In comparing the germination of the controls (seeds from untreated fruit) with that of seed extracted immediately after thawing, it is evident that at 28°F. there was no impairment of germination. At 18°F., however, the Cleopatra mandarin and sour orange seeds suffered some cold damage, whereas the Rough lemon and sweet orange seeds were not injured. The Cleopatra mandarin fruits, as already noted, were small, and their interior temperature drop was more abrupt than that of the larger fruited varieties. Difference in fruit sizes, however, does not explain the seeming damage to the sour orange seeds.

Any impairment of germination of seeds removed from the fruit 7 and 14 days after freezing would be attributed to a fermentation effect in the decomposing fruit. Sour orange and sweet orange seeds in both the 18° and the 28° lots apparently suffered damage from this effect after 14 days in the injured fruit. Cleopatra mandarin and Rough lemon seeds appear not to have been affected by the fermentation process (extracted immediately compared with 14 days after thawing).

Summary and Conclusions

Seeds of sweet orange extracted from sound fruit and placed at controlled temperatures of 25, 20, and 15°F. for 24 hours were not injured at 25°, partially damaged at 20°, and practically all killed at 15°.

Seeds taken from fruit which had been severely frozen had reduced viability if the temperature within the center of the fruit reached a critical temperature for a sufficient period. These limits were not definitely established in this study because of the differences in the times for fruits of the several varieties to reach the minimum exposure temperature at the center. However, with fruit exposed to 28°F. for 12 hours none of the varieties suffered seed damage. Seeds of Cleopatra mandarin and sour orange from fruit exposed for 12 hours at 18°F. showed some reduction of viability, but those of Rough lemon and sweet orange did not. Presumably this varietal difference was largely due to differences in rate of fruit cooling. From a practical standpoint the experiment demonstrated that citrus seeds can be cold-injured in the fruit by a severe freeze but that for this to happen temperatures of 20°F. and lower would have to be of considerable duration.

It was also demonstrated that seed viability can be reduced in some varieties by fermentation within fruit which has been badly frozen even though the actual temperatures are not low enough to injure the seed. In the work reported here the viability of both sweet and sour orange seed was lowered, but not that of Cleopatra mandarin or Rough lemon, by 14 days of fermentation in badly frozen fruit.

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INFLUENCE OF VARIOUS ROOTSTOCKS ON THE COLD RESISTANCE OF THE SCION VARIETY

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Numerous observations in citrus plantings support the general belief that the rootstock frequently influences the cold resistance of the scion variety. In general these observations place the cold hardiness effect of the commonly used stocks in the descending order as follows: *P. trifoliata*, sour orange, Cleopatra mandarin, sweet orange, and Rough lemon. It is well known that this is the same order in which the unbudded stocks themselves tolerate low temperatures, and this agreement might lead one, perhaps erroneously, to the conclusion that a stock which is itself cold-resistant would automatically confer resistance on the scion variety. The relationship is probably not so simple. If, as generally agreed, cold resistance of the scion variety is determined chiefly by its degree of dormancy at the time of the low temperatures, then any *rootstock* which confers dormancy on the scion should thereby

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confer cold hardiness regardless of the hardiness of the stock itself.

Although there are many field observations of alleged rootstock influence on cold resistance, there are few based on experiments with strictly comparable conditions of exposure, variety, tree age and size, and cultural treatment. Webber (2) reported on the cold damage in an experimental block of 4-year-old Satsuma oranges on various rootstocks at Oroville, California. The rootstocks in this test block were rated according to their effects on cold resistance, with *P. trifoliata* at the top, followed in descending order by tangerine, citrange, sour orange, Sampson tangelo, grapefruit, and Rough lemon.

Cooper (1) reported on cold injury and recovery in his extensive rootstock plantings in the Rio Grande Valley during the severe winter of 1950-51. The first freeze came on December 7, 1950, and caused considerable defoliation and bark splitting on limbs up to one inch in diameter in a 3-year-old experimental planting of Red Blush grapefruit well replicated on 39 rootstocks. All trees were in a flush of new growth when the second and more severe freeze struck on January 31, 1951 and killed all trees to the banks. Many of these trees recovered by means of new shoots from below the banks; the percentage that survived on the different rootstocks was recorded. The survival data showed no consistent relation to the anticipated cold resistance based on previous observations of stock effect. Therefore, Cooper was inclined to the view that the survival is determined by the vigor and health of the trees and not by the inherent cold hardiness of the stock-scion combination. However, in the first and less damaging freeze of December 7 the degrees of defoliation and bark splitting were assumed to represent rootstock influence. Cooper's findings will be considered in some detail later in this paper in comparison with our own.

There is a marked relationship between the amount of cold damage and tree size: small trees suffer more than larger ones and open trees and those with a poor canopy more than those with dense foliage. These relationships are so pronounced that other factors such as rootstock effects are easily masked if trees of different size are being compared. The tree-size effect was very evident during the winter of 1957-58, and in the present study it was taken into account in the evaluation of the effect of the rootstock on cold resistance.

Methods

The observations on cold damage reported were made on a 10-year-old experimental rootstock planting at Weirsdale, Florida, which was badly injured during several freezes in the winter of 1957-58. The planting consisted of a large number of rootstocks all budded with Valencia sweet orange and planted in pairs in four replications. The land sloped uniformly to the south with the replications extending east and west across the slope. Trees in replicate 1 at the upper side of the slope were only moderately hurt by the cold, and the degree of injury increased with succeeding replications southward until practically all trees regardless of rootstock were killed to the ground in replicate 4. This last replicate was omitted from the data calculations.

No temperature records were made in the planting itself. Close to the upper and warmest side of the block the temperature dropped to 32°F. by 11:30 p.m. on the night of December 11, 1957, and continued to drop to 23° at 7:30 a.m. on December 12. On the following day, December 13, the temperature was 25°F. at 4 a.m. and 24° at 7:30 a.m. The lower portion of the experimental block was considerably colder during the second night, probably as much as 4° or 5°F. Several subsequent cold nights during the winter no doubt contributed to the final damage recorded.

On June 18, 1958, when there had been ample opportunity for the extent of the damage to become well defined, the trees were individually rated from 1 through 8, as follows:

1. A few terminals, not more than 12, killed back 6 to 12″.
2. A few terminals, not more than 12, killed back 12 to 24″.
3. As many as 24 terminals killed back to 24″.
4. All periphery shoots dead 24 to 30″ back.
5. All periphery shoots dead back to wood 1″ in diameter.
6. Main branches and trunk killed to within 3′ of the ground.
7. Main trunk below 3′ showing some life.
8. Completely dead to the ground line.

Table 1. Cold-injury ratings and tree size of Valencia orange tops on 41 rootstocks

Rootstock	Adjusted cold-injury rating	Unadjusted cold-injury rating	Tree size - (trunk circumference in cm.
Bergamia sour orange	3.48	3.17	50.0
Florida sweet seedling	3.74	3.17	53.6
Trifoliata, large-flowered	3.94	5.83	29.1
Sampson tangelo	4.41	3.67	55.9
Bitter Sweet orange	4.51	4.17	50.5
Savage citrange	4.54	5.17	36.8
Trifoliata, small-flowered	4.64	5.33	26.3
Duncan grapefruit	4.70	3.83	57.9
Sunshine tangelo	4.81	4.17	55.0
Leonardy grapefruit	4.86	4.83	46.1
Hamlin sweet orange	4.91	4.67	49.0
Cleopatra mandarin	5.08	4.17	58.4
Ogami pummelo	5.14	5.67	38.3
Pina tangelo	5.30	5.17	47.5
Iran lemon	5.31	5.67	40.6
Dancy tangerine	5.32	4.67	54.7
Sauvage sour orange	5.33	4.67	54.9
Ponkan mandarin	5.34	5.00	50.4
Watt tangelo	5.40	4.83	53.7
Swatow mandarin	5.44	5.67	42.5
Sunki mandarin	5.50	6.33	34.1
Satsumelo, CPB 52010	5.56	5.67	44.1
Citrumelo, CPB 4475	5.62	6.17	38.0
Thong Dee pummelo	5.64	6.17	38.2
King orange	5.72	5.17	53.4
Sour orange No. 2	5.77	5.50	49.5
Minneola tangelo	5.82	5.50	50.1
Yalaha tangelo	5.85	6.00	43.5
Rangpur lime	6.03	6.33	41.5
Williams tangelo	6.03	6.00	46.1
Suwanee tangelo	6.06	6.50	39.5
Citrangor, CPB 42681	6.21	8.00	20.6
Umatilla tangelo	6.25	6.17	46.8
Siamese pummelo	6.27	6.67	40.1
Seminole tangelo	6.43	7.17	35.4
Clementine tangerine	6.54	6.67	43.9
Kalpi lime	6.54	5.50	60.3
Cuban shaddock	6.56	6.83	41.9
Lakeland limequat	6.66	6.83	43.2
Tangor, CPB 653	6.76	6.00	56.3
Rough lemon	6.80	6.00	56.7
L S D, odds of 19 to 1	1.62	1.72	8.42
L S D, odds of 99 to 1	2.15	2.28	11.16

Table 2. Comparison of the author's and Cooper's rating of cold damage on all citrus rootstocks used in both experiments

Author's rating - degree of wood killing		Cooper's rating - degree of bark splitting	
Rootstock	Rating	Rootstock	Rating
Bergamia sour orange	3.48	Hamlin sweet orange	.3
Florida sweet seedling	3.74	Sunshine tangelo	.6
Sampson tangelo	4.41	Bergamia sour orange	.8
Bitter Sweet orange	4.51	Bitter Sweet orange	.8
Savage citrange	4.54	Sauvage sour orange	.8
Duncan grapefruit	4.70	Sour orange No. 2	.9
Sunshine tangelo	4.81	Leonardy grapefruit	.9
Leonardy grapefruit	4.86	Pina tangelo	.9
Hamlin sweet orange	4.91	Watt tangelo	.9
Cleopatra mandarin	5.08	Williams tangelo	.9
Pina tangelo	5.30	Florida sweet seedling	1.0
Dancy tangerine	5.32	Savage citrange	1.0
Sauvage sour orange	5.33	Duncan grapefruit	1.0
Watt tangelo	5.40	Sunki mandarin	1.0
Sunki mandarin	5.50	Sampson tangelo	1.1
Citrumelo, CPB 4475	5.62	Dancy tangerine	1.1
Thong Dee pummelo	5.64	Citrumelo, CPB 4475	1.2
King orange	5.72	Rangpur lime	1.2
Sour orange No. 2	5.77	Thong Dee pummelo	1.2
Minneola tangelo	5.82	Minneola tangelo	1.2
Yalaha tangelo	5.85	Yalaha tangelo	1.2
Rangpur lime	6.03	Siamese pummelo	1.3
Williams tangelo	6.03	King orange	1.4
Suwannee tangelo	6.06	Umatilla tangelo	1.4
Umatilla tangelo	6.25	Kalpi lime	1.4
Siamese pummelo	6.27	Suwanee tangelo	1.5
Kalpi lime	6.54	Rough lemon	1.6
Rough lemon	6.80	Cleopatra mandarin	1.8
L S D, odds of 19 to 1	1.62	L S D not calculated	
L S D, odds of 99 to 1	2.15		

The 8 categories were distinct, and the ratings made independently by two observers were in complete agreement. The average of these ratings for the 6 trees on each rootstock were adjusted for tree-size effect by an analysis of covariance in which the cold-damage score is the dependent variable and tree size (trunk circumference) the independent variable. In other words, the adjusted cold-damage ratings are those which would have obtained if all the trees in the experiment had been of exactly the same size.

Results

Table 1 shows the tree size, the cold-injury ratings regardless of tree size, and the ratings adjusted for tree size. In this experiment the correlation coefficient expressing the degree of correlation between tree size and cold injury was —.67. The column headed "adjusted cold-injury rating" ranks all the stocks

from the most cold-resistant (Bergamia sour orange) to the least resistant (Rough lemon) on the basis of all trees being the same size.

It is evident that the rootstock effect on cold resistance of the scion is very real even though the differences are statistically significant only when stocks widely separated in the ranked column are compared. Thus the differences btween the ratings of the top 12 stocks are not considered to be significant, although all this group are significantly more cold-hardy than the trees on Rough lemon.

Mention has been made of the report by Cooper (1) on the cold injury ratings in a rootstock test block in Texas in which stocks were very similar to those in the present experiment. In fact, the seedlings for his test and for ours were grown from seed collected in Florida at the same time. A portion of each seed lot was eventually budded with Red Blush grapefruit in Texas and the remainder budded with Valencia orange in Florida. Cooper's rootstock field planting consisted of 4 replications of 3 trees each, a total of 12 trees, on each of 39 stocks. Following a freeze on December 7, 1950, when the trees had been 3 years in the field, Cooper rated each tree for the amount of bark splitting. He rated no splitting 0, splitting on small twigs 1, and that on large limbs 2. The similarity of the rootstocks in his experiment and ours permits an interesting comparison. All stocks common to both experiments are listed in Table 2 in order of their cold-resistant effect on the scion variety.

Considering the difference in location, scion variety, age of tree, criterion of injury, and the winter of damage, there is a rather remarkable agreement in the order of the ranked cold resistance between Cooper's results and ours. With most of the stocks the position within the two ranked columns is very close. In no instance is the deviation as great as the limits of the statistical significance except in the case of Cleopatra mandarin. Cooper's placement of Cleopatra at the bottom of his list, even below Rough lemon, is in sharp contrast with our relatively high rating of this stock and is contrary to all orchard observations of its cold resistance. Apart from this glaring exception, the two rankings support each other within rather close limits.

Discussion

It should be pointed out that Cooper (1) presented data not only on the degree of bark splitting as influenced by rootstock but also on the degree of defoliation following the same cold period. We arbitrarily selected the bark-splitting data for comparison with ours because of the agreement in rootstock performance. Cooper's defoliation data bear little or no similarity to his bark-splitting data and raise the question whether defoliation, usually considered a criterion of the amount of cold injury, is a reliable index. We can offer no logical explanation of this seeming paradox and can only point to our wood-damage ratings and to Cooper's bark-splitting estimates as agreeing far beyond the element of chance.

The adjusted cold-injury ratings in Table 1 support, in the main, the belief that cold-resistant rootstocks tend to induce cold resistance in the scion variety. There are, however, a number of exceptions to this generalization. For example, Clementine tangerine, a rather cold-hardy variety itself, is near the bottom of the list when used as a rootstock; the sweet oranges rank high as rootstocks but as scion varieties they are not as cold-hardy as many of the varieties ranked much lower. Table 1 discloses a number of other such inconsistencies. Thus it appears that a cold-susceptible rootstock variety may induce a considerable degree of cold resistance in the scion and, conversely, a cold-resistant stock may result in cold susceptibility. No doubt the evaluation of the cold resistance of a rootstock itself is, at least in part, an expression of its degree of dormancy even though there are many instances of inherent differences in cold resistance between stocks unrelated to their dormancy.

From a practical standpoint there is no doubt that the use of rootstocks near the top of Table 1 would result in more cold-resistant trees than the use of rootstocks near the bottom of the list. Because of the numerous variables which make each instance different from every other instance, it is not possible to state how great such an advantage, in terms of temperature degrees, might thus be gained. It is obvious that the temperatures in some winters or in some locations might be low enough to overcome the few degrees' advantage con-

ferred by a cold-resistant stock. However, in many cold periods this advantage is of real practical value. In this experiment the trees on the most resistant stocks in replicate 1, in the warmest portion of the plot, were almost uninjured, whereas in replicate 4, at the low portion of the plot, the same rootstock combinations were killed to the ground. It is probable that the temperature differential from top to bottom of the slope did not exceed 4° to 5°F.

Summary and Conclusions

Freezing temperatures during the winter of 1957-58 resulted in severe damage in a rootstock test block near Weirsdale, Florida, and provided opportunity for evaluation of the effect of rootstock on the degree of injury to the Valencia orange tops. Forty-one rootstocks were rated according to the amount of killing of the Valencia tops and the results were analyzed statistically. A strong negative correlation between tree size and cold damage makes it necessary to take into account this relationship in evaluating the effect of rootstock on cold resistance of the scion variety.

In general, rootstocks which are themselves cold-resistant impart cold resistance to the scion variety. However, the numerous exceptions to this generalization suggest that some cold-susceptible stocks may also impart cold resistance and, conversely, some cold-resistant stocks may result in cold susceptibility of the scion. It is probable that the effect of the rootstock on cold resistance is an expression of the degree of dormancy produced in the scion.

The amount of protection against cold damage conferred by use of a cold-resistant stock, as compared with a cold-susceptible stock such as Rough lemon, may represent only a few degrees of temperature. In many instances this relatively small differential, however, can be of very real practical advantage.

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UNFRUITFULNESS IN THE ORLANDO TANGELO

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The Orlando (Lake) tangelo, a hybrid of Bowen grapefruit with Dancy tangerine, has in recent years become important as an early season specialty fruit. Of considerable concern to the grower has been the unfruitfulness commonly associated with this variety. The widespread nature of the problem is indicated by the frequent inquiries, concerning possible remedial measures, which have been received by the Citrus Experiment Station.

Research was initiated in the summer of 1957 to determine the cause of the unfruitfulness and devise means for increasing yields. Subsequent work showed that the unfruitfulness and low yields were due to the lack of strong, consistent parthenocarpy coupled with sexual self-incompatibility, and that fruiting could be induced by cross-pollinating the Orlando with the appropriate pollen variety.

Materials and Methods

Survey Work. A preliminary survey was made of unfruitful and fruitful Orlando groves in the summer of 1957 to determine if there were any apparent reasons for the lack of fruiting.

In 1958 a large number of Orlando groves bordering or interplanted with other varieties were evaluated as to the size of crop and seed content to determine any possible influence of cross-pollination. Based on visual observations, the size of the crop was arbitrarily estimated as satisfactory, fair, or poor. Seediness was determined from a random sample of 25 fruit. Only Orlando trees immediately adjacent to the other varieties were used in evaluating possible crossing, and only Orlando trees definitely isolated from these varieties were used in evaluating selfing.

Natural Selfing and Malformed Flowers. Systematic inspections of a number of Orlando

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