing 10 melons from the first harvest and 9 melons from the second, were selected through the matched-sample technique. The melons harvested on July 11 were submerged 10 minutes in solutions containing 0, 25 or 250 ppm of CEPA. Those harvested 7 days later were submerged in water solutions containing 0, 100 or 1000 ppm of CEPA. After immersion they were stored in lined field lugs at an