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RIO GRANDE VALLEY
HORTICULTURAL
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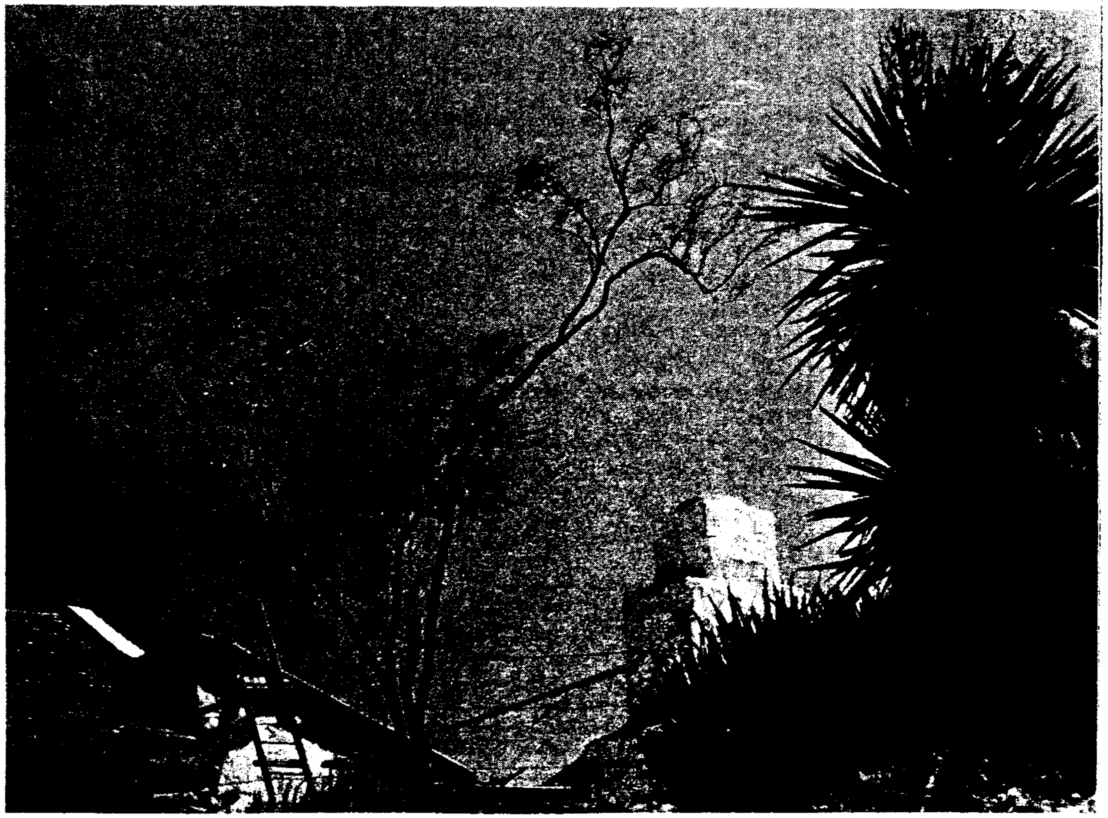
Volume 17, 1963



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RIO GRANDE VALLEY HORTICULTURAL SOCIETY

Volume 17, 1963

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Aims and Objectives of the Society

The purpose of the Rio Grande Valley Horticultural Society is the advancement and development of horticulture in the Lower Rio Grande Valley. It is the aim of the Society to stimulate interest in research and its practical application to Valley problems with fruit, vegetables and ornamentals.

At monthly meetings subjects of interest are presented by specialists in their fields. These presentations are followed by open forums. The Newsletter announces and discusses the monthly programs and brings other news of interest to Society members.

The Society has sponsored 17 annual Institutes, where outstanding speakers from all parts of the country present new developments in the field of horticulture. Panel discussions, social get-togethers and a barbecue round up the all-day program.

Talks given at the Institute and reports of Valley research are published in its Journal, which provides a continuing record of horticultural progress in the Valley.

Anyone interested in horticulture can become a member of the Society. The annual fee is $4.00, which includes the Journal. Applications for membership, and annual dues should be sent to the Secretary-Treasurer, Rio Grande Valley Horticultural Society, Box 107, Weslaco, Texas.

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1962 - 1963

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The Arthur T. Potts Award

Given for meritorious service in behalf of horticulture in the Lower Rio Grande Valley. Recipients of this award include:

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Paul W. Leeper

Paul W. Leeper

Recipient of the Arthur T. Potts Award

January 22, 1963

With his associates, Paul W. Leeper pioneered in the research and development of tomato strains with multiple resistance to the major diseases prevalent in the South and Southwest. He was largely responsible for the development of the Chico, a processing tomato variety adaptable to mechanical harvesting. His research to develop strains of tomatoes for staked production has also been outstanding. He helped develop tomatoes resistant to Fusarium wilt and grey leaf spot. These were released as "Weshaven" and "Rio Grande."

In the lettuce-breeding program at Weslaco, Mr. Leeper in 1956 discovered a source of resistance to downey mildew disease. His research in subsequent seasons was largely responsible for Valverde, a variety with immunity to this disease.

Likewise, Mr. Leeper has made significant contributions to potato-, spinach- and onion-breeding programs under way.

This research has improved the Valley's vegetable industry, and reflect great credit on the Texas Agricultural Experiment Station, which employs his talents.

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Citrus and Vegetable Forum .... Dr. Geo. Schulz, Moderator
McAllen, Tex.

The panel consisted of the program speakers and P. W. Rohrbaugh, Norman Maxwell, Edward Olson. M. W. Held, Stanley Crockett, Sr., Jack Balock and Bailey Sleeth.

BUSINESSES SPONSORING ACTIVITIES OF RIO GRANDE VALLEY HORTICULTURAL SOCIETY

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CITRUS AND SUBTROPICAL FRUIT SECTION

Climate – Cold Hardiness – Citrus[1]

ROGER YOUNG[2]

Many citrus growers consider that the most important problem in citrus culture is how to grow trees which will survive the frequent-occurring freezes. This problem has been dramatically pointed out in the severe freezes of 1894, 1957, and 1962 in Florida; 1913, 1922, 1937, and 1963 in California; and 1949, 1951, and 1962 in Texas. Many less severe but damaging freezes have also occurred from year to year in all citrus-growing areas. To the grower, injury from freezes is a continual threat rather than an occasional occurrence. This problem is better exemplified in the following pertinent weather data.

Table 1. Average intervals between freezes of various temperatures during various periods at selected locations in California, Florida, and Texas.[a]

Temperature and Location	*Observation Period*	*Interval between freezes (years)*
29° F or lower:		
Riverside, Calif.	1922-1958	1.1
Orlando, Florida	1937-1958	2.2
Weslaco, Texas	1925-1958	2.9
25°F or lower:		
Riverside, Calif.	1922-1958	3.1
Orlando, Florida	1894-1958	3.6
Weslaco, Texas	1925-1958	5.0
22°F or lower:		
Riverside, Calif.	1894-1958	10.8
Orlando, Florida	1895-1958	8.0
Weslaco, Texas	1925-1958	11.7

[a] Reprinted from an article in the Proc. Amer. Soc. Hort. Sci. 74: 333-347, 1959.

In Table 1 is summarized the average interval between freeze years of various minimum temperatures in selected locations in California, Florida, and Texas (Cooper and Peynado, 1959). For freeze years of 29°F and lower, the interval ranged from 1.1 years in Riverside, Cali-

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[1] Part of a talk given before the Annual Institute of Rio Grande Valley Horticultural Society, January 22, 1963.

[2] Physiologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Weslaco, Texas.

fornia, to 2.9 years in Weslaco, Texas. The difference between Riverside and Weslaco is even greater than these data indicate, as although 29° minimums occur practically every year in Riverside, they also occur on an average of 6 times a year. For 25° or lower, the interval ranged from 3.1 years in Riverside to 5.0 years in Weslaco. And, for 22° and lower, the interval ranged from 8.0 years in Orlando, Florida, to 11.7 years in Weslaco. The interval between freezes of 22° to 29° temperatures was longer at Weslaco than at Riverside or Orlando, but similar to Riverside for hard freezes 22° and lower. At Orlando hard freezes occurred more often. However, these averages cannot be relied on for predicting freezes since the interval between freezes is irregular. For example, the Rio Grande Valley experienced severe freezes in 1949, 1951, and 1962 which was not consistent with the average interval between freezes. Florida experienced severe freezes in 1957 and 1962, also inconsistent with the average interval between freezes.

The occurrence of freezes 25°F and lower at Brownsville, Texas, since 1880 is summarized in Table 2. At Brownsville, usually the warmest area in the Valley during freezes, many moderate to severe freezes occurred from 1880 to 1962. Weather records show that the mid- and upper-Valley temperatures were lower during these freezes; frequent other freezes 25° or lower which did not occur in Brownsville occurred in mid- and upper-Valley areas.

It is evident that the hazards from freezing weather are great in all citrus-growing areas in the United States including the Rio Grande Valley and that injury to citrus from freezes will be frequent and recurring.

Cold hardiness in plants has been studied for many years, but very little specific information on citrus is available. It is recognized, through grower experience and field research, that citrus trees in mid-winter are usually more cold hardy than in the fall or spring and that actively growing trees are less cold hardy than dormant or non-growing ones. Winter dormancy has been established as a key factor in the development of cold hardiness, and there is little doubt now that the induction of winter dormancy is brought about by changes in temperature.

Changes in dormancy and cold-hardiness characteristics of 10-year-old Red Blush grapefruit trees during the winter of 1960-61 are shown in Figure 1 (Young and Peynado, 1961). Trees were exposed to 23°F for 4 hours in November, December, January, and February. In November, prior to any cool-temperature exposures, leaf and twig injury were severe. Twig cambial activity, a rough indication of twig dormancy, was high. In December, after 2 weeks of cool-temperature exposure, leaf and twig injury were substantially reduced and twig cambial activity was reduced. After 6 weeks of cool-temperature exposure – in January – leaf injury was slight and twig injury none. Twig cambial activity was again reduced. Between November and January buds remained dormant and did not grow. In the second week of February, day and night temperatures increased substantially. Buds on the trees swelled, broke dormancy, and began to grow. Upon exposure to 23°F for 4 hours, leaf and

Table 2. Minimum temperatures of 25°F or lower recorded at Brownsville, Texas, from 1880 to 1962, inclusive.[a]

Observation date	*25°F or lower*
1880	23
	18
	21
1881	18
1884	25
1886	23
	22
1888	23
	21
1895	22
	24
	23
	25
	22
1899	24
	25
	16
	12
	18
1900	25
1901	20
	25
	25
1905	22
1911	21
1912	24
1917	24
	24
	24
1918	25
1919	24
1930	24
	25
1940	25
1949	25
	23
1951	22
	25
	25
1962	24
	25
	19

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[a] Data obtained from the U. S. Weather Bureau, Texas Agricultural Experiment Station, Weslaco, Texas.

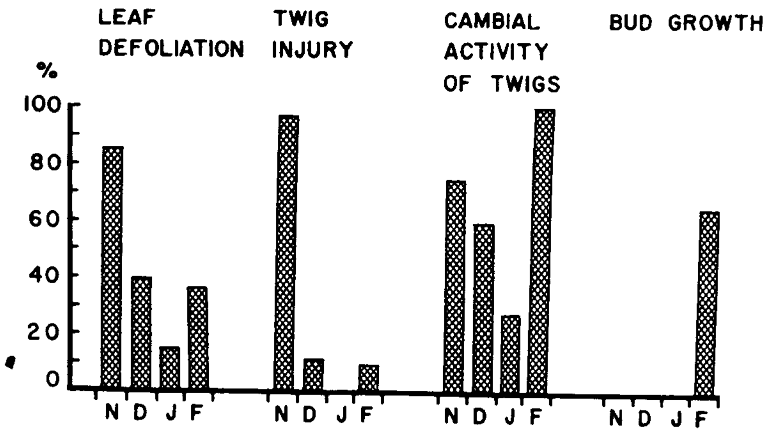

Figure 1. Cold hardiness of 10-year-old Red Blush grapefruit trees exposed to 23°F for 4 hours in November and December 1960 and January and February 1961. Reprinted from article in Proc. Rio Grande Valley Hort. Sci. 15: 59-67. 1961.

twig injury increased as did twig cambial activity over that observed in January. When the trees were frozen at various temperatures in January, it was also found the trees had acquired approximately 4 degrees cold hardiness during mid-winter. Thus, changes in day and night temperatures in the winter were related to the induction of winter cold hardiness.

Similar results were obtained when citrus seedlings were exposed to cool day and night temperatures in growth chambers. Grapefruit seedlings were exposed to several successive day-night temperature treatments for 2 weeks (Table 3). Leaf cold hardiness increased as the preconditioning temperatures were gradually lowered. A decrease in twig cambial activity indicating increased dormancy was correlated with the increase in leaf cold hardiness. The L.D. 50 temperatures listed are those at which 50% of the leaves were killed after exposure for 4 hours. In this experiment the seedlings acquired 7 degrees of cold hardiness.

Table 3. Effects of low temperature exposure on the cold hardiness of Red Blush grapefruit seedlings.

Day/night temperature treatment[a]	*Cambial activity twigs*[b]	*L.D. 50 for leaves*[c] *(°F)*
80°/70°	2.0	26.0
70°/50°	2.0	26.0
60°/40°	1.6	24.5
50°/30°	0.6	21.5
45°/26°	0.7	19.0

[a] Plants were exposed to each day/night temperature for 2 weeks.
[b] 0 = bark does not peel; 1 = bark barely peels;
2 = bark peels easily; 3 = bark peels easily and is moist.
[c] Temperature at which 50% of leaves are killed after a 4-hour exposure.

Thus, a major factor in the development of winter cold hardiness is the preconditioning of plants with cool day and night temperatures and the induction of bud and cambium dormancy. A similar mechanism, based on cool temperature exposure and dormancy induction exists which explains, in part, the wide variation in cold-hardiness behaviors of citrus varieties and species (Young and Peynado, 1962). Many field observations have shown that varieties and species which develop bud and cambium dormancy earlier in the fall and remain dormant later in the spring generally exhibit more winter dormancy and cold hardiness. This is true, for instance, of trifoliate orange, citranges, citrumelos, and most mandarins. In contrast, limes and lemons, which are notoriously cold-sensitive, do not exhibit much winter cold hardiness and usually grow actively during mid-winter. With controlled temperatures in a growth chamber, it has been demonstrated that most citrus types which exhibit more winter dormancy and cold hardiness stop active growth at higher night temperatures. In contrast, types such as the limes and lemons which are very cold-sensitive require exposure to a much lower night temperature before growth stops.

Climate, specifically cooler temperatures during the winter, is the major factor affecting the induction of dormancy and cold hardiness in citrus. Variations in the specific temperature requirement for bud and cambium dormancy explain the wide range of winter-dormancy and cold-hardiness characteristics exhibited by citrus varieties and species.

With this background, let us look at the behavior of citrus in the Valley during the freeze in January 1962.

Tree condition was an important factor in the survival of citrus during the freeze. Trees were as dormant as might be expected in the Valley. Buds and twig and small-limb cambium were dormant but large-limb and trunk cambium were active.

Temperature conditioning prior to the freeze was similar to that in previous years. Summarized in Table 4 is a comparison of the average maximum and minimum temperatures for the 9-week period prior to the freeze with the average maximum and minimum temperatures for the same 9-week period for the years 1951 to 1962 inclusive. From these records it is obvious that the trees were not preconditioned to any greater extent by temperature since the temperatures were similar to those of previous years. However, in general, the trees appeared less succulent than usual. An examination of the bark indicated the tissues were generally dry; and a look at the weather records also indicated that rainfall and humidity were below normal for the fall and winter period prior to the freeze. It is entirely possible that the drier condition of the trees contributed additional cold hardiness. If the trees had been growing at the time of the freeze, as they were prior to the 1951 freeze, few trees would have survived the 1962 freeze.

Table 4. A comparison of average maximum and minimum temperatures before the 1962 freeze with the average maximum and minimum temperatures for the same period for the years 1951 to 1961 inclusive.[a]

Month	*1951-1961* *Max.*	*1951-1961* *Min.*	*1961-1962* *Max.*	*1961-1962* *Min.*
November	76	56	75	58
December	72	51	72	54
January (1-9)	71	51	71	47

[a] Data obtained from the U. S. Weather Bureau, Texas Agricultural Experiment Station, Weslaco, Texas.

The freeze in 1962 was very severe. Temperatures remained below 32°F for as long as 70 hours and below 20° for 3 to 11 hours depending on location. Minimum temperatures ranged from 10° to 19° and humidity from 20 to 40 percent. In general, the freeze was a dry, desiccating type and because of the strong accompanying winds considerable heat and moisture were lost from the trees and the soil.

Freeze injury was extensive and variable, and location had only a slight effect. Trees in warmer areas were less injured but trees in high and low areas were generally injured to the same degree. Young trees 3 to 6 years old were severely injured and generally the wood was killed to the crotch or below; many whole trees were killed, and bark splitting was severe. Trees 7 to 15 years old were less injured and were generally killed back to 1- to 3-inch wood. Generally, bark splitting was only slight. Trees 20 years and older which had suffered severe wood injury in the 1951 freeze were again severely injured. These trees generally were killed back to 3- to 5-inch wood and were not considered economically salvageable. Some groves of trees in this age category were not as severely injured and will be salvaged.

Large differences in injury existed among trees on different rootstocks. Injury to 12-year-old Red Blush grapefruit on various rootstocks is summarized in Table 5 (Young and Olson, 1963). Trees on Cleopatra and Suenkat mandarins were injured the least. Trees on these rootstocks were also injured least in a 10-year-old Red Blush grapefruit rootstock planting in Mission and 8- and 6-year-old plantings in Monte Alto. Trees on sour orange, Rusk citrange, Troyer citrange, and Savage citrange were severely injured and trees on Uvalde citrange, Rough lemon, and Rangpur lime were the most severely injured. The behaviors of the citranges, limes, and lemons were consistent in other grapefruit rootstock plantings of different ages. The cold-sensitivity of the citranges, in contrast to its cold hardiness in Florida and California, is possibly related to its poor salt tolerance. Trees with an increased salt uptake are known to be more cold-sensitive in the winter (Cooper and Shull, 1953; Peynado and Young, 1963).

Table 5. Freeze injury[a] to and recovery rating[b] of xyloporosis- and exocortis-infected old-line 12-year-old Shary Red grapefruit on 45 rootstocks at Monte Alto, Texas.[c]

Rootstock[d]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Cleopatra mandarin	2.9	0	1.6
Suenkat mandarin	3.0	0	1.6
Sampson tangelo	3.0	0	2.0
4475 citrumelo	2.3	0	2.0
Altoona tangelo	2.3	0	2.0
Thomasville citrangequat	2.0	0	2.0
Webber tangelo	2.9	0	2.1
Watt tangelo	2.1	0	2.2
Pong Koa mandarin	2.0	0	2.2
Kinnow mandarin	2.0	16	2.2
Williams tangelo	2.9	0	2.2
Lau Chang mandarin	2.7	0	2.3
Cadena orange	2.7	0	2.3
Calashu mandarin	2.3	0	2.4
Sunki mandarin	1.9	0	2.4
Louisiana sweet orange	2.9	0	2.4
Oneco mandarin	1.7	0	2.5
African shaddock	1.3	0	2.6
Avena orange	2.1	0	2.6
Ponkan mandarin	1.9	0	2.7
Citrangeor	1.9	0	2.7
Dancy mandarin	1.9	16	2.7
Red Blush grapefruit	2.1	0	2.8
Sour orange	1.7	0	2.8
Minneola tangelo	2.0	0	2.8
Changsha mandarin	1.9	0	2.9
Sanguinea mandarin	1.5	0	2.9
Rusk citrange	1.0	16	3.0
Kusaie mandarin-lime	1.1	33	3.0
Troyer citrange	1.0	16	3.0
Red shaddock	1.1	0	3.0
San Jacinto tangelo	2.0	0	3.1
Rustic citrange	1.0	16	3.1
Savage citrange	0.9	16	3.2
Precose de Valence orange	1.6	0	3.2
Weldon orange	2.0	0	3.2
"Rose" lemon	1.1	16	3.2
Citremon CES 1449	1.1	0	3.2
Cuban shaddock	0.7	33	3.3
Bergaldin grapefruit	1.3	0	3.4
Duncan grapefruit	1.0	33	3.4
Thornton tangelo	1.3	16	3.5
Uvalde citrange	0.9	16	3.8
Rough lemon	0.7	33	4.2
Rangpur mandarin-lime	0.3	67	4.3
L.S.D. .05	0.3		0.3
.01	0.4		0.4

[a] Etimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Reprinted from article in Proc. Amer. Soc. Hort. Sci. (In Press).

[d] Six randomized single-tree replicates were employed for each scion-rootstock combination.

Table 6. Freeze injury[a] to and recovery rating[b] of virus-free[c], old-line 12-year-old Valencia oranges on 29 rootstocks at Monte Alto, Texas.[d]

Rootstock[e]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Dancy mandarin	3.0	0	1.4
Ponkan mandarin	3.0	0	1.4
Cleopatra mandarin	3.0	0	1.5
Yalsha tangelo	3.0	0	1.5
Leonardy grapefruit	3.0	0	1.5
Minneola tangelo	3.0	0	1.5
Changsha mandarin	3.0	0	1.5
Sunshine tangelo	3.0	0	1.5
Sampson tangelo	3.0	0	1.5
Rusk citrange	3.0	0	1.5
Red Blush grapefruit	3.0	0	1.5
Watt tangelo	3.0	0	1.5
Altoona tangelo	3.0	0	1.5
African shaddock	3.0	0	1.5
Calamondin	3.0	0	1.5
Thornton tangelo	2.8	0	1.5
Satsuma mandarin	3.0	0	1.5
Parson Brown orange	3.0	0	1.5
Louisiana sweet orange	3.0	0	1.5
Rangpur mandarin-lime	3.0	0	1.5
Sour orange	3.0	0	1.6
Lemonquat	2.4	0	1.9
Pineapple orange	2.2	0	1.9
Rose lemon	2.4	0	2.0
Columbian sweet lime	3.0	0	2.0
Choa Chou Tien Chieh mandarin	2.2	20	2.2
Kusaie mandarin-lime	1.2	20	2.3
Rough lemon	2.2	0	2.5
Cuban shaddock	0.2	80	4.0
L.S.D. .05	0.2		0.2
.01	0.3		0.3

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] The following rootstocks were found to contain the diseases listed: Kusaie mandarin-lime and rough lemon – Rangpur lime disease; Leonardy grapefruit, Choa Chou Chieh mandarin, Thornton tangelo, rough lemon, and Cuban shaddock – xyloporosis virus; lemonquat and Calamondin – bud union crease disorder.

[d] Reprinted from article appearing in Proc. Amer. Soc. Hort. Sci. (In Press).

[e] Five randomized single-tree replicates were employed for each scion-rootstock combination.

The injury to 12-year-old Valencia oranges on a series of rootstocks is summarized in Table 6 (Young and Olson, 1963). Trees on several rootstocks including Cleopatra mandarin, Dancy mandarin, Ponkan mandarin, and sour orange showed much less injury than those on Rough lemon and Cuban shaddock. Trees on Cleopatra mandarin and sour orange rootstocks also showed less injury than trees on other rootstocks in a planting of 8- and 6-year-old Valencia trees.

In numerous rootstock plantings, only Cleopatra mandarin was consistently better than sour orange as a rootstock. However, Cleopatra mandarin rootstock has weaknesses since it produces smaller and sometimes more acid fruit, and young trees on this rootstock are susceptable to iron chlorosis on calcareous soils.

Table 7. Freeze injury[a] to and recovery rating[b] of virus-free 3-year-old citrus scions at Monte Alto, Texas.[c]

Scion[d]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Frost Washington Navel orange	2.0	0	1.5
Hybrid 6-5-15[e]	1.4	0	1.9
Frost Valencia orange	1.6	0	2.2
Olinda Valencia orange	1.3	20	2.5
Campbell Vaelncia orange	1.3	30	2.6
Cutter Valencia orange	1.2	30	2.7
Frost Dancy mandarin	0.7	50	2.8
Hybrid 6-12-26[e]	0.6	50	2.8
Red Blush grapefruit (California)	1.2	0	2.8
Dancy Mandarin (California)	0.2	90	2.8
Frost Marsh White grapefruit	1.1	10	2.8
Frost Eureka lemon	0.0	100	4.0
L.S.D. .05	0.4		0.5
.01	0.6		0.7

[a] Estimated wood diameter (inches) in which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Reprinted from article in Proc. Amer. Soc. Hort. Sci. (In Press).

[d] Three trees of each scion were on Rangpur mandarin-lime, Orlando tangelo, sour orange, and Morton citrange rootstocks.

[e] Hybrids resulting from a cross between Clementine mandarin and Orlando tangelo.

Large differences also existed among trees of different varieties and species. Three-year-old trees of different citrus types showed a wide range of injury (Table 7; Young and Olson, 1963). In this planting Frost Washington Navel and hybrid 6-5-15 were the least injured followed by several Valencia orange selections, Dancy mandarin, Red

Blush and Frost Marsh White grapefruit, and Eureka lemon. Dancy mandarin, considered cold hardy in Florida and California, did not exhibit cold hardiness during the 1962 freeze in the Valley.

Table 8. Freeze injury[a] to and recovery rating[b] of 8-year-old citrus scions[c] on sour orange rootstock at Monte Alto, Texas.[d]

Scion[e]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Jaffa orange	3.0	0	0.7
Valencia orange	3.0	0	0.9
Red Blush grapefruit	2.9	0	1.5
Marrs orange	2.3	0	2.1
Meyer lemon	1.4	60	2.7
L.S.D. .05	0.4		0.5
.01	0.6		0.7

[a] Estimated wood diameter (inches) in which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] The virus status of the varieties was as follows: Jaffa orange and Red Blush grapefruit - exocortis and xyloporosis; Valencia and Marrs orange and Meyer lemon - virus free.

[d] Reprinted from article in Proc. Amer. Soc. Hort. Sci. (In Press).

[e] Ten randomized single-tree replicates were surveyed on each variety.

Eight-year-old Jaffa and Valencia orange trees were more cold hardy than Red Blush grapefruit, Marrs oranges, and Meyer lemons (Table 8; Young and Olson, 1963). The early-maturing Marrs orange was not as hardy as the late-maturing Valencia.

In another planting, 12-year-old Clementine mandarins showed the least injury followed by Valencia and Navel oranges, Ruby and Marsh pink grapefruit, Dancy mardarin, and Mexican lime trees (Table 9; Young and Olson, 1963). Again, Dancy mandarins were severely injured. A comparison of 12-year-old Valencia oranges and Red Blush grapefruit, the two principal varieties in the Valley, indicated Valencia orange slightly but significantly more cold hardy than Red Blush grapefruit (Table 10; Young and Olson, 1963).

Many varieties and species, as single trees, were also growing in a variety block at Monte Alto. Trifoliate orange trees and its hybrids — the citranges, citrumelos, citrangeors, citrangequats and citremons — all showed only leaf injury. Mandarins varied in cold hardiness. Satsuma, Changsha, Suenkat, and Kara mandarins showed only leaf injury, whereas the Murcott, Ponkan, Sunki, and Dancy mandarins showed moderate wood injury. Most tangelos, oranges, and grapefruit showed moderate wood injury, whereas the limes and lemons showed severe wood injury.

In summary, the cold-hardiness problem is well defined, and the tools with which to attack it are available. The induction of dormancy in citrus may increase cold hardiness as much as 7°F. By using cold-hardy rootstocks, an increase of as much as 3 to 5 more degrees of cold hardiness may be possible, and at least 10° difference in cold hardiness may

Table 9. Freeze injury[a] to and recovery rating[b] of 12-year-old citrus scions[c] on Cleopatra mandarin rootstock at Monte Alto, Texas.[d]

Scion[e]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Clementine mandarin	2.4	0	1.2
Valencia orange	2.7	0	1.4
Texas Navel orange	3.0	0	1.5
Temple orange	2.9	0	1.5
Ruby grapefruit	3.0	0	1.5
Marsh pink grapefruit	3.0	0	1.6
Dancy mandarin	0.6	30	3.5
Mexican lime	0.0	100	4.5
L.S.D. .05	0.6		0.6
.01	0.7		0.7

[a] Estimated wood diameter (inches) in which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Virus status unknown.

[d] Reprinted from article in Proc. Amer. Soc. Hort. Sci. (In Press).

[e] Seven randomized single-tree replicates were surveyed on each variety.

Table 10. Freeze injury[a] to and recovery rating[b] of 12-year-old Valencia orange and Red Blush grapefruit trees[c] on sour orange rootstock in Harlingen and Monte Alto, Texas.[d]

Scion[e]	*Recovery rating*	*Dead trees (%)*	*Freeze injury to wood (inches)*
Valencia orange	2.8	0	1.7
Red Blush grapefruit	2.6	0	2.2

[a] Estimated wood diameter (inches) in which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Virus status unknown.

[d] Reprinted from article in Proc. Amer. Soc. Hort. Sci. (In Press).

[e] Ten single-tree replicates were surveyed in each of 14 Valencia orange and Red Blush grapefruit groves.

exist between species and varieties. The goal, a difficult one, is commercial citrus varieties with 3 to 5 degrees more cold hardiness than those presently grown.

The cold-hardiness problem is complex and difficult to solve. Through research on the physiology and chemistry of cold hardiness and with the development of more cold-hardy rootstocks and fruiting trees, giant strides will be made toward solving this ever-occurring problem.

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A Comparison of Three Major Texas Freezes and a Description of Tissue Temperatures of Valencia Orange Tree Parts During The January 9 to 12, 1962 Freeze[1]

A. Peynado, Roger Young, and W. C. Cooper[2]

Three major freezes (January 29 to 31, 1949; January 29 to February 3, 1951; January 9 to 12, 1962) caused severe damage to citrus in the Lower Rio Grande Valley of Texas. Following each freeze, citrus fruit production declined and injured trees and groves were renovated or bulldozed out.

The three freezes differed in minimum temperatures, duration of subfreezing temperatures, wind velocity, and amount of frost, rain, or icing associated with the cold temperatures. This paper compares the three freezes and documents climatic conditions and tissue temperatures of leaves, twigs, fruit, and trunk of a Valencia orange tree during the January 9 to 12, 1962 freeze.

INSTRUMENTS FOR RECORDING AIR, SOIL, AND TISSUE TEMPERATURES

Air temperatures during the 1949 and 1951 freezes (Figure 1) were recorded by a thermograph (inside a U. S. Weather Bureau shelter) adjacent to citrus at the Texas Agricultural Experiment Station at Weslaco, Texas.

Instruments for recording climate and tissue temperatures during the 1962 freeze were those used in a 5-year-program, initiated in 1960, to investigate the responses of mature Valencia orange trees to climate. These instruments were located in a grove 2 miles northwest of Monte Alto adjacent to 30-year-old Valencia orange trees on sour orange rootstock. Copper-constantan, 24 B & S gauge, thermocouples were used to sense temperatures of the air, soil, and tissue in or adjacent to a 30-year-old Valencia tree. An electronic temperature recorder with 2-minute cyclomatic print and 2-inches-per-hour chart speed recorded temperatures of:

1) air, 7, 20, and 40 feet from the ground on a 40-foot pole (the thermocouples were shaded),

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[1] The work was part of a cooperative project of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Weslaco, Texas, the Texas Agricultural Experiment Station, Weslaco, and Rio Farms, Inc., Monte Alto, Texas.

[2] Chemist, Weslaco; Physiologist, Weslaco; Physiologist, Orlando, Florida.

2) leaves, exposed to the sky and shaded by leaf canopy of the tree (the thermocouple was sandwiched between the lower and upper surface of two leaves and held together with a paper clip),

3) twigs on north and south side of the tree (the thermocouple was inserted under a flap of bark and taped back into place),

4) fruit (the thermocouple was inserted one inch into the fruit and lodged in the flesh),

5) trunk (the thermocouple was placed under the bark in the same manner as in twigs),

6) soil (two thermocouples were placed in each of two thin-walled glass vials with a plastic tube on the open end and filled with fine dry soil. The thermocouples in the vials were buried 6 and 12 inches below the ground surface at the drip line of the tree with the plastic tube protruding above the ground).

A second recorder measured temperatures of wet and dry bulb (in weather shelter), soil (12 inches below the ground surface), and black sphere (solar heat absorption). Accumulative miles of wind passing through an annemometer and wind direction were recorded with a third instrument.

COMPARISON OF THREE MAJOR FREEZES

The rate of cooling and duration of sub-freezing and minimum temperatures of the three major freezes in the Rio Grande Valley are indicated by temperature curves (Figure 1). The coldest days of sub-freezing temperatures of the three freezes were synchronized to compare temperatures more easily. Sub-freezing temperatures of January 13, 1962, with minimum of 25°F, are not shown because these temperatures presumably did not injure the trees further. Temperatures of the 1949 and 1951 freezes were recorded at Weslaco; the 1962 temperatures were recorded at Monte Alto, 16 miles north of Weslaco. Temperatures at the Monte Alto area are generally several degrees cooler than those at the Weslaco area during freezes.

1949 freeze. A cold front of polar air moved into the Valley during the afternoon of January 28. By sunrise of January 29 temperatures were near freezing. The cold air mass was accompanied by overcast skies which remained so until sunset of January 30. The fresh to strong northerly winds accompanying the cold air mass persisted and brought strong dry winds on the last night under clear skies (Menton, 1949). Minimum temperatures and duration of sub-freezing temperatures during this freeze period were not as severe as the 1951 and 1962 freeze periods (Table 1).

Injuries to citrus in various sections of the Valley were similar. Most citrus trees were growing vigorously; many were in bloom and had many new shoots 8 to 12 inches long with leaves nearly half grown. Actively growing trees were severely injured (Rohrbaugh and Maxwell, 1951).

Trees 1 to 4 years old were actively growing and severely injured. Trees 1 to 2 years old were killed to the bud union or to the banks, while trees 3 to 4 years old had severe bark splitting and considerable wood killed.

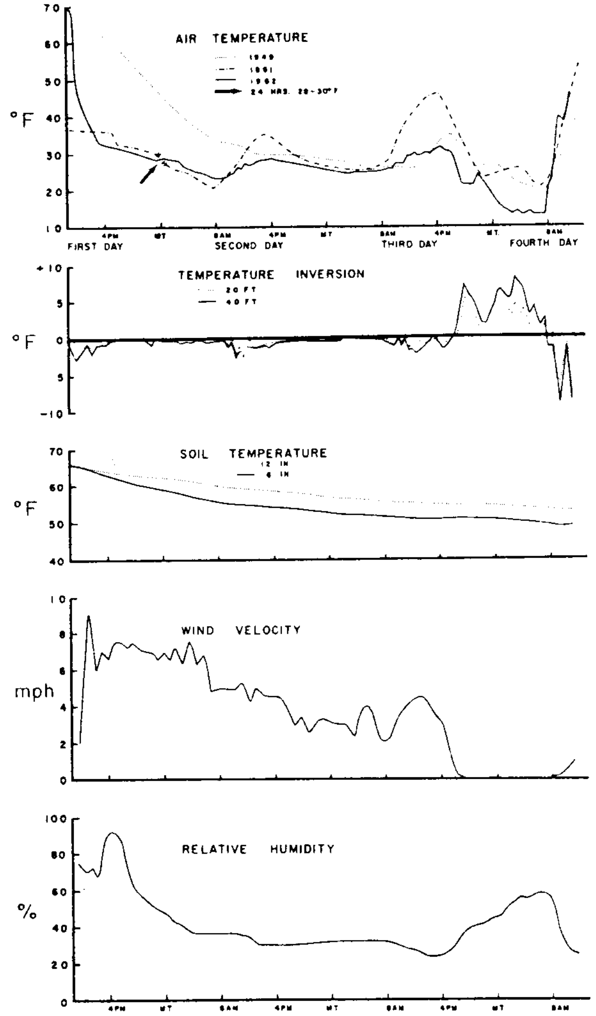

Figure 1. Air temperature curves during three major freezes recorded in the Rio Grande Valley of Texas (1949 and 1951 recorded at Weslaco, and 1962 recorded at Monte Alto), and temperature inversions at 20 and 40 feet, temperatures 6 and 12 inches below the soil surface, wind velocity (accumulated miles per hour), and relative humidity during the 1962 freeze recorded in a 30-year-old Valencia orange grove 2 miles northwest of Monte Alto, Texas.

Table 1. Minimum temperatures and total hours' duration of sub-freezing temperatures during three severe freezes[1].

Location and date		Minimum temperatures (°F.)	Hours[3] at or below indicated temperature (°F.)									
			32°	28°	25°	23°	21°	19°	17°	15°	13°	12°
Monte Alto: [2]												
1962 Jan.	9	28										
	10	24										
	11	18	66.0	47.0	23.0	11.5	9.5	8.7	7.7	6.0	3.0	1.5
	12	12										
	13	25										
Weslaco: [4]												
1950 Dec.	7	24.0	14.1	10.2	4.0							
1951 Jan.	29	30.0										
	30	28.5										
	31	27.0										
Feb.	1	20.0	99.4	77.4	30.4	16.9	5.8	1.7				
	2	25.0										
	3	19.0										
Weslaco: [4]												
1949 Jan.	29	28.3										
	30	25.8	41.5	26.8	7.8	6.0	3.5					
	31	20.0										

[1] From temperature records of U. S. Weather Bureau at Brownsville, Texas. RGV Fruit-Frost Reports of 1948-1949, 1950-1951, and 1961-1962 seasons.

[2] Temperatures recorded at Rio Farms grove, 2 miles northwest of Monte Alto, Texas.

[3] Total hours (not necessarily continuous).

[4] Temperatures recorded at Texas Agricultural Experiment Station at Weslaco.

Injury to trees 5 to 10 years old and older depending on the state of growth ranged from twig damage to death of branches less than 2 inches in diameter. Large patches of bark were killed in the crotches of older trees.

1950 freeze. Temperatures of 25°F and below (Table 1) for a period of 3 hours, with a minimum temperature of 24°, occurred the morning of December 7, 1960, at Weslaco. This minor freeze is important primarily because it increased tree sensitivity to a subsequent freeze the same winter. These temperatures caused leaf and small-twig injury and defoliation. A new flush of growth followed the defoliation. This growth activity increased the severity of injury to citrus trees from the 1951 freeze which occurred 7 weeks after the 1950 freeze.

1951 freeze. A shallow but very cold air mass entered the Valley early the morning of January 29 and rapidly lowered temperatures (Figure 1). Winds gusting to 20 mph during the first 72 hours and a cloud cover accompanied the cold front. A light freezing drizzle the first 38 hours added a coat of ice to the trees. The sky was clear the last night (Menton, 1951). Very cold temperatures and long-duration sub-freezing temperatures occurred during this period (Table 1). Young trees were killed to the banks and older trees sustained injury on large limbs (Cooper, 1952; Maxwell, 1952). An estimated 5 million trees were killed or so badly injured in the 1951 freeze that they were bulldozed out.

1962 freeze. The arctic front of January 9 ushered in unusually cold air from the north northwest at 11:30 AM and rapidly lowered temperatures to sub-freezing by midnight. The 1962 freeze combined long duration of sub-freezing temperatures, extremely low temperatures, and comparatively dry strong winds (Figure 1; Table 1). Such low temperatures had not been recorded in the Lower Rio Grande Valley since the great cold wave of 1889 (Jensen, 1962). Winds averaging as high as 9 mph, with gusts 21 to 35 mph and as high as 40 mph, and an overcast sky accompanied the cold air mass. High winds prevailed through the first three days. The wind weakened slightly the second day and had subsided by 7 PM the third day.

During the daylight hours of the first two days of strong winds, air temperatures at 20- and 40-foot levels were 2° to 2½°F colder than air at the 7-foot level; at night there was no difference. The third night when the winds subsided, air at the 20- and 40-foot levels was 5° to 8½° warmer than air at 7-foot level.

This freeze was relatively dry compared with the severe freezes of 1949 and 1951. The relative humidity dropped from 92 to 37% by early morning the second day and to 30% the same afternoon. A low of 24% was reached by early afternoon of the third day. The relative humidity increased the third afternoon as the wind subsided and the clouds disappeared. Temperatures fell from near 32° at 4 PM January 11 to 21.5° at 7:30 PM as winds ceased and to a low of 12° by early morning the following day.

Soil temperatures dropped slowly and continuously as sub-freezing temperatures and high winds continued. Minimum soil temperatures of 48.7°F. at 6-inch level and 53.0° at 12-inch levels were recorded.

During the 2-week period before the freeze, minimum night temperatures ranged from 31°F to 42°, with a heavy frost on December 24, 1961 and a light frost on January 2, 1962. The cool nights induced bud dormancy and growth flushes ceased. The terminal flush of 30-year-old Valencia trees was mature. The bark-slipping rating (Cooper et al., 1955) of the trunk was recorded as 2.4; 3- to 4-inch-diameter scaffold limbs, 1.7; 1-inch branches 1.4; and ¼-inch twigs, 1.4 (1 = bark barely peels; 2 = bark peels easily; 3 = bark peels easily and is moist).

TISSUE TEMPERATURES OF A VALENCIA ORANGE TREE DURING 1962 FREEZE

Leaf temperatures. Leaves on the outer surface of the canopy of the tree were warmed 6°F above air temperature by the sun's radiation during the day and cooled 0° to 4° below air temperature by radiation to the clear sky during the night (Figure 2). The first two nights exposed leaves did not cool below air temperature, but the last night they cooled 3° to 4° below air temperature. The minimum temperature of exposed leaves was 9.5°, when air temperature under clear skies was at a minimum of 12°. Leaves inside the tree canopy were at air temperature or 1° to 2° warmer than the air during the entire freeze period. The freezing point of leaf tissue was not detected, probably because high winds quickly equilibrated leaf and air temperatures during the 32-minute time lapse between recordings. However, the water-soaked appearance of the foliage indicated that the leaves had frozen before daybreak the first morning.

Twig temperatures. Twig temperatures followed the temperature pattern of leaves inside the canopy of the tree and reached a minimum of 11.5°F. Twig watersoaking was observed at 10 AM the first morning, and twig splitting was observed at 2 AM the last morning.

Trunk temperatures. The bark of the trunk was warmer than the air and reached a low of 26°F the first night and a minimum of 21° the coldest morning. The freezing point of the trunk was not detected.

Fruit temperatures. Fruit temperatures dropped as air temperatures dropped until about 6 AM the first morning, when fruit temperatures rose 2° to 3°F above the air temperature. This temperature rise characterized heat liberated by ice formation in the flesh. Ice crystals were observed in the flesh of the fruit the first morning, and the fruit was firm by 2:45 PM and iced by 4 PM of January 11. By 11:30 PM, January 11, the fruit was frozen solid. The two fruits attached to the thermocouples reached minimum temperatures of 18° and 19°.

TREE INJURY FROM 1962 FREEZE

Freeze injury was difficult to assess immediately after the freeze because conditions did not favor immediate tree growth. Temperatures were low and skies were overcast. Three days after the freeze, 32% of the fruit showed peel breakdown. Fruit drop was rapid, and 12 days after

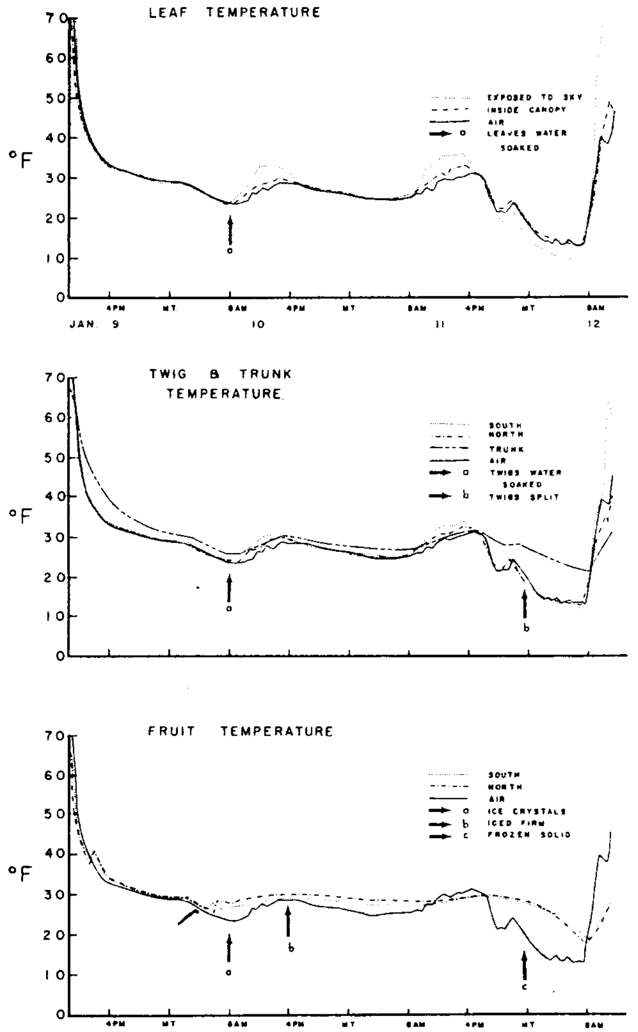

Figure 2. Temperatures of air (7 foot level), leaf, twig, trunk, and fruit tissue recorded during the 1962 freeze in a 30-year-old Valencia orange tree in a grove 2 miles northwest of Monte Alto, Texas. Observations of the occurrence of water-soaking in leaves and twigs, bark splitting of twigs, and ice formation inside the fruit are indicated by the arrows.

the freeze 75% of the fruit had dropped. After 14 days, more than 50% of the dead leaves remained on the tree. All leaves were killed by the freeze. After 12 days, twigs were still green and showed a trace of bark splitting. The cambium layer was very tight and dry. The cambial layer of 1-inch branches had a brownish tinge; that of the scaffold limbs was moist and in some cases had a brownish color; that of the trunk was moist.

Freeze injury to the 30-year-old Valencia trees was severe. One of the least-injured trees is shown in Figure 3. The tree in which thermocouples were inserted during the freeze was killed to the trunk.

A month after the freeze, regrowth occurred on limbs 4 inches in diameter or larger; many shoots adjacent to dead bark on heavy limbs died back. Regrowth was generally poor. Some trees with moderate amounts of regrowth had badly injured crotches and extensive areas of dead bark on scaffold limbs. A few months later the entire grove was bulldozed out as unsalvageable.

Freeze injury to other trees in the Monte Alto area was severe (Young and Peynado, 1963). Injury to trees Valley-wide was severe, but less injury was apparent in the Mission area. Valencia orange and Red Blush grapefruit trees 3 to 7 years old were killed to wood 3 inches in diameter, which, in many cases, included the crotches. Many trees were killed below the bud union. Trees 12 to 15 years old were killed to wood 1½ to 2½ inches in diameter. Regrowth was poor on 3- to 7-year-old trees and good on 12- to 15-year-old ones.

Figure 3. One of the least injured 30-year-old Valencia orange trees on sour orange rootstock one year after the January 9 to 12, 1962, freeze.

SUMMARY

Three major Texas freezes of 1949, 1951, and 1962 varied in duration of sub-freezing temperatures, minimum temperatures, accompanying climatic conditions, and the extent of damage incurred by the citrus orchards.

During the 1962 freeze, minimum temperatures in air and in a 30-year-old Valencia orange tree's tissues were recorded with thermocouples. The minimum air temperature adjacent to the tree at the 7-foot level was 12°F. Leaves exposed to the sky were 9.5°; leaves inside the tree's canopy, 12°; twigs, 11.5°; trunk bark, 21°; and fruit, 18°.

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Freeze Injury to Citrus Trees of Different Ages and in Different Locations in the Rio Grande Valley of Texas in 1962[1]

Roger Young and Ascension Peynado[2]

Previous reports have described rather pronounced differences in freeze injury to citrus trees on different rootstocks and to varieties of citrus during the January 1962 freeze (Young, 1963, a,b; Young and Olson, 1963, a,b). Many other factors during the freeze affected the resulting injury.

This report summarizes some effects of tree age and grove location in the Valley on freze injury to citrus in 1962 in the Rio Grande Valley of Texas.

MATERIALS AND METHODS

Plant materials. Citrus surveyed included 6- and 12-year-old Valencia orange and Red Blush grapefruit trees on sour orange rootstock in Harlingen and Weslaco; 1 to 3, 3 to 4, 4 to 5, 5 to 6, 12-, and 30 to 33-year-old Valencia orange and Red Blush grapefruit trees on sour orange rootstock at Rio Farms, Monte Alto; and 12-year-old Valencia orange and Red Blush grapefruit trees on sour orange rootstock in Mission (Goodwin's) and Pride O'Texas. Some trees listed as 12-year-old in Monte Alto and Mission were actually planted in 1945 and were frozen back severely in the 1951 freeze; they had 12-year-old tops at the time of the 1962 freeze.

Freeze-injury and recovery evaluations. Freeze-injury and recovery evaluations were made between April 1 and May 15, 1962, in Monte Alto, Harlingen, and Weslaco, and between December 11, 1962, and January 8, 1963, in Mission and Pride O'Texas. Percent dead wood was estimated on terminals, ½-, 1-, 2-, 3-, and 4-inch diameter wood on each tree. Each tree was also arbitrarily assigned a recovery rating as follows: 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing. From these data each tree was given a freeze-injury rating which indicated the diameter of wood (inches) to which half the branches were killed, and a recovery rating which indicated the recovery visible when the trees were surveyed. The ratings may not indicate subsequent injury or recovery changes.

Temperatures during the freeze. Total numbers of hours below various temperatures in Harlingen, Monte Alto, Weslaco, and Pride O'Texas during the 1962 freeze are summarized in Table 1. These data were compiled by the U. S. Weather Bureau Station at Brownsville, Texas (Jensen, 1962). The temperatures do not represent actual grove temperatures since the recorders were not in the groves.

Table 1. Duration of temperatures at Harlingen, Monte Alto, Weslaco, and Pride O'Texas, Texas, during the 1962 freeze in the Lower Rio Grande Valley.

Temperatures (°F)	*Hours below indicated temperatures at indicated station*[a]			
	Harlingen	*Monte Alto*	*Weslaco*	*Pride O'Texas*
32	68	66	65	63
31	67	62	57	50
30	67	59	55	47
29	60	55	51	41
28	54	47	40	30
27	42	38	30	22
26	32	31	22	14
25	27	23	16	12
24	20	17	9	11
23	12	12	8	11
22	7	10	8	10
21	6	10	7	10
20	5	9	7	10
19	5	9	4	10
18	4	8	4	9
17	4	8	1	7
16	2	8	1	4
15	2	6	0	2
14	1	6	0	1
13	0	3	0	0
12	0	2	0	0
11	0	0	0	0

[a] Temperature data from the 1961-62 Annual Fruit-Frost Report, U. S. Department of Commerce, Weather Bureau Airport, Brownsville, Texas.

Temperatures were lowest in Monte Alto, followed by Pride O'Texas, Harlingen, Weslaco, and Mission. Approximately 6 hours of 15°F or lower were experienced in Monte Alto and 2, 2, 0, and 0 in Harlingen, Pride O'Texas, Weslaco, and Mission, respectively. A minimum temperature of 12° occurred in Monte Alto, 14° in Harlingen and Pride

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[1] The work was part of a cooperative project of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, the Texas Agricultural Experiment Station, Weslaco, Texas, and Rio Farms, Inc., Monte Alto, Texas. The writers acknowledge the assistance of Albert Purcell, Utilization Research Division, Weslaco, Texas, Stanley B. Crockett, Jr., Harlingen, Texas, Art Shull, Rio Farms, Inc., Monte Alto, Texas, and Gene Goodwin, Mission, Texas.

[2] Physiologist and Chemist, CRD, ARS, U. S. Department of Agriculture, Weslaco, Texas.

O'Texas, 16° in Weslaco, and 15° in Mission. Temperatures for the Goodwin groves in Mission were obtained from Gene Goodwin, Mission, Texas.

RESULTS AND DISCUSSION

Freeze injury to different-aged trees. Freeze injury to different-aged Valencia orange and Red Blush grapefruit trees in Monte Alto is summarized in Table 2. Trees 1 to 3 years old, which were banked, were killed back to the banks. These trees, with ¾- to 2½-inch trunks, generally survived the freeze in better condition than older trees. Unbanked trees 1 to 3 years old were killed to the ground.

Table 2. Freeze injury[a] to and recovery[b] of different-aged Valencia orange and Red Blush grapefruit trees on sour orange rootstock in Monte Alto.[c]

	Valencia orange			*Red Blush grapefruit*		
Age (years)	*dead trees (%)*	*recovery rating*	*freeze injury to wood (inches)*	*dead trees (%)*	*recovery rating*	*freeze injury to wood (inches)*
1 to 3[d]	0	----	----	0	----	----
3 to 4	----	----	----	6	0.9	3.0
4 to 5	20	0.8	3.2	3	1.0	3.1
5 to 6	10	0.9	3.1	0	1.7	3.0
6 to 7	0	1.5	3.4	0	1.2	2.8
12 to 15	0	2.9	1.6	0	2.1	2.6
30 to 33	0	2.9	2.1	0	1.6	4.0

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Three orchards, 10 trees each, were surveyed for freeze injury in each category, except the following: 3 to 4 and 5 to 6 year old grapefruit and 4 to 5 year old Valencias, 2 orchards; 5 to 6 year old Valencias, 1 orchard; 6 to 7 year old grapefruit, 4 orchards.

[d] Trees banked. Wood injury and recovery not comparable with other age categories.

Valencia orange trees 3 to 7 years old had wood killed to approximately the same diameter as the same-aged Red Blush grapefruit trees. Trees in this age category showed severe bark splitting and most of them were killed below the crotch. More Valencia orange trees were killed than Red Blush grapefruit, primarily because Valencias had smaller diameter trunks which were more readily frozen. Valencia orange and Red Blush grapefruit trees 3 to 7 years old were not included in the survey because they were so severely injured that they had been removed previously. A high percentage of these trees were killed below the bud union.

Trees 12 to 15 years old showed the least wood injury for trees older than 3 years. They had much less bark splitting than younger trees and survived the freeze in good condition. Some of these trees set and matured some fruit.

Trees 30 to 33 years old were more severely injured than those 12 to 15 years old. These trees were apparently physiologically weak because they showed severe wood injury caused by the 1951 freeze. Grapefruit trees were more severely injured than Valencia trees.

Injury records on trees 15 to 25 years old were not obtained in Monte Alto because of lack of adequate numbers of groves. It was noted, however, that in most parts of the Valley trees 15 to 25 years old not weakened from the 1951 freeze had freeze injury in 1962 similar to that on 12 to 15-year-old trees. Trees in the 15 to 25-year-old age group severely injured in the 1951 freeze were generally injured to the same degree as the 30 to 33-year-old trees.

Trees 12 to 15 and 1 to 3 years old recovered best following the freeze. Young trees 3 to 7 years old were poor in recovery, and in many cases some nutritional disorders developed.

Location effects on freeze injury. Freeze injury to 6- and 12-year-old Valencia orange and Red Blush grapefruit trees in Harlingen, Monte Alto, Weslaco, Mission, and Pride O'Texas is summarized in Table 3. Injury, as indicated by diameter of wood killed, was generally more severe in Harlingen and Monte Alto than Weslaco, Pride O'Texas, and Mission. The least wood injury was noted in Mission. Trees at Pride O'Texas were injured to the same degree as those at Weslaco. Differences in the extent of injury in the various areas were apparently related to the minimum temperature and the duration of subfreezing temperature in each area (Table 1).

Bark splitting was more severe in Harlingen and Monte Alto than in Weslaco, Mission, and Pride O'Texas. In general, 6-year-old trees were more severely injured than 12-year-old ones.

Trees planted in low areas generally were injured to the same degree as those on higher locations. Where trees were planted in lower areas with an associated high water table or poor drainage, injury was more severe (Table 4). Trees surveyed in several such areas exhibited salt-injury symptoms in the leaves prior to the freeze and the trees were definitely smaller. More trees were killed in the affected areas.

Groves planted south of or downwind from large bodies of water survived the freeze better. This was evident in a grove southeast of Delta Lake and several groves south of resacas in Bayview.

Fruit Production in 1962-63. Fruit production for the 1962-63 season was virtually eliminated. Only a trace of fruit was found in Harlingen, Weslaco, Monte Alto, and Pride O'Texas. Most of the fruit was grapefruit located on large limbs inside older trees. In Mission, considerably more fruit (also primarily grapefruit) were found. In some groves, as many as 2 to 4 boxes of grapefruit and ½ to 2 boxes of Valencias per tree were estimated. Official estimates set the Valley citrus production at 200,000 boxes of grapefruit and 80,000 boxes of oranges. The fruit were primarily in groves with less freeze injury. More grapefruit were produced because of the ability of grapefruit trees to set large amounts of fruit on large limbs inside the tree. Oranges generally set fruit only on terminal wood, most of which was killed in the freeze.

Table 3. Freeze injury[a] to and recovery[b] of 6- and 12-year-old Valencia orange and Red Blush grapefruit trees on sour orange rootstock in Harlingen, Monte Alto, Weslaco, Pride O'Texas, and Mission.

		Valencia orange[c]			*Red Blush grapefruit*[c]		
Location	*Age*	*dead trees (%)*	*recovery rating*	*freeze injury to wood (inches)*	*dead trees (%)*	*recovery rating*	*freeze injury to wood (inches)*
Harlingen	6	2	1.6	3.0	0	1.4	3.0
	12	0	2.8	2.0	0	2.7	2.5
Monte Alto	6	0	1.5	3.4	0	1.2	2.6
	12	0	2.9	1.6	0	2.1	2.6
Weslaco	6	20	1.5	2.6	0	1.6	2.6
	12	0	2.7	1.6	0	2.9	1.7
Pride O'Texas	12	0	3.0	2.2	0	3.0	2.1
Mission	12	0	2.9	0.8	0	3.0	1.7

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing;
2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

[c] Ten trees, in each of 4 groves, were surveyed for each age group in each area except 6-year-old Valencias in Harlingen and Weslaco where 3 groves were surveyed.

Table 4. Freeze injury[a] to 6-year-old Red Blush grapefruit trees on sour orange rootstock in areas with and without high water tables in Monte Alto.

	Low water table			*High water table*		
Block no.[b]	*% dead trees*	*diameter of trunks (inches)*	*wood injury (inches)*	*% dead trees*	*diameter of trunks (inches)*	*wood injury (inches)*
1	0	5-6	3.6	90	3-4	3.4
2	0	5-6	3.4	90	3-4	4.1

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] Ten trees were surveyed in each block.

SUMMARY

Six- and 12-year-old budded Valencia orange and Red Blush grapefruit trees in Harlingen, Weslaco, Monte Alto, Mission, and Pride O'Texas were surveyed for freeze injury after the January 9 to 13, 1962 freeze. Trees in Harlingen and Monte Alto were more severely injured than those in Weslaco, Mission, and Pride O'Texas. Trees in Mission were injured the least and produced most of the Valley's citrus crop for 1962-63. Freeze injury was related to the minimum temperature and duration of subfreezing temperatures in each area.

Trees 3 to 7 and 30 to 33 years old were injured more severely than 12 to 15 year-old trees. Trees 12 to 15 years old were the least injured and showed the best recovery after the freeze. Most trees 30 to 33 years old were more severely injured than 12 to 15 year-old trees, presumably because of previous injury in the 1951 freeze.

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Freeze Injury to Four- and Nine-Year-Old Citrus Cultivars and Related Species in the Lower Rio Grande Valley of Texas[1]

ROGER YOUNG[2]

Previous reports have shown large differences in freeze injury to 3-, 5-, 8-, 12-, and 27 to 30-year-old budded citrus varieties and to 9- to 36-month-old citrus cultivar seedlings from the January 1962 freeze in the Rio Grande Valley (Young and Olson, 1963; Young, 1963). In those studies citrus trees were replicated and the extent of freeze injury was considered representative of performance. However, other less well known cultivars also occurred as one or more specimen trees. Records on the cold hardiness of these selections have importance in evaluating their potential value as scions, as rootstocks, and in breeding and physiological research. The information here presented, although meager, is the only available information on cold hardiness of these cultivars.

This report summarizes freeze injury to individual trees of 4- and 9-year-old citrus cultivars and related species from the January 1962 freeze.

METHODS AND MATERIALS

Plant materials. Four- and nine-year-old seedling and budded citrus cultivar trees were growing in a small grove at Monte Alto, Texas. Grove care was provided by Rio Farms, Inc., and was similar to the usual grove care in the Valley.

Most of the 4-year-old cultivars were budded trees on sour orange rootstock, but several were budded on Cleopatra mandarin, Morton citrange, and Rangpur mandarin-lime rootstocks and several were seedlings.

Most of the 9-year-old cultivars were seedlings or trees budded on Cleopatra mandarin rootstock. Several were budded on sour orange rootstock.

Freeze-injury and recovery evaluations. Freeze-injury and recovery evaluations were made between April 1 and May 15, 1962. Percent dead wood was estimated on terminals and ¼-, ½-, 1-, 2-, 3-, and 4-inch wood on each tree. Each tree was also arbitrarily assigned a recovery rating as follows: 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing. From these data each tree was given a freeze-injury rating based on the estimated size of wood (inches) to which half the branches were dead, and a recovery rating which indicated the recovery visible 4 months after the freeze. The ratings may not indicate subsequent injury or recovery changes.

RESULTS

Four-year-old cultivars. A wide range of freeze injury was apparent among 4-year-old citrus cultivars and related species (Table 1). *Poncirus trifoliata* was the least injured followed with increasing wood injury by some mandarins, oranges, tangelos, grapefruit, and limes and lemons as groups. *Poncirus trifoliata,* Viciedo mandarin, Long Huang Kat mandarin, Hamlin orange, Pope summer orange, Thornton tangelo, Hybrid 1-20-34 mandarin, and Ichang lemon were least injured of the 4-year-old types whereas Palermo mandarin, Frost Dancy mandarin, DFS Dancy mandarin, grapefruit, limes, and lemons were injured the most. Recovery was inversely correlated to the degree of injury; cultivars or related species with more injury showed poorer recovery 4 months after the freeze.

Nine-year-old cultivars. Nine-year-old cultivars also exhibited a wide range of freeze injury (Table 2). *Poncirus trifoliata* hybrids had no wood injury whereas most mandarins had only slight wood injury. Oranges, tangelos, grapefruit, limes, and lemons had increasing wood injury in that order. Bouquet de Fleur sour orange, Louisiana sweet orange, Hamlin orange, Parson Brown orange, Ruvel orange, Kara mandarin, Suwanee tangelo, Ichang lemon, and lemonquat were only slightly injured and Murcott, Lau Chang, and Sunki mandarins were severely injured. Recovery 4 months after the freeze was again inversely correlated to the degree of freeze injury.

DISCUSSION

While the reliability of observations from unreplicated cultivars may be subject to question, it is noted that a number of single-tree cultivars behaved similarly to replicated plantings in the same area. Dancy mandarin, hybrids 6-12-26 and 6-5-15, Washington navel and Valencia oranges, Red Blush grapefruit, and Frost Eureka lemons, as single trees, behaved similarly to replicated plantings previously described (Young and Olson, 1963).

Other single-tree cultivars behaved similarly in the January 1962 freeze to the reported behavior of the same cultivars exposed to freezes in other citrus-growing areas. These included *Poncirus trifoliata,* Changsha mandarin, Eureka lemon, Ichang lemon, several citranges and citrumelos, and Kara mandarin (Swingle, 1948; Furr and Armstrong, 1959). Dancy and Sunki mandarins, previously reported very cold hardy (Furr and Armstrong, 1959), were very cold-sensitive during the January 1962 freeze in Texas. Murcott mandarin and Orlando tangelo, which were

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[1] The work was part of a cooperative project of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, the Texas Agricultural Experiment Station, Weslaco, Texas, and Rio Farms, Inc., Monte Alto, Texas.

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Table 1. Freeze injury[a] and recovery rating[b] of 4-year-old citrus cultivars and related species in Monte Alto, Texas.

Cultivar or related specie	No. of trees	Seedling or budded on indicated rootstock	Recovery rating	Freeze injury to wood (inches)
Poncirus trifoliata	1	seedling	3.0	0.0
Mandarins:				
Palermo	1	sour	0.0	4.0
Viciedo	1	sour	3.0	0.1
Avana	1	sour	1.0	2.5
Frost Dancy	1	sour	1.0	3.5
DFS Dancy	1	sour	1.0	3.5
Long Huang Kat	1	seedling	3.0	0.2
Hybrid 6-8-16	1	sour	1.0	2.5
Hybrid 1-20-34	1	sour	2.0	1.6
Hybrid 1-31-17	1	sour	0.0	4.0
Hybrid 1-32-14	1	sour	1.0	4.5
Hybrid 1-21-33	1	sour	1.0	3.5
Hybrid 1-15-7	1	sour	1.0	3.0
Hybrid 1-36-14	1	sour	1.0	4.5
Hybrid 6-12-26	1	sour	1.0	3.5
Hybrid 6-5-15	1	sour	1.0	2.5
Hybrid 1-21-31	1	sour	1.0	3.5
Ave.			1.2	2.9
Oranges:				
Shamouti variant	3	sour	1.0	3.0
Biondo	1	sour	1.0	3.5
Ovaletto	1	sour	1.0	3.5
Salustiana	1	sour	1.0	3.5
Seguin	1	sour	1.0	3.5
Doble Fina	1	sour	0.0	4.0
Vaniglia	1	sour	0.0	4.0
Vaccaro	1	sour	1.0	3.5
Cuscano	1	sour	1.0	3.5
Hamlin	1	Cleopatra	3.0	0.3
Pope Summer	1	Cleopatra	3.0	0.5
Jaffa	1	Cleopatra	1.0	3.2
Frost Navel	1	sour	1.0	2.5
Washington Navel	1	Cleopatra	1.0	3.0
Curry	1	Rangpur	2.0	3.5
Marrs	1	Rangpur	2.0	3.5
Macetera	1	sour	1.0	3.0
Belladonna	1	sour	1.0	2.7
Biondo riccio	1	sour	1.0	3.5
Sanguinello	1	sour	0.0	4.0
Oranges: Cont'd.				
Entrefina	1	sour	1.0	3.5
Mak Som Von	1	sour	1.0	3.5
Joppa	1	Cleopatra	1.0	3.5
Cutter Valencia	1	sour	1.0	3.5
Frost Valencia	1	Morton	1.0	3.5
Olinda Valencia	1	sour	1.0	2.5
Campbell Valencia	1	sour	1.0	4.5
Ave.			1.0	3.3
Tangelos:				
Thornton	1	Cleopatra	3.0	1.0
Webber	1	seedling	0.0	4.0
Ave.			1.5	2.5
Grapefruit:				
Ruby	1	Morton	0.0	4.0
Shary	1	Cleopatra	0.0	4.0
Red Blush	1	Rangpur	0.0	4.0
CES Red Blush	1	sour	0.0	4.0
Riddle	1	Cleopatra	0.0	4.0
Curry	1	Cleopatra	0.0	4.0
Garner White Marsh	1	sour	0.0	4.0
Frost Marsh	1	sour	0.0	4.0
Ave.			0.0	4.0
Limes and Lemons:				
Eustis limequat	1	Rangpur	1.0	3.5
Meyer lemon variants	2	Cleopatra	0.0	4.0
C. moi	1	seedling	0.0	4.0
Otaheite lime	1	seedling	1.0	4.5
Kusner lemon	3	seedling	0.0	4.5
Frost Eureka lemon	1	sour	0.0	4.5
Karna Khatta lemon	1	seedling	1.0	3.5
Sipora lemon	1	sour	0.0	4.0
Ichang lemon	1	seedling	3.0	0.0
Ave.			0.7	3.6
Others:				
c. *macroptera*	1	sour	1.0	3.5
c. *assamensis*	1	sour	1.0	3.5
c. *macrophylla*	1	sour	1.0	2.5
c. *volkameriana*	1	sour	0.0	5.0

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

Table 2. Freeze injury[a] and recovery rating[b] of 9-year-old citrus cultivars and related species in Monte Alto, Texas.

Cultivar or related specie	*No. of trees*	*Seedling or budded on indicated rootstock*	*Recovery rating*	*Freeze injury to wood (inches)*
Poncirus trifoliata hybrids:				
Rustic citrange	1	Cleopatra	3.0	0.0
Uvalde citrange	1	Cleopatra	3.0	0.0
Troyer citrange	1	Cleopatra	3.0	0.0
Savage citrange	2	Cleopatra	3.0	0.0
Carrizo citrange	2	seedling	3.0	0.0
Morton citrange	1	seedling	3.0	0.0
Sacaton citrumelo	1	Cleopatra	3.0	0.0
Citremon 1449	1	Cleopatra	3.0	0.3
Etonia citrange	1	Cleopatra	3.0	0.0
Citradia	1	Cleopatra	3.0	0.0
Citrangeor	1	Cleopatra	3.0	0.0
Thomasville citrangequat	1	Cleopatra	3.0	0.0
Ave.			3.0	0.0
Mandarins:				
Murcott	2	seedling	0.5	6.0
Ponkan	2	seedling	3.0	4.0
Sunki	1	seedling	2.0	3.5
Pong Koa	1	seedling	3.0	0.5
Lau Chang	1	seedling	3.0	3.4
Suenkat	1	seedling	3.0	0.0
Kunembo	1	seedling	3.0	0.0
Citrus taiwanica	1	seedling	3.0	0.0
Kansu	1	Cleopatra	3.0	0.3
Dancy	1	Cleopatra	3.0	1.0
Calamondin	1	Cleopatra	2.0	2.5
Sun Chu Sha Kat	1	seedling	3.0	0.0
Changsha	1	seedling	3.0	0.0
Variant Satsuma	1	seedling	2.0	2.5
Kara	1	Cleopatra	3.0	0.0
Hybrid 1-36-19	1	sour	2.0	3.5
Ave.			2.9	1.7
Oranges:				
Torregrossa	1	seedling	2.0	2.5
Lambs Summer	1	seedling	2.0	3.5
Ovale Sangre	1	seedling	2.0	3.5
Ruby	1	seedling	2.0	3.5
Pope Summer	1	seedling	2.0	3.5
Bouquet de Fleur sour	1	Cleopatra	3.0	0.3
Pineapple	2	Cleopatra	3.0	2.5
Louisiana Sweet	1	Cleopatra	3.0	0.5
Hamlin	1	Cleopatra	3.0	0.3
Parson Brown	1	Cleopatra	3.0	0.5
Oranges: Cont'd.				
Cadena	1	Cleopatra	3.0	2.0
Ruvel	1	Cleopatra	3.0	0.4
Jaffa	1	seedling	2.0	3.5
Ave.			2.4	2.2
Tangelos:				
Pina	1	seedling	3.0	2.5
Pearl	1	seedling	3.0	2.0
Orlando	1	sour	2.0	4.5
Sunshine	1	seedling	2.0	3.5
Watt	1	seedling	2.0	4.5
Wekiwa	1	Cleopatra	3.0	2.0
Minneola	1	seedling	2.0	3.5
Suwannee	1	Cleopatra	3.0	0.4
Ave.			2.5	2.9
Grapefruit and shaddocks:				
Foster grapefruit	2	seedling	3.0	2.5
Duncan grapefruit	1	seedling	2.0	3.0
Ogami shaddock	1	Cleopatra	2.0	3.5
Koa Phang shaddock	1	Cleopatra	2.0	3.5
Siam pummelo	1	Cleopatra	2.0	3.5
Oani Kin Kan grapefruit	1	seedling	2.0	3.5
Red Mexican grapefruit	2	seedling	2.0	2.5
Red Blush grapefruit	1	Cleopatra	3.0	2.6
Bergaldin grapefruit	1	Cleopatra	3.0	2.0
Ave.			2.3	3.0
Limes and Lemons:				
Key lime	1	seedling	0.0	6.0
Ponderosa lemon	1	sour	1.0	3.5
Lakeland limequat	1	seedling	2.0	2.5
Columbian sweet lime	1	Cleopatra	1.0	4.5
Lemonquat	1	Cleopatra	3.0	0.5
Hayden lemon	1	Cleopatra	0.0	5.0
Chinese citron	1	Cleopatra	1.0	3.5
Rangpur mandarin-lime	1	seedling	0.0	5.0
Nicaragua lime	1	seedling	0.0	5.0
C. *limonia Indica* lime	1	seedling	0.0	5.0
Kuasaie mandarin-lime	2	seedling	0.0	5.0
Ichang lemon	1	Cleopatra	3.0	0.0
Ave.			0.9	3.8

Table 2. Continued.

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = tree dead; 1 = 1 to 10 scion shoots growing; 2 = 10 to 20 scion shoots growing; 3 = more than 20 scion shoots growing.

slightly less injured than Valencia orange in the 1962 Florida freeze, were more severely injured than many sweet oranges in the 1962 Texas freeze.

Although various single-tree cultivars behaved similarly to the same cultivars in replicated plantings, a reliable cold-hardiness index of a cultivar can only be obtained from replicated plantings. The results presented in this report may serve as a guide for selecting cultivars for further cold-hardiness research and testing.

SUMMARY

Four- and nine-year-old seedling and budded trees of many citrus cultivars and related species were exposed to a severe freeze in January 1962 in the Rio Grande Valley. *Poncirus trifoliata* and its hybrids were least injured followed with increasing injury to oranges, tangelos, grapefruit, limes, and lemons. Mandarins were variable in injury; some were slightly injured while others were severely injured. Recovery 4 months after the freeze was inversely correlated to freeze injury; cultivars with the most injury showed the poorest recovery.

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Freeze Injury to Young Seedlings of Citrus Cultivars and Related Species in the Lower Rio Grande Valley[1]

ROGER YOUNG[2]

The behaviors of a wide range of mature citrus cultivars and related species during natural freezes have been reported (Hodgson, 1933; Webber, 1948; Young and Olson, 1963). *Poncirus trifoliata* was most cold hardy followed with decreasing hardiness by citranges, citrumelos, oranges, grapefruit, limes, and lemons. Mandarins varied in cold hardiness; some were as cold hardy as the citranges while others were only as cold hardy as the grapefruit. Nine-month-old seedlings of citrus cultivars and related species exposed to cool days and nights in controlled-temperature chambers exhibited dormancy and cold hardiness characteristics similar to those of mature seedlings exposed to natural freezes under field conditions (Young and Peynado, 1962).

Many 9- to 36-month-old seedlings of citrus cultivars and related species growing in nurseries in the Rio Grande Valley during the January 1962 freeze afforded the opportunity for observation of their cold hardiness in the field.

MATERIALS AND METHODS

Plant materials. At the time of the January 1962 freeze, seedlings of 102 different citrus cultivars and related species were growing in 4 nurseries. Two nurseries in Monte Alto and one in Weslaco were in the field. Another nursery in Weslaco was in a lathhouse. All seedlings in the field were close-planted in nursery rows, unbanked, and grown with usual nursery practices. Those in the lathhouse were in 6-inch metal pots and unbanked.

Freeze-injury evaluation. Freeze-injury evaluation was made between February 1 and 15, 1962. This consisted of estimating percent defoliation, percent terminal injury, percent injury to ¼- to ½-inch and ½- to 1-inch wood, and percent plants dead to the ground.

Freeze temperatures. Temperatures during the freeze were colder in Monte Alto than Weslaco (Jensen, 1962). The minimum official temperature in Monte Alto was 12°F. and at Weslaco was 16°. Temperatures in the lathhouse in Weslaco were several degrees higher than in the field.

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[1] The work was part of a cooperative project of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, The Texas Agricultural Experiment Station, Weslaco, Texas, and Rio Farms, Inc., Monte Alto, Texas.

[2] Physiologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Weslaco, Texas.

RESULTS AND DISCUSSION

In Weslaco, field-grown seedlings showed a wide range of injury (Table 1). *Poncirus trifoliata* selections and Troyer citrange seedlings were uninjured. Other citranges, citrumelos, lemonquat, Thomasville citrangequat, False Hybrid satsuma mandarin, Changsha mandarin, Red Blush grapefruit, Oani Kin Kan grapefruit, lemonquat, and *Severinia buxifolia* seedlings were only slightly injured. Limequat, rough lemon, *Citrus macrophylla*, and Mexican lime seedlings were severely injured.

Seedlings in the lathhouse were not as severely injured as those in the field (Table 2). Seedlings of 24 different *Poncirus trifoliata* selections, citrumelo 4475, and citradia were not injured. Citrangeor, calamondin, citrangequat 48011, Morton citrange, sour orange, and Sacaton citrumelo seedlings were slightly injured, and Mexican lime seedlings were severely injured.

In Monte Alto, temperatures during the freeze were lower and plant injury was greater. Seedlings of 24- to 28-month-old *Poncirus trifoliata*, *P. trifoliata* hybrids, and several other citrus types were slightly injured (Table 3). Calamondin, Orlando tangelo, Red Blush grapefruit, sour orange, Precose de Valence orange, Aziza orange, Poorman's orange, Rangpur mandarin-lime, Mexican lime, Columbian sweet lime, and rough lemon seedlings were serevely injured.

Table 1. Freeze injury to 9- to 12-month-old open-pollinated seedlings of citrus cultivars and related species in a nursery at Weslaco, Texas.

Cultivar or related specie	*No. of plants*	*Percent defoliation*	*Percent twig injury*		*Percent plants dead to ground*
			terminals	*¼"-½"*	
Poncirus trifoliata[a]:					
'Rubidoux'	1	0	0	–	0
'Christian'	8	0	0	0	0
'English Dwarf'	1	0	0	–	0
Troyer citrange	2	0	0	0	0
Thomasville citrangequat	24	40	0	–	0
Citrumelo 4561	4	100	0	–	0
Citrumelo 4481[b]	28	100	0	0	0
Citrumelo 4475	21	80	0	0	0
Morton citrange	3	90	0	0	0
Sanders citrange	16	100	0	0	0
Lemonquat	22	100	0	0	0
False Hybrid satsuma mandarin	4	100	5	–	0
Severinia buxifolia	28	40	10	–	0
Red Blush grapefruit	58	100	10	0	0
Oani Kin Kan grapefruit	37	100	10	–	0
Changsha mandarin	34	100	50	–	0
Limequat[b]	30	100	100	100	100
Rough lemon	63	100	100	100	100
Citrus macrophylla	11	100	100	100	100
Mexican lime	5	100	100	100	100

[a] *Poncirus trifoliata* selections did not contain leaves at the time of the freeze.
[b] Segregating populations.

Table 2. Freeze injury to 12- to 18-month-old open-pollinated seedlings of citrus cultivars and related species in a lathhouse at Weslaco, Texas.

Cultivar or related specie	*No. of plants*	*Percent defoliation*	*Percent twig injury terminals*	*Percent plants dead to ground*
Poncirus trifoliata[a]:				
'Benecke'	20	0	0	0
'Winterhaven'	140	0	0	0
'Rich 12-2'	10	0	0	0
'Davis A'	10	0	0	0
'English large'	10	0	0	0
'Kryder 60-2'	10	0	0	0
'Kryder 5-5'	10	0	0	0
'Kryder 55-1'	10	0	0	0
'Rich 21-3'	10	0	0	0
'Benoit'	10	0	0	0
'Rich 16-6'	10	0	0	0
'Kryder 15-3'	10	0	0	0
'Davis B'	10	0	0	0
'Rich 7-5'	10	0	0	0
'Town G'	10	0	0	0
'Kryder 8-5'	10	0	0	0
'Kryder 28-3'	10	0	0	0
'Rich 12-2'	10	0	0	0
'Ronase'	10	0	0	0
'Argentina'	10	0	0	0
'Kryder 43-3'	10	0	0	0
'Rich 5-2'	10	0	0	0
'Town F'	10	0	0	0
'Kryder 25-4'	10	0	0	0
Citrumelo 4475	16	0	0	0
Citradia	15	0	0	0
Citrangequat 48011	15	10	0	0
Citrangeor	15	10	0	0
Calamondin	150	20	0	0
Morton citrange	120	95	0	0
Sacaton citrumelo	15	100	0	0
Sour orange	100	95	10	0
Mexican lime	20	100	100	100

[a] *Poncirus trifoliata* selections did not contain leaves at the time of the freeze.

Table. 3. Freeze injury to 24- to 28-month-old open-pollinated seedlings of citrus cultivars and related species in a nursery at Monte Alto, Texas.

Cultivar or related specie	*No. of plants*	*Percent defoliation*	*Percent twig injury*		*Percent plants dead to ground*
			terminals	*¼"-½"*	
Poncirus trifoliata[a]	50	0	0	0	0
Yuma citrange	50	100	0	0	0
Morton citrange	200	98	0	–	0
Shekwasha mandarin x *Poncirus trifoliata* hybrid 59-54	56	100	0	0	0
Norris orange x *Poncirus trifoliata* hybrid 7-20-12	55	0	0	0	0
Glen citrangedin	13	100	5	–	0
Carrizo citrange	58	100	10	–	0
King orange[b]	200	100	10	–	0
Rangpur mandarin-lime x *Poncirus trifoliata* hybrid 59-24	47	100	10	0	0
Jaffa orange x *Poncirus trifoliata* hybrid 7-19-9[b]	52	100	2	0	1
Leonardy grapefruit x *Poncirus trifoliata* hybrid 7-17-10[b]	20	100	25	–	0
Minneola tangelo x *Poncirus trifoliata* hybrid 7-18-9[b]	19	100	10	10	0
Pajarito tangelo	50	100	30	–	0
Siam shaddock[b]	100	100	30	–	0
Mott orange	75	98	50	–	0
Wheeny grapefruit[b]	60	98	50	0	0
Sanguine mandarin	100	100	60	–	0
Citrus taiwanica	95	100	50	0	0
Mandarinette[b]	250	100	80	–	0
Sour orange	700	100	100	62	50
Calamondin	40	100	100	100	100
Orlando tangelo	115	100	100	100	100
Red Blush grapefruit	500	100	100	100	100
Poorman's orange[b]	49	100	100	100	100
Precose de Valence orange	51	100	100	100	100
Orogold orange	43	100	100	100	100
Rangpur mandarin-lime	200	100	100	100	100
Aziza orange	41	100	100	100	100
Rough lemon	150	100	100	100	100
Mexican lime	250	100	100	100	100
Columbian sweet lime	200	100	100	100	100

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[a] *Poncirus trifoliata* did not contain leaves at the time of the freeze.

[b] Segregating populations.

Table 4. Freeze injury to 24- to 36-month-old open-pollinated and F[1] hybrid seedlings of citrus cultivars and related species in a nursery at Monte Alto, Texas.

Cultivar or related specie	*No. of plants*	*Percent defoliation*	*Percent twig injury*			*Percent plants dead to ground*
			terminals	*¼"-½"*	*½"-1"*	
Poncirus trifoliata[a]	3	0	0	0	0	0
Cleopatra mandarin x *Poncirus trifoliata* F1 hybrid	1	100	0	0	0	0
Shekwasha mandarin x *Poncirus trifoliata* F1 hybrids	3	100	0	0	0	0
Rangpur mandarin-lime x *Poncirus trifoliata* F1 hybrids	2	100	0	0	0	0
Sunki mandarin x *Poncirus trifoliata* hybrid 58-191	25	100	0	0	0	0
Rangpur mandarin-lime x Troyer citrange hybrid 58-148[b]	6	100	33	33	33	33
Pera orange	2	100	100	100	0	0
Frua mandarin	1	100	100	100	0	0
African shaddock x *Poncirus trifoliata* hyrid 58-172[b]	2	100	100	100	50	50
Sunki mandarin x Troyer citrange hybrid 58-193[b]	10	100	100	100	50	50
Rangpur mandarin-lime x Savage citrange hyrid 58-143[b]	10	100	100	100	66	66
Rangpur mandarin-lime x Carrizo citrange hybrid 58-144	3	100	100	100	100	100
Citrumelo 4481[b]	11	100	100	100	–	100
Ellendale mandarin	6	100	100	100	–	100
Citrus latipes	4	100	100	100	100	100
Nakon pummelo	10	100	100	100	100	100

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[a] *Poncirus trifoliata* did not contain leaves at the time of the freeze.

[b] Segregating populations.

Poncirus trifoliata seedlings, 24- to 36-month-old, were uninjured (Table 4.) A group of F^1 hybrids, with *P. trifoliata* as the pollen parent, were only defoliated. These included hybrids with Cleopatra mandarin, Shekwasha mandarin, Sunki mandarin, and Rangpur mandarin-lime as seed parents. Plants from the African shaddock x *P. trifoliata* cross were variously injured.

Plants from Rangpur mandarin-lime and Sunki mandarin x Troyer citrange crosses were variable in injury as were those from the Rangpur mandarin-lime x Savage citrange cross. Plants from the Rangpur mandarin-lime x Carrizo citrange cross, citrumelo 4481, Ellendale mandarin, *Citrus latipes,* and Nakon pummelo were severely injured.

These results indicated that seedlings of *Poncirus trifoliata,* some *P. trifoliata* hybrids, and some mandarin selections were more cold hardy than other citrus cultivar seedlings. Oranges, grapefruit, limes, and lemons were less cold hardy in that order. These results with young seedlings are similar to those reported for mature seedlings exposed to natural freezes and suggest that young seedlings may be screened for cold hardiness characteristics without waiting for them to mature.

SUMMARY

Seedlings of 102 different citrus cultivars and related species 9- to 36-month-old were exposed to a severe freeze in January 1962 in the Rio Grande Valley. *Poncirus trifoliata* seedlings were the most cold hardy followed with decreasing hardiness by *Poncirus trifoliata* hybrids, oranges, grapefruit, limes, and lemons. Mandarins were variable in hardiness. Some were as hardy as *P. trifoliata* hybrids, while others were only as hardy as the oranges. The relative cold hardiness behavior of 9- to 36-month-old citrus cultivar seedlings and related species was similar to those reported for mature seedlings.

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Freeze Injury to Citrus in the Rio Grande Valley in 1963 in Relation to 1951 and 1962 Freeze Injury[1]

Roger Young and Ascension Peynado[2]

Freeze injury to citrus from the January 1962 freeze was extensive and variable. Varietal differences ranged from loss of wood ½ to 4 inches in diameter (Young and Olson, 1963). Trees on different rootstocks varied greatly in injury (Young and Olson, 1963) as did trees of different ages and trees exposed to different temperatures (Young and Peynado, 1963).

Trees 15 years old and older, which were severely injured by the 1951 freeze, were severly injured again by the 1962 freeze (Young and Peynado, 1963). These observations suggested a relation between the severities of previous freeze injury and of freeze injury in a following freeze. Although this relationship has been expressed by growers. no published information related to this problem was found. Several freezes during the 1962-63 winter afforded an opportunity to observe the injury to citrus which had a previous freeze history.

This report relates freeze injury to citrus in the Rio Grande Valley in 1963 to 1951 and 1962 freeze injury.

METHODS AND MATERIALS

Plant materials. Trees surveyed in Monte Alto included Valencia oranges and Red Blush grapefruit in the following age categories: 3 to 4, 4 to 5, 6 to 7, 8 to 9, 12 to 15, and 30 years old. Valencia orange and and Red Blush grapefruit trees 5 to 6 and 12 to 15 years old were surveyed in Harlingen and trees 4 to 5, 12 to 15, and 30 years old were surveyed in the Mission-Pride O'Texas area. In Monte Alto 10 trees in each freeze-injury category were surveyed while in the Harlingen and Mission-Pride O'Texas areas 5 trees in each were surveyed. In most cases, freeze-injury categories within each age group were found in the same grove. However, in several instances it was necessary to obtain data from another grove in the same area.

Freeze-injury and recovery evaluations. Freeze-injury and recovery evaluations of 1962 and 1963 freeze injury were made between

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[1] The work was part of a cooperative project of the Agricultural Research Service U. S. Department of Agriculture, the Texas Agricultural Experiment Station, Weslaco, Texas, and Rio Farms, Inc., Monte Alto, Texas.

[2] Physiologist and chemist, respectively, U. S. Department of Agriculture, Crops Research Division, Agricultural Research Service, Weslaco, Texas.

March 1 and 20, 1963. Percent dead wood resulting from the 1962 freeze was estimated on ¼-, ½-, 1-, 2-, 3-, and 4-inch wood on each tree. From these data each tree was given a freeze-injury rating which indicated the size of wood (inches) to which half the branches were killed. Trunk bark-splitting was estimated on each tree as follows: 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; 5 = very severe. Each tree was also examined for the presence of a dead crotch, number of new main shoots regrown since the 1962 freeze, and general recovery.

Freeze-injury ratings following the 1963 freezes on each tree included percent defoliation, percnt ¼-, ½-, and 1-inch wood killed.

Freeze injury reported reflects only the status of the trees at the time of survey and does not indicate subsequent changes or the economic potential of the trees. Data presented represent various types of injury occurring in the age groups surveyed in each area of the Valley, but are not intended to suggest the severity of injury to trees in various locations in the Valley.

RESULTS AND DISCUSSION

Temperatures and tree and fruit injury during the 1962-63 winter. The 1962-63 winter period in the Rio Grande Valley was one of the coldest in many years, even though there were no extreme lows as in 1961-62. Average monthly maximum and minimum temperatures at Weslaco were 5 to 11 degrees cooler in December and February and 9 to 10 degrees cooler in January than for the 10-year average of 1948 to 1957 for the same months (Table 1). The cooler weather resulted from a series of arctic cold fronts which, after the middle of December, entered the Valley every 4 to 5 days. Subfreezing temperatures occurred at least 14 times, and injury to citrus occurred on 3 occasions: January 13, January 24, and February 11 to 13 (Table 2).

On January 13, minimum temperatures ranged from 25° to 30°F Valley-wide and caused slight leaf injury to citrus. This injury was hardly noticeable since many trees had been partially defoliated from severe mesophyll collapse and mite injury in late October.

Table 1. Average monthly maximum and minimum temperatures for November through February for 1948 to 1957 inclusive, and 1962-63 at Weslaco, Texas.

Month	*1948 to 1957*[a]		*1962-63*[b]	
	max.	*min.*	*max.*	*min.*
November	77	56	77	53
December	74	53	67	49
January	74	53	65	43
February	77	56	72	45

[a] Data obtained from U. S. Weather Bureau, Texas Agricultural Experiment Station, Weslaco, Texas.

[b] Data obtained from a weather station 5 miles north of Weslaco, Texas.

Table 2. Occurrence of subfreezing temperatures and injury to citrus during the winter of 1962-63 in a grove 5 miles north of Mercedes, Texas.

Date	*Minimum temperature*	*Injury observed on citrus*
January 12	30	No
13	27	Yes
19	30	No
20	28	No
21	30	No
23	28	No
24	23	Yes
27	30	No
February 3	32	No
4	32	No
5	32	No
11	26	Yes
12	26	Yes
13	27	Yes

Most freeze injury during the 1962-63 winter occurred as a result of the subfreezing temperatures on January 24. Temperatures Valley-wide ranged from minimums of 21° to 24°F in the citrus-growing areas with durations at the minimum temperatures up to approximately one hour. Injury occurred to the leaves, wood, and fruit and, in some cases, was severe enough to kill the entire tree.

Leaf, fruit, limb, and trunk temperatures were recorded during the January 24 freeze in a grapefruit grove 5 miles north of Mercedes. The minimum air temperature recorded was 23°F, but the following minimums were recorded in the tissues: fruit 23.5°F; leaf 22.7°; 1½-inch limb 24.5°; 2-inch limb 25.0°; 8-inch trunk 26.1°. On an adjacent tree the minimum temperature under the bark of a newly grown ¾-inch limb was 23.5°. Where temperatures were recorded injury was limited to the leaves and fruit. The trees lost some 1-inch wood in the 1962 freeze, and because of the excellent recovery after the 1962 freeze and the below-normal temperatures during December and January the trees were conditioned for the freezing temperatures of January 24, 1963. Other trees in the same area severely injured in 1962 showed severe injury to leaves and wood subsequently regrown. Valencia oranges and grapefruit were cut at 7 AM, January 24, and ice was found in the rind and segments of fruit of both varieties.

The minimum temperatures 30°F or below, and in some cases 26°, recorded between February 11 and 13 resulted in slight injury to citrus.

This injury occurred primarily on young, immature shoots ½ to 2 inches in length (Figure 1). Injury, noted throughout the Valley, was not extensive.

Freeze injury discussed herein is a summation of that occurring at various times during the 1962-63 winter. However, most injury occurred on January 24.

Relation between 1963 freeze injury and previous freeze injury. Freeze injury to different-aged Valencia orange and Red Blush grapefruit trees in Monte Alto is summarized in Tables 3 and 4. In most age groups, several 1962 freeze-injury categories are presented with accompanying recovery data and 1963 freeze-injury records. In every instance where 1962 freeze injury was more severe or recovery poorer the injury in 1963 was more severe. Leaf and wood injuries were apparent on trees of all ages, and generally more wood injury was apparent on trees 3 to 7 and 30 years old (Figures 2 to 4). Trees 3 to 7 and 30 years old were more severely injured in the 1962 freeze (Young and Peynado, 1963). Valencia orange and Red Blush grapefruit trees severely injured in both the 1951 and 1962 freezes were severely injured in 1963. These trees included those currently older than 15 years not banked in 1951. Trees currently 12 to 15 years old which were banked in 1951 regrew strong tops after the 1951 freeze, were moderately injured in 1962, and sustained slight injury in 1963. Grapefruit trees were generally injured more

Figure 1. Freeze injury to young shoots of Red Blush grapefruit on February 11 to 13, 1963.

Table 3. Freeze injury to different-aged Valencia orange trees in 1963 in relation to 1951 and 1962 freeze injury, Monte Alto area.

	1962 Freeze injury			*Recovery since 1962 freeze*		*1963 Freeze injury*			
Age	*wood injury*[a] *(inches)*	*bark splitting trunk*[b]	*% dead crotches*	*no. main shoots regrown*	*general recovery rating*	*% defol.*	*wood injury (%) 1/4"*	*1/2"*	*1"*
3 to 4	1.6	0.9	0	12.3	good	65	1	0	0
	3.9	1.1	100	5.5	fair	84	24	4	0
	3.9	2.5	100	2.3	poor	100	97	93	7
4 to 5	3.5	1.0	70	12.1	fair	56	0	0	0
	4.4	2.8	100	5.8	poor	92	18	5	0
6 to 7	1.9	0.0	0	21.5	good	60	0	0	0
	3.5	0.4	20	14.4	fair	80	4	2	0
	5.5	4.7	100	4.6	poor	85	34	0	0
8 to 9	0.4	0.0	0	30.0	good	45	0	0	0
	2.0	0.7	0	23.0	good	71	16	0	0
	5.0	3.0	80	10.9	poor	89	23	0	0
12 to 15[c]	1.5	0.0	0	30.0	good	43	6	0	0
	2.7	0.1	0	23.0	good	89	9	1	0
	5.1	1.6	80	11.6	poor-fair	100	31	12	1
30[c]	5.3	0.3	40	30.0	good	77	31	3	0

[a] Estimated wood diameter (inches) to which half the branches were killed.
[b] 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; 5 = very severe.
[c] Trees were 1 to 4 and 19 years old during the 1951 freeze and were killed to the banks or were severely injured in 1951.

Table 4. Freeze injury to different-aged Red Blush grapefruit trees in 1963 in relation to 1951 and 1962 freeze injury, Monte Alto area.

	1962 Freeze injury			Recovery since 1962 freeze		1963 Freeze injury			
							wood injury (%)		
Age	wood injury[a] (inches)	bark splitting trunk[b]	% dead crotches	no. main shoots regrown	general recovery rating	% defol.	1/4"	1/2"	1"
3 to 4	2.5	1.7	90	11.3	good	100	2	0	0
	4.0	1.9	100	5.9	fair	100	54	27	6
	3.8	2.5	100	2.8	poor	100	95	94	45
4 to 5	2.6	0.8	90	16.9	good	100	0	0	0
	3.8	2.4	100	7.8	poor-fair	100	51	0	0
6 to 7	1.0	0.0	0	30.0	good	63	0	0	0
	2.8	0.0	0	12.5	good	94	0	0	0
	5.5	2.6	100	9.3	good	100	57	7	0
	5.5	4.3	100	2.7	poor	100	94	84	52
8 to 9	0.5	0.0	0	30.0	good	58	0	0	0
	2.6	0.1	0	21.0	good	91	2	0	0
	3.8	1.4	80	10.2	fair	99	6	1	0
12 to 15[c]	0.9	0.9	0	30.0	good	64	0	0	0
	2.6	0.4	0	25.0	good	100	4	0	0
	5.3	4.2	100	8.6	fair	98	3	0	0
30[c]	6.5	0.2	60	15.7	fair	100	95	91	56

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; 5 = very severe.

[c] Trees were 1 to 4 and 19 years old during the 1951 freeze and were killed to the banks or severely injured in 1951.

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than Valencia orange trees. Similar observations were made on trees in several age groups in the Mission-Pride O'Texas and Harlingen areas (Tables 5 and 6). In some cases, trees which may have eventually regrown new tops were killed by severe 1963 freeze injury.

Fruit of Valencia orange and Red Blush grapefruit contained some freeze injury in March 1963, when the freeze-injury surveys were con-

Figure 2. Freeze injury in 1963 to Red Blush grapefruit trees.

(A) 4 years old with moderate 1962 injury.

(B) 4 years old with severe 1962 injury.

(C) 12 years old with slight 1962 injury.

(D) 12 years old with severe 1962 injury.

ducted. This injury appeared as partially dried segments. Most fruit had been harvested by the time of the January freezes, and it was difficult to estimate the severity of the fruit injury throughout the Valley.

From these data, it was apparent that 1963 freeze injury to citrus was variable and extensive throughout the Valley. Injury in 1963, for the most part, was related to 1951 and 1962 freeze injury. Trees injured

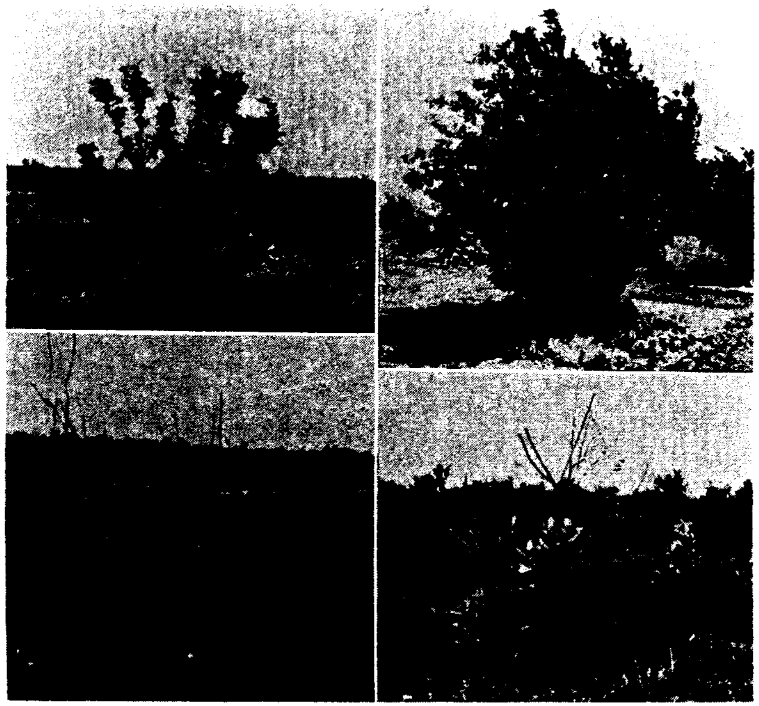

Figure 3. Freeze injury in 1963 to Valencia orange trees.

(A) 4 years old with moderate 1962 injury,

(B) 4 years old with severe 1962 injury,

(C) 12 years old with moderate 1962 injury,

(D) 12 years old with severe 1962 injury.

by previous freezes were more freeze-susceptible to the freezes which occurred in the 1962-63 winter. With below-normal temperatures during the 1962-63 winter, it is likely that had any trees been present which were not previously injured by freezes they would have been only slightly injured by the freezing temperatures experienced during the 1962-63 winter because of greater cool-temperature conditioning.

Figure 4. Freeze injury in 1963 to 30 year old Valencia orange trees,

(A) with moderate 1962 injury,

(B) severe 1962 injury, and 30 year old Red Blush grapefruit trees,

(C) with moderate 1962 injury,

(D) severe 1962 injury.

Table 5. Freeze injury to different-aged Valencia orange and Red Blush grapefruit trees in 1963 in relation to 1951 and 1962 freeze injury, Mission – Pride O'Texas area.

Age and variety	*1962 Freeze injury*			*Recovery since 1962 freeze*		*1963 Freeze injury*			
	wood injury[a] *(inches)*	*bark splitting trunk*[b]	*% dead crotches*	*no. main shoots regrown*	*general recovery rating*	*% defol.*	*wood injury (%)* *1/4"*	*1/2"*	*1"*
Valencia:									
4 to 5	4.0	2.2	100	7.6	good	5	0	0	0
	4.4	3.2	100	3.0	poor	36	6	0	0
	4.4	3.4	100	2.4	poor	100	96	94	0
12 to 15[d]	0.6	0.0	0	30.0	good	28	2	0	0
	1.6	0.0	0	30.0	good	47	16	0	0
	2.9	1.9	40	14.6	poor	84	33	2	0
30[d]	2.7	0.0	0	30.0	good	28	7	0	0
	5.2	1.9	60	17.0	poor	100	94	50	20
Red Blush:									
4 to 5	3.4	0.0	80	9.1	good	36	5	0	0
	3.5	0.0	100	5.6	fair	100	65	33	6
	3.5	0.0	100	6.0	poor	100	100	100	50
12 to 15[d]	0.4	0.0	0	30.0	good	44	27	2	0
	2.2	0.2	0	30.0	good	85	84	75	0
	2.9	1.0	20	15.2	poor	100	89	83	0
30[d]	2.5	0.0	0[c]	30.0	good	32	1	0	0
	3.9	0.4	0[c]	22.4	fair	98	35	0	0
	5.5	2.6	80	8.4	poor	100	97	91	–

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; 5 = very severe.

[c] Center portion of the crotch dead.

[d] Trees were 1 to 4 and 19 years old during the 1951 freeze and were killed to the banks or severely injured in 1951.

Table 6. Freeze injury to different-aged Valencia orange and Red Blush grapefruit trees in 1963 in relation to 1962 freeze injury, Harlingen area.

Age and variety	*1962 Freeze injury*			*Recovery since 1962 freeze*		*1963 Freeze injury*			
	wood injury[a] *(inches)*	*bark splitting trunk*[b]	*% dead crotches*	*no. main shoots regrown*	*general recovery rating*	*% defol.*	*wood injury (%)* *1/4"*	*1/2"*	*1"*
Valencia:									
5 to 6	2.9	1.6	20	19.0	good	73	0	0	0
	3.4	2.6	60	7.6	fair	98	9	0	0
	3.9	3.6	100	6.0	poor	98	71	50	0
12 to 15[c]	2.0	0.0	0	30.0	good	52	24	1	0
	2.9	0.0	0	17.0	poor	99	74	40	0
Red Blush:									
5 to 6	2.3	1.0	0	25.0	good	58	4	0	0
	1.9	1.9	60	12.4	fair	87	34	11	0
	5.3	3.8	100	3.4	poor	100	95	95	0
12 to 15[c]	0.5	0.0	0	30.0	good	83	0	0	0
	2.5	0.0	0	30.0	good	61	2	0	0
	3.3	0.4	0	17.0	poor	100	54	27	0

[a] Estimated wood diameter (inches) to which half the branches were killed.

[b] 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; 5 = very severe.

[c] Trees were 1 to 4 years old during the 1951 freeze and were killed to the banks in 1951.

SUMMARY

Citrus trees, after one year's recovery from the 1962 freeze, were subjected to subfreezing temperatures during the 1962-63 winter in the Rio Grande Valley. Variable and extensive injury was present on citrus Valley-wide. Trees most severely injured in 1951 and 1962 were most severely injured in 1963. Grapefruit trees were generally injured more than Valencia trees, and trees 3 to 7 and 30 years old were injured more than 8 to 15 year olds. Injury during the 1962-63 winter included leaves, fruit, and wood up to 1 inch in diameter.

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Cold Damage to Young Navel Orange Trees on Various Rootstocks in Freezes of 1962 and 1963 in the Winter Garden Area of Texas[1]

JOHN M. CREEL, JR. and E. O. OLSON[2]

Freezes limit citrus production in the Winter Garden area, about 200 miles north and west of the main Texas citrus area in the Lower Rio Grande Valley. Since 1930 when weather records began at Crystal City, minimum temperatures of 20°F. or less have been recorded in 8 years (Table 1). However, in only three years has the cold damage to citrus been disasterous. The first was in February 1951, when the temperature dropped to 12°F. Then on January 12, 1962 the temperature dropped to 11°, and was preceded by two days of continuous freezing weather. On January 24, 1963 the temperature dropped to 16°.

Table 1. Days with minimum temperatures of 20° F. or below at Substation #19, Crystal City.

Date	*Temperature (°F)*
February 8, 1933	18
January 22, 1935	19
January 19, 1940	19
January 30, 1949	17
January 31, 1949	19
February 1, 1951	19
February 2, 1951	12
February 3, 1951	15
December 12, 1957	20
January 10, 1962	18
January 11, 1962	20
January 12, 1962	11
January 13, 1962	17
January 24, 1963	16
January 25, 1963	19

Citrus trees in the Winter Garden area have been subjected to temperatures as low as 20° without serious defoliation or wood damage.

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[1] A portion of cooperative rootstock investigations of the Texas Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] Agronomist, Texas Agricultural Experiment Station, Crystal City, Texas and Pathologist, U. S. Department of Agriculture, Agricultural Research Service, Weslaco, Texas.

However, rootstock effects on cold hardiness were observed after the 1951 freeze with a minimum of 12°F. after 4 days of freezing temperatures Seventeen-year-old Hamlin orange trees on *Poncirus trifoliata* rootstock suffered less than those on Cunningham or Uvalde rootstock. Eighteen-year-old Hamlin trees on Changsha mandarin or Thomasville citrangequat rootstocks showed less damage than those on *P. trifoliata*. Likewise, freeze damage to 7-year-old navel orange trees varied with rootstocks (Mortensen, 1954).

Mortensen (1954) obtained his best yields from trees on Rusk, Carrizo and Uvalde citrange, Sacaton citrumelo and sour orange rootstocks, and found that Washington navel oranges were especially productive on *P. trifoliata* rootstock. Cleopatra mandarin rootstock was not included in these trials.

METHODS

In order to make further rootstock investigations, Washington navel orange trees on 28 rootstocks were set out in 1952 at Crystal City, Texas. Trees on each rootstock were planted in 2-tree plots replicated 5 times. However, many trees died in the first three years and these were replaced with trees on other rootstocks. By January 1962, trees on 29 rootstocks remained in the test. All but 4 rootstocks were in the initial planting. Trees on Shekwasha, Sunki and Kunembo mandarin and *Citrus taiwanica* rootstocks were set out as replacements for missing trees in January 1956.

Fruit was harvested in 1960 and 1961. Each tree's fruit was harvested separately and the yield recorded (Table 2). Some fruit was harvested in 1959, but yields were not recorded.

Damage from the January 1962 freeze was evaluated in April 1962 (Table 2). The damage was recorded as per cent of the top killed. Damage of 10% signified that the tips of the small twigs were killed; 90% damage indicated that the main limbs were killed back to within a foot of the main trunk.

Following the January 1963 freeze, the trees were evaluated in May when sprouting on green wood made possible clear-cut distinction between living and dead wood. Trees were placed in one of four categories: dead, poor, fair, or good. Dead trees included dead trees and unsalvageable trees with some sprouting on main trunk, which had severe bark injury to at least one side. Poor trees produced some sprouts in the crotch area, which had sound bark on the trunk. Trees given a rating of fair varied considerably. Some had suffered severe damage in 1962, but the regrowth was not killed in 1963; other trees were not damaged as severely in 1962, but lost more old wood in 1963. Trees in the good category were not damaged severely by either freeze. These trees retained a high percentage of top growth through the 1962 freeze and lost little or no wood in 1963.

Trunk measurements were made in the summer of 1962 (Table 2).

Table 2. Size, yield, and cold hardiness of Washington Navel trees on various rootstocks.

Rootstock group and variety	*Planting date*	*Trees in trial (No.)*	*Tree trunk diameter (Inches)*	*Fruit produced in 2 years (Boxes)*	*Damage from 2 freezes* Jan. 1962 (% top dead)	*Damage from 2 freezes* Jan. 1963 (% dead and poor trees)
Mandarins:						
Calamondin	1952	7	6.7	3.6	52	48
Calashu	1952	7	6.3	5.5	64	29
Cleopatra	1952	7	5.9	4.7	45	14
Kunembo	1956	10	4.2	1.2	83	90
Shekwasha	1956	10	3.7	0.5	95	90
Sunki	1956	9	4.6	2.9	84	78
C. Taiwanica	1956	8	4.6	0.7	75	50
Trifoliate hybrids:						
Cunningham citrange	1952	7	6.9	5.2	90	100
Morton citrange	1952	10	7.8	5.1	61	40
Norton citrange	1952	9	7.1	3.7	90	100
Rustic citrange	1952	10	6.9	5.2	86	90
Savage citrange	1952	9	6.1	4.9	87	100
Troyer citrange	1952	7	6.6	5.6	79	86
Citrangequat 48032	1952	9	5.8	3.9	78	78
Thomasville citrangequat	1952	5	5.6	3.9	47	20
Citranguma	1952	8	6.6	2.9	88	87
Citrumelo	1952	5	6.0	3.1	87	80
Tangelos:						
Minneola	1952	9	7.0	4.1	59	44
Sampson	1952	8	7.9	5.3	53	37
San Jacinto	1952	10	5.2	3.5	88	80
Seminole	1952	6	7.7	6.7	57	33
Webber	1952	7	6.6	4.4	56	29
Miscellaneous:						
Palestine sweet lime	1952	10	7.1	6.3	49	60
Rangpur mandarin lime	1952	6	6.1	5.7	45	57
Florida sweet orange	1952	10	7.7	6.2	63	40
Koethen sweet orange	1952	7	7.4	5.1	62	29
La. sweet orange	1952	8	8.3	4.2	73	87
Sour orange	1952	8	6.6	5.0	58	37
Rough lemon	1952	4	5.3	8.0	40	50

The diameter of the trunk was measured with a shop-made caliper. Measurements were made at a point 8 inches above the bud union at a prepainted circle.

RESULTS

Yields varied greatly from tree to tree on the same rootstock. Two years of yield data are inadequate to evaluate the performance of any rootstock. The highest yield for the 2 years, 1960 and 1961, was produced on trees growing on Rough lemon rootstock. However, only 4 of the original 10 trees on Rough lemon remained (Table 2). Rough lemon was followed in yield by Seminole tangelo, Palestine sweet lime and Florida sweet orange. Trees on mandarin rootstock produced only average yields of fruit. Trees on citrange rootstocks produced average yields and none were outstanding. Trees on Troyer, Cunningham and Norton citrange rootstocks produced the highest yields of those on citrange or other *P. trifoliata*-hybrid rootstocks.

Washington navel trees on Cleopatra rootstock were outstanding in cold tolerance (Table 2). Only one tree died from cold damage and none were in poor condition. When the number of trees in dead or poor condition were compared to those in fair and good condition, trees on Cleopatra mandarin rootstock survived the 2 freezes the best. Of the trees on Cleopatra mandarin rootstock, 86% were in fair or good condition, 5 of 7 remaining in good condition. Trees on Thomasville citrangequat rootstock exhibited better cold tolerance than those on other *P. trifoliata*-hybrid rootstocks. As a group, trees on citrange rootstocks were heavily damaged. All trees on Savage, Norton, and Cunningham citrange rootstocks died or were unsalvageable.

In an area such as the Winter Garden of Texas where damaging freezes occur, tree survival after freezes is extremely important. On the basis of tree survival and condition of Washington navel trees following 2 years with severe freezes, Cleopatra mandarin rootstock may have advantages for new plantings in the Winter Garden area. Other rootstocks such as Thomasville citrangequat are potentially useful, but compared to Cleopatra mandarin, less is known about them in commercial citrus areas. Effects of various rootstocks on yield and cold hardiness in the Winter Garden have been studied (Mortensen, 1954), but only nursery trees on Cleopatra mandarin rootstock were compared in Mortensen's report. Mortensen (1954) noted that nursery trees of Washington navel on *P. trifoliata* and mandarin rootstocks had good survival from the 1951 freeze in the Winter Garden area.

The general effect of rootstock varieties on cold hardiness of tops in the Winter Garden during 1962 and 1963 winters was similar to that occurring in the Lower Rio Grande Valley of Texas (Young and Olson, 1963). Trees on Cleopatra mandarin rootstock had superior cold hardiness in the Winter Garden area, where water salinity is not a problem, and in the Lower Rio Grande Valley, where it is. This fact is evidence that the superior cold tolerance of trees on Cleopatra mandarin rootstock in this instance cannot be attributed to the salt tolerance of trees on Cleopatra mandarin rootstocks.

SUMMARY

Washington navel orange trees on 29 rootstocks planted in 1952 and 1956 were exposed to severe freezes in 1962 and 1963. Trees on Cleopatra mandarin rootstock were outstanding in their cold tolerance. Trees on citrange rootstocks were heavily damaged, and those on Thomasville citrangequat had greater cold tolerance than those on other *Poncirus-trifoliata*-hybrid rootstocks.

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Toxicity of Three Salts to Greenhouse-Grown Grapefruit Trees and Their Effects on Ion Accumulation and Cold Hardiness

Ascension Peynado and Roger H. Young[1]

Water of high salt content is injurious to citrus and induced toxic effects due to excessive accumulation of specific salt constituents such as sodium and chloride (Cooper and Edwards, 1950; Cooper et al., 1952). Salt-toxicity symptoms were associated with accumulation of sodium in the leaves (Martin et al., 1953).

The present paper presents data on the toxicity of three salts to greenhouse-grown grapefruit trees and their effects on ion accumulation and cold hardiness.

METHODS AND MATERIALS

One-year-old nucellar Red Blush grapefruit trees on sour orange rootstock were potted in 5-gallon glazed-clay crocks; 16 trees were bare-rooted and potted in washed coarse masonry sand and 16 trees were potted undisturbed in sandy loam. Trees were put in the greenhouse and irrigated with standard nutrient solution or rain water until the trees were established and a healthy mature flush developed on all plants.

The trees were set 3 ft. apart, alternating sand and loam crocks, and and treatments arranged in a Latin square. Eight trees (4 in sand and 4 in loam) were watered with each differential treatment. The four differential treatments were A, rain water; B, 4,000 ppm NaCl (1,572 ppm Na; 2,430 ppm Cl); C, 4,860 ppm Na_2SO_4 (1,572 ppm Na; 3,290 ppm SO_4); D, 3,810 ppm $CaCl_2$ (1,372 ppm Ca; 2,430 ppm Cl). Sodium in the Na_2SO_4 treatment and Cl in the $CaCl_2$ treatment were equal to the NaCl treatment. Thus, the concentration of treatments C and D varied from 4,000 ppm to produce sodium and chloride ions equal to the concentration of NaCl in treatment B.

The trees were watered twice a week with 3 liters of respective salt solutions. Every 2 weeks, for the first 12 weeks' treatment, a modified Hoagland's nutrient solution was substituted for one of the two weekly salt treatments. This solution contained nitrogen, 168 ppm as NO_3 and 14 ppm as NH_4; calcium 200 ppm; potassium 78 ppm; phosphorus 31 ppm; magnesium 48 ppm; boron 0.1 ppm; manganese 0.5 ppm; zinc .05 ppm; copper .02 ppm, molybdenum .01 ppm; and iron 5 ppm from chelate 138. For the remaining 8 weeks rain water was used every two weeks.

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The tree trunks were of 4.5- to 5-cm circumference at a mark 4 inches above the bud union when treatments were started on May 5, 1961. The treatments continued during the summer for 20 weeks. Temperatures in the greenhouse varied from 70 to 95°F during this period.

Two samples of (a) 20 mature leaves and (b) 15 terminal leaves, varying from tender to nearly mature, were taken from each tree after 11 weeks' treatment. This sampling preceded defoliation. Leaves were analyzed for boron (carmine method, Hatcher and Wilcox, 1950), chloride (Volhard method; A.O.A.C., 1945), sulfate (turbidimetric; Rasmussen and Smith, 1957), sodium and potassium (flame photometer), calcium + magnesium (versenate titration), magnesium (colorimetric, Smith, 1944). Calcium was calculated by difference between the versenate titration and the magnesium determination.

After 18 weeks of treatment the trees were given a 2-week hardening period in a growth chamber, equipped with 1,000 ft.-candles fluorescent and incandescent light at plant level. The growth chamber provided 60°F day and 40° night temperatures.

The test trees plus 4 unhardened control trees grown continuously in the greenhouse were tested for cold hardiness in the freezing chamber. The trees were exposed to 22°F for 4 hours, and temperatures were lowered from and raised to the 35° starting point at a rate of 2° per hour. The foliage was observed monthly for salt injury and after the freezing period for freeze injury. Circumference of tree trunks was measured at a mark 4 inches above the bud union at the begnning of salt treatments and just before the freeze test.

RESULTS AND DISCUSSION

Cooper et al. (1951) indicated that the usual symptoms of excess salt on citrus were bronzing and necrosis of the foliage and defoliation; however, iron-deficiency chlorosis may also be associated with high soil salinity (Cooper and Peynado, 1959). Bronzing as used in the present report refers to salt-induced bronzing, not to magnesium deficiency. Likewise, the chlorosis, which appears similar to iron-deficiency chlorosis, is salt-induced chlorosis. In this test the chlorotic patterns persisted regardless of iron present as chelate 138 HFe in the nutrient solution.

Plants were rated for bronzing and chlorosis (Table 1). Five weeks after treatment started, moderate bronzing appeared in the mature leaves on trees exposed to the $CaCl_2$ and NaCl treatments in loam and a trace of bronzing developed in plants exposed to the same two treatments in sand. New growth in the NaCl treatments showed more bronzing in both loam and sand cultures than did new growth exposed to other treatments.

Chlorosis of the new foliage of salted trees appeared after 9½ weeks' treatment and was rated in the order $CaCl_2 > Na_2SO_4 > NaCl$ in both sand and loam cultures. Bronzing was rated $CaCl_2 > NaCl > Na_2SO_4$ in the mature leaves. After 17 weeks' treatment, when all foliage was nearly mature, bronzing was severe and

Table 1. Toxicity ratings, growth and mineral uptake of nucellar Red Blush grapefruit trees on sour orange rootstock, planted in loam and in sand and treated with 3 salt solutions in the greenhouse.

	Loam treatment[1]				Sand treatment[1]			
Toxicity symptons and mineral analysis after indicated times	*rain water*	*NaCl*	*Na_2SO_4*	*$CaCl_2$*	*rain water*	*NaCl*	*Na_2SO_4*	*$CaCl_2$*
5 weeks:								
Bronzing rating[2]								
Mature leaves	0.2	2.5	0.8	2.6	0.0	1.1	0.0	0.8
Immature terminal leaves	0.0	1.0	0.5	0.5	0.0	2.5	1.0	1.3
11 weeks:								
Bronzing rating[2]								
Mature leaves	0.5	3.0	1.8	4.2	0.0	2.0	1.0	3.0
Immature terminal leaves	0.0	3.0	1.0	1.8	0.0	3.0	2.0	3.0
Chlorotic new growth[2]	0.0	1.0	1.8	2.0	0.0	1.0	1.8	2.0
17 weeks:								
Bronzing rating of entire tree[2]	0.0	3.5	2.0	4.8	0.0	3.5	2.8	3.5
No. of plants defoliating	0	3	0	4	0	2	0	3
No. of plants with twig die-back	0	1	0	4	0	0	0	0
20 weeks:								
Total growth increase (cm^2)[3]:	1.54	0.89	0.93	1.29	1.73	1.19	1.23	1.24
11 weeks:								
Chloride (%)[4]:								
Mature leaves	0.06	1.96	0.04	2.66	0.02	1.66	0.02	2.68
Immature terminal leaves	0.04	3.15	0.02	5.13	0.05	2.77	0.02	3.23
Sulfate (%):								
Mature leaves	0.97	0.64	2.18	0.77	0.70	0.67	1.82	0.48
Immature terminal leaves	0.58	0.31	1.75	0.32	0.73	0.31	1.63	0.34

Table 1. Continued

	Loam treatment[1]				Sand treatment[1]			
Toxicity symptons and mineral analysis after indicated times	*rain water*	*NaCl*	*Na_2SO_4*	*$CaCl_2$*	*rain water*	*NaCl*	*Na_2SO_4*	*$CaCl_2$*
Boron (ppm):								
Mature leaves	326	304	323	305	118	174	174	146
Immature terminal leaves	187	154	207	126	103	68	96	98
Sodium (%):								
Mature leaves	0.13	0.66	0.39	0.14	0.10	0.99	0.75	0.12
Immature terminal leaves	0.11	1.18	0.45	0.08	0.13	1.93	1.04	0.08
Potassium (%):								
Mature leaves	1.55	1.72	1.82	1.48	1.31	1.04	1.26	1.02
Immature terminal leaves	1.36	1.61	1.60	1.50	1.18	1.23	1.35	1.28
Calcium (%):								
Mature leaves	3.62	3.52	3.32	4.65	3.42	4.07	4.22	4.64
Immature terminal leaves	2.35	2.12	1.78	4.74	3.21	1.57	1.61	3.79
Magnesium (%):								
Mature leaves	0.32	0.34	0.32	0.36	0.39	0.39	0.36	0.30
Immature terminal leaves	0.24	0.25	0.28	0.18	0.36	0.22	0.25	0.16

[1] Treatments were rain water; 4,000 ppm NaCl; 4,860 ppm Na_2SO_4, 3,810 ppm $CaCl_2$.

[2] Rating of visual observations of toxicities were 1, trace; 2, slight; 3, moderate; 4, heavy; 5, severe.

[3] Total growth of the trees reported is the increase in area of cross section of the trunk at a mark 4 inches above the bud union.

[4] % of dried leaf.

in the order $CaCl_2 > NaCl > Na_2SO_4$ in both loam and sand cultures. On trees exposed to $CaCl_2$ and NaCl treatments, defoliation and twig die-back accompanied bronzing when the trees were grown in loam; only defoliation occurred when they were grown in sand. There was no defoliation or twig die-back in loam or sand cultures with the Na_2SO_4 treatment.

While trees in sand, both salted and controls, grew more than trees in loam (Table 1), growth was retarded by the salt treatments. NaCl and Na_2SO_4 additions to the loam depressed growth more than $CaCl_2$ additions.

The leaves of all trees were sampled for chemical analysis at the time the trees were rated for bronzing and chlorosis after 11 weeks' treatment (Table 1). More chloride accumulated in the mature and immature leaves of trees treated with $CaCl_2$ and less sodium accumulated in foliage of trees treated with Na_2SO_4 than in those treated with NaCl. Terminal immature leaves contained more chloride than mature ones. Terminal immature leaves of the NaCl treatment contained more sodium than leaves from trees treated with Na_2SO_4. Bronzing was associated with chloride accumulation in the leaves and chlorosis was associated with both chloride and sodium in the leaves, especially so with chloride.

The amount of sodium in the leaves of trees in loam treated with Na_2SO_4 and NaCl was ½ to ¾ that of the identical treatment in sand. Either the sodium stayed in the roots (Cooper et al., 1958) or was bound by the exchange complex of the soil.

Foliage of trees treated with Na_2SO_4 contained more sulfates, while NaCl and $CaCl_2$ treatments slightly depressed sulfate accumulation (Table 1). Boron was higher in the foliage of trees grown in loam, but exceptionally lower in the immature leaves of trees under salt treatment and grown in sand. Potassium was also lower in the foliage of trees grown in sand and at a deficiency level in the mature leaves of trees treated with NaCl and $CaCl_2$ and grown in sand. Calcium was higher in foliage of trees treated with $CaCl_2$ and lower in the immature leaves of trees treated with NaCl and Na_2SO_4. Magnesium in the foliage was at a deficiency level in trees treated with $CaCl_2$ and grown in loam or sand.

After hard freezes in the Rio Grande Valley trees in saline areas show more freeze damage than trees adjacent to the saline area. In this test the different salt treatments affected the degree of freeze injury sustained by the trees (Table 2). The salts seemed to reduce the ability of the trees to condition to cold temperatures. Some defoliation even occurred on the trees under salt treatment when they were exposed to 60°F days and 40°F nights in a growth chamber.

Freeze injury sustained by the trees was more severe on unhardened trees and trees treated with $CaCl_2$. Less injury occurred on trees treated with NaCl and Na_2SO_4. Untreated trees showed the least injury. Freeze injury to the unhardened control and to trees treated with $CaCl_2$ was so

Table 2. Freeze injury of 1-year-old nucellar Red Blush grapefruit trees on sour orange rootstock after 20 weeks of salt treatment, hardened for 2 weeks at 60°F day and 40° night, and given a freeze test of 4 hr. at 22°.

Treatment preceding exposure to freeze		*% leaf injury*	*% twig injury*	*Size of other wood injured*
Loam cultures:				
Treatment: [1]	rain water	52	10	1/4-in. shoots trace
	NaCl	100	75	1/2-in. wood
	Na_2SO_4	90	26	None
	$CaCl_2$	100	100	5/8-to 3/4-in. main trunk
Sand cultures:				
Treatment:	rain water	72	20	1/4-in. shoots trace
	NaCl	82	40	None
	Na_2SO_4	96	10	None
	$CaCl_2$	100	100	5/8-to 3/4-in. main trunk
Loam cultures:	rain water[2] unhardened	100	100	3/4-in. main trunk to bud union

[1] Treatments were rain water control; 4,000 ppm NaCl; 4,860 ppm Na_2SO_4; 3,810 ppm $CaCl_2$.

[2] Unhardened trees watered with rain water had been in the 75-85°F greenhouse and had not been given the 60-40°F 2-week hardening period before the freezing test.

severe that leaves did not defoliate but hung on the twigs (Fig. 1.) In all cases the salt treatments reduced the cold hardiness of the trees. The trees treated with $CaCl_2$ and NaCl sustained more severe injury than the ones treated with Na_2SO_4, and the trees treated with $CaCl_2$ behaved like the unhardened ones.

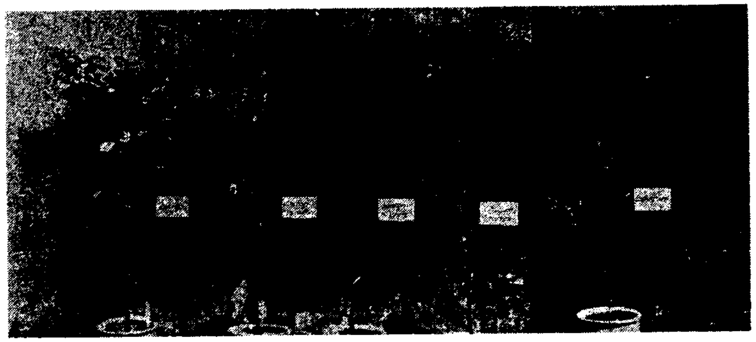

Figure 1. One-year-old nucellar Red Blush grapefruit trees on sour orange rootstock 2 weeks after freezing test of 22°F for 4 hours. The trees had been under salt treatment for 20 weeks and, except for the unhardened control tree at far right, hardened for 2 weeks at 60°F day and 40°F night prior to freezing.

SUMMARY

One-year-old nucellar Red Blush grapefruit trees on sour orange rootstock, planted in loam and sand cultures, were watered with rain water and 3 salt solutions, 4,000 ppm NaCl, 4,860 ppm Na_2SO_4, and 3,810 ppm $CaCl_2$, for 20 weeks. Following the salt treatments, the trees were given a 2-week cool-temperature conditioning period and tested for cold hardiness.

Chlorosis, which appeared similar to iron-deficiency, first appeared after 9½ weeks on all salt treatments and after 11 weeks chlorosis was rated in the order $CaCl_2 > Na_2SO_4 > NaCl$.

In nearly all instances, salt-induced bronzing was greater in the terminal immature leaves in the $NaCl > CaCl_2 > Na_2SO_4$ treatments. After 17 weeks' treatment bronzing on the entire tree was greater and in the order $CaCl_2 > NaCl > Na_2SO_4$ in both loam and sand cultures.

More chloride accumulated in the leaves of trees watered with $CaCl_2$ solution (much greater in the terminal immature leaves) and less sodium accumulated in the leaves of trees watered with Na_2SO_4 solution, compared to those watered with NaCl solution.

Bronzing was associated with chloride accumulation in the leaves and chlorosis was associated with both chloride and sodium, especially so with chloride.

Tree growth was retarded by all salt treatments, and trees in sand cultures, both salted and control, generally grew more than the trees in loam.

Boron was exceptionally low in the immature leaves of trees in all salt treatments in sand cultures; potassium and magnesium were at deficiency levels in some instances.

Different salts affected the trees' ability to condition to cold temperatures. Severity of freeze injury was in the order $CaCl_2 > NaCl > Na_2SO_4 >$ control; trees treated with $CaCl_2$ and unhardened trees were killed to the bud union.

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Influence of Timing of Fertilizer Applications on Yield, Quality, and Cold Hardiness of Red Grapefruit in the Rio Grande Valley of Texas

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After the severe freeze of 1951, it seemed important to determine the influence of micro-nutrients and the timing of nitrogen applications on the cold hardiness of Texas red grapefruit trees. Any deficiency is likely to predispose citrus trees to cold injury (Lawless and Camp, 1940). In Florida, use of minor elements, in addition to nitrogen, phosphorus and potassium minimized the effects of low temperatures; whereas a deficiency of one or more of these elements intensified the damage from low temperatures (Lawless, 1941.)

A series of treatments combining nitrogen, phosphate, potash, magnesium, zinc and manganese were included in the present test at Monte Alto, Texas. The test trees were eleven-year-old Red Blush grapefruit budded on sour orange rootstock. Since the trees were frozen to the soil banks in 1949 and again in 1951, the tops were four years old in 1955 when the test started. In 1955 the orchard was in a permanent sod culture but the sod was removed about two years later. Red grapefruit responded to added nitrogen under sod culture (Maxwell and Dacus, 1958).

Ammonium nitrate, muriate of potash and magnesium sulphate was broadcast by hand around the drip of the tree from two feet beyond the drip to two feet from the trunk. Treble super-phosphate was put into a trench about four inches deep on two sides of the tree. After placement of the fertilizer, the trenches were covered with soil. An application of zinc sulphate and manganese sulphate was sprayed on the trees in February or March.

RESULTS AND DISCUSSION

The data from 1957 through 1960 on yield of fruit by tons per acre are given in Table 1. The variability in yield in 1957 can be attributed to damage suffered from mesophyll collapse in the winter of 1956 which affected the bloom and fruit set for the 1957 season. In the winter of 1957-58, a light freeze also caused a variation in fruit set on the plots. The 1959 and 1960 seasons were normal and generally free from severe climatic stresses. In 1959 and 1960, there were no outstanding yield differences between treatments. The check trees on plots without added nitrogen since 1955 yielded as much fruit as trees on plots receiving three pounds of elemental nitrogen per tree. Phosphate, potash, magnesium, zinc and manganese additions did not affect yield.

After the January 1962 freeze, freeze damage to individual trees was evaluated to determine whether the application of micro or macronutrients and timing of nitrogen affected cold hardiness. The cold hardiness of the trees was not affected by application of various elements or timing of the nitrogen treatments. (Table 1).

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[1] Horticulturist, Texas Agricultural Experiment Station, Weslaco, and Head, Citrus Production Dept., Rio Farms Inc., Edcouch, Texas. W. C. Cooper, U. S. Dept. of Agriculture, Orlando Florida, assisted in planning the experiment.

Table 1. Effect of fertilizer additions on yield and cold hardiness of Red Grapefruit at Monte Alto, Texas.

	Fertilizer treatments at indicated times of year					*Yield of Grapefruit (Tons per acre)*					
Treat No.	*N 3 lbs.*	*P_2O_5 5 lbs.*	*K_2O 3 lbs.*	*MgO 4 lbs.*	*ZN SO_4+ Mn SO_4 Spray*	*57*[a]	*58*[b]	*59*	*60*	*4-Year Average (Tons per acre)*	*Freeze damage index*[c]
1	0					3.4	10.0	16.6	16.3	11.6	3.6
2	Jan. Sept.					4.0	9.1	16.9	14.8	11.2	3.4
3	Jan. May Sept.					4.6	7.7	16.7	14.8	10.9	3.7
4	Jan. May Nov.					3.6	8.3	15.5	17.9	11.3	3.9
5	Nov.					6.5	9.3	15.9	14.4	11.5	3.6
6	Jan. Sept.			Jan.		5.2	8.0	15.9	15.1	11.0	3.7
7	Jan. Sept.			Jan.	March or April	5.9	9.4	15.8	15.5	11.6	4.1
8	Jan. Sept.	Jan.	Jan.	Jan.	March or April	6.9	9.7	16.6	15.1	12.0	4.0

[a] Trees injured by mesophyll collapse in Nov. 1956 caused erratic bloom and fruit set.

[b] Light freeze in winter of 1957 caused sufficient damage to make a light bloom and fruit set on part of the trees.

[c] Index values for estimating cold damage.
1. Small wood frozen, up to 1" diameter
2. Wood frozen up to 2" diameter
3. Wood frozen up to 3"-4" diameter
4. Wood frozen up to 5" diameter (dehorn)
5. Tree frozen to crotch
6. Tree dead

CONCLUSIONS

The following conclusions were derived from this test.

1. When using sod culture, extra nitrogen must be applied to the trees to compensate for nitrogen needs of the sod or fruit yields will be reduced. (Maxwell and Dacus, 1958).
2. Climatic factors and not soil fertility is one of the major causes of differences in fruit yield in the Rio Grande Valley from season to season.
3. In this test, nitrogen applications at various times of the year did not influence the total fruit yield.
4. No increases in yield or in fruit quality were obtained from using phosphate and potash.
5. Cold hardiness was not influenced in this test by either timing of applications of nitrogen or by addition of minor elements.

From these results and those obtained from other fertilizer tests in several areas of the Valley, nitrogen is the only macro-nutrient needed in most Valley citrus groves. The present experiment also showed that some Valley groves do not need nitrogen every year. However, most citrus growers should plan to use nitrogen each year as a part of their care program, since it is not always feasible to determine which groves need no nitrogen.

Leaf analyses probably is the most feasible way to determine nitrogen status of the tree. However, such test methods are not available to every grower, and necessary background research information on relation of leaf status to yield in Texas is inadequate.

The trees in the present test apparently were not suffering nitrogen deficiencies and added fertilizer did not influence cold hardiness. Thus, these results are in agreement with Smith and Rasmussen's (1958) observation that nutrient status of the tree above deficiency levels had but slight effect on cold tolerance.

Reuther and Smith (1954) found that in Florida on orange trees, neither the time of application nor the number of applications of a given adequate annual rate of nitrogen fertilization profoundly affects yield or tree vigor.

Another publication from Florida by Reuther, Smith, Scudder, and Hrnciar (1957) states that on Valencia oranges in Florida the effects of nitrogen timing, rate, and ratio treatments were strongly conditioned by season, but no predictable influence large enough to be of appreciable economic significance in commercial orchards was noted.

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Chemical Composition of Grapefruit Leaf Tissue as Influenced by Rootstock, Variety, Cultural Practice, Fertilizer, and Season[1]

R. F. LEYDEN[2]

Plant tissue analysis is well established as a research tool for many crops (Goodall and Gregory, 1947; Ulrich, 1948). It has been used in the investigation of the accumulation of salts in citrus trees in Texas (Cooper, 1962). The technique is also applied as a guide to the nutritional status of commercial plantings of specific crops (Clements, 1961; De Villers and Beyers, 1961; Walker et al., 1950). Before such use can be made, a background of research information as to the plant part to be sampled, time and method of sampling, analytical methods, and reference levels must be developed.

For tissue analysis of citrus 4- to 10-month-old leaves from the spring cycle of growth are recommended (Chapman and Brown, 1950; Reuther and Smith, 1954). Leaves from nonfruiting terminals are preferred (Harding et al., 1962). Date of sampling influences the results (Jones and Parker, 1950; Reitz and Long, 1952). There is a high degree of similarity in reference levels arrived at in different climatic regions of the world (Smith, 1962).

Reports on tissue analysis of grapefruit are not as common as on oranges. Since grapefruit is the major citrus crop in the Lower Rio Grande Valley of Texas, the work reported herein was undertaken to determine the influence of rootstock, variety, cultural practice, fertilizer, and season on the chemical composition of grapefruit leaf tissue.

MATERIALS AND METHODS

Trees grown in experimental blocks, on Victoria clay loam soil, at the Texas College of Arts and Industries Citrus Center near Weslaco were the source of leaf tissue. A variety block, set out in 1953, included trees of Webb Redblush, Foster Pink, and Marsh White grapefruit on sour orange and Cleopatra mandarin rootstock. Trees of Webb Redblush were grown on both rootstocks under 3 cultural systems: sod culture, clean cultivation, and chemical weed control with no tillage. Other Webb Redblush trees, on both rootstocks, were grown under various levels of nitrogen and phosphate, supplied as ammonium nitrate and 45% superphosphate.

Leaf samples were taken on a monthly basis from January 1959 through December 1961. Individual samples consisted of 20 leaves, 3 to 6 months of age, from nonfruiting terminals on each of 2 trees in a plot. Leaves were taken from all sides of the tree between 2 and 7 feet above the ground. Sampling was confined to the hours between 7 and 10 A.M. As soon after collecting as possible, leaves were rinsed in tap water plus detergent, then in 4 portions of distilled water, dried at 60 degrees C under forced draft, and ground in a Wiley mill to pass a 40-mesh screen.

Before taking sub-samples for chemical analysis the tissue was placed in an oven at 60 degrees C overnight. Nitrogen was determined by the Kjeldahl method. A nitricperchloric acid digestion provided material suitable for the determination of calcium, magnesium, phosphorus, potassium, and sodium. Calcium and magnesium were determined by an EDTA titration, phosphorus by the molybdophosphoric blue color method, potassium and sodium with a flame spectrophotometer.

RESULTS AND DISCUSSION

Rootstock: Table 1 presents the percent N, P, K, Mg, Ca, and Na in leaf tissue from 3 grapefruit varieties on 2 rootstocks, averaged for the September samplings 1959, 1960, and 1961. Significant differences between rootstocks were found with K and Mg each year. Leaves from trees on sour orange rootstock had K values significantly higher than did leaves from trees on Cleopatra mandarin rootstock. Leaves from trees on Cleopatra rootstock had significantly higher Mg values than did leaves from trees on sour. These differences were typical of all comparisons of the 2 rootstocks.

There were no significant differences between rootstocks with regard to the other elements considered.

Variety: There were no significant differences between varieties with respect to the elements considered (Table 1).

Cultural practice: Table 2 presents data averaged for the September

Table 1. The influence of variety and rootstock on the chemical composition of grapefruit leaf tissue, average of September sampling 1959, 1960, and 1961.

Variety	*Rootstock*	*N*	*P*	*K*	*Mg*	*Ca*	*Na*
				percent	*dry matter*		
Duncan	sour	2.36	0.12	1.14	0.40	4.83	0.07
	Cleo.	2.37	0.12	0.81	0.50	5.01	0.08
Foster	sour	2.35	0.12	1.08	0.44	5.25	0.05
	Cleo.	2.31	0.11	0.75	0.61	5.04	0.05
Webb	sour	2.38	0.12	1.11	0.39	5.15	0.05
	Cleo.	2.36	0.11	0.74	0.56	5.22	0.06

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[1] Cooperative citrus research of Texas College of Arts & Industries and Texas Agricultural Experiment Station.

[2] Assoc. Prof. of Agriculture, Texas College of Arts & Industries, Citrus Center, Weslaco, Texas.

samplings 1959, 1960, and 1961 from trees of Webb Redblush, grown on 2 rootstocks, under 3 cultural systems. Leaf K levels were higher in trees on sod culture than on chemical weed control with no tillage or on clean cultivation. Leaf N levels were slightly lower in trees on chemical weed control than on the other cultural systems.

Differences between rootstocks with respect to the uptake of Mg were apparent under all cultural systems. Differences with respect to the uptake of K were not as clear cut as those reported in Table 1.

Fertilizer: Differential rates of N fertilizer, applied from the time the trees were set out, resulted in significant differences in leaf N, P, and K in 4-year-old Webb Redblush on sour and Cleopatra rootstock. Table 3 presents the data for trees on sour; results with Cleopatra were similar.

Each increment of N fertilizer increased N content of the leaf tissue. The 1- and 2-pound rates were significant over no N and over the ½-pound rate.

Table 2. The influence of cultural practice and rootstock on the chemical composition of grapefruit leaf tissue, average of September sampling 1959, 1960, and 1961.

Cultural Practice	*Root-stock*	*N*	*P*	*K*	*Mg*	*Ca*	*Na*
				percent	*dry matter*		
Sod culture	sour	2.18	0.10	0.99	0.35	5.90	0.05
	Cleo.	2.29	0.12	0.90	0.50	5.16	0.04
Chemical weed control	sour	2.11	0.09	0.78	0.31	6.31	0.08
	Cleo.	2.07	0.11	0.72	0.55	5.62	0.05
Cultivated	sour	2.18	0.12	0.77	0.37	6.41	0.06
	Cleo.	2.16	0.11	0.79	0.57	5.33	0.06

Table 3. The influence of nitrogen fertilizer applications on the chemical composition of the leaves of 4-year-old Webb Redblush grapefruit on sour orange rootstock.

Rate of nitrogen[1] application	*N*	*P*	*K*	*Mg*	*Ca*	*Na*
			percent	*dry matter*		
O	1.65b	0.25b	1.98a	0.24	6.82	0.13
½ lb/tree/yr	1.76b	0.14a	1.54b	0.30	7.20	0.10
1 lb/tree/yr	1.95a	0.11a	1.31bc	0.27	7.30	0.09
2 lb/tree/yr	2.08a	0.10a	1.16c	0.30	7.07	0.08
significance	°	°	°	ns	ns	ns

° indicates significance at the 5% level
means having the same letter do not differ significantly

[1] supplied as ammonium nitrate

Leaf P decreased with each increment of N fertilizer added. Trees receiving no N had significantly more leaf P than did trees receiving N. Among the 3 rates of added N fertilizer, differences in leaf P were not significant at the 5% level. Although no phosphate fertilizer was applied during this study, the lowest values found for leaf P were within the optimum range.

Leaf K decreased as the rate of N application increased. All rates of N fertilizer resulted in significantly lower leaf K than did no N. The 2-pound rate of N was significant over the ½-pound rate with regard to leaf K.

There were no significant differences related to rate of N application with respect to Ca, Mg, or Na. A trend toward decreased leaf Na as leaf N increased seemed to exist but failed to reach the 5% level of significance.

Three years of differential N applications to 12-year-old Webb Redblush grapefruit trees did not significantly affect chemical composition of the leaf tissue (Table 4), but applied N fertilizer did increase production.

The application of various rates of phosphate fertilizer, with a constant rate of 2 pounds of N a tree yearly, did not significantly affect the chemical composition of the leaves of young grapefruit trees (Table 5). Values for leaf N and P are similar to those reported in Table 3 at the 1- and 2-pound rates of N with no added P. The application of phosphate fertilizer over a 4-year-period did not influence leaf P although sodium-bicarbonate-soluble P in soils of plots receiving the high rate of phosphate was nearly double that of plots receiving no phosphate fertilizer: 42 and 25 ppm respectively.

Season: Typical seasonal patterns for N in leaf tissue are shown in Fig. 1 for 1959, 1960, and 1961. The pattern was not influenced by rootstock,

Table 4. The influence of 3 years of differential nitrogen fertilizer applications on the chemical composition of the leaves, and on the fruit production of 12-year-old red grapefruit trees on sour orange rootstock.

Rate of nitrogen[1] application	*N*	*P*	*K*	*Ma*	*Ca*	*Na*	*Yield 1962 lbs/tree*
			percent	*dry matter*			
O	2.28	0.11	1.28	0.46	4.86	0.07	199a
1 lb/tree/yr	2.33	0.11	1.08	0.36	5.07	0.06	318b
2 lb/tree/yr	2.35	0.10	0.95	0.36	5.34	0.07	308b
significance	ns	ns	ns	ns	ns	ns	°

° indicates significance at the 5% level
means having the same letter do not differ significantly

[1] supplied as ammonium nitrate

variety, or cultural practice, but was influenced by timing of fertilizer application.

Table 5. The influence of phosphorus fertilizer applications on the chemical composition of the leaves of 4-year-old Webb Redblush grapefruit on sour orange rootstock.

Rate of phosphorus[1] *application*	*N*	*P*	*K*	*Mg*	*Ca*	*Na*
			percent dry matter			
O	2.02	0.11	1.47	0.24	7.05	0.12
1 lb/tree/yr	2.04	0.10	1.35	0.26	7.28	0.12
2 lb/tree/yr	1.96	0.11	1.39	0.23	6.90	0.10
3 lb/tree/yr	1.98	0.12	1.52	0.22	6.45	0.11
significance	ns	ns	ns	ns	ns	ns

[1] supplied as 45% superphosphate, all treatments received 2 lbs of N a tree yearly supplied as ammonium nitrate.

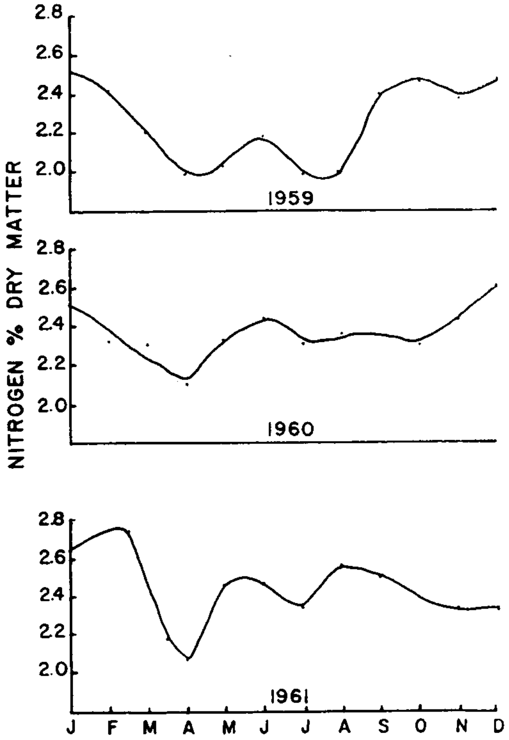

Figure 1. Seasonal variation in nitrogen content of Webb Redblush grapefruit leaves.

In 1959 N was applied 3 times: 1/3 in March, 1/3 in May, and 1/3 in August. At the time of bloom and fruit set the N level in the leaf tissue began to drop, reaching a low of about 2% at the April sampling. Following the second fertilizer application, a temporary increase in leaf N occurred. The level then dropped to less than 2% during July and August. After the third application the N level in the leaf tissue increased and remained stable for the fall and winter months.

During 1960 and 1961 the total amount of N applied was the same as in 1959: 1½ pounds of N a tree yearly. However, in 1960 and 1961 the fertilizer was applied ½ in January and ½ in May. The pre-bloom application reduced the severity of the drop in leaf N at the time of bloom and permitted a more rapid recovery in leaf N which was sustained by the second application.

The lowest leaf N content in each year occurred in April.

Table 6 presents data on the leaf content of P, K, Mg, Ca, and Na for Webb Redblush on sour orange rootstock growing under sod culture. The pattern for P, K, and Mg is similar to that for N: a drop at time of bloom followed by a slow recovery to a high during the winter months. This was typical of all comparisons regardless of variety, rootstock, or cultural practice.

Ca content of leaf tissue varied from about 4 to 7%. No consistent seasonal pattern was exhibited during the 3-year test.

There was no consistent seasonal pattern of Na in the leaves. Lowest Na values were associated with periods of heavy rainfall, however the differences were not significant at the 5% level.

Table 6. Seasonal variation in mineral composition of grapefruit leaf tissue, Webb Redblush on sour orange rootstock. 1961.

Month	*P*	*K*	*Mg*	*Ca*	*Na*
			percent dry matter		
January	0.14	0.95	0.39	4.21	0.02
February	0.13	1.04	0.27	4.54	0.02
March	0.12	0.70	0.33	5.20	0.03
April	0.09	0.85	0.26	5.23	0.02
May	0.12	1.17	0.30	4.98	0.02
June	0.11	1.13	0.39	5.30	0.02
July	0.11	1.08	0.30	5.65	0.04
August	0.14	1.33	0.42	4.70	0.03
September	0.13	1.26	0.47	4.77	0.04
October	0.12	1.15	0.47	5.00	0.04
November	0.10	1.05	0.48	5.37	0.05
December	0.13	1.24	0.45	5.57	0.05

SUMMARY AND CONCLUSIONS

Rootstock influenced the chemical composition of grapefruit leaf tissue only with respect to K and Mg content. Leaves from trees on sour orange rootstock had significantly more K and less Mg than did leaves from trees on Cleopatra rootstock.

Among the white, pink, and red varieties there were no significant differences in the chemical composition of the leaf tissue. This is in agreement with the findings reported in the literature for closely related species of citrus. A single set of standards would appear to be acceptable for all grapefruit varieties.

Among cultural practices leaves from trees on sod culture had the highest K levels. Leaves from trees on chemical weed control with no tillage had slightly lower N levels than those from trees on sod culture or clean cultivation.

On young grapefruit trees each increment of N fertilizer resulted in an increase in leaf N and in a decrease in leaf P and K. With bearing trees, which had received differential N fertilizer for 3 years, this was not the case. Chemical composition of the leaf tissue was not significantly influenced by the various rates of N over the 3 year period. Production, however, was reduced where no N was applied. Thus, foliar N level cannot be taken as a single value criterion related to productivity.

Differential rates of phosphate fertilizer, with a constant rate of N, did not significantly affect the chemical composition of the leaves of young grapefruit trees. The added phosphate, although measurable in the soil as sodium-bicarbonate-soluble phosphate, was not reflected in the leaf tissue.

The patterns for seasonal variation were similar for N, P, K, and Mg. Lowest values occurred at the time of bloom and fruit set followed by a recovery during the summer with highest values occurring during the winter months. No consistent seasonal pattern was exhibited by Ca or Na. The sampling period from May to November best reflects the nutritional status of the tree.

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The Marrs Orange, a Navel-Orange-Sport Variety Popular in Texas[1]

Edward O. Olson[2]

Increasing acreage of Texas citrus is being planted to Marrs orange, a variety unknown in other citrus areas. Marrs is the most popular early orange in Texas, according to nurserymen's sales reports. Its merits and weaknesses have ben discussed by Texas growers, canners, visitors and researchers. The purpose of this article is to review the scattered information about the variety, and evaluate its current place in Texas citriculture.

Description of Marrs orange:

Fruit, light-orange colored; shape, round; skin, slightly rough; size, medium to large for early oranges (diameter and height 2½-3 inches); flesh, pale orange, medium texture; juice, abundant; seediness, variable, 5 to 15 polyembryonic seeds. Low-acid and high-brix juice meets Texas maturity standards of 8:1 brix-acid ratio in September; maturity in November-January. Rind thickness equivalent to other oranges; flavor equivalent to Hamlin orange. Trees are generally semidwarf and smaller than Hamlin trees; fruiting often precocious and heavy, with fruit in clusters, on young trees.

Origin:

On the basis of information supplied by Miss Gwynevere Marrs, daughter of the originator, Waibel (1953) described the origin of the Marrs as follows:

In 1925 Mr. O. F. Marrs of Donna, Texas, received 26 navel orange trees from the Nuisbickle Warren Nursery in California. In 1927, Mr. Marrs discovered that a limb on one tree hung almost to the ground with heavy clusters of perfectly round fruit with no navels. Of 200 trees budded from this branch in 1929, all but 4 budded trees were lost in a freeze in 1929. The next year Mr. Marrs budded 200 more trees, but again lost all but 6 trees in that year's freeze. The ten remaining trees were planted and were heavily laden with fruit in 1933 when the September hurricane twisted and split the small trees and tore the sport limb from the original mother tree. In a short time the young trees were again producing fruit, similar to that on the original sport branch. The first trees were sold in 1940.

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[1] These investigations are part of a cooperative citrus research project conducted jointly by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station. Rio Farms, Inc., of Monte Alto, Texas also cooperates.

[2] Plant pathologist, Citrus and Subtropical Fruit Investigations, Crops Research Division, ARS, USDA.

"The trees bear cluster fruit at an early age. The fruit is uniform in size and pass maturity tests in late August and early September. The trees do not grow large but produce heavy crops" (Waibel, 1953).

Marrs orange trees in January 1962 were about as cold hardy as Hamlin orange and Washington navel orange trees.

Yielding ability of the Marrs is indicated by experience in one grove at Rio Farms. One block held 5489 Marrs trees, of which 4056 were planted in 1947-48, and 1433 were planted in 1948-49. The average yield per tree in successive years was as follows: 1950, 32 lbs.; 1951, 3 lbs. (after a severe freeze); 1952, 21 lbs.; 1953, 49 lbs.; 1954, 64 lbs.; 1955, 109 lbs.; 1956, 120 lbs.; 1957, 164 lbs.; 1958, 189 lbs.; 1959, 265 lbs.; 1960, 329 lbs.; 1961, 347 lbs. But, the story is more involved: 1370 trees were replanted in 1953-54 to replace trees killed in the January 1951 freeze. Yield records in fall of 1961 indicated that the 7-year-old replacements yielded 163 lbs., and the original trees averaged 467 lbs. of fruit. This grove was frozen in the January 1962 freeze and no fruit is expected in the fall of 1962.

Rind-oil spotting:

The Marrs orange passes Texas maturity standards while the peel is still green. Rind-oil spotting caused considerable loss for several years and some shippers were reluctant to handle the Marrs. The affected areas of the peel remained green in contrast to the yellow color of the normal peel after degreening with ethylene gas. Studies over several seasons by Johnson et al. (1961) showed moisture relations to be an underlying factor in the Marrs' susceptibility to spotting. The Marrs could be harvested while green, provided that certain practices, listed in order of importance, were followed:

a. Pick fruit in afternoons of clear, sunny days.

b. Defer picking 2 or 3 days after rain or irrigation.

c. Use fiberboard-lined field boxes or padded trailers.

d. Pickers use cotton gloves.

As a result of the recommendations of Johnson et al. (1961), the rind-oil spotting problem diminished in importance.

Virus studies:

The original Marrs selection was probably free of recognized citrus viruses, since several virus-indexed progeny seem to be free of psorosis, tristeza, exocortis, xyloporosis and other recognized citrus viruses (Olson, Cooper and Shull. 1959). Budwood from a virus-indexed Marrs orange tree was released to nurserymen (Sleeth and Olson. 1961). However, virus-free Marrs trees, like any others, may become virus-infected if improper nursery practices are followed. Virus-infected trees of Marrs also occur.

Fruit and juice characteristics:

In 1961-62 season, juice of Marrs oranges showed higher Brix and color values than juice from Hamlin oranges (Table 1). The low acid values obtained from Marrs, however, indicated that a high quality juice product, for concentrate purposes, could be prepared from this variety only by blending with juice from another variety such as Valencia (Lime and Tucker. 1962). During the 1960-61 season, Marrs fruit was shipped to Florida to provide high-solid, low-acid juice to blend with low-solid, high-acid Valencia juice available at one portion of Florida's season.

Data on rootstock effects on the properties of fruit from young Marrs trees are reproduced in Table 2 (Woodruff and Olson. 1960).

The Marrs may be legally "mature" in September, but on the basis of flavor and of color-break of rind and juice, it matures in November in Texas. Thus, the Marrs should be considered an early-to-midseason orange in Texas.

Table 1. Properties of Marrs orange juice over 1961-62 season, Rio Farms.[1]

Sampling date	*Juice yield %*	*Brix degrees*	*Acid %*	*B/A*	*Visual color*[2]	*Solids per 90 lb. box*
10-17	54.7	10.0	0.72	13.9	4	4.92
11-14	55.4	11.3	0.62	18.2	4	5.63
12-13	55.8	11.8	0.58	20.3	2-3	5.92
1-9	52.3	12.4	0.57	21.8	2-3	5.84

[1] Based on data of Lime and Tucker, 1962. JRGV Hort. Soc. 16: 78-82.

[2] Visual tube: Number of tube matching sample. Color tubes were furnished by the Processed Products Inspection Branch, A.M.S., U.S.D.A.

Table 2. Properties of Marrs orange fruit from trees on various rootstocks. Rio Farms, Dec. 15, 1959[1]

Rootstock	*Fruit weight (grams)*	*cc juice per kilogram of fruit*	*Rind thickness (mm.)*	*Acid %*	*Soluble solids*	*Solids: acid ratios*
Sour orange	284	483	4.1	.50	10.0	19.9
Sunki mandarin	269	482	4.1	.49	9.6	19.7
Rangpur lime	276	485	4.2	.47	9.4	20.1
Sweet lime	274	466	4.2	.50	9.0	18.3
Morton citrange	259	466	4.2	.45	9.0	21.9
Carrizo citrange	291	479	4.2	.49	9.4	19.3
Rough lemon	293	461	4.5	.46	8.7	18.9

[1] Based on data of Woodruff and Olson, 1960. JRGV Hort. Soc. 14: 77-84.

Why growers like Marrs:

Since 1940 the Marrs has increased in popularity with Texas growers, until now it is the dominant early-orange variety in Texas, replacing Hamlin. Reasons for its popularity are:

a) Good-sized early oranges had a good market, and Marrs trees provided the biggest early oranges for fresh-fruit sales.

b) Texas oranges are legally "mature" when the Brix-acid ratio is 8:1 or higher, and the low acid content enables the Marrs to pass legal maturity tests before other varieties.

c) The variety has a relatively long harvesting season, since the variety meets the legal standards for maturity in October or earlier, and holds on trees until January, if needed.

d) The hazard of freezes destroying fruit on the trees is less with Marrs than with late varieties.

Opinions of canners and concentrators:

Marrs oranges are not popular with canners of single-strength orange juice. By the time the juice passes minimum color requirements, the Marrs lacks the acidity required to make a Grade A single-strength product. Failure to have Grade A juice penalizes the canner in his sales programs. The single-strength canner, unlike the concentrator, has little opportunity to use Marrs juice by blending it with the juice of highly-colored, acid varieties.

Marrs oranges also present problems to the concentrate industry. Juice develops good color late in the Marrs' season. But, by the time the Marrs' juice has good color, the acid is low. In 1961-62 there was only a short period late in the season when Marrs juice barely made color, Brix, and acid standards. Thus, blending was generally necessary. Concentrators do not object to Marrs as long as they have sufficient highly colored, highly acid juice from other varieties for blending. In practical terms, this means that the concentrator wants heavy plantings of Valencias – perhaps half the orange acreage – to accompany heavy plantings of Marrs.

Opinions of consumers:

Information on this subject is unavailable or unreliable. There is some speculation that many consumers prefer high-solid, low-acid fruit and juice. Those who buy Marrs oranges which are legally "mature" in late September and early October are mostly disappointed in the unripe fruit. By November the fruit is ripe and the flavor is infinitely better than the flavor in September.

Is the Marrs a navel sport?

The Marrs is reported by its originator to be a bud sport from a navel orange. A comparison of the Marrs and the Washington navel orange is given in Table 3.

Many of the properties in which the Marrs differs from the navel can be explained by the fruiting changes arising from changes in pollen fertility. The navel orange has no pollen, while the Marrs has abundant viable pollen. However, differences in abundance of pollen do not explain all the differences between Marrs and navel oranges.

If the Marrs arose as a sudden genetic mutation, it must have involved several genes affecting pollen abundance, juice bitterness and navel structure. The navel orange variety is considered to have arisen from the Selecta orange, which is not a navel variety, but does ocasionally develop a few fruit with navels (Webber, 1946). Since the navel itself supposedly arose from another variety, it is as reasonable to suppose that the Marrs arose as a sport branch on the navel orange. Shamel (1946) has shown that there are a great number of variants – mostly undesirable – in the Washington navel variety, so that indications of another variant strain should come as no surprise. It is further true that certain branches of certain Marrs trees have consistently shown fruit with navels, suggesting that on occasion, the Marrs reverts to the navel orange from which it arose.

In many of these navel-like fruit, the style is persistent, remaining covered or almost covered by the ovary wall. Such navel-like structures are similar to those sometimes occurring on varieties like Orlando tangelo. Progeny from some of the navel sport branches on Marrs are presently being evaluated by several nurserymen and researchers. Nurserymen have also sought to find Marrs trees or branches which would consistently bear only seedless fruit. But, to date, trees with seedless fruit one year have had seedy fruit in other years. Seediness thus may be a reflection of pollen source and seasonal conditions rather than a constant characteristic of the Marrs variety.

Table 3. Comparison of certain characters of Washington navel and Marrs orange.

Character	*Washington navel*	*Marrs orange*
bearing	few fruit	many fruit
pollen	infertile	fertile
juice	bitter after standing	not bitter after standing
seeds	0 to 10 usually seedless	variable, 5 to 15
navel	consistently present	present on occasion, very common on some sport branches of Marrs
season	very early to midseason	very early to midseason
fruit size	3-3 ½"	2 ½-3"
fruit shape	oval	round
tree size	large	semidwarf

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The Parson Brown Compared with the Pineapple Orange in Texas

E. O. Olson[1] and Bruce J. Lime[2]

The Texas processing industry needs an orange that matures before the Valencia, and some processors have indicated an interest in the Pineapple orange as the best variety to fill this need. There is, however, some confusion in the Rio Grande Valley as to the identity of Pineapple oranges. In Texas, almost any seedy midseason oranges may pass as Pineapple. Parson Brown, Ruby, Marrs, Mediterranean sweet, and other varieties have passed as Pineapple, particularly Parson Brown. Many so-called Pineapple oranges in Texas are actually Parson Brown. Webber (1946) classed the Parson Brown as one of the best early-maturing oranges and considered the Pineapple as a midseason selection of high quality. He noted that both are grown to some extent in Texas. As shown in Table 1, Parson Brown and Pineapple are distinctly different.

There is considerable doubt that the true Pineapple variety is the best midseason orange for Texas, where cold damage is probably the greatest hazard. Lawless and Camp (1940) noted that Valencia, Hamlin, and Parson Brown sweet orange trees showed the same relative resistance to 3 Florida freezes and that the Pineapple orange trees suffered more than those of any other orange at the Experiment Station at Lake Alfred, Florida. After Florida's freeze in December 1962, Pineapple trees again showed greater freeze damage than Parson Brown, Hamlin, or Valencia orange trees (Cooper et al., 1963).

Table 1. Comparisons of Parson Brown and Pineapple orange fruits.

Fruit characteristic	*Parson Brown*	*Pineapple*
Maturity	Early season	Midseason
Seed	Fat, numerous	Thin, pointed, numerous
Rind	Yellow	Reddish-yellow
Shape	Elongate	Nearly spherical
Skin	Rough, pebbly	Slick, smooth
Oilgland surface	Convex, papillate	Depressed

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Friend and Wood (1941) noted that the Parson Brown is an early-maturing variety similar in many respects to Pineapple and is sold through commercial channels as Pineapple. The trees of Parson Brown have high productive capacity and bear every year and the fruit matures at the same season as Hamlin and somewhat earlier than Pineapple. Because of its seediness, Parson Brown lost favor with Valley growers. Parson Brown trees yielded an average of 383 lbs. per year of fruit over a 5-year period, while comparable Pineapple trees yielded only 303 lbs. (Friend and Wood, 1941).

The seediness of the Parson Brown is objectionable for fresh-fruit sales, but would not limit sales for concentrate. Compared with Pineapple variety, the Parson Brown has earlier maturity, greater productivity, more cold-hardiness, and better juice color, and matures earlier, all of which are characteristics of interest to growers planning to sell fruit to Texas concentrate plants.

A Parson Brown seedling provides a budwood source for propagation of the variety. A bud from a Parson Brown seedling was budded on Cleopatra mandarin rootstock in 1949 and the tree was set out in the Rio Farms Variety Block at Monte Alto in November, 1953. The Parson Brown seedling from which buds were taken was probably from a nucellar seed. The budded tree has borne fruit since 1958. It was frozen back to ½-inch wood in January 1962; in the same freeze, 2 adjacent Pineapple nucellar trees on Cleopatra rootstock were frozen back to 3- to 4-inch wood.

The fruit of the nucellar Parson Brown combined good color with fairly high solids and acids when harvested during December and January and before the Valencia harvest. Table 2 compares the juice quality of the nucellar Parson Brown with that of Pineapple, Hamlin and Marrs sweet oranges. During December and January of the 1961-62 season, fruit juice from the seedling had the best color among 17 different orange varieties observed. The fruit had rough, pebbly skin, was yellow in color; the fruit shape was spherical to elongate; seedy (10-15 large seeds) and had the characteristics excepted of a Parson Brown selection (Table 1). The juice had very good color, better than that of Pineapple, Marrs, or Hamlin orange available during the same period (Table 2). Taste analyses of chilled nucellar Parson Brown juice samples after 3 weeks of storage gave no indication of development of off-flavor.

The budwood-source tree of nucellar Parson Brown was indexed on sensitive stock and determined virus-free.

The nucellar Parson Brown offers sufficient promise to justify additional tests on a small scale by Texas growers.

Table 2. Comparisons of color, Brix, and acid of juice of 4 varieties: Parson Brown, Pineapple, Hamlin, and Marrs.[1]

Sampling date top/rootstock combinations	*Visual color of juice*[2]	*Brix (degrees)*	*Acid (%)*	*Brix-acid ratio*
Dec. 16, 1960:				
Parson Brown/Cleo	good	11.4	0.81	14.1
Pineapple/sour	medium	11.0	0.86	12.8
Hamlin/Cleo	poor	11.2	0.71	15.8
Nov. 1, 1961:				
Parson Brown/Cleo	poor (4)	9.9	1.04	9.5
Pineapple seedling	poor (4)	10.5	.87	12.1
Hamlin/Cleo	poor (4)	10.3	.74	13.9
Marrs/Rangpur	poor (4)	10.7	.65	16.5
Dec. 6, 1961:				
Parson Brown/Cleo	good (2-3)	10.1	.78	12.9
Pineapple seedling	poor (4-)	11.5	.75	15.3
Hamlin/Cleo	poor (4-)	11.3	.71	15.9
Marrs/Rangpur	medium (3-4)	9.5	.50	19.0
Jan. 11, 1962:				
Parson Brown/Cleo	very good (1-2)	10.3	.74	13.8
Hamlin/Cleo	poor (4)	11.2	.65	17.2
Marrs/Rangpur	good (2-3)	12.4	.57	21.8

[1] Juice for juice analysis was obtained by halving the fruit and reaming by hand with a burr-type juice extractor. Large pieces of pulp and pieces of rag were removed by gently working the juice through a 16-mesh stainless-steel screen. The acid content was determined by titration with standard sodium hydroxide and reported as anhydrous citric. The Brix was determined by direct reading with an "Abbe 56" refractometer. Color notations were made by comparing the juice sample with color tubes of USDA Color Standards for Orange juice. The tubes were numbered 1 to 4, 1 having the deepest orange color.

[2] Numbered in parenthesis is the number of the tube matching sample. Color tubes were furnished by the Processed Products Inspection Branch, AMS, USDA.

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Breeding New Varieties of Citrus Fruits and Rootstocks For the Southwest[1]

J. R. Furr, J. B. Carpenter and A. A. Hewitt[2]

INTRODUCTION

Once somewhat of a rarity, citrus fruits are now considered an essential part of our diet. Until 30 years ago the citrus industry in California, Arizona and Texas was based largely on a few varieties. At that time a California horticulturist expressed the opinion that no new citrus varieties were needed in California. He considered Washington Navel and Valencia oranges, Marsh grapefruit and Eureka and Lisbon lemons adequate to meet the needs of the commercial citrus industry and thought that the introduction of new varieties would only complicate marketing problems. So few tangerines, tangelos and limes were grown in California then that they were not mentioned. Commercial plantings in Texas were even more limited as to varieties, being largely Marsh grapefruit; the red grapefruit sports that later became popular had only just appeared.

Since World War II, several changes in the citrus industry have created a growing interest in new varieties of fruit and in new, better rootstocks. The competition of frozen citrus juice concentrate with fresh fruit has increased the demand for new fresh fruit varieties with better shipping and eating qualities. The frozen-concentrate industry needs new early-ripening oranges of high-quality that would lengthen the season of concentrate production.

Severe damage from freezes in recent years has stimulated interest in cold-hardy varieties and rootstocks. Extensive work on citrus viruses since World War II has demonstrated the sensitivity of some kinds of rootstock and shown the need for combining virus tolerance with other desirable qualities. In California and Arizona urbanization of large areas of former citrus lands and availability of Colorado River water have created a demand for new fruit and rootstock varieties especially suitable for use in newly developed hot desert areas. Improvement in education and living standards of the American people and rapid increase in population have stimulated demand for greater variety and greater quantity of citrus fruit.

The needs of the citrus industry for new and improved varieties of fruit and rootstocks and the broad outlines of the breeding programs undertaken by the U. S. Department of Agriculture and cooperating state experiment stations in an effort to meet these needs were recently described by Cooper (1962).

The current citrus breeding program of the U. S. Date Field Station, Indio, and the Southwestern Irrigation Field Station, Brawley, California, was started in 1952. Actually a few citrus crosses were made at Indio in 1948, but since there was little space at Indio for growing the seedlings, no further crosses were made until land and funds became available at Brawley.

The primary object of the early crosses made in 1948, 1952, 1953, and 1954 was the production of fruits, especially the mandarin-types of high quality suited to the climatic conditions of the hot, interior-desert areas. The objective was soon broadened to include the production of an early high-quality sweet orange, a Temple-like orange free of exocortis virus, a red grapefruit with improved color, cold-hardy varieties, especially grapefruit, and rootstocks with specific characteristics.

The aim in breeding new rootstocks is to combine one or more special traits, such as tolerance to Phytophthora root rot, to saline or high-lime soil or to cold, with these characteristics useful in all good rootstocks: inducing high yields and good size and quality of fruit and producing a high percentage of nucellar seedlings.

This report outlines the materials and methods used in the breeding and testing of new scion and rootstock varieties and presents some preliminary results and plans for future work.

MATERIALS AND METHODS

The method of citrus breeding generally employed from the early work of W. T. Swingle and H. J. Webber conducted in Florida in the 1890's (Cooper et al, 1962) to the present has been hybridization and selection from the first filial (F_1) generation. Citrus is cross-pollinated and is highly heterozygous; consequently, when hybrids are produced by crossing different varieties or species or by crossing citrus with related genera, segregation of many characters occurs in the F_1 generation.

Most of the named varieties of citrus tested before 1954, except pummelos and lemons, were found to produce a high proportion of nucellar seedlings. Nucellar embryony and seedlessness of some of the best varieties have greatly limited the choice of seed parents from which a fairly good yield of hybrid seedlings could be expected. A few varieties, however, produce seed containing only zygotic (sexual) embryos. Clementine mandarin and Temple orange, when pollinated with trifoliate orange pollen, produced only hybrid trifoliate-leaved seedlings (Furr and Reece 1946). By the method of seed dissection recommended by Frost (1943), Clement tangelo and Altoona and Umatilla tangors were found to produce only monoembryonic seeds and were assumed to have zygotic embryos. Breeding tests proved this assumption to be correct. Frost (1943) obtained a fair yield of hybrid seed from King mandarin, and Honey

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[1] A portion of a talk given before the Institute of the Rio Grande Valley Horticultural Society, January 22, 1963, Weslaco, Texas.

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mandarin hand-pollinated with trifoliate orange pollen at Indio in 1948 yielded 15 or 20 percent hybrid seed. Selection of seed parents used in the 1948-54 crosses at Indio was largely based upon the foregoing information.

Parlevliet and Cameron (1959) showed that the F_1 progeny from parents which produce only monoembryonic seed are likely to produce only monoembryonic seed and that about half of the F_1 progeny of a monoembryonic X polyembryonic cross will produce monembryonic seed. Since a great diversity of types among F_1 seedlings of the monoembryonic varieties Clementine, Temple, Umatilla and Wilking are now in bearing, the number of desirable seed parents that will produce a high percentage of hybrid seedlings has been increased greatly and is increasing yearly as new hybrids come into bearing.

The procedures of hybridization and evaluation of progenies are as follows:

Branches up to about 1 inch in diameter are selected and tagged, and all open flowers and flower buds too young to pollinate are removed from the branch. The operator's hands and forceps are washed with 80 percent alcohol to destroy contaminating pollen; then the unopened nearly mature flower is emasculated by removing the entire corolla and the stamens. The emasculated flower is immediately pollinated, usually with fresh pollen or dried refrigerated pollen from the desired parent. Since our observations indicated that bees rarely visit citrus flowers from which all petals and stamens have been removed, the emasculated flowers are not covered for protection from insects except in special cases such as selfing or tests of compatibility. The seeds are harvested from mature fruit and in November or December are sown in flats containing a mixture of peatmoss and vermiculite, where they are grown until spring. Seedlings to be evaluated as fruiting varieties are grown in the field on their own roots at a spacing of 3x15 feet. Most of them fruit in 4 to 8 years after the seeds are sown.

Numbered labels are attached to seedlings that develop promising fruits and brief descriptions of the fruits are recorded; the other fruiting seedlings are removed and discarded. Seedlings that show the most promise are propagated on standard rootstocks for a second test. Second tests were conducted as a further screening procedure to observe performance under nearly normal conditions of spacing, rootstock effect, exposure, and other environmental effects.

Second-test plantings have been made by the U. S. Department of Agriculture at Indio and Weslaco, by the University of California Citrus Research Center at Riverside, California, and by several cooperating growers in the Coachella, Imperial and San Joaquin Valleys.

The F_1 seedlings of rootstock types are planted in the field for fruiting and their open-pollinated seedlings are tested as potential rootstocks or young F_1 seedlings are screened for tolerance to Phytophthora root rot and to saline or high-lime soil. In some crosses of rootstock varieties nucellar embryony results in a low yield of hybrid seedlings. The F_1 hybrids from such crosses are usually fruited and the open-pollinated seedlings given screening tests.

To determine their tolerance to Phytophthora root rot, young seedlings are inoculated by immersing their roots in aerated water containing zoospores of *Phytophthora parasitica* Dastur and are grown in soil beds for 2 months or longer (Carpenter and Furr 1962).

In screening for salt tolerance, young F_1 hybrids or seedlings grown from open-pollinated seed of F_1 hybrids are planted in soil plots. As soon as the seedlings are well established, they are irrigated with water salinized with equal amounts of sodium and calcium chlorides. During the first 3 weeks the salt content of saline water is increased to 6,000 parts per million (ppm) and thereafter the trees are irrigated at 1- or 2-week intervals during the growing season with water containing 6,000 ppm of total soluble salt. In winter, when the trees are dormant, Colorado River water containing approximately 800 ppm of salts is applied to the salt plots. The plants are rated at intervals for salt injury as expressed by leaf burn and stem die-back on an arbitrary scale as follows:

0. No leaves or stems showing symptoms of injury

1. Up to 25 percent of leaves or stems showing symptoms of injury

2. 26 to 50 percent of leaves or stems showing symptoms of injury

3. 51 to 100 percent of leaves or stems showing symptoms of injury

4. All leaf surface and/or stems dead. The percentage of defoliation is also estimated. A stem die-back rating of 4 usually indicates a dead plant though the root system may be alive after all above-ground parts are dead.

RESULTS AND DISCUSSION

Scion varieties

The breeding program in 1948 and 1952-54 was largely confined to hybridization of scion varieties; 155 different crosses were made, many of them in 2 or more years. About 1,000 hybrid seedlings from the 1948 crosses were planted at Indio and over 15,000 from the 1952-54 crosses at Brawley. Progenies from a few seed parents — Navel oranges, grapefruit, and the mandarins Dancy and Honey — contained few or no hybrids. Most other progenies, however, were from seed parents that produce only zygotic embryos or a high proportion of zygotic embryos.

A small part of the seedlings fruited 3 years after planting, and fruiting occurred in rapidly increasing numbers during the next few years.

At first, as trees came into bearing fruits were described, but later such large numbers fruited each year that only fruits from seedlings that seemed promising enough for retention were described. The fruit descriptions were helpful in making selections of promising seedlings for the second test and, with general notes on progenies, constituted the usual records made of the original field plantings.

Though the size of F_1 families varied, some notion of the value of the different female parents in transmitting desirable traits to progeny may be gained from the relation of the number of crosses in which a seed parent was used and the number of progenies of that parent from which second-test selections were made. This relationship and also the number of second-test selections made from progenies of each seed parent variety are shown in Table 1, in which are listed all the seed-parent varieties used in the crosses of scion varieties, the number of pollen-parent varieties crossed with each seed parent and the number of second-test selections made from the progenies of each seed-parent variety.

More mandarins were used as seed parents than any other group, and both the number of crosses from which second-test selections were made and the number of second-test selections made from this group were greater than from any other.

The tangors (tangerine X orange) were used as seed parents in a large number of crosses from which a relatively large number of second-test selections were made. The other groups were poor seed parents, but some of the progeny may prove useful in further breeding work.

In the cold-hardy citradia group, one open-pollinated seedling showed considerable promise and will be used in breeding to improve cold hardiness of grapefruit. The crosses in which grapefruit was the seed parent yielded largely nucellar seedlings and the few hybrid seedlings have been slow in coming into bearing. One hybrid seedling of Redblush grapefruit X Webber pummelo (Fig. 1, C) shows promise of being useful as a mild-flavored, low-acid, red-fleshed grapefruit. Intensification of red flesh color of grapefruit was obtained from the cross Redblush grapefruit X Red grapefruit (Fig. 1, A) and its reciprocal (Fig. 1, B). The few hybrids obtained in these two crosses tended to produce rather weak trees. The fruit was of mediocre quality but had the intense red flesh of the Red grapefruit parent. These hybrids may be useful in breeding for improvement of color in the red grapefruit varieties.

Crosses made to produce cold-hardy lemon varieties, all between the Meyer and other commercial varieties of lemon, were disappointing. The 2 second-test selections are inferior in quality to Lisbon and Eureka but may have more cold tolerance than those varieties.

Crosses betwen Kao Panne pummelo and Orlando (Fig. 1, D) or Minneola tangelos produce several hybrids that have characters somewhat intermediate between those of the parents. The fruits are about the size of Marsh grapefruit, subacid, sprightly and pleasingly flavored but seedy and not very attractive. The selections made from a supposed progeny of Kao Phuang pummelo X Shamouti orange are apparently all pure pummelos. In this cross, flowers were protected from insects by bagging, but apparently some flowers were selfed by pollen from anthers that had dehisced before the flowers were emasculated or were contaminated by pummelo pollen in some other manner. Several of these selections have excellent quality and seem to be somewhat superior to most of the named pummelo varieties available in this country.

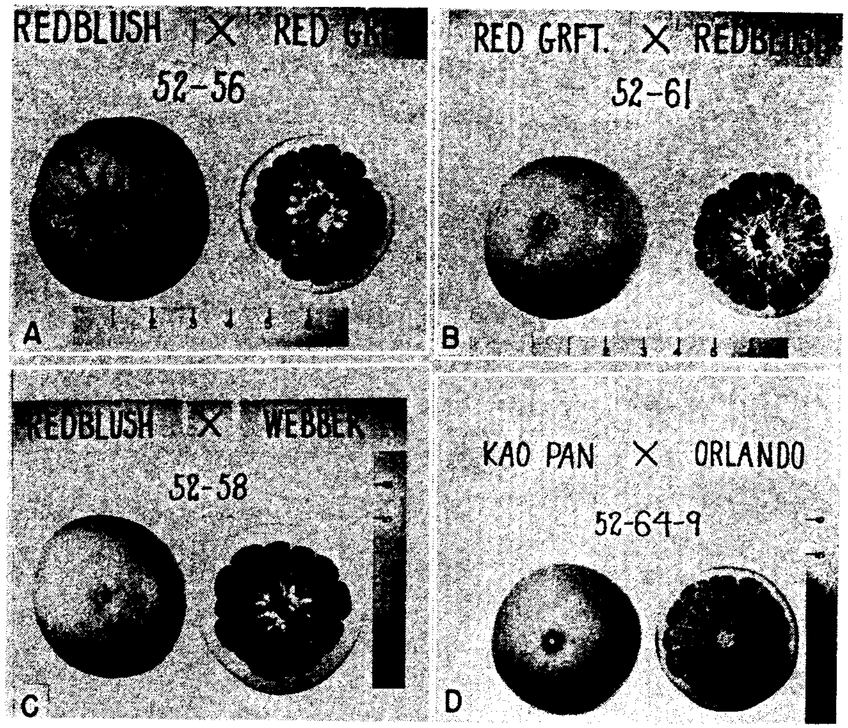

Figure 1. Fruits of F_1 hybrids: A, Redblush grapefruit X Red grapefruit; B, Red grapefruit X Redblush grapefruit; C, Redblush grapefruit X Webber pummelo; D, Kao Panne pummelo X Orlando tangelo.

An attempt was made to produce early-ripening tangors of high quality by pollinating Washington Navel orange with pollen of Clementine, Honey and Dancy mandarins. From several thousand flowers pollinated no hybrids were obtained.

Because Clement tangelo is monoembryonic and very early-ripening, it was used as a seed parent in crosses with several varieties of each of the following kinds: mandarin, tangelo, sweet orange, tangor. Most of the progeny of Clement had coarse, insipid and unattractive but juicy fruit like Clement itself. Only one selection for second test, a seedling of Clement tangelo X Orlando tangelo, was made. Clement has little merit and apparently should not be used as a parent in spite of its monoembryonic seed.

The numbers of second-test selections made from F_1 progenies of the top five seed parents—Clementine, Honey and King mandarins and Temple and Umatilla tangors—and the various pollen varieties with

Table 1. Seed parent varieties, number of pollen varieties crossed with each seed parent, number of crosses from which selections for second test were made, and number of selections made for second test from progeny of each seed parent.

Seed-parent variety or selection	*Pollen-parent varieties (no.)*	*Crosses producing second-test selections (no.)*	*Second-test selections (no.)*
Citradia:			
C.P.B. 50097 [a]	1	1	1
Grapefruit:			
Redblush	3	1	1
Red grapefruit [a]	3	0	0
Lemon:			
Eureka	4	0	0
Lisbon	2	1	1
Messina	1	1	1
Meyer	2	0	0
Mandarin:			
Clementine	47	21	94
Dancy	4	0	0
King	8	5	13
Honey	6	2	12
Pummelo:			
African [a]	1	0	0
Kao Panne	3	2	5
Kao Phuang	4	1	9
Red shaddock [a]	1	0	0
Webber	1	0	0
Sweet orange:			
Washington Navel	4	0	0
Tangelo:			
Clement	12	1	1
Tangor:			
Altoona	1	0	0
Temple	40	16	31
Umatilla	7	5	16

[a] Selection, description not published.

which they were crossed are listed in Table 2. Of the 166 selections made from these 5 seed parents, 93 were from Clementine and 31 from Temple; thus, nearly three-fourths of the selections were from Clementine or Temple progenies. These two parents proved to have considerable merit

Table 2. Number of second test selections made from F_1 progenies of the top 5 seed parents and the indicated pollen parents.

Pollen-parent variety or selection	*Seed-Parent Variety*				
	Clementine	*Honey*	*King*	*Temple*	*Umatilla*
Mandarin:					
Batangas			1		
Clementine			1		3
Dancy	15			2	
Frua	3			2	
Honey	14			1	10
King	1				
Kinnow	2			2	
Owari	1				
Ponkan	1			2	
Silverhill	7				
Swatow [a]				1	
Wilking	6				
Pummelo:					
Kao Phuang	1				
Red shaddock [a]				1	
Sweet orange:					
Hamlin	5				
Mediterranean	2				
Oasis [a]				1	
Parson Brown				1	
Ruby	1				
Valencia					1
Viciedo				1	
Tangelo:					
Allspice	2				
Minneola	7	6	3	7	1
Orlando	7	7	4	1	
Pearl	4			1	
San Jacinto	5			3	
Seminole	1				
Sunshine	2				
Tangor:					
Ruddy				2	
Temple	6		4	3	1

[a] Selection, decription not published.

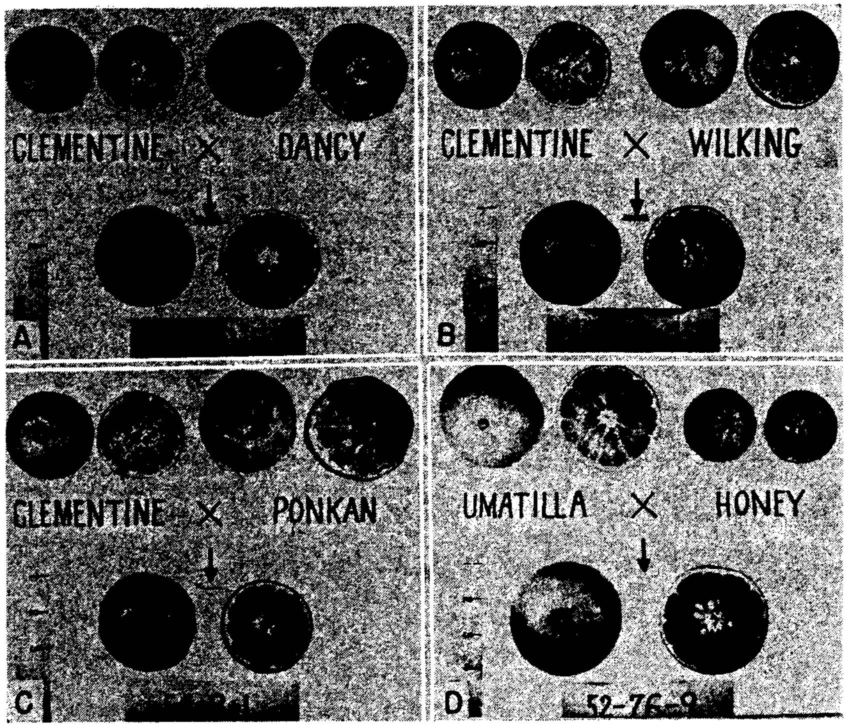

Figure 2. Fruits of parents and their F_1 hybrids: A, Clementine mandarin X Dancy mandarin; B, Clementine mandarin X Wilking mandarin; C, Clementine mandarin X Ponkan mandarin; D, Umatilla tangor X Honey mandarin.

in transmitting desirable traits to many of their seedlings and also were good hybrid-seed producers. Fifteen hundred F_1 seedlings of the cross Clementine X Dancy alone were planted and also large numbers of seedlings resulted from crosses with Honey, Pearl, Orlando, Hamlin, Temple and other pollen parents. Clementine seedlings were generally moderately vigorous and survived in the field and finally fruited. These factors resulted in a greater production of seedlings of merit from Clementine than from any other parent in the crosses of the 1948 and 1952-54 series.

Three Clementine crosses – Clementine X Dancy, Clementine X Wilking, and Clementine X Ponkan – produced F_1 hybrids of outstanding merit (Fig. 2, A,B,C). Of these, a Clementine X Dancy F_1 (accession no. 48-9-6), is attractive, of good quality and late in ripening; a Clementine X Wilking F_1 hybrid ripens with Clementine and has bright orange-red skin and excellent fruit quality; a Clementine X Ponkan F_1 ripens in mid-season, also has attractive orange-red skin and high quality and is resistant to granulation, a trait of great value in hot desert areas.

Temple was crossed with almost as many different pollen varieties as Clementine (Table 1), but far fewer flowers were pollinated and the number of fruit set and number of seeds per fruit of Temple were lower than those of Clementine. Consequently fewer trees were grown from Temple seed than from Clementine seed.

Relatively few pollen varieties were crossed with Honey, King and Umatilla (Table 1) and correspondingly few seedlings were derived from these crosses. Honey produces a low percentage of hybrid seed, and King varies from year to year both in total seed production and in percentage of hybrid seed from hand-pollinated flowers. Umatilla was misjudged as a seed parent and therefore only a small number of crosses were made from it. The F_1 hybrids of Umatilla tangor X Honey mandarin have proved to be relatively cold hardy, and the fruits in general have good quality, size and appearance. One of the best of these, Umatilla tangor X Honey mandarin (accession no. 52-76-9) (Fig. 2,D), is being used in breeding for high-quality, cold-hardy mandarins and oranges.

In this study, the value of seed parents was based on performance of seedling progenies on their own roots in dense plantings; very few second-test trees had fruited by 1962. From the observations made the seed parents which have the greatest merit may be ranked in approximately the following order: King, Temple, Clementine, Umatilla. The few hybrids of Wilking produced in the early crosses indicate that it also is an excellent seed parent. To estimate the value of pollen parents is more difficult because many more of them were used. The following pollen parents produced some of the most promising seedlings: Dancy, Temple, Clementine, Wilking, Ponkan, Minneola, Kinnow, Honey, Orlando, King. The performance of a parent is probably the same whether as female or male, but in citrus a distinction must be made with respect to feasibility of a cross; e.g., Dancy may be used as pollen parent but not as seed parent because it produces only nucellar seeds. Unless some special technique, such as growing potted plants in the greenhouse, is employed, King can be used in many crosses only as a female parent because it usually flowers very late in the season.

Rootstock varieties

Over 1,000 seedlings, approximately half of which were F_1 hybrids, were screened for salt tolerance. The F_1 families of hybrids showed segregation in degree of injury and salt tolerance. The results of analyses for chlorides in oven-dried leaf samples from seedlings of several families of hybrids and the average ratings of salt-injury symptoms show, as would be expected from the work of Cooper and associates (Cooper 1961), that, in general, the severity of salt-injury symptoms increased as the concentration of chloride in the leaves increased (Table 3). The relation between chloride concentration and severity of symptoms of injury was not, however, extremely close, especially among the plants that accumulated less than 3 percent of chloride. Apparently, chloride analysis of leaves is a more reliable measure of salt tolerance among the relatively tolerant plants than is rating for severity of symptoms of injury in leaves and stems.

Table 3. Chloride content of dried leaves, sampled in 1960, in relation to leaf-burn, stem die-back, and defoliation of some families of F_1 hybrids irrigated with saline water in summers of 1960 and 1961.

Year and chloride class interval (percent)	*Plants (no.)*	*Injury ratings, year and cross*					
		Leaf-burn rating [a]		*Stem die-back rating* [a]		*Defoliation (percent)*	
1960		1960	1961	1960	1961	1960	1961
		55-24 (Cleopatra mandarin X Swingle trifoliate orange F_1)					
0-1	6	0.8	1.3	0.3	1.3	9.3	28.3
1-2	0	----	----	----	----	----	----
2-3	0	----	----	----	----	----	----
3-4	4	2.0	3.0	1.0	2.5	46.2	93.5
4-5	1	3.0	4.0	2.0	3.0	100.0	100.0
5-7	1	3.0	4.0	2.0	3.0	80.0	100.0
		55-12 (Shekwasha mandarin X Swingle trifoliate orange F_1)					
0-1	0	----	----	----	----	----	----
1-2	3	0.7	1.0	0.3	1.3	5.7	25.0
2-3	3	1.0	2.3	1.0	2.0	16.7	60.0
3-4	3	1.0	3.7	1.0	2.7	26.7	96.7
4-5	3	2.7	4.0	1.7	3.0	76.7	96.7
5-7	2	3.3	4.0	3.0	4.0	100.0	100.0
		57-50 (Rangpur lime X African pummelo F_1)					
0-1	14	0.7	1.1	0.0	0.6	0.1	17.9
1-2	3	1.0	1.0	0.0	1.0	0.7	28.3
2-3	1	1.0	1.0	0.0	0.0	5.0	70.0
3-4	0	----	----	----	----	----	----
4-5	2	2.0	3.5	0.0	3.5	17.5	100.0
5-7	2	1.5	4.0	0.5	4.0	30.0	100.0
		57-48 (Rangpur lime X Cleopatra mandarin F_1[b])					
0-1	30	0.6	1.0	0.1	0.7	2.2	27.3
1-2	4	0.7	1.7	0.0	1.2	0.5	46.2
2-3	3	1.0	1.0	0.7	1.0	11.7	33.3
3-4	1	1.0	4.0	1.0	4.0	25.0	100.0
4-5	0	----	----	----	----	----	----
5-7	2	2.5	3.0	0.5	3.5	3.0	100.0

[a] Leaf-burn and stem die-back rating.

0. No leaves or stems showing symptons of injury.
1. Up to 25 percent of leaves or stems showing symptons of injury.
2. 26—50 percent of leaves or stems showing symptons of injury.
3. 51-100 percent of leaves or stems showing symptoms of injury.
4. All leaf surface and/or all stems dead.

[b] Twelve plants were dead and leaves abscised when leaf samples for chloride analysis were taken July 26, 1960.

Salt tolerance and resistance to accumulation of chloride in the leaves seems to be inherited as a quantitative character in citrus. Distribution of seedlings according to chloride-concentration classes of several families of F_1 hybrids (Table 3) varied considerably. In the two families in which one parent was a trifoliate orange of low-salt tolerance, the numerical distribution of seedlings over the range of leaf-chloride concentration is more nearly uniform than in the other two families in which the parents each have moderate or high chloride tolerance. In family 57-48, Rangpur lime X Cleopatra mandarin, both parents are highly tolerant to chlorides and apparently many seedlings received a double dose of genes for chloride tolerance; 30 seedlings out of the 52 in the family fell in the 0- to 1-percent chloride class.

Near the end of the growing season in September 1961, over 100 hybrid seedlings were selected for salt tolerance on the basis of appearance and propagated. Most weight was given to relative freedom from symptoms of salt injury, but vigor, growth habit, and freedom from mineral-deficiency symptoms were also taken into consideration. The leaf-chloride percentages and the ratings of salt-injury symptoms of the most salt tolerant seedling from each of 18 families of F_1 hybrids from rootstock crosses show considerable variation (Table 4). Some plants with relatively low leaf-chloride content show slightly more severe symptoms of injury than some others with a lower percentage of chloride in the leaves. This observation indicates that not only is there a difference in the accumulation of chlorides by different seedlings but also the tissues of the leaves and stems vary in susceptibility to injury from about the same concentration of chloride in the leaves.

A selection and breeding project to develop rootstocks tolerant to infection by Phytophthora, especially *P. parasitica*, the most common species in the hot interior deserts of California and Arizona, was initiated at the Indio Station (Furr and Carpenter, 1961; Carpenter and Furr, 1962) in 1956. More than 40,000 seedlings representing 580 varieties and selections of *Citrus* and related genera were inoculated during the period 1956 to 1962, and about 1,000 survivors were retained for further study.

Seedlings tolerant to initial inoculations were planted in infested soil. Since 1960, rooted cuttings of 328 superior seedlings have been reinoculated; cuttings from 83 seedlings were highly tolerant. The 83 selections include one or more seedlings of Carrizo, Sacaton, Sanford, Saunders, Savage, Willits, and Yuma citranges; C.E.S.[2] 1452, C.P.B. 4475, C.P.B. 4590, and Sacaton citrumelos; C.E.S. 1437 and C.P.B. 50097 citradias; C.P.B. 42681 citrangor; C.E.S. 343, Foster, and Triumph grapefruit; Kao Ruan Tia and Kao Phuang pummelos; C.E.S. 2446 and C.E.S. 2455 alemows; Altoona tangor, Karna hybrid, Mesilla Park trifoliate orange, Orogold sweet orange, rough lemon, Clone X, Pearl tangelo, box orange, Volkamer lemon, Khasi papeda, *Citrus sp.* from India, (Clementine mandarin X Troyer citrange) F_1, (Glen sour orange X Kao Ruan Tia pummelo) F_1, (Honey mandarin X trifoliate orange) X O.P., (Rangpur lime X grapefruit C.E.S. 343) F_1, (Sweet Spanish orange X trifoliate

Table 4. Chloride content of dried leaves and rating of leaf-burn, die-back, and defoliation of the most salt tolerant selections from some families of F₁ hybrids.

Accession number and cross	*Plants in family (no.)*	*Chloride (percent)*	*Leaf-burn rating*[a]	*Stem die-back rating*[a]	*Defol-iation (percent)*
55-6-39 (Rangpur lime X Brazil sour orange)	44	0.25	1	1	25
55-11-70 (Rangpur lime X Kao Ruan Tia pummelo)	88	0.14	1	0	5
55-12-114 (Shekwasha mandarin X Swingle trifoliate orange)	14	1.67	1	1	25
55-13-4 (Shekwasha mandarin X African pummelo)	5	1.22	1	1	25
55-14-2 (Shekwasha mandarin X Kao Ruan Tia pummelo)	4	1.02	1	1	20
55-15-10 (Shekwasha mandarin X Koethen sweet orange)	12	0.27	0	0	0
55-16-21 (Shekwasha mandarin X Brazil sour orange)	23	0.64	1	1	15
55-18-8 (Brazil sour orange X Oasis sweet orange)	16	1.98	1	1	20
55-24-108 (Cleopatra mandarin X Swingle trifoliate orange)	12	0.44	1	1	10
55-25-104 (Glen sour orange X Kao Ruan Tia pummelo)	17	2.22	1	1	25
56-16-30 (Rangpur lime X C.E.S. 343 grapefruit)	35	0.62	1	1	0
56-19-6 (Rangpur lime X Sunshine tangelo)	16	0.24	1	0	0
56-20-9 (Rangpur lime X Troyer citrange)	13	0.81	1	1	5
56-21-1 (Rangpur lime X Rough lemon)	4	0.77	1	1	0
56-24-24 (Yuma Rangpur lime X Cleopatra mandarin)	5	0.85	1	0	0
57-48-27 (Rangpur lime X Cleopatra mandarin)	50	0.11	1	1	10
57-49-14 (Rangpur lime X Marsh grapefruit)	33	0.13	1	1	25
57-50-1 (Rangpur lime X African pummelo)	22	0.56	1	0	5

[a] See footnote "a", Table 3.

orange) F₁, (African shaddock X Rubidoux trifoliate orange) F₁, (Sunki mandarin X Barnes trifoliate orange) F₁, and (Koethen sweet orange X trifoliate orange) F₁.

Forty seedlings of the highly tolerant group were re-propagated as rooted cuttings in 1961 and plants of each selection were inoculated with tristeza, cachexia, and exocortis to study their reaction to these viruses. Also, some cuttings were planted for trunk-inoculation studies and some were tested for salt tolerance. The control plants in the virus studies also will provide information on the performance of these selections with nucellar Marsh grapefruit tops.

Partial or complete stem girdling is often a culminating and critical phase of Phytophthora root disease that is not always manifested promptly in small infected seedlings. Some of the tolerant seedlings, especially of the pummelo, grapefruit, sweet orange, tangelo, and rough lemon selections, planted in Phytophthora-infested soil have been severely damaged or killed by foot rot at 3 to 5 years of age. A few selections that were tolerant to root inoculations when tested as young seedlings and as cuttings have been affected by severe foot rot after they were several years old. All seedling candidates selected for tolerance to root rot, therefore, have been or will be inoculated in the trunk.

Kumquats have been considered good sources of inheritance of cold hardiness because they become dormant and remain so at relatively high temperatures. Swingle (1913; 1946) used this character of the kumquat in breeding cold-hardy lemons and limes. Koltz and Fawcett (1930) and Koltz (1960) reported that Meiwa and Nagami kumquats were resistant to *Phytophthora citrophthora* (R. E. Sm. & E. H. Sm.) Leon. in California, but Gondell (1946) found the Nagami kumquat among the varieties most susceptible to infection by *P. citrophthora, P. megasperma* Drechsler and *P. parasitica*. In 1962 several varieties and hybrids of kumquat were included in the *Phytophthora* inoculation tests. From 894 seedlings consisting of kumquat varieties or selections of C.E.S. 132, Marumi, Meiwa, Nagami and Pollock none survived; from 413 plants in 7 lots of citrangequats 8 survived; and from 237 plants in 4 lots of limequats and lemonquats 1 survived. Obviously, seedlings of the kumquat varieties and hybrids tested showed little tolerance to *P. parasitica*.

Some selections of trifoliate orange have been considered highly tolerant to *Phutophthora* (Bowman 1956, Webber 1948, Klotz 1960), especially to *P. citrophthora* and other low-temperature species, the principal ones in most areas where trifoliate orange is a common rootstock. Under experimental conditions at Indio, however, trifoliate oranges have not been especially tolerant to *P. parasitica*. From 4733 seedlings representing 45 selections, 16 percent survived. In 25 lots of rooted cuttings of tolerant trifoliate orange seedlings inoculated with *P. parasitica* 1

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[2] Abbreviations: C.E.S. = University of California Citrus Experiment Station; C.P.B. = Crops Physiology and Breeding, U.S.D.A.; O.P. = open-pollinated.

lot survived. The discrepancy between the performance of trifoliate orange as seedlings or rooted cuttings under experimental conditions and its performance as rootstocks under field conditions has not been explained. Involved, perhaps, are differences in susceptibility of trifoliate oranges to the different species of *Phytophthora* and differences between young and old root systems of trifoliate orange. In spite of its fairly low tolerance to *P. parasitica,* the trifoliate orange, seems to be one of the best sources available for breeding tolerant rootstocks. Hybrids between trifoliate orange and highly susceptible citrus species such as sweet orange, grapefruit, and mandarin have given some progeny more consistently tolerant to *P. parasitica* than most of the pure trifoliate orange selections.

Table 5. Evaluation of open-pollinated seedlings of Sunki mandarin X Swingle trifoliate orange F_1 hybrids for Phytophthora root rot tolerance and for conformity to rootstock type.

Accession number	*P.R.R. test survivors [a] percent*		*Suitability for rootstock rating [b]*	*Combined P.R.R. and rootstock rating[c]*
	1961	1962	1961-1962	(+,-,?)
56-36-13	57	37	fair	–
56-36-22	....	62	poor	–
56-36-30	65	....	good	+
56-36-31	0	....	poor	–
56-36-32	6	44	fair	–
56-36-41	89	....	poor	–
56-36-45	0	....	fair	–
56-36-47	57	....	good	+
56-36-53	100	38	good	?
56-36-73	18	93	fair	–
56-36-74	10	....	fair	–
56-36-79	4	....	fair	–
56-36-80	84	....	fair	?
56-36-86	24	20	good	–
56-36-87	80	29	fair	?
56-36-88	29	....	fair	–
56-36-95	68	88	poor	?

[a] P.R.R. = Phytophthora root rot.

[b] Rootstock ratings:

Good = high percentage of nucellar seedlings, upright growth, freedom from mineral deficiency symptoms;

Fair = 50 percent or more nucellar seedlings, freedom from mineral deficiency symptoms, fairly upright growth habit;

Poor = highly variable, poor leaf color, or weak, or much branched and spreading habit.

[c] + = satisfactory P.R.R. and rootstock rating.

– = unsatisfactory P.R.R. or rootstock rating.

? = a questionable P.R.R. or rootstock rating.

The open-pollinated seedlings of 17 Sunki mandarin X Swingle trifoliate orange F_1 hybrids were tested for tolerance to Phytophthora root rot and rated for suitability as rootstocks. The results (Table 5) illustrate uncertainties and difficulties in such testing. The percentages of survival in the root-rot tests were often not consistent in different seasons, and most of the lots of seedlings with high percentages of survival in root-rot tests did not receive good ratings in the rootstock tests. Survival of seedlings in the root-rot tests is apparently affected by a number of factors (Carpenter and Furr, 1962), any one of which may result in variations in survival in different seasons. The retention of an F_1 hybrid is dependent upon the survival of its open-pollinated seedlings in the root-rot screening test. If survival of the seedlings was 50 percent or greater, the F_1 is retained and its seedlings retested for several seasons or until seedling survival drops below 50 percent. This procedure, it is hoped, will provide an effective means of selecting consistently tolerant plants, if there are such, and eliminating the relatively less tolerant ones.

SUMMARY

A program of breeding citrus scion and rootstock varieties suited to the hot desert areas of the Southwest was begun in 1948 at the U. S. Date Field Station, Indio, California. Primary objects were the production of high-quality mandarin types, an early-maturing, high-quality sweet orange, cold-hardy varieties, red grapefruit of improved color, a virus-free Temple-orange type and rootstocks with various special characteristics, such as tolerance to Phytopthora root rot and to saline soils. The methods of breeding, selecting and testing are described. From 155 crosses made in 1948-54 for improving fruit types and involving parent varieties of mandarin orange, sweet orange, tangor, tangelo, grapefruit, pummelo and lemon, approximately 16,000 F_1 hybrid seedlings were grown. For second test, 185 of the most promising seedlings were propagated on standard rootstocks. Only the few varieties known to produce a high proportion of zygotic embryos were used extensively as seed parents; five of these provided most of the selections for second test, distributed as follows: Clementine mandarin 93, Temple orange 31, Umatilla tangor 16, King mandarin 13, Honey mandarin 12. The following pollen parents produced some of the most promising seedlings: Dancy, Clementine, Wilking, Ponkan, Kinnow, Honey and King mandarins; Temple orange; Minneola and Orlando tangelos.

Over 1,000 seedlings of rootstock types were screened for salt tolerance in field plots irrigated with water containing 6,000 parts per million of salts (sodium and calcium chlorides in equal amounts). The severity of salt-injury symptoms, in general, increased with increase in chloride concentration in the leaves, but below 3 percent chloride the relationship was not close. Salt tolerance or resistance to accumulation of chlorides in the leaves seems to be inherited as a quantitative character. If both parents were highly tolerant, a large proportion of the F_1 seedlings were tolerant, but in the progenies of one tolerant and one non-tolerant parent the distribution of numbers of plants in the several leaf-chloride classes was relatively uniform over the range of chloride concentration. From 18 families of F_1 hybrids over 100 salt-tolerant seedlings were selected and propagated for further tests to determine their potential value as rootstocks. In selecting and breeding rootstocks for tolerance to root rot caused by *Phytophthora parasitica,* over 40,000 seedlings representing 580 varieties and selections of Citrus and related genera were inoculated. About 1,000 survivors have been planted in infested soil for further tests, including trunk inoculation after the trees are several years old. Tolerant seedlings have been found in many groups, including citrange, citrumelo, citradia, pummelo, tangelo, sour orange, Rough lemon, Volkamer lemon, trifoliate orange and various hybrids.

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Effect of Exocortis and Xyloporosis Viruses on Growth of Nucellar Grapefruit on Different Rootstock

BAILEY SLEETH[1]

There has been much speculation and some evidence that growth of virus-infected citrus trees, which are tolerant of or are symptomless carriers of exocortis and xyloporosis viruses, do not grow as rapidly as virus-free trees. The symptomless carrier is usually a combination of two virus-tolerant citrus varieties, rootstock and scion. Cooper, et al (1957) reported that 28 citrus varieties, including Cleopatra mandarin, citrumelo 4475, Pineapple orange, red grapefruit and sour orange are tolerant to exocortis and xyloporosis. In 1960, Sinclair and Brown reported that exocortis adversely affected the growth of Washington navel orange on Cleopatra mandarin and sweet orange rootstock, even though no typical exocortis symptoms were exhibited. Virus-free 12-year-old Valencia orange trees on Cleopatra mandarin, rough lemon and sour orange rootstocks had slight but consistent increased growth and yield over exocortis-xyloporosis infected trees (Olson and Shull, 1962). No typical symptoms of infection were evident on the virus-infected trees.

Of the old-line grapefruit trees indexed for viruses in Texas, all have carried either exocortis or xyloporosis or both viruses. Most, if not all, of the productive grapefruit trees in South Texas are infected and symptomless carriers of one or more viruses. Under these circumstances, it is impossible to assess any adverse effect of these viruses on growth and yield under grove conditions because virus-free trees of comparable age are nonexistent. To obtain information on the effect virus infection on the growth of grapefruit on tolerant rootstocks, a field test was established.

PROCEDURE

Seedlings of Cleopatra mandarin, Orlando tangelo, Rangpur lime and Sacaton citrumelo were budded in the Spring of 1957 with buds from a virus-free red grapefruit seedling clone, 5 years from seed. In the fall of 1957, the red grapefruit tops were bud-inoculated with virus-infected buds from 5 grapefruit trees whose virus status had been determined previously in an indexing program. Of the 5 virus-source trees, two carried both exocortis and xyloporosis; two carried exocortis; and one carried xyloporosis.

Virus infection of the budded trees was considered to have taken place if the inserted bud was green and a more or less permanent union had taken place between the scion bud and the rootstock within 14 days after budding. Shoot development from the virus-infected buds was prevented by pinching off the small shoots as they developed. In this manner virus-infected nucellar grapefruit tops were grown on the different rootstocks.

The virus-inoculated grapefruit trees on various rootstocks and controls were transplanted in May 1958, at a spacing of 6 by 12 feet. A randomized-block planting arrangement was used and ranged from 12 trees on Orlando tangelo to 30 trees on Cleopatra mandarin.

The test trees were severely damaged by a freeze in January 1962 and the test was discontinued in December 1962. The comparative growth response of virus-free and virus-infected grapefruit trees (Table 1) was based upon trunk measurements taken 5 years after the trees were bud-infected with exocortis and xyloporosis viruses. The circumference of each tree trunk was measured 6 inches above the bud union and the cross-sectional area calculated.

RESULTS

Exocortis and xyloporosis viruses, either alone or together, retarded growth of 5-year-old red grapefruit trees on Cleopatra mandarin, Sacaton citrumelo, Rangpur lime or Orlando tangelo rootstocks (Table 1). The retardation in growth from virus infection was least on tolerant rootstocks; —Cleopatra mandarin and Sacaton citrumelo. Virus-free trees on Rangpur lime were larger than virus-free trees on the other rootstocks; intermediate in size on Orlando tangelo and Cleopatra mandarin, and smallest on Sacaton citrumelo.

Table 1. Growth response of 5-year-old virus-infected nucellar grapefruit trees on different rootstocks.[1]

Viruses used to inoculate budlings	*Cross-sectional area grapefruit tree trunks on four rootstocks*			
	Cleopatra mandarin	*Sacaton citrumelo*	*Rangpur lime*	*Orlando tangelo*
	Sq. in.	*Sq. in.*	*Sq. in.*	*Sq. in.*
Exocortis and Xyloporosis	10.9	9.8	5.4	8.1
Exocortis and Xyloporosis	9.6	9.2[2]	6.4	7.1[3]
Exocortis	9.9	–	–	–
Exocortis	9.7	–	–	–
Xyloporosis	10.9	10.3	17.5	–
Control, no virus	13.2	11.1	18.1	13.3

[1] Growth based on calculated cross-sectional area of trunk 6 inches above the bud union of 5 trees except as otherwise indicated.

[2] Average of 4 trees.

[3] Average of 2 trees.

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[1] Plant Pathologist, Texas Agricultural Experiment Station, Weslaco.

Virus-free grapefruit trees, on Cleopatra mandarin rootstock were 20 to 37 percent larger than those infected with either exocortis or xyloporosis or a combination of both. There was little or no difference in the effect of the two viruses on the size of 5-year-old grapefruit trees. On the other hand, a combination of the two viruses did not cause greater suppression of growth than when infected with each separately. There were no symptoms of infection by either virus on Cleopatra mandarin rootstock.

Xyloporosis-infected grapefruit trees on Sacaton citrumelo rootstock were only slightly smaller than the virus-free trees. On the other hand, non-infected trees on citrumelo were 13 to 20 percent larger than the trees infected with both exocortis and xyloporosis. Sacaton citrumelo rootstock was less sensitive to the exocortis virus than either Cleopatra mandarin, Rangpur lime or Orlando tangelo.

The greatest suppression of tree growth occurred when Rangpur lime rootstock was infected with both exocortis and xyloporosis. This suppression of growth was attributed to the exocortis virus since the xyloporosis virus alone suppressed growth only slightly, less than 4 percent. No external symptoms of xyloporosis infection developed on the Rangpur lime rootstock.

Grapefruit trees on Orlando tangelo rootstock infected with both exocortis and xyloporosis were 39 to 46 percent smaller than the non-infected controls. Since Orlando rootstock is especially sensitive to the xyloporosis virus, the retardation of growth is attributed mainly to this virus. Unfortunately, no grapefruit trees on Orlando rootstock were infected with exocortis or xyloporosis alone.

DISCUSSION

The results obtained in this test, (Table 1) are substantially in agreement with those reported by Cooper et al (1957), Sinclair and Brown (1960) and Olson and Shull (1962), in that growth of virus-infected grapefruit trees on virus-tolerant rootstocks were retarded in growth. Such trees have been called symptomless virus carriers and appear to be disease-free, even though retarded in growth. It is evident that virus-free budwood is to be preferred to virus-infected budwood in the propagation of nursery stock, regardless of rootstock used. Even though certain rootstocks as Cleopatra mandarin and Sacaton citrumelo exhibit considerable tolerance to exocortis and xyloporosis viruses in young citrus trees, the adverse effects will doubtless increase as the trees grow older. It is possible that the productive life of Valley citrus trees, particularly red grapefruit, is shortened by bud transmitted viruses as exocortis and xyloporosis. Psorosis is known to cause mature trees to decline and shorten their productive life.

SUMMARY

Nucellar virus-free red grapefruit budlings on Cleopatra mandarin, Sacaton citrumelo, Orlando tangelo and Rangpur lime were bud-inoculated with either exocortis, xyloporosis or both viruses from virus-infected grapefruit trees. No shoot growth was allowed to develop from the inserted buds. After 5 years growth, in a 12 x 6 foot spaced planting, the virus-free trees were consistently larger than the virus infected trees on the four rootstocks. The retardation in growth from virus infection was greatest in the trees on rootstocks most sensitive to the specific virus. However, the growth of red grapefruit tops on Cleopatra mandarin, considered a symptomless carrier, was retarded by both exocortis or xyloporosis. Growth of virus-free grapefruit trees was influenced by rootstock; the most rapid growth was on Rangpur lime, intermediate on Orlando tangelo and Cleopatra mandarin and least on Sacaton citrumelo.

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Puss Caterpillars on Citrus

H. A. Dean and Michael F. Schuster[1]

Larvae of puss caterpillars, *Megalopyge* sp. (Megalopygidae: Lepidoptera), were unusually abundant on citrus during the fall of 1955 throughout the Lower Rio Grande Valley area. Infestations were great enough in certain cases to cause noticeable loss of foliage. Predominant colors of the larvae were tan and gray. Investigations were begun to determine if more than one species was present and to obtain other biological information relative to this insect.

Micks (1956) determined that the life cycle of the puss caterpillar, *Megalopyge opercularis* (J. E. Smith), required approximately 3 months. The larval period of development was about six weeks. He reported no particular problem in rearing the caterpillars in the laboratory in battery jars, adding leaves for food as needed, and suggested the possibility of rearing several generations per year. Bishopp (1923) reported from field studies that the maximum number of grown larvae of the first brood seemed to occur in June and July and of the second brood in September and October at Dallas, Texas. Watson and Berger (1937) reported *M. opercularis* occasionally feeds on orange trees in Florida. They found two broods of caterpillars each year, one in early summer and the other in late fall.

Host plants listed in the literature are numerous for *M. opercularis* but only the more common hosts will be mentioned here. Bishopp (1923) listed, in order, host preferences of *M. opercularis* in Texas as follows: hackberry (*Celtis occidentalis*), elm (*Ulmus*, two or three species), cultivated and wild plum (*Prunus* spp.), sycamore (*Platanus occidentalis*), and oak (*Quercus*, several species), and frequently on rose bushes (*Rosa* spp.). Flitters (1960) reported from the Brownsville, Texas area the following host plants: hackberry, Turks Cap (*Malvaviscus* sp.), pyracantha, crepe myrtle, ash (*Fraxinus* sp.), mulberry (*Morus nigra*, etc.), willow (*Salix* sp.), and the abundant acacia shrubs. Wene and Riherd (1953) suggested that home owners should examine their hackberry, crepe myrtle and pyracantha trees during the months of April and May and again in September for the presence of these caterpillars if they are to start control measures when these caterpillars are small.

Parasites of *M. opercularis* have been reported by several authors. Bishopp (1923) found a bacterial disease in the larvae, but concluded that it was of lesser importance in control than the tachinid parasites, *Exorista flavirostris* v. d. w. and *Phorocera claripennis* Macq. In one lot of cocoons, Bishopp found 75% of the larvae of the fall generation parasitized by the two species. The hymenopterous parasites, *Chalcis ovata* Say and *Compsocryptus retentor* (Brulle) were also collected from cocoons in November. Micks (1956) reported 20% parasitism of *opercularis* in the fall by tachinid flies, *Carcelia lagoae* (Tns.) and *Phorocera*, probably *claripennis* (Macq.) the latter of little importance. *Compsocryptus retentor* (Brulle) was also found. Flitters (1960) found the tachinid parasites, *P. claripennis*, *C. lagoae* and *E. flavirostris*, were the dominate parasites of *M. opercularis* in the Brownsville area. An occasional speciman was parasitized by *C. retentor*, *C. ovata* and a bacterial disease.

Larvae were collected during the fall of 1955 from citrus trees and brought to the laboratory for rearing. Larvae were reared on grapefruit leaves in either 1 quart cylindrical cardboard food containers or 1 gallon battery jars. Some tan-colored larvae were observed to change to a gray color during development. The gray-colored larvae that were observed remained gray throughout all larval stages. Color of the last larval instar was preserved in the cocoon by incorporation of larval hairs in the cocoon. The larvae spun cocoons in late October or early November and individuals remained in the cocoons until the following spring. Adults emerged the middle of May 1956 but no indications had been found as to the time of pupation. Very few puss caterpillars were observed during 1956 and 1957. Cocoons were collected in the early spring of 1962. Only a few individuals were found and pupation occurred with these during mid-April.

Larvae of the first brood were observed on citrus, hackberry and pyracantha from late May to late July. The variability in size of larvae indicated oviposition over a lengthy period. Adults emerged in August about a month after the last instar larvae formed cocoons in late July. Eggs were laid in clusters covered with hair from the female.

Adults, larvae and cocoons from laboratory rearings were submitted for identification together with adults collected from a light trap. A white puss caterpillar moth, *Norape virgo* (Bulter), was identified from a few light trap specimens. However, all other specimens were identified as *Megalopyge opercularis* (J. E. Sm.). Therefore, the only species involved on citrus in this area was *M. opercularis*. The larvae of *M. opercularis* were also collected from hibiscus, Japanese yew and Pigmy date palm (*Phoenix roebelenii*).

Light trap collections at Weslaco showed a distinct increase in the number of puss caterpillar moths during the April-May and August-September periods, as shown in Table 1. These increased moth populations during the two particular periods gave rise to the late May-July and the late September-early November broods of larvae found on citrus. Collections of *N. virgo* also showed the same peaks in moth flights. Males were the predominant sex of *N. virgo* collected except that a few females

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were taken during the heaviest flight periods. The U. S. National Museum reported no records of food plants for *N. virgo.* A similar seasonal flight trend for *M. opercularis* had been shown in light trap collections during 1953 at Weslaco by Riherd and Wene (1955).

Numerous *M. opercularis* larvae were collected during October 1955 which appeared to be infected with a virus disease. A subsequent determination by E. A. Steinhaus showed the larvae were infected with a granulosis virus and this was his first record of a granulousis virus in this insect. The very humid and extended rainy conditions at the outset of this generation in September were apparently very favorable for dissemination of the virus. Records of per cent larval infection were not made during this period. Puss caterpillars were very scarce during the following seven years.

A rather common caterpillar parasite, *Achaetoneura aletiae* Riley (Tachinidae), was reared from *M. opercularis* in November 1955. Shriveled and sick-looking caterpillars were moved to cylindrical cardboard food containers or low form "stender" dishes. One to three fly larvae emerged from last instar puss caterpillar larvae and pupated. The incidence of virus infection appeared to be much more common than the incidence of parasitism during the fall season of 1955 in our observations.

Table 1. Number of puss caterpillar moths taken in light trap[a] each month at Weslaco, Texas.

Month	*Megalopyge Opercularis*	*Norape virgo*
January 1956	0	0
February	4	0
March	15	0
April	79	0
May	434	50
June	1[b]	6[b]
July	0	1
August	35	5
September	300	125
October	3[c]	56[c]
November	0	1
December	0	0
January 1957	2	0
February	4	0
March	10	0
April	151	29
May	161	55

[a] Four baffle, modified Minnesota light trap with four 15-watt black lights, five feet high

[b] Only last two weeks of month record

[c] Only first two weeks of month record.

SUMMARY

Puss caterpillars were very numerous on citrus in the Lower Rio Grande Valley during the fall of 1955. Populations were very small during the following 7 years. Two broods of caterpillars were found to be periodical in the field during late May-July and late September-early November. Identification of reared specimens proved *Megalopyge opercularis* (J. E. Sm.) was the only species involved on citrus even though different-colored larvae were present.

Numerous larvae of *M. opercularis* were found infected with a granulosis virus during October 1953. A tachinid parasite, *Achaetoneura aletiae,* was reared from several larvae.

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Control of Texas Citrus Mites with Various Spray Oil Fractions

H. A. Dean and Jack C. Bailey[1]

The Texas citrus mite, *Eutetranychus banksi* (McG.), has been a pest of citrus in this area for many years. Growers had relied on sulfur dust for control until recent years when some growers began using other miticides which provided longer residual control. The present investigations were begun in 1959 to determine the effectiveness of various spray oil fractions in the control of the mite during the summer and fall seasons.

Information on the mite was scanty for many years. Unpublished records at this Substation gave only a casual mention in 1930. The mite was reported in increasing numbers in 1935 when S. W. Clark submitted specimens which were identified as a new species, *Anychus clarki* McG., intermediate between *A. banksi* and *A. rusti,* according to McGregor (1935). This mite had formerly been confused with the citrus red mite, *Panonychus citri* (McG.), but Dean (1952) found no valid record of the mite from Texas. However, the citrus red mite has since been found on 2 backyard citrus trees in the Houston area. Pritchard and Baker (1955) considered several species, such as *clarki* and *rusti,* as synonyms of *banksi.*

Seasonal build-up of the mite and miticide-control investigations were important considerations in any program for maintaining small populations throughout the year. Various dust and spray formulations were investigated by Dean (1952), Dean (1959), Dean and Sleeth (1959), Thomas (1960) and Bailey and Dean (1962). Residual control with materials applied as dusts was not as long as with the same materials applied as sprays. Greater populations resulted when a controlling agent was not added at the post-bloom application. Dean (1959) found the period of greatest increase during the May-July period during 1954-56. During those years, there was a much smaller increase period during December and January. Other increase periods occurred and have since been found to occur when warmer and drier weather conditions prevailed in this area. However, results indicated that a longer-residual controlling agent applied at post-bloom might keep Texas citrus mites in very small numbers through the May-July rapid-increase period before a summer oil application for scale control might be applied.

MATERIALS AND METHODS[2]

Spray materials were applied from a ground rig. Single nozzle guns (6/64 orifice size at post-bloom and 8/64 orifice size during summer applications) were used with 550-600 psi pressure at the tank. Trees were sprayed from each quandrant position to accomplish thorough coverage. Tree height varied from 9-14 feet at the Rio Farms grove, 12-18 feet at the Texsun grove, 7-8 feet at the Crockett grove and 7-10 feet at the Substation No. 15 grove.

Plot size varied somewhat in each experiment. The 4-tree plots at Rio Farms were surrounded by at least one row of buffer trees and were replicated three times. Plots were 4 trees in size at the Texsun grove and were replicated 5 times. At the Crockett grove the 4-tree plots were surrounded by one buffer row (non-oil plots consisted of 4 trees scattered nine times throughout the experiment) and were replicated 4 times. Plots at Substation No. 15 were 2 rows wide and leaf samples were taken at 4 points within the treated area.

Dosages of the various spray materials per 100 gallons of mixture are given as follows:

a. Copper – 1 lb. brown copper oxide (75% metallic)

b. Kelthane, 1, 1-bis (p-chlorophenyl) – 2, 2-, 2-trichloroethanol-1 quart 18.5% EC (except as noted)

c. Oils – 1.6 gal (see Table 1 for physical properties)

d. Tedion – 2, 4, 5, 5-tetrachlorodiphenyl sulfone – 1 lb. 25% WP

e. Zineb – 1 lb. 75% WP

f. Triton B-1956 (Rohm and Haas Co.) spreader-sticker

The oil-soluble nonionic surfactants Sponto 200[3] and 9D-207[4] were incorporated in the various oils for regulation of their oil-depositing properties. The surfactants are of the type, alkyl aryl polyether alcohols and related compounds.

Mite populations were estimated by collecting 40 leaves per plot, brushing the mites from the leaves with a mite-brushing machine onto a 5-inch plate and counting the mites on one-half the area under a stereoscopic microscope.

RESULTS

In the Rio Farms experiment, longer residual control of Texas citrus mites was found with the paraffinic oils D and F and the Kelthane treatment than with the napthenic oils A and B as shown in Table 2. It should be noted that oils A, D and F, in 1959 contained too much (1.75%) Sponto 200 surfactant. Laboratory tests subsequently showed 0.5 volume per cent would deposit the desired amount of oil (this formulation of Sponto 200 no longer in use). The reduced deposit of oil with the 1959

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[2] Thanks are due Rohm and Haas Co. and Niagara Chemical Division for supplying miticides for this experiment.

[3] Sponto 200 manufactured by Retzloff Chemical Company, Houston, Texas.

[4] 9D-207 manufactured by Rohm and Haas Company, Philadelphia, Pennsylvania.

formulations were considered a contributing cause for poor residual control of the mite. Smaller populations were found in plots of the higher molecular weight oil F. Mite populations were comparable in the non-oil and oil D plots.

Rainfall measurements (1-inch or greater) are given to show the expected effect on Texas citrus mite populations after summer application. During 1959, rainfall measurements were as follows: 8/24 – 2.0, 10/4 – 2.2, 10/14 – 1.1, and 11/18 – 1.4. The following recordings were made in 1960: 8/13 – 4.4, 8/15 – 1.1, 8/30 – 1.6, 9/6 – 3.8, 10/17 – 1.8 and 12/14 – 2.2. During 1961, rainfall was as follows: 7/20 – 3.3, 8/8 – 2.0, 8/16 – 1.0, 8/19 – 1.5, 10/15 – 6.0 and 10/2 – 1.0. Rainfall was insignificant in 1959 following application for exertion of much effect on mite populations. During 1960, rainfall was sufficient between the first and third population counts after application to prevent greater increases than found. The greater amount of rainfall that fell in the 2 month period following application in 1961 was considered sufficient to reduce mite populations. Therefore, rainfall was greater after summer application in 1960 and 1961 and frequently appeared to have reduced existing populations of the mite similar to that as shown by Dean (1952).

Greater wind movement appeared associated with Texas citrus mite build-up following the July application. The total miles of wind and the

Table 1. Summary of spray oil properties.

	A	B	C	D	E	F	G	H
Gravity, °API[a]	30.5	30.2	29.5	34.1	35.3	33.0	35.7	34.4
Molecular weight (mills)	303	292	350	333	330	361	338	365
Viscosity, SSU @ 100F	73.6	68.5	103.7	80.2	73.4	105	76.2	98.6
Oil, %	99.50	98.0	99.75	99.5	99.75	99.5	99.75	99.75
Unsulphonated residue, (ASTM) %	94	92	93	92	96.4	90	99	93
Distillation at 10 millimeters pressure, 50% point, °F	404	395	442	449	447	475	460	469
Maximum boiling range (10-90%)	82	132	72	90	78	55	89	72
Surfactant	S-200	[c]	9D-207	S-200	9D-207	S-200	9D-207	9D-207
Per cent	0.5[b]	[c]	0.25	0.5[b]	0.25	0.5[b]	0.25	0.25

[a] Oils A, B, and C are naphthenic; oils D, E, F, G, and H are paraffinic.
[b] In 1959, 1.75% was used.
[c] Surfactant and per cent were not known.

Table 2. Spray treatments (with zineb) applied to red grapefruit trees at the Rio Farms grove and their effect on Texas citrus mite and citrus rust mite populations.

	Oil A			Oil D			Oil F			Oil B			Kelthane		
Date	TCM[a]	TCME[b]	RM[c]	TCM	TCME	RM	TCM	TCME	RM	TCM	TCME	RM	TCM	TCME	RM
6-18-59	6.0	13.63	.9	4.1	9.3	.9	3.8	10.5	1.2	11.2	27.7	1.0	5.0	15.8	.8
7-1&2	Sprayed			Sprayed			Sprayed			Sprayed			Sprayed		
8-3	1.2	1.1	–	.1	.1	–	.02	.4	–	1.1	1.4	–	–	.03	–
9-1	10.8	34.1	.1	2.8	8.0	.03	.8	4.0	.03	8.5	20.3	.02	1.0	6.0	.02
9-23	29.4	54.3	.02	22.0	27.6	–	7.3	11.8	.03	23.3	34.1	–	14.5	24.1	.1
10-21	12.3	7.9	.6	21.0	10.9	2.4	20.3	9.1	1.8	16.3	9.0	1.1	17.5	9.0	1.0
3-17-60	.6	.5	.2	.2	.2	.3	–	.2	.3	.5	.2	.2	.4	.5	.2
4-7&8	Sprayed all plots[d]														
6-27	1.5	2.6	–	1.4	2.4	–	1.6	2.3	.1	1.5	2.0	.1	2.2	3.0	.1
7-5&6	Sprayed			Sprayed			Sprayed			Sprayed			Sprayed		
8-10	.2	.3	–	–	.1	–	–	.1	–	.1	.3	–	.1	.3	–
9-14	8.2	2.3	.1	1.8	.8	.1	.7	.4	–	10.7	3.1	.1	.8	.2	–
10-11	1.7	1.1	.8	2.2	.7	2.6	1.0	.3	3.1	1.5	.3	2.8	1.1	.4	2.1
3-14-61	2.2	4.5	4.7	5.3	3.6	4.2	2.8	3.4	2.3	3.4	3.4	7.6	5.3	3.9	3.5
4-5	Sprayed all plots[e]														
6-15	.1	–	–	.2	–	–	.3	–	–	.3	–	–	.1	–	–
7-3,4,5	Sprayed			Sprayed			Sprayed			Sprayed			Sprayed		
8-28	.1	.3	–	.01	.1	–	.01	–	–	.4	.5	–	.3	.1	–
10-9	.7	.8	.3	.6	.6	.7	.1	.2	.7	1.0	.4	.2	.4	.4	.2
11-16	.03	.4	.5	.2	.4	1.0	.1	.2	2.0	.02	.1	.3	.1	.3	.3

[a] Texas citrus mites per leaf.
[b] Texas citrus mite eggs per leaf.
[c] Citrus rust mites per leaf.
[d] All plots sprayed with 1 lb. 75% zineb, 1 pint 18.5% EC Kelthane and 2 oz Triton B-1956 per 100 gal of mixture.
[e] All plots sprayed with 1 lb. 75% zineb, 1½ pints 18.5% EC Kelthane and 2 oz Triton B-1956 per 100 gal of mixture.

number of days which had 75 miles of wind movement or greater are given as follows for July, August and September for the indicated years: 2043 (15), 2012 (14) and 2218 (17) – 1959; 2123 (13), 2142 (12) and 1139 (1) – 1960; and 1658 (3), 1237 (0) and 1755 (6) – 1961. During 1961, wind movement was less with fewer wind storms. Wind movement was greater during the period in 1959 and appeared as a possible associating factor favorable for increase of Texas citrus mites. Mites were not controlled as well by chemical treatment in 1959. Wind movement is considered here only as a premise for future investigations.

Residual control of citrus rust mites lasted for 3 months during 1959 and 1960 after the summer applications and extended to 4 months during 1961. Sprays were applied for control after these periods. Populations had increased in particular just prior to the post-bloom application in 1961.

At the Texsun grove near Edinburg, populations of Texas citrus mites were small well into the fourth month after application with all treatments, as shown in Table 3. Populations of mites were somewhat less in the paraffinic oil plots E and G. All plots were sprayed on May 23, 1961 which resulted in very small populations before the summer sprays were applied. This condition was very favorable for long residual control.

Rainfall was probably not great enough to affect Texas citrus mite populations during July (0.97 inches) or August (1.18 inches). However, the 5.32 inches of September rainfall was principally associated with Hurricane Carla during September 11-13 and probably deterred the increase of this mite.

Counts of citrus rust mites showed small populations well into the fifth month after treatment. A very small population was present just prior to the summer application while an increasing population was found just prior to post-bloom.

The same treatments as used in the Rio Farms experiment were used in an experiment at Substation No. 15. An initial application was made September 1, 1959 and held populations of Texas citrus mites at small levels. The experiment was sprayed on March 25, 1960 with 1 pint 18.5% EC Kelthane and 1 lb. 75% WP zineb per 100 gallons mixture. Mite populations were 0.2 mites per leaf or less just prior to application. After 3 months, mites had increased to 3.5 per leaf and greater. Just before the summer treatments were applied ½ month later (July 12), mite populations had increased threefold. Three months after application, mite population in the paraffinic oil plots and Kelthane non-oil plots were smaller (0.9 mites per leaf and less) than in the naphthenic oil plots A and B as determined by the mite and egg counts.

During 1960, an experiment was conducted at the Crockett grapefruit grove near Harlingen to determine the possible tree reaction affects from paraffinic oil H applied on various dates during the summer season. Only Texas citrus mite information is reported here since citrus rust mite

Table 3. Spray treatments (with zineb) applied to pineapple orange trees at the Texsun grove and their effect on Texas citrus mite and citrus rust mite populations.

Date	Oil A			Oil E			Oil G			Oil C			Kelthane		
	TCM[a]	*TCME*[b]	*RM*[c]	*TCM*	*TCME*	*RM*	*TCM*	*TCME*	*RM*	*TCM*	*TCME*	*RM*	*TCM*	*TCME*	*RM*
5-17-61	14.6	18.1	1.6	16.1	21.2	1.8	25.5	26.9	3.0	18.6	22.1	2.0	14.9	20.6	5.6
5-23	All plots sprayed[d]														
7-6	.01	–	–	.03	.1	.01	.02	.02	.03	.03	.1	.01	.02	.1	–
7-10&11	Sprayed			Sprayed			Sprayed			Sprayed			Sprayed		
8-24	.1	.1	.03	–	.02	–	–	.1	.02	.03	.04	.01	.03	.02	.02
9-28	.7	.2	–	.1	.02	–	.02	.02	–	.1	.2	–	1.0	1.0	–
10-26	1.1	.5	–	.2	.1	–	.1	.1	.01	.4	.1	–	.4	.2	–
11-20	2.6	1.5	.01	1.1	.8	–	.6	.2	.01	1.6	.8	.1	1.4	.8	–
12-17	3.3	1.4	.03	2.5	1.0	.02	2.3	.9	.5	3.9	1.6	.02	3.5	.9	.04

[a] Texas citrus mites per leaf.
[b] Texas citrus mite eggs per leaf.
[c] Citrus rust mites per leaf.
[d] All plots sprayed with 10 lbs. WP sulfur, 1 lb. 75% WP zineb and ½ lb. 25% WP Tedion per 100 gallons mixture.

populations were extremely small throughout the course of the experiment. The entire experiment was sprayed on April 4 with 1 lb. 25% WP Tedion plus 1 lb. 75% WP zineb plus 1 lb. brown copper oxide (75% metallic copper)per 100 gallons of mixture. Pre-treatment mite populations varied from 1.3 to 4.3 mites per leaf and 1.2 to 3.8 eggs per leaf. Oil H was applied to various plots on the following dates: July 1, July 15, August 1, and September 1. The non-oil treatment was 1 quart 18.5% EC Kelthane with 1 lb. 75% WP zineb applied on September 1. Coverage was very good. Texas citrus mite populations were extremely small and reached the greatest level of 0.6 mite per leaf just prior to application of oil H in September. Mites during the remainder of the year were almost absent from the trees. Oil H was derived from higher boiling fractions and cannot be recommended for grower use.

SUMMARY

Residual control of Texas citrus mites was somewhat longer with the paraffinic than with the napthenic oils. A slightly smaller population was found in the higher molecular weight paraffinic oil plots while populations in the lower molecular weight paraffinic oil plots were comparable with those in the non-oil Kelthane plots. The higher molecular weight napthenic oil plots showed somewhat smaller populations than in the lower molecular weight naphthenic oil plots. Indications were that where smaller populations were present just prior to summer application, longer residual control resulted. Rainfall was a climatic factor of importance following application.

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The Development of Chromoplasts and Carotenoids in Colored Grapefruit

Albert E. Purcell[1], Jarrell H. Carra[2], and Ines V. deGruy[2]

It has been suggested that carotenoids in tomato fruits may be synthesized in chloroplast fragments (Purcell and Thompson, 1961).

Straus (1950, 1953, 1956) has extensively studied the chromoplasts of carrots and reported the presence of a protein stroma within the crystalline forms. He further demonstrated that chromoplasts of different colors had the same ratio of the various carotenoids and concluded the difference in color was due to the amount of total carotenoids in the stroma.

Frey-Wyssling and Kreutzer (1958^a, 1958^b) have shown that chromoplasts in fruit of peppers and flowers of buttercup are formed by the deposition of lipids and carotenoids in fragments of ruptured chloroplasts, thus accounting for the origin of the stroma observed by Straus.

It has been observed that most chromoplasts of mature red grapefruit appear as red needles similar to those observed by Straus in tomatoes (personal communication). As part of a study of carotenogenesis in colored grapefruit the seasonal development of chromoplasts in Red Blush grapefruit has been studied. A parallel study of white grapefruit has been made.

EXPERIMENTAL

The red grapefruit used in this study were picked from a Ruby Red tree and the white from a Marsh White tree, at Texas A. & M. Experiment Station Branch 15, Weslaco, Texas. Fruit were picked and examined periodically from April 1960 until April 1961. In addition to direct microscopic examination, chromoplast concentrates of the larger fruit were prepared by centrifugation.

Direct examination. The juice sacs of very immature fruit one to three cm, were too tough to yield sufficiently thin sections or to be mashed. It was necessary to digest the juice sacs with 2% cellulase preparation (Rohm & Haas No. 36)[3] for several hours at room temperature be-

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[3] The mention of firm names or trade products does not imply that they are endorsed or recommended by the Department of Agriculture over other firms or similar products not mentioned.

fore they could be mashed sufficiently for microscopic examination of the intracellular plastids. The "mashes" were examined without fixing and characteristic chloroplasts or chromoplasts were photographed by direct and polarized light.

Preparation of concentrates. When the fruit reached a size of four to five cm diameter (July 7), the chromoplasts were concentrated by centrifugation. Fruit were peeled to yield approximately 200 grams of carpels. The carpels were blended for one minute in a Waring Blendor[3] at full line voltage in three volumes of a solution containing 0.25 M sucrose, 0.1 M potassium phosphate buffer pH 8 and 0.01 M potassium floride. The fruit and solutions were chilled to 4° C. before blending. The blended carpels were strained through four layers of cheesecloth, then through "Miracloth" paper[3]. The filtrate was centrifuged at 3000xg. for five minutes. The clear supernatant was discarded. The large pellet was resuspended in 0.25 M sucrose and centrifuged at 20,000xg. for ten minutes. The supernatant was discarded. The pellet was compact and at least two distinct layers were formed. The upper layer (red, in case of red fruit, gray-green in the white) was scraped from the small but dense white bottom layer and resuspended in 1.0 M sucrose. The suspended material was centrifuged at 20,000xg. for 20 minutes. Chromoplasts in the floating oily layer were obtained by carefully collecting the oily layer with a medicine dropper, resuspending in 0.25 M sucrose and centrifuging at 12,000xg. for ten minutes. The resulting pellet was suspended in a minimum volume of 0.25 M sucrose. These preparations contained appreciable amounts of materials stainable with methylene blue and the amount increased sharply in the late part of this study (January to March). In order to obtain cleaner preparations the second pellet (0.25 M sucrose, 20,000xg.) was resuspended in two volumes of 50% cupriethylenediamine hydroxide (cuene), warmed to 22° C. This mixture was immediately diluted with eight volumes of 4° C, 0.25 M KC1, and centrifuged at 12,000xg. for ten minutes. Excess cuene was removed by resuspending the pellet in 0.25 M KC1 and centrifuging as before. The washed pellet was then resuspended in 1.0 sucrose and treated as mentioned above. This procedure yielded chromoplasts with very small amounts of materials stainable with methylene blue.

Microscopy. At each sampling period, photomicrographs of plastids were taken with natural and polarized light. The microscope was equipped with a 90 X oil immersion objective and a 10 X periplan ocular. Illumination was by the Orthoilluminator of American Optical Company[3]. Polarized light was achieved by insertion of polaroid sheets in substage condenser and ocular. A drop of the suspension was placed under a cover glass and photographed at a magnification of 2000 X. When the eyepiece was rotated until the polars were in the extinction position, the rose colored needle-like crystals and the lighter trapezoidal platelets from red grapefruit were both brilliantly birefringent. Occasional colorless plastids in suspensions from white grapefruit were also birefringent. Photomicrographs were made with Kodak Contrast Process Orthofilm[3] with a K-2 filter.

RESULTS

Seasonal development. (Table 1.) At the beginning of this study (March 2, 1960) the fruit were about one cm. in diameter, most of which was albedo. The carpels were about two to three mm. in diameter, and light green in color. Microscopic examination showed the presence of apparently normal chloroplasts. As the fruit matured no evidence of starch accumulation in the chloroplasts as reported by Frey-Wyssling and Kreutzer (1958[a]) in capsicum fruits was noted, but the color of the carpels and chloroplasts decreased. By June 1, the fruit had reached about four to six cm. in diameter and the inside was nearly colorless. A few pale chloroplasts could still be found.

By June 13 the fruit had increased to five to seven cm. in diameter, and the peel had a slight pink color but no chromoplasts were found.

On July 7 (fruit six to eight cm. in diameter), pink color could be seen in the carpels. The remaining chloroplasts were much enlarged and pale. Rose colored droplets were found in direct examination of the albedo but none were found in the carpels. Examination of a chromoplast concentrate of the carpels revealed the presence of some pink droplets.

On August 23 (fruit eight to nine cm. in diameter) the carpels were deep red. Red droplets were common and showed birefringence. Birefringence of the droplets increased and color continued to increase.

Table 1. Description of Chromoplasts and Changes in Pigment Content During Development of Ruby Red Grapefruit.

Date	*Fruit size*	*Pigment content*[1] *mg.* *L*	*%* *C*	*Description of chloroplasts and changes*
March 2	1 cm.	----	----	Apparently normal chloroplasts.
June 1	6 cm.	----	----	Few pale chloroplasts.
June 13	7 cm.	----	----	Chloroplasts less abundant and paler.
July 7	7 cm.	.20	.03	Few remaining chloroplasts enlarged and nearly colorless. Colored droplets found in albedo.
Aug. 23	8 cm.	1.70	.18	No chloroplasts, red birefringent droplets common in carpels.
Sept. 22	9 cm.	1.74	.24	Birefringent red needle-like crystals common in carpels.
Oct. 13	9 cm.	1.55	.28	Many needle-like red chromoplasts, few platelets the same color.
Dec. 22	9 cm.	.70	.48	Needle-like chromoplasts larger and paler. Platelets more abundant.

[1] Estimated from curves of pigment content obtained from adjacent groves.

By September 22 (fruit eight to ten cm. in diameter), highly birefringent needle-like crystals were common and birefringent colored droplets were still found.

Analysis of the pigments by the method of Purcell (1958), showed that the lycopene content of the fruit had reached a maximum by September 15, but had not decreased by September 22. By October 13 the lycopene content of the fruit had declined about 10%, while the *B*-carotene content continued to increase. At this time many well-defined needle-like chromoplasts were present and a few platelet-like chromoplasts were found. On December 22 the visible color of the carpels had changed from red to orange. Lycopene content had declined to about 40% of the maximum on September 15, while carotene content about doubled. The crystalline chromoplasts appeared larger and paler. Platelet-shaped chromoplasts were somewhat more abundant than before but were the same color as the needle-shaped chromoplasts.

The most prominent feature in late season was the slight fading of color in the chromoplasts.

Seasonal development in white fruit. Until June 1, there was no gross histological nor chemical difference between white and red fruit. The chloroplasts in white fruit enlarged slightly and faded as in red fruit. In white fruit the chloroplasts seemed to disappear and the development of chromoplasts could not definitely be detected. After October 13 some small colorless birefringent droplets could be found but these were few compared to the birefringent colored bodies in red fruit. After the disappearance of the chloroplasts, small clearly transparent spheres about the size of enlarged chloroplasts were often noticed. These bodies were occasionally seen in red fruit but not as often as in white.

DISCUSSION

The development of chromoplasts in colored grapefruit seems to parallel the observations reported by Frey-Wyssling and Kreutzer (1958^{a}, 1958^{b}) on the development of chromoplasts in peppers and flowers. The main difference is formation of crystal-like chromoplasts.

It is interesting that while lycopene is the predominant carotenoid of grapefruit the chromoplasts appear as needles, as in tomatoes, but as the abundance of *B*-carotene increases, platelet-shaped chromoplasts similar to those of carrots appear. The platelets of grapefruit, however, are pink in contrast to the yellow or orange color of carrot chromoplasts.

It may be argued that since lycopene crystallizes as needles and *B*-carotene as platelets, the change in shape of grapefruit chromoplasts indicate they are indeed crystals of pigment. The difference of color between chromoplasts and crystals does not support this. The work of Straus (1950, 1953, 1956) on carrot chromoplasts appears conclusive and there is no reason at present to believe that grapefruit chromoplasts represent a special case.

In reviewing the work of Frey-Wyssling and Kreutzer (1958^{a}, 1958^{b}) there is the implication that accumulation of carotenoids in fruits and flowers leading to formation of chromoplasts may depend upon fragmentation of chloroplasts. The data presented here seem to support this implication. In colored fruit the disappearance of chloroplasts and early stages of chromoplast development apparently parallel their work. In white fruit, very little accumulation of pigment occurs and, although inconclusive, it appears that chloroplasts do not fragment as they do in high carotenoid colored fruit.

SUMMARY

In colored grapefruit it appears that chromoplasts are formed by the deposition of carotenoids into bodies probably arising from fragmented chloroplasts. While lycopene is the major pigment, the chromoplasts are needle-like but as *B*-carotene increases, platelet-like chromoplasts are found. In white grapefruit chromoplast-like bodies do not form after chloroplasts have faded but colorless spheres the size of chloroplasts still persist.

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Terminal Necrosis and Wilt of Papayas

ROBERT C. LAMBE[1]

Commercial production of papayas (*Carica papaya* L.) has been negligible because of cold and disease in the Lower Rio Grande Valley of Texas. However, papayas are a common home-yard plant and do provide considerable fruit for home consumption. Collapse of plants in this area has been attributed to an accumulation of chlorides in the roots (Cooper, 1953) and root rot (Olson, 1950). Recently, the susceptibility of young papaya plants to infection by tobacco ringspot virus was demonstrated (McLean and Olson, 1962). They did not test for the natural occurrence of tobacco ringspot virus in declining, fruiting papaya plants. Papaya production in Florida has been curtailed due to virus diseases in recent years (Harkness, 1960). A virus-caused mosaic disease was reported in 1961 as causing severe losses in commercial plantings in Hawaii (Ishii, et al, 1961).

In a ¼ acre planting of fruiting papayas near Progreso, Texas, a serious disease situation had developed in September, 1962, and considerable loss had occurred. The disease symptoms were wilting and complete collapse. In early stage of wilt, plants commonly showed necrosis of the terminal growing point (Figure 1). Plants in advanced stages of wilt also had discolored decaying roots. The fungi, *Rhizoctonia solani* Kuhn, and *Fusarium* spp., were isolated from the necrotic margins of decaying roots.

Experimental Procedure and Results

Five immature papaya plants approximately two feet tall were mechanically inoculated with juice from triturated terminal leaves of wilted papayas. Within seven days, terminal necrosis and wilting had developed in all plants. The experiment was repeated with five more plants with similar results. Terminal necrosis developed eight days following inoculation of terminal leaves on two papaya plants, approximately six feet tall. Female blossoms developed necrosis near the base.

Young cucumbers and cowpea plants in the 3- or 4-leaf stage were inoculated with juice from wilting papaya plants. Four days after inoculation, yellow stippling developed on the inoculated cucumber leaves and necrotic spots on the inoculated cowpea leaves. Terminal necrosis occurred on cowpeas 7 days following inoculation. These symptoms are characteristic of the tobacco ringspot virus infections. Thus, results demonstrate tobacco ringspot virus to be a cause of decline of fruiting papaya plants in the Lower Rio Grande Valley.

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Figure 1 A male papaya tree, badly wilted, infected with tobacco ringspot.

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Association in Young Avocado Trees of Azteca Disease with Sunblotch Virus

E. O. Olson[1]

"Azteca", a bud-perpetuated rootstock disorder, is characterized by deep grooves in the bark of West Indian rootstock of young avocado trees of certain varieties. It is especially common in budded progeny of Mexican varieties introduced into Texas as budwood from the region near Ciudad Victoria, Tamaulipas, Mexico (Olson et al., 1958). Sunblotch virus, transmitted through seed from symptomless carriers (Wallace, 1958), occurs in some of the avocado varieties whose grafted progeny display Azteca symptoms on West Indian rootstock (Olson et al., 1958; Schroeder and Frolich, 1958). The original purpose of the present trial was to study the scion-rootstock relations of Azteca, but certain host relationships of the Sunblotch disease which developed during the work seemed worth reporting.

METHODS

Avocado trees of Lula, R-1, and Arsola 29-9 were propagated by J. B. Chambers, Jr., Harlingen, Texas, on each of 4 rootstocks (West Indian, Lula, Diaz, and Guatemalan) grown from seed obtained from Texas-grown trees. R-1 is a variety of the Mexican race; Arsola 29-9 and Diaz are probably Mexican x West Indian race hybrids. Trees of each scion-rootstock combination were set out in December 1958 as 6 replications of 2-tree blocks in a planting maintained by Rio Farms, Inc., Monte Alto. Some of these trees died soon after planting; most of the losses are attributed to rootstock's lack of salt tolerance, compared to citrus (Cooper et al., 1952).

RESULTS

Thirty-nine months after planting, Lula, R-1, and Arsola 29-9 trees on West Indian, Lula, and Guatemalan rootstocks showed no Sunblotch symptoms (Table 1). However, 5 Lula and 8 R-1 trees on Diaz rootstock showed clear-cut Sunblotch symptoms. All the Arsola 29-9 trees on Diaz rootstock were free of Sunblotch symptoms.

DISCUSSION

The Lula and R-1 selections on West Indian rootstock did not develop Azteca symptoms, and the fact that on rootstocks other than Diaz they developed no symptoms seems to indicate that the Lula and R-1 varieties did not carry Sunblotch virus in this test. The budded trees of Diaz and Arsola 29-9 have consistently shown Azteca symptoms on the West Indian rootstock (Olson et al., 1958). In the present experiment, Diaz seedlings were symptomless carriers of the Sunblotch virus. Sunblotch symptoms developed when Sunblotch-expressing varieties, such as Lula and R-1, were grafted on Diaz seedlings.

The Arsola 29-9 selection showed no Sunblotch symptoms when grafted on Diaz rootstocks carrying Sunblotch virus; this is evidence that the Arsola 29-9 selection is also a symptomless carrier of Sunblotch virus. It is also evidence that infected symptomless carriers can be propagated by grafting them on rootstock seedlings which likewise are infected symptomless carriers and otherwise acceptable as rootstocks.

Since Arsola 29-9 and Diaz trees carry Sunblotch virus and Azteca symptoms are common on the West Indian rootstocks of Arsola 29-9 and Diaz trees (Olson et al., 1958), the results of the present trial are additional evidence that the cause of Azteca disease is associated with or identical with Sunblotch virus.

SUMMARY

Twenty-nine months after planting, Sunblotch symptoms occurred in Lula and R-1 (Mexican race) trees but not in Arsola 29-9 (Mexican x West Indian hybrid) trees on Diaz (Mexican x West Indian hybrid) rootstocks in a planting of these varieties on 4 seedling avocado rootstocks: West Indian, Diaz, Lula, and Guatemalan. It thus appears that

Table 1. Occurrence of Sunblotch symptoms in avocado trees on various rootstocks, 29 months after planting.

Scion-rootstock combination	*Trees in test (Total)*	*Trees with Sunblotch symptoms in foilage (Number)*
Lula:		
West Indian	12	0
Lula	7	0
Diaz	5	5
Guatemalan	8	0
R-1:		
West Indian	12	0
Lula	7	0
Diaz	9	8
Guatemalan	12	0
Arsola 29-9:		
West Indian	12	0
Lula	9	0
Diaz	10	0
Guatemalan	10	0

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the Sunblotch virus is seedborne in Diaz and that both Diaz and Arsola 29-9 are symptomless carriers. The casual agent of Azteca disease of West Indian rootstocks is associated with or identical with Sunblotch virus carried by Arsola 29-9 and Diaz selections.

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Strawberry Production Practices in the Lower Rio Grande Valley[1]

Lewis Dillon[2]

Strawberries generally require cool climate, good water, and acid soils. When grown in the Lower Rio Grande Valley, berries are grown in a warm climate, sometimes salty water and alkaline soils. Thus, strawberry production in the Lower Rio Grande Valley is a unique operation, and only through the perseverance of a few individuals and the constant help of several experiment stations and the USDA has it remained an industry in the Lower Rio Grande Valley. Time of planting, varieties, cultural practices, labor problems, water problems, and many other factors change from year to year, so only basic principles of today's Valley berry production are presented.

SOIL

The soil in which berries are to be grown is one of the most important factors. A well drained, sandy loam soil is the most acceptable. However, this soil should be as free as possible of salts and free carbonates. Strawberry plants have a very low tolerance of salts, and they are quite susceptible to calcium-induced iron chlorosis.

The soil for a prospective berry crop is planted to a cover crop, manured, fertilized, and farmed for one year in advance of planting berries. Then in late June and early July the land is prepared for the planting of the berry plants. This preparation generally consist of rowing-up the soil, squaring off the beds, and a preplant irrigation. When these preparations are completed, the beds are ready to plant.

PLANTING STOCK

At the present time, practically all of our plants are being grown in Tennessee and Arkansas by commercial growers. Their parent-plant stock is planted in March, allowed to grow and make runners over the summer, and plants for our use are dug in the Fall. Each state has its own plant-certification program, and all of our plants must be certified. Once the plants are dug and certified, they are placed into cold storage, frozen, and remain there until we plant in late August and early September.

Three varieties of berry plants are adaptable to Valley conditions. They are the Missionary, Florida 90, and the Solana. The Missionary was

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[1] Presented before the Annual Institute of the Rio Grande Valley Horticultural Society, January 22, 1963, Weslaco, Texas.

[2] Production Superintendent, Stites Berry Farms, Donna, Texas.

grown in past years, however, it has been replaced by a new and improved variety known as the Florida 90. The Solana variety is still experimental and has not proven its adaptibility to Valley conditions. The main variety at the present time is the Florida 90.

The plants come to us frozen, and they must undergo certain preparations before they are planted. First, they are thawed and the dead leaves removed. Next, the roots are trimmed, and finally they are dipped into a fungicide to protect them from disease. The plants are ready to go to the field.

PLANTING AND GROWING

The process of planting is strictly a hand operation and generally requires approximately one hundred man-hours per acre. There are two ways the plants are planted in relation to the bed, and the method employed is generally dictated by conditions at the time of planting. For an example, this year there was an abundance of plants, but a shortage of water, so two rows of plants were planted to the bed. In other years there were shortages of plants so only one row was planted to the bed. In the former method of planting, there is a great population of plants at planting time and the plants are not allowed to make runners. In second method, the plants are allowed to make runner plants, and a row of runner plants is planted on either side of the mother plant row to complete the bed. Both methods have their advantages and disadvantages and the conditions at planting time generally dictate which method is preferable.

After the plants have established themselves in the field, the next three months involves a great deal of hand labor for weeding, irrigating, and the setting of runners. Also, during this period a complete fertilizer (10-20-10) at the rate of five hundred pounds per acre is added to the soil in dry form as a sidedress application. Insects pose a threat to the plants in this period of time. The leaf roller, aphid, red spider, army worm, tropical mite, flea beetle, and others use the berry plant for a host until properly applied insecticide destroy them. A fungicide is generally added to the application to control such diseases as leaf spot which is always a threat to the plants.

This past season a herbicide was used to control our annual weeds, and it has proven very successful.

HARVESTING BERRIES

Having nurtured the plants through the foregoing three months, the plants (barring adverse weather conditions) should be entering their reproductive cycle in the next thirty days. Harvest usually starts in late February and early March, and generally the harvest continues until mid-May. During the harvest season many people are employed, for each field must be picked every day. In a normal year approximately ten men per acre are employed to harvest the berries. Each field has its own packing shed, and the berries are picked, graded, and packed in the field. Once the berries are packed, they are brought directly to a precooler where they are held at 33° F. for twenty-four hours before shipment. The precooler consists of a fifty by sixty foot redwood vault with sixty tons of refrigeration, designed specifically for the handling of fresh strawberries. From here the berries are shipped to practically all major cities North and East of Texas and into Canada by rail and truck. Almost all of the shipments are to wholesale concerns in the major cities. While all the picking crews are working, the plants still need constant care. There is the never-ending weed problem, irrigation, insect and disease problems, which must be cared for in the harvest season. So as a general rule, everyone is busy during the harvest season.

FROZEN BERRIES

Frozen berries are also processed on the farm. All of the over-ripe, small, and slightly damaged berries are cleaned, washed, sugared, and put into 28-pound tins for market. The bulk of these berries are used in the preserve and ice cream industries which want fresh frozen berries for the manufacture of their products. Frozen berries thus serve as an outlet for otherwise nonmarketable berries.

I believe that strawberry growing is possibly one of the most fascinating farming operations in the Valley today. However, it is similar to all farming operations in that it may promise more and offer less than any other business.

VEGETABLE AND ORNAMENTAL SECTION

The Fertilizer Requirements of Vegetable Crops and Some Factors Affecting Their Response to Applied Nutrients[1]

C. A. Burleson[2]

There are a number of factors that affect or determine the fertilizer requirement of vegetable crops. A consideration of these factors cannot be ignored if a sound program of fertilization is to be developed by a grower. The variability of Valley soils, the broad range of vegetable crops grown, and other important variables almost require that every field on every farm be given separate consideration. With the multiplicity of factors involved, it will not be possible in the time alloted here to discuss specific problems associated with the variety of Valley grown crops. I would, however, like to discuss some of the factors which determine the nutrient requirements of vegetable crops and to briefly discuss some of the conditions which may influence crop response to applied nutrients.

If we are to understand the many factors which affect the response of crops to fertilizers we must have at least a general understanding of the soils on which the crops are grown.

Let us briefly review the make up or the nature of soils and then relate them in some detail to crop response to applied nutrients.

Soil is much more than pulverized rocks mixed with organic matter. Soil is light, air, water, weathered rocks, and decayed organic matter together with the plants and animals that live in it. Soil is a live, changing, physical, chemical and biological complex. Without life there is no soil. In this living, dynamic soil both constructive and destructive processes are taking place concurrently. Soils have been developed by the interaction of natural factors. When man alters any of these factors in the production of crops – he also changes the balance of the physical, chemical and biological factors in the soil.

So we are dealing with a complex system which is responsive to treatment and environment, and for that reason there are many factors which affect or modify the response of vegetable crops to applied nutrients.

First of all, let us consider the matter of inherent or native fertility. Soils of the Lower Rio Grande Valley are inherently fertile as are most

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[1] Presented at the Annual Institute of the Rio Grande Valley Horticultural Society, January 22, 1963, Weslaco, Texas.

[2] Associate Agronomist, Texas A. & M. College, Lower Rio Grande Valley Experiment Station, Weslaco.

soils developed under similar conditions. However, under an intensified irrigated agriculture in a subtropical climate, the need for supplementing inherent fertility became apparent rather early in the cropping history of the area.

As would be expected under such intensive cultivation and under existing climatic conditions, soil organic matter was rapidly depleted with the result that available nitrogen in nearly all irrigated soils of the Valley is inadequate for optimum production of most crops; nitrogen fertilization is needed almost without exception if maximum yields of high quality vegetables are to be produced.

The status of the plant nutrient, phosphorus, is somewhat different. Results of soil tests of Valley soils over a period of years have revealed that Valley soils vary rather widely in content of available phosphorus. In Cameron County, soil tests have shown the soils to range from low to high in available phosphorus with the bulk of the soils falling in the low to medium range. On the other hand, in Hidalgo County, the soils generally run from medium to high with some soils in the low and very high ranges. In Willacy County, the bulk of soil tests show the soils to range from high to very high with lower levels reported in few instances.

Thus we can see from this very broad summary of soil tests, over a period of years, that the available phosphorus content of Valley soils ranges from low to very high with more than half of the soils tested falling in the medium to high range. Vegetable crop response to applied phosphorus varies, with cool season crops often responding to phosphorus fertilization and warm season crops often showing no response.

The fertility status of Valley soils with respect to potassium is considerably different from that of nitrogen and phosphorus. Almost without exception, soil tests of irrigated soils reveal a very high level of available potassium. Fertilizer trials with a number of vegetable crops over a period of years have likewise failed to indicate any significant improvement in yields or quality from the use of fertilizers containing potassium. When we consider only the primary nutrients, nitrogen, phosphorus and potassium, we can safely say that supplemental nitrogen is required for maximum production of nearly all vegetable crops on most Valley soils; phosphorus requirements vary over a wide range of conditions with the degree of response often depending upon seasonal and other environmental factors. In most cases, potassium fertilizers are not generally needed and response to potassium fertilizers should not generally be expected.

Of no less importance in the nutrition of vegetable crops, however, are the secondary and micronutrients. Generally, deficiencies of the secondary elements, sulfur, calcium and magnesium are not usually prevalent in vegetable production on Valley soils. On the other hand on certain soils and with specific vegetable crops, applications of some of these nutrient elements have been beneficial. This, however, is the exception rather than the rule.

The situation with respect to the micronutrients is becoming more and more important. Micronutrient deficiencies have been noted in recent years in a number of vegetable crops and over a wide range of soil conditions. The micronutrients, sometimes referred to as minor elements or trace elements, are those nutrient elements required only in small or micro amounts. Although required only in micro quantities, they are of no less importance than the primary and secondary elements. The micronutrients are iron, zinc, manganese, boron, copper, and molybdenum and more recently cobalt has been added to the list for some crops.

Valley soils seem to be borderline with respect to the micronutrients. That is to say that severe and widespread deficiencies are not apparent at the present time; however, with unfavorable growing conditions micronutrient deficiencies in certain soils frequently show up on a number of vegetable crops. Extensive research is currently underway in an attempt to delineate the crops and soils where micronutrient applications are profitable.

From what I have said up to now, it might appear that the matter of fulfilling the nutritional requirements of vegetable crops might be reduced to rather simple terms. Know the crop requirements, take an inventory of your soil by soil tests to determine the supply of available nutrients, and then supplement the supply in the soil by fertilization to fulfill the crop requirements.

Unfortunately the nutrition of vegetable crops cannot be reduced to such simple terms. To believe that such a system of plant nutrition will result in maximum production of high quality vegetable crops is to acknowledge our lack of a basic understanding of the soil, and of the relationship between crops and soils, and of the affect of outside environment on this relationship.

Equally as important as knowing how much and what kind of fertilizers to apply is the matter of proper use of fertilizers.

Certain general principles, involving the character of the soil, the crop and the fertilizer materials influence the choice of methods of application of fertilizers. Generally band applications of fertilizers are more efficient than broadcast applications. This is especially true in row crops. By banding his fertilizer, the grower is able to place the fertilizers where they are needed – in close proximity to young seedlings and in the root zone where they will be readily utilized. This is especially important with phosphorus fertilizers which move very slowly in the soil and, therefore, should be placed where they can be readily used by the plants. On the other hand when fertilizers are banded too far from the seed or roots, growth may be retarded until the roots reach the supply of plant nutrients. Care should be exercised to avoid placing large quantities of fertilizer too close to the seeds as poor germination will result and salt damage to young seedlings may occur. This is particularly true where soil moisture becomes limiting. When fertilizers are applied in a band the fertilizer materials are not intimately mixed with the soil and, therefore, fixation of plant nutrients into unavailable forms does not occur as readily as when mixed with the soil.

Although justified under some conditions, the broadcast application of fertilizer materials is not the most efficient method of application. Broadcasting and thorough mixing of fertilizers with the soil brings the plant nutrients into intimate contact with the soil, which is a condition most favorable for the fixation of phosphorus. Broadcast application also readily furnishes plant nutrients to weeds growing between the crops. Such method of fertilizer application may be justified at times in closely spaced crops or for raising the general fertility level of the entire tilled layer of the soil.

The application of plant nutrients in the irrigation water is essentially broadcast application and is not the most efficient method. The application of fertilizers by this method generally results in uneven distribution, losses of fertilizers in the head ditch and tail waters and, under some conditions, nitrogen may be lost to the atmosphere. At its best, the distribution of fertilizer applied in irrigation water is no better than the distribution of water. Again the application of fertilizers through the irrigation water may be justified in some circumstances.

The foliar application of plant nutrients has its place in the nutrition of vegetable crops but should not be relied upon as the only method of applying plant nutrients. Foliar feeding has generally been most effective as a method of applying the micronutrients where deficiencies of these nutrients exist and rapid alleviation of the deficiencies is needed. The use of such materials when micronutrient deficiencies are not present is a waste of money and only adds to the cost of production and decreases the growers profits. A good policy is to try such materials on a limited basis leaving adequate untreated adjacent areas for comparison. The application of the fertilizer nutrients other than the micronutrients as foliar sprays is sometimes justified but certainly should not be the sole source of those plant nutrients.

Whether to use dry or liquid fertilizers is frequently a question that confronts the grower. This question is far less important that we are frequently led to believe. The bulk of research information available on the subject does not favor one over the other, but under favorable conditions and using good application efficiency, the grower should expect equally as good results from either dry or liquid sources of nutrients. The unit cost of the nutrients, and the form of material that best fits into the growers farming operation and equipment, are the prime factors to be considered. There are some occasions under certain soil and climatic conditions where one form of fertilizer nutrient may be advantageous over another.

The fertilizer requirement of vegetable crops and subsequent plant response to applied nutrients may frequently be influenced by climatic conditions. Under favorable growing conditions, plant roots generally are able to explore more soil for nutrients and as a result may require fewer

applied nutrients. On the other hand under unfavorable soil conditions such as cold, wet soils, root extension is limited, the volume of soil in which the roots are growing is smaller, and soils may not be able to supply an adequate level of certain plant nutrients to provide maximum growth and production. This may be a result not only of limited root extension but of a decrease in the activity of certain beneficial soil organisms which aid in the decomposition of plant residues and subsequent release of nutrient elements. Climatic conditions may also influence the response of crops to certain forms of fertilizer nutrients. For instance under prolonged conditions of cold soil, where nitrogen is needed immediately, the readily available nitrate form of nitrogen would be more beneficial than nitrogen from an ammonium or urea source which require conversion to the nitrate form by nitrifying organisms. The activity of these nitrifying organisms decreases with decreasing soil temperatures. On the other hand if preplanting applications of nitrogen fertilizers are made during the winter for spring vegetables, the ammonium or urea sources of nitrogen would be less subject to leaching losses than would readily leachable nitrate forms of nitrogen.

Micronutrient deficiencies in vegetable crops are usually more prevalent during a cold growing season – such deficiencies may not occur under warmer and more favorable conditions. This again is often related to the activity and extension of the roots and to the decomposition of organic matter.

Many other affects of climate may occur but these few are mentioned only to point out that plant nutrient requirements and plant response to applied nutrients are affected by climatic factors and the grower must consider them in his effort to supply the nutritional requirements for his crops.

Another factor that affects the response of applied nutrients to vegetable crops is salinity. Fertilizers should not be expected to nullify or overcome salinity effects. To the contrary, the application of fertilizers to a saline condition further contributes to the problem in that the bulk of the fertilizers we use are inorganic salts themselves. Frequently, the application of fertilizers to already marginal land with respect to salts, will tip the balance toward higher salinity and germination and seedling emergence will be impaired. Under such conditions, fertilization should be delayed until plants are well established and then used conservatively under conditoins of adequate soil moisture. The grower should beware of materials offered with fabulous claims of "counteracting" or "neutralizing" salinity. Often many of these materials are expensive and actually have little value.

The utilization of plant nutrients by plants is many times dependent upon or related to the availability or balance of other nutrient elements. The mechanisms and processes involved in the absorption of specific nutrients by plants do not operate independently of other nutrients but to the contrary may be affected by or be dependent upon the level of other elements. A few examples of such nutrient balance may be cited. The available boron supply in some soils may be affected by the level of soluble clacium. In some plants normal growth is possible only when a certain balance of calcium and boron intake occurs and this balance may vary with different plants. Lime-induced iron chlorosis in plants, caused by the inactivation of iron within the plants, is another example with which we are familiar. Excessive quantities of available phosphorus in the soil may induce deficiencies of boron, copper and zinc. Phosphorus-induced zince deficiencies have occurred with increasing frequency in the last few years.

There are many other examples of the effect of nutrient balance on the growth of plants – I mention these few with which you may be familiar only to point out that such relationships do exist among the various plant nutrients. The grower should avoid the indiscriminate use of fertilizer materials, as the continued use of uneeded nutrient elements could lead to serious nutritional disorders. The grower should keep adequate records of fertilizers applied to each block of land and with periodic soil tests follow the "build up" or "decline" of plant nutrients that may occur. Soil tests are not infallible but are of value in assessing the fertility status of soils.

Other factors may influence the response of vegetable crops to applied nutrients. Previous land use or cropping history is an important consideration. Residual fertility may be high following certain cropping sequences. On the other hand vegetable crops following high-residue crops may need a bonus application of fertiilzer during the period of residue decomposition to avoid nutrient deficiencies in current crops. Fertilizer practices planned with the whole sequence of crops in mind are usually more efficient and more profitable to the grower.

Cultural practices often influence the requirement of crops for nutrients. Where considerable top soil has been removed during land forming or land leveling operations, the requirement of applied nutrients may be considerably greater than before such operations. Not only the amount of nutrients, but the kind of nutrients required may differ. Plant population or spacing will also affect the crop requirement for nutrients. Double-row vegetable crops can profitably utilize more applied nutrients per acre than single row plantings of the same crop.

Soil texture also has a bearing on the nutrient requirement of crops. Heavy textured soils such as your clay soils have a higher fertility holding capacity and being less subject to losses from leaching may often have more fertility in reserve than the lighter textured sandy soils. On the other hand these same heavy textured soils usually have a greater capacity to fix certain plant nutrients chemically and physically into forms unavailable to growing crops. These differences in soil texture may affect not only the amounts of fertilizer required but also the time, method and frequency of application.

There are other factors that may contribute to the requirement of vegetable crops for fertilizer nutrients, and no doubt there are numerous factors both known and unknown to all of us that affect the way vegetable crops respond to applied nutrients. Some of these factors we can alter, others we cannot. However, it is only as we achieve a better understanding of the soil and crops, and of the relationships between crops and soils, and the affect of outside environment upon these relationships, that we can do our best as vegetable growers and agricultural workers in providing the nutritional needs of our vegetable crops.

Symptoms of Tobacco Ringspot Virus Infections on 8 Important Vegetables in the Rio Grande Valley

D. M. McLean[1]

Tobacco ringspot virus (TRSV) is wide-spread in the Lower Rio Grande Valley of Texas, where it infects numerous weed and crop plants (McLean, 1960, 1962). The virus is transmitted through soil and it is present in many soil types in this region (McLean and Machmer, 1963). In spite of the common occurrence and wide distribution of the virus in various important vegetables, exhaustive studies elsewhere have failed to reveal an insect vector. The virus is readily transmitted mechanically in expressed sap from infected plants. Eggplant, squash, watermelon, cucumber, cantaloupe, southern pea and bean are good indicator plants for the presence of the virus and when these are grown on diverse soil types some plants show symptoms of infection. Crop rotation does not seem to lessen infections, which are often numerous after citrus, cotton, grain sorghum, vegetables, or forage crops. Infections have been numerous and severe on plants grown in uncropped soil and in fields fumigated for nematodes. Infections usually are more numerous in fall than in spring. Soil temperatures near 80° F. were most favorable for soil transmission; however very high temperatures cause masking of symptoms in certain vegetables. Field increase of TRSV infections is rapid without visible evidence of reservoirs of initial infections.

Studies by Fulton (1962) in Arkansas showed that the dagger nematode, *Xiphinema americanum* Cobb., transmitted TRSV to cucumbers in greenhouse pot cultures, and to watermelon in studies by Hendrix (1961) and to spearmint in work by Stone et al. (1962). McLean and Machmer (1963) failed to find an association of *Xiphinema* spp. with field infections in cucurbits and eggplant in the Rio Grande Valley. This paper describes symptoms of TRSV infections on 8 important vegetables in the Lower Rio Grande Valley.

SYMPTOMS

Eggplant (*Solanum melongena* L.)

The first symptom of infection on eggplant is greenish-yellow spots on young leaves. These spots enlarge rapidly and frequently follow the veins until entire leaves are yellowed. Eventually the entire plant may lose chlorophyll until it appears almost white, alluding to the common designation of the disease as "yellows" (Fig. 1). Generally fruits are unaffected, but occasionally they may be stunted, misshapen, or streaked, probably depending on the stage of development at the time of infection. Infected plants do not recover. McLean and Machmer (1963) showed soil transmission to occur after 45 days in the greenhouse. Symptoms were frequently delayed for 4-8 weeks after mechanical inoculations of young plants. High virus concentration was not obtained in expressed sap from eggplant, and mechanical inoculations to eggplant were not always successful. During the fall of 1962, field infection increased from 9 to 1172 plants in a field of eggplant in 60 days. Jones (1942) reduced eggplant yellows by applying sulfur, sulfur-pyrethrum, sulfur-cube, Fuller's earth-cube, or hydrated lime to either the soil or the foliage. Systemic insecticides applied to soil also have reduced infections in eggplant.[2] Dale (1954) in Trinidad reported transmission of a virus, thought to be TRSV, to eggplant by the fleabeetle (*Epitrix* sp.).

Squash (*Cucurbita pepo* L.)

Early symptoms appear as chlorotic stippling and ringspots on new growth. Infected older plants are severely stunted with prominent leaf perforations caused by growth inhibition at points of local chlorotic lesions, making leaves irregularly shaped with coarse yellow mottling (Fig. 2). Fruits on yellow summer varieties are severely misshapen and have irregular sunken or raised dark-green areas, which sometimes join and form irregular striations. Symptoms tend to become severe on older plants, which do not recover.

TRSV is the most severe mosaic virus affecting squash in the Lower Rio Grande Valley. Although soil transmission has not been demonstrated, field spread is probably through soil.

Watermelon (*Citrullus vulgaris* Schrad.)

Stippled chlorotic spots appear on new growth characterized by shortened internodes with prominent upright growth of terminals. Leaves on affected shoots may show perforations and chlorotic spots which coalesce into larger ringspots and become necrotic on older leaves (Fig. 3. Pronounced symptoms often disappear on older plants with symptoms remaining only on fruits. Fruits are roughened with small intumescences that accounts for the common designation of the disease as "pimples". Symptoms are pronounced on fruits of dark-rind varieties.

Hendrix (1961) in Arkansas showed that the virus may be transmitted through soil to watermelon.

Cucumber (*Cucumis sativus* L.)

Chlorotic flecks appear first on new growth which enlarge to conspicuous spots and rings sometimes followed by mild mosaic mottle in

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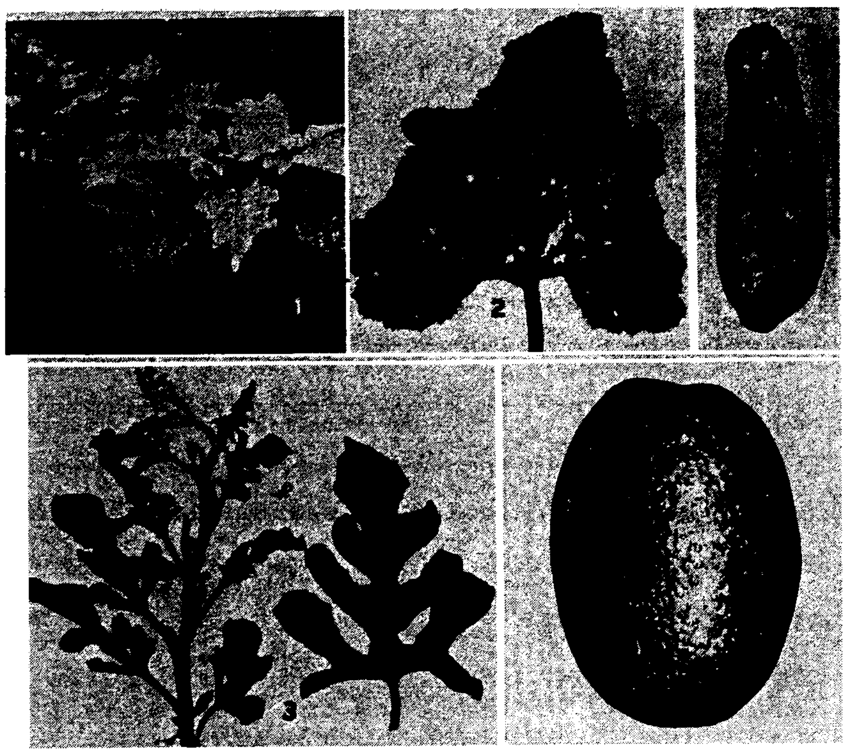
[1] Plant Pathologist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, in cooperation with the Texas Agricultural Experiment Station, Weslaco, Texas.

[2] Unpublished data from J. A. Harding, Entomologist, Texas Agricultural Experiment Station, Crystal City, Texas.



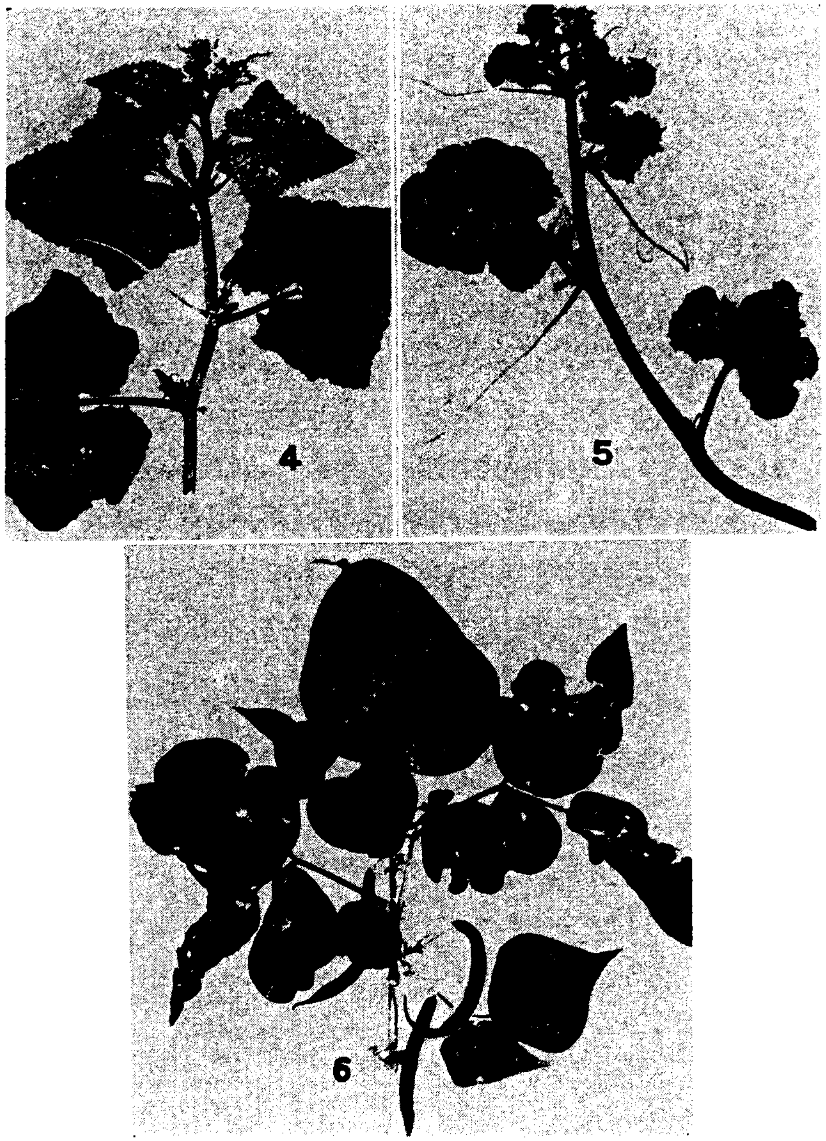
Figures 1-3. Symptoms of TRSV infections on (1) eggplant, note loss of chlorophyll or "yellows"; (2) straightneck squash leaf showing chlorotic stippling and perforations, and misshapen fruit; (3) Blackstone watermelon shoot and leaf showing chlorotic stippling and fruit with intumescences or "pimples."

only terminals (Fig. 4). Older plants are severely stunted but foliar symptoms disappear or are seldom prominent. Fruits are sometimes mildly mottled light-green, have some ringspots, and are often slightly misshapen with dark-green bumps. Cucumber has been used extensively to demonstrate soil transmission by several workers (Fulton 1962, Hendrix 1961, McLean and Machmer 1963, Stone et al. 1962).

Cantaloupe (*Cucumis melo* L.)

Small chlorotic spots to broad ringspots appear on young leaves (Fig. 5). Leaves on older infected plants have a dull crepe-paper appearance. Tip leaves are often irregularly perforated and have necrotic flecks with water-soaked halos. Symptoms often fade or disappear in mature plants even though virus is present. Fruits are without external symptoms, but may be poorly netted and have light-colored flesh.

McLean (1962) reported the virus to be seed-borne in cantaloupe.



Figures 4-6. Symptoms of TRSV infections on (4) cucumber shoot showing chlorotic flecks and spots; (5) cantaloupe shoot showing chlorotic spots and ringspots; (6) bean plant showing chlorotic or necrotic spots with prominent leaf distortion.

Soil transmission to cantaloupe has not been demonstrated, but transmission probably is the same as to squash, cucumber, and watermelon.

Southern Pea (*Vigna sinensis* (Torn.) Savi) and Bean (*Phaseolus vulgaris* L.)

Southern pea and bean are seriously affected by TRSV, which often causes death of infected plants. Conspicuous necrosis of terminals accompanied by reddish to necrotic streaks on stems and leaf veins appears on infected southern peas. Only a few infected plants survive. Both pole and bush beans are affected. Foliar symptoms on beans usually consist of chlorotic or necrotic flecks, spots, or ringspots with occasional necrosis of veins. In early infections leaves are prominently curled downward with pronounced epinasty and abscission (Fig. 6). In some varieties necrosis of terminals may inhibit growth or cause death of plants. Plants infected while young are unproductive or may produce small, distorted pods with necrotic spots. Most bean varieties are susceptible.

McLean and Machmer (1963) showed soil transmission to southern pea, whereas Stone et al. (1962) in Indiana demonstrated soil transmission of TRSV to bean. The disease probably causes greater loss in these crops in the Rio Grande Valley than commonly recognized as young infected plants are quickly over-grown by adjacent healthy ones.

Okra (*Hibiscus esculentus* L.)

TRSV infections usually are not severe in okra and symptoms on older plants are often difficult to detect. Chlorotic spots or ringspots may appear on newly formed leaves, which are sometimes crinkled and faintly mottled. Zonate chlorotic spots sometimes appear on pods. Infected plants are seldom stunted and their pod production is not measurably reduced.

DISCUSSION

Eggplant, squash, watermelon, cucumber, cantaloupe, southern pea, and bean show conspicuous symptoms of TRSV-infections at various stages of growth and crop losses are serious in some of these vegetables in the Rio Grande Valley. Symptoms are not recognized on other vegetables although some may carry the virus. Symptoms are recognized on other crop plants, such as okra, spinach, soybean, lima bean, English pea, Crotalaria, guar, and papaya as well as on numerous weeds (McLean, 1960, 1962).

While published articles indicate that sulfur and insecticides have reduced "yellows" in eggplant, they do not suggest either control of insect vectors or reasons why these materials seemed effective in reducing TRSV infections. The pattern and rapidity of field spread of the virus are not indicative of nematode transmission, although it has been repeatedly shown that the virus is soil-borne.

SUMMARY

Symptoms of tobacco ringspot virus infections are described on eggplant, squash, watermelon, cucumber, cantaloupe, southern pea, bean, and okra. An insect vector that would account for the wide distribution of the virus in various important vegetables in the Rio Grande Valley has not been found. The pattern and rapidity of field spread of the virus are not indicative of nematode transmission, although it has been repeatedly shown that the virus is soil-borne.

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Tests with the FMC Mechanical Tomato Harvester in 1962[1]

Tom D. Longbrake[2]

The cost of harvesting vegetables with hand labor has increased considerable with the minimum wage law on braceros and it is becoming uneconomical to continue using them. We must look forward to mechanical harvesting of tomatoes as we have successfully done in snap beans, beets and carrots.

The Food Machinery Corporation (FMC), as well as four other companies, has been working on the development of a mechanical tomato harvester for the past three years. FMC will go into production with a machine in the Fall of 1962 so that it will be available for the 1963 season. FMC tested this machine in the Rio Grande Valley in June, 1962 with some very interesting results.

Procedures

The Valley Experiment Station breeding trials in the Progreso area were used for the first test run. Pre-grades were taken before the plots were machine harvested. Pre-grades were recorded from 3 ten foot plots hand harvested. All tomatoes were picked and separated into three categories—ripe usable fruit, green fruit (including all orange and pink colored fruit) and rotten fruit. Then each category was weighed separately and the yield pre-graded by varieties are given in Table 1.

M-41, M-21, M-39 and M-37 are all pear-type lines closely related to Chico. M-47 and M-15 are small round plum-type fruit, while M-30 and M-27 are new large fruited lines with some pear-type ancestors. The Holcomb Chico was a commercial field of Chico planted 2 rows 13 inches apart on 80-inch beds.

The percent usable fruit ranged from 60-84%. This indicates varietal differences in concentrated maturity with the larger round types having less concentrated maturity than the pear or plum type.

In yield, the pear types were best followed closely by the plum types with the large round types lagging considerably behind.

Field Results with Machine

One row 411 feet long of eight breeding lines was harvested separately. Yield in number of boxes per row and the time it took the machine to harvest were recorded. From this, the tons per acre and tons per hour were calculated. The percent recovery is the yield by machine divided by the usable yield from the pre-harvest sample taken by hand. This comparison is shown in Table II.

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[1] Presented at the Annual Institute of the Rio Grande Valley Horticultural Society, January 22, 1963, Weslaco, Texas.

[2] Vegetable Specialist, Texas Agricultural Extension Service, Weslaco.

Table 1. Yield and grade of tomatoes harvested by hand.

Variety	*Fruit Diameter (inches)*	*Plants Per 10 ft. (no.)*	*Usable Fruit %*	*Green Fruit %*	*Rotten Fruit %*	*Usable Tons/acre*
M-41	1 ¾	9.7	74	25	1	19.7
M-21	1 ½	8.7	80	16	4	20.6
M-39	1 ¾	6.7	84	13	3	17.1
M-37	1 ¾	7.3	78	19	3	16.2
M-20	1 ¾	7.0	79	19	2	16.2
M-47	1 ¼	6.0	84	11	5	14.4
M-15	1 ¼	7.0	73	23	4	13.6
M-30	3	7.3	64	28	8	12.0
M-27	3	6.7	60	22	18	8.7
Holcomb Chico	1 ¾	31	60	35	5	16.5

Table 2. Yield and efficiency of tomato harvest by machine.

Variety	*Length of row (feet)*	*Harvest time per plot (minutes)*	*Fruit yield per plot (50 lb. boxes)*	*Fruit yield per acre (tons)*	*Fruit yield per hour (tons)*	*Usable fruit recovered (%)* [1]
M-21	411	8.2	39	16.3	7.2	79
M-41	411	8.2	32	13.4	5.5	68
M-39	411	....	35	14.7	....	86
M-20	411	8.3	33	13.8	5.9	85
M-47	411	6.7	24	10.0	5.4	70
M-15	411	7.3	24	10.0	5.0	73
M-30	411	7.3	20	8.4	4.1	70
M-27	411	6.5	10	4.2	2.3	48
Holcomb Chico	(1.112 ac)	(3 hrs, 38 min.)	390	8.8	2.7	53

1 This is percent of usable fruit that the machine harvested, compared to hand harvested.

This test definitely shows that the pear type is more adaptable to machine harvest. Two main reasons for this are: (1) total yield potential is higher, and (2) a higher percent is usable at one time.

All tests were on 76-inch beds with one row of plants spaced 12-15 inches apart in the row. The test was conducted under ideal conditions. The weather was clear, hot and dry. The soil was dry with very few clods. The rows were wide, causing no damage to adjacent unharvested rows. The percent ripe fruit was high (64-83%) and the perecent rot was low, especially on the pear types.

Description and Operation of the Machine

The one-row self-propelled machine weighs 4700 lbs. It is 17 feet long and 16¾ feet wide when in operating position. The machine has 3 forward gears and a reverse gear with forward speeds ranging from ½ to 10 MPH. The 30 H.P. VH 4 Wisconsin motor uses about 1½ gallons gas per hour. Maintenance is very low since it has no grease fittings and conveyor chains require no oiling. Flat-bed trailers pulled by a tractor are used to catch the lug boxes off the sorting belt from the side of the machine. It operates best on 48" row spacing but will harvest 40" rows with some damage to the next un-harvested row. Two rows spaced 13 inches apart on wide beds can be harvested but the efficiency is reduced considerably.

Machine Capacity

The tons-per-hour harvested will vary directly with the field conditions and the yield potential per acre. In test run at Progreso, capacity varied from 5.5 to 7.2 tons per hour on pear-type tomatoes in a sustained run. By figuring 40% downtime to include turning, unloading trailers, repairs, etc., a commercial run should yield 3.3 to 4.3 tons per hour in tomatoes running 70-75% usable fruit and a minimum of 6 tons per acre.

Commercial Field Test on Chico

A one-acre field test was run on the new pear-type canning tomato, Chico, in order to compare the difference in yield per acre on a once-over machine harvest to a regular hand-picking operation (2 or 3 harvests).

The location was on the Jack Holcomb farm at Progreso where the soil type is Harlingen clay. The field was direct-seeded in February with 2 rows planted 12-13 inches apart on 80 inch beds. The stand averaged 3.1 plants per foot. As shown in Table 1, the pre-grade indicated 16.5 tons per acre, 60% by weight usable fruit. Machine recovery on one acre was 8.8 tons or 53%.

This field was very difficult to harvest because it had two rows per bed that had to be harvested simultaneously. There was more dirt picked up, partly because of the wide bed and partly because of the cloddy clay soil. It was felt that the maturity of fruit was wider spread, therefore yielding less ripe fruit at one time, because of the heavy stand. In addition, this field received 120 pounds actual nitrogen per acre which is one-third more than the normal recommendation. This probably spread maturity and accounted for the large vines.

There was a general opinion expressed by Valley people that the machine should be more ruggedly built.

The new Chico pear-type tomato is well adapted for machine harvest because of its heavy yield and concentrated set. The vine is relatively small and the fruit have resistance to cracking. It was evident this year on hand picking that many fields were picked too soon which damaged the vines, knocked off a lot of green fruit, and allowed extensive sunburning of unripened fruit.

The best yield and quality combination was obtained this year in fields where 60-65% of the fruit was allowed to ripen before harvesting the first time; then followed in 7-10 days with a second and final pick. This two-pick system will require a larger labor crew per field which will require a sequence or spreading of the field maturity by regulating planting dates.

With the correct cultural practices, one should expect to get 70% of the potential yield by machine harvest, while hand harvesting will probably run about 85% of potential yield.

Recommended Cultural Practices For Chico Tomatoes

Rowspacing – Use a minimum of 40 inch rows and up to 60 inch rows. The wider rows will allow easier and later cutlivation, a wider row for irrigation and more room for picking with less damage to vines.

Plant Spacing – Every indication this year showed that plants spaced one foot apart gave the best results.

Fertilizer – 80 lbs. P_2O_5 and 80 lbs. actual nitrogen per acre gave good results this spring. The phosphorus should all be put down in a band below the seed prior to or at planting. The source of phosphorus should be either 400 lbs. of 0-20-0 or 180 lbs. of 0-45-0. The nitrogen should be applied in 2 applications of 40 lbs. each. By using calcium nitrate, especially in the spring, the incidence of blossom end rot should be reduced by the extra calcium being available to the plant. Apply the first nitrogen sidedressing 4-6 weeks after direct seeding or just prior to the second irrigation after transplanting. The second application should be sidedressed at first bloom.

Soil Preference – Tomatoes do better on a sandy loam or loam soil than on clay soils. Do not plant on land known to be infested with nematodes or cotton root rot. Before buying transplants, check the roots for galls that may be caused by root knot nematodes.

Effects of Boron, as a Foliar Spray, on Internal Black Spot of Table Beets

T. D. LONGBRAKE and BAILEY SLEETH[1]

Symptoms. The early internal black spot symptoms (Sleeth, 1961) in the tap root of beets are irregular necrotic spots that vary in size, shape, and location and are hard and corky in texture. The spots usually occur on the outer ring of the beet and are not visible in the early stages until after peeling. These black spot symptoms are similar to those described for boron deficiency in other areas and boron applications, either to the soil and as a foliar spray or dust, is commonly recommended as a control measure, but it is not always effective in preventing the occurrence of black spots.

Boron deficiencies in Texas are commonly associated with calcareous soils and moisture stress on the plant and it is presumed that the black spots are caused by or related to a lack of readily available boron.

Procedures. The field location was on heavy clay soil located in the Rio Grande River floodway, where the incidence of internal black spot has been reported to be higher than on lighter sandy or loam soil. The beets were planted on February 5, 1962. Solubor, boron 20%, was applied as a foliage spray at the rates of 10, 20 and 30 pounds per acre on April 13 when the largest bulbs were 0.5 to 0.75 inches in diameter. Each sprayed plot consisted of two rows on a 40 inch bed and 10 feet long. Each treatment was replicated 3 times. The beets were harvested May 9, 93 days after planting; the tops cut off, the roots weighed, and yield calculated in tons per acre. Twenty-five beet roots, 1½-2½ inches in size, were cut from each plot and inspected for internal black spot. The results are given in Table 1.

Table 1. Yield and percent infection of internal black spot of beets treated with boron.

Treatment	*Root Yield Tons/Ac.*	*Root Infection Percent*
Solubor, 10 lbs/Ac	13.25	0
Solubor, 20 lbs/Ac	14.04	0
Solubor, 30 lbs/Ac	14.44	0
Untreated	14.78	8

There was no evidence of burning or phytotoxic effects to the foliage or roots of beets from the boron treatments. None of the boron treated beets showed any black spot at harvest while 6 out of 75, or 8%, of the untreated check had internal black spots.

The past history of black spot occurrences in beet roots grown in heavy, saline or calcareous soils indicates that preventative control measures should be practiced. Use 10 pounds of Solubor per acre when the first beets are ½ to ¾ inches in diameter. Apply as a spray in at least 25 gallons water per acre directly over the foliage.

Summary. Boron, in the form of Solubor, applied as a foliar spray on table beets at rates of 10, 20 and 30 pounds per acre gave complete control of internal black spot in trials conducted south of Donna in Spring, 1962. In the untreated plots, 8% of the beets were affected with black spot.

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Sleeth, Bailey, 1961. Varietal resistance of canning beets to internal black spot. Journal Rio Grande Valley Horticultural Society. 15:99-101.

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Tenderometer Values Used to Estimate Can-Fill for Canning of California Blackeye No. 5 Variety of Southern Peas

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Canning of Southern peas (*Vigna sinensis*) began to assume importance early in the 1940's – a development frequently attributed to the fact that booming war industries caused the migration of workers from the South to distant parts of the country. These workers, accustomed to eating Southern peas, provided a ready market for the canned product. Processors and distributors took advantage of the demand to add the new product to their lines. As reported in Canned Food Pack Statistics, 1961, this new product increased from 1,234,000 cases in 1949 to a record high in 1958 of 2,275,424 cases.

Increased production has emphasized canning problems of Southern peas. One problem which may be directly associated with maturity is the difficulty in determining a fill-in weight which will assure a uniform drained weight after processing. A fill-in weight which results in correct drained weight for one lot of peas may result in slack fill for another, and an over-fill for a third.

The answer to this problem appears to be a quick satisfactory method of measuring maturity of each load of peas as it is brought to the canning plant, something which canners of Southern peas have lacked. Canners of English peas have been using the tenderometer to measure the maturity of both smooth (*Pisum arvens*) and wrinkled (*Pisum sativum*) peas for several years with satisfactory results. Using the Alaska and Thomas Laxton varieties of English peas, Kramer (1948) found that maximum yields of optimum maturity peas could be estimated from tenderometer values.

Makower and Burr (1954) tested cooked English peas, and found that a variation of 50 gms. from the normal 200 gm. fill of the tenderometer grid cup caused as much as 6.4% increase, or 5.5% decrease in tenderometer value, and the more mature the peas, the greater the difference. They also found that variations of temperature of the samples produced changes in tenderometer values. Cain (1951) found that blanching reduced the tenderometer values of Southern peas. Cain (1951) also reported there was no relationship between tenderometer values and total solids of different varieties and strains of Southern peas. Stephens, Lime and Griffiths (1954) determined tenderometer readings on mature, immature, and various mixtures of mature and immature peas. Samples of these mixtures were canned and it was found that the tenderometer values increased uniformly as the drained weight increased from immature to mature samples. Hoover and Dennison (1953) found the specific gravity of both blanched and unblanched Southern peas increased with maturity. They also reported that alcohol-insoluble solids increased in an almost straight line relationship with maturity (1954). Malcom, Powers, Lopez, and Pratt (1956) reported that alcohol-insoluble solids or moisture content of raw peas was a good index of maturity, and that alcohol-insoluble solids of canned peas was a good indication of the maturity of the raw product prior to canning.

The first objective of the investigations reported in this paper was to determine whether a decrease in tenderometer values between fresh field-run peas (unblanched) and blanched field-run peas is consistent and in agreement with changes in alcohol-insoluble solids and total solids percentages. The second objective was to determine whether the tenderometer values of different mixtures of green immature and white mature peas may be correlated with alcohol-insoluble solids and total solids. A third objective was to find out if the drained weights of cans of field-run peas would coincide with the drained weights predicted from graphs prepared from tenderometer values, can fill-in weights and drained weights of the mixtures of immature and mature peas.

MATERIALS AND METHODS

A one hundred pound lot of pods of California Blackeye No. 5 peas was harvested from a 1-acre planting May 13, 1955. Another one hundred pound lot was harvested May 16, and 60 pounds on May 23 from the same acre of peas. The picking crew was instructed to harvest only yellow mature pods in order to obtain lots of shelled peas which would approximate in maturity peas which may be delivered to a canning plant for processing. The pods were brought to the laboratory and shelled in a Sinclair-Scott laboratory model pea huller[3] operated at a paddle speed of 475-500 r.p.m., and fitted with 5/8 inch screens. The shelled peas were blanched 4 minutes in water at 85° C. (185° F.) and cooled to 20° C. (68° F.), then separated in an 18° salometer brine solution at 20° C. (68° F.), similar to the method described by Smith and Kramer (1946). The green immature peas, together with a few white mature peas, floated, and white mature peas, along with some green immature peas, sank. White mature floaters and green immature sinkers were picked out by hand and discarded. To prepare samples of different maturity for ten-

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[3] The mention of firm names or trade products does not imply that they are endorsed or recommended by the Department of Agriculture over other firms or similar products not mentioned.

derometer readings, alcohol-insoluble solids, total solids, and canning, the green immature peas that floated and white mature peas that sank were used in the following proportions:

First	100% green immature peas
Second	75% green immature, 25% white mature
Third	50% green immature, 50% white mature
Fourth	25% green immature, 75% white mature
Fifth	100% white mature
Field-run peas	(Not separated)

A standard model of the Tenderometer (A.R.-676) manufactured by Food Machinery and Chemical Corporation,[3] with weights WCT-136A and WTC-137A, and Scale No. 2, which is recommended for English peas, was used to obtain values based on the degree of toughness of the sample tested. The tenderometer registers the force necessary to shear through a known quantity or weight of the material being tested. The greater the toughness or firmness of the sample the higher the numerical values on the tenderometer scale. Standard procedure in use of the tenderometer for determining maturity values on English peas is to completely fill the grid cup. This was found impractical with Southern peas, because they are so tough that when the grid cup was completely filled the machine would trip and fail to operate. Therefore it was decided to measure the samples of peas by weight, and 60 gms. was fixed upon for the sake of accuracy in reading the values. With greater weights of peas, at the higher levels of maturity, the pointer sometimes went beyond the numerical limits of the scale.

As outlined in the Service Manual, 1953, position of the weights on the counterweight shaft was changed so that a 117-lb. 3 oz. weight on the test bar would perfectly balance the machine. An accurately weighed 60 gm. sample at a temperature of 23° C. (73° F.) was used for each tenderometer measurement. The tenderometer cup was rinsed after each series of measurements. Tenderometer determinations were repeated 4 times on the maturity levels of green immature and white mature peas and on the field-run peas.

The method of Lindquist, Dietrich, and Boggs (1950) was used to determine alcohol-insoluble solids and total solids. Duplicate representative samples of 100 gms. of peas from each maturity level and field-run sample were weighed to the nearest 0.1 gm., transferred to preweighed pint Mason jars and covered with about 100 cc. of 95% alcohol. The jars were sealed and set aside until several samples had been prepared. The peas and alcohol were transferred quantitatively to a 500 ml. Waring Blendor[3] jar with a screw type lid and blended 4 minutes. The blendor was stopped and the sides of the container washed down with a small amount of 95% alcohol from a wash bottle. The blending was continued for one minute, then the mixture transferred quantitatively with the aid of about 300 cc. of 95% alcohol back into the Mason jar, sealed, and re-weighed.

In preparation for total solids determination, the Mason jar cap of the jar contining the slurried sample was replaced with one containing two holes. The alcohol slurry was thoroughly blended by a stirrer which passed through one hole of the cap and attached to a variable speed stirring motor. A 25 cc. graduated pipette with the tip cut off was used for removing the sample through the second hole. The stirring was continued and about 15 cc. of mixture was drawn into the pipette and transferred to an aluminum weighing dish. The dish was immediately covered and weighed. The cover was removed and the slurry evaporated to dryness on a steam bath. The dish was transferred to an air oven and dried overnight at 70° C. and then to a vacuum oven where it was dried 48 hours at 70° C. The dish was allowed to cool in a desiccator, weighed, and percent total solids calculated.

Alcohol-insoluble solids were determined, using the same sample of slurry. Immediately after removing the sample for total solids the same pipette was used to transfer about 25 cc. of sample to a tared 50 ml. centrifuge tube which was immediately weighed. A 50 ml. beaker was used to keep the centrifuge tube covered, except during weighing. The sample was centrifuged 3 minutes or until the residue settled. The supernatant liquid was poured off and the residue washed twice with 15 cc. of 80% alcohol and twice with 15 cc. of 95% alcohol with centrifuging, and the washings discarded. In washing, 10 cc. of alcohol was added to the solid residue and the residue broken up and stirred by means of a stirring rod. The last 5 cc. of alcohol were used to wash the rod and sides of the centrifuge tube. The residue was dried as for total solids on a steam bath and in the air and vacuum ovens, weighed, and percent alcohol-insoluble solids calculated.

The maturity levels of green immature and white mature peas and the field-run sample were canned in "C" enamel cans as recommended by Cain and Brittingham, (1950). Six cans were accurately filled with 210 gms. into each can, 6 with 220 gms., 6 with 230 gms., and 6 with 240 gms. of the first maturity level of peas, i.e., 100 percent green immature peas. The sequence of filling cans with peas was repeated for the second, third, fourth and fifth maturity levels and for the field-run peas. Each can of peas was filled with boiling 2 percent brine solution, exhausted to a center-can temperature of 82.2° C. (180° F.), closed and cooked at 115.5° C. (240° F.) for 35 minutes.

The cans of peas were stored 3 months at room temperature, then drained weight determined according to a modification of the procedure outlined in the U. S. Standards for Grades of Canned Field Peas and Canned Blackeye Peas (1950). The contents of each container were emptied on a No. 8 screen (.0937 inch openings) 8 inches in diameter, and allowed to drain. The drained peas were washed 1 minute under a stiff spray of tap water and allowed to drain 2 minutes. The bottom of the drain screen was dried with a towel, the screen and peas weighed, and drained weight recorded.

RESULTS AND DISCUSSION

The first objective of this investigation was not necessary in order to predict can fill-in weight from tenderometer values. However, if the tenderometer could be used by canning plant operators to determine maturity and estimate can fill, it would be awkward if first the peas had to be blanched. In this investigation it was expedient to blanch the peas before they were brine separated into green immature peas that floated and white mature peas that sank, in order to obtain a more precise separation. Other investigators also have reported that blanching resulted in a more precise separation of peas (Malcom et al, 1956).

Results presented in Table 1 show there was a decrease between fresh peas and blanched peas of 40 tenderometer points for those harvested on May 13, 44 on May 16, and 44 on May 23. For the same harvest dates there was a decrease in alcohol-insoluble solids between fresh peas and blanched peas of 3.8, 4.0 and 4.2 percent, and a decrease in total solids between fresh and blanched peas of 4.4, 5.2 and 5.0 percent. The determinations indicate that had it been possible to use fresh rather than blanched peas throughout this investigation the tenderometer values, alcohol-insoluble solids and total solids percentages would have been higher for fresh peas but the increases would have been consistent. In order to conclusively establish such a possibility, it would, of course, be necessary to make numerous determinations on fresh and blanched peas. However, the three sets of data indicate it would be possible for a canning plant operator to use tenderometer values of fresh peas to estimate maturity and can fill-in weight.

The second objective, supported by data presented in Figures 1 and 2, shows the reliability of the tenderometer to determine the differences in shear of the various mixtures of blanched peas. When the mean tenderometer values of the maturity levels were plotted with alcohol-insoluble solids or total solids the resulting coordinates deviated slightly from a straight line connecting the coordinates of the green immature with the white mature pea samples. The mixture containing 50 percent green immature peas and 50 percent white mature peas for the May 23 harvest was the only coordinate which did not conform to a straight line relationship. The data for alcohol-insoluble solids and total solids were both low, indicating a probable error in laboratory procedure rather than a difference due to maturity. It was anticipated that all the coordinates plotted in Figures 1 and 2 would fall approximately along the same line, irrespective of the date the pods were harvested. The difference expected between the coordinates obtained from tenderometer values and alcohol-insoluble solids or total solids on different dates was an extension of the coordinates to either higher or lower values as the levels of maturity increased or decreased. As shown in Figures 1 and 2, this did not occur. There are several reasons that might have caused the maturity level coordinates to fall along different lines. Probably the most important is that the picking crew was inconsistent in their ability to harvest pods of the same maturity. Table 1 shows that pods harvested May 13 produced peas which would be considered fairly immature. The tenderometer value

Table 1. The tenderometer values, alcohol-insoluble solids, total solids and drained weights of different maturity levels of California Blackeye No. 5 peas.

Sample	*Harvest date*	*Tenderometer value*	*Alcohol-insoluble solids %*	*Total solids %*	*Drained weights for can fills of 210 gms.*	*220 gms.*	*230 gms.*	*240 gms.*
Fresh peas (field run)	5-13-55	104	26.8	31.4				
	5-16-55	129	35.0	40.4				
	5-23-55	119	32.4	37.8				
Blanched peas (field run)	5-13-55	64	23.0	27.0	225	245	255	265
	5-16-55	85	31.0	35.2	251	266	275	289
	5-23-55	75	28.2	32.8	253	264	273	285
100% Green immature	5-13-55	61	19.4	21.4	224	242	256	268
	5-16-55	68	24.6	27.6	240	250	263	273
	5-23-55	62	23.4	27.0	241	253	259	272
75% Green immature + 25% White mature	5-13-55	73	22.8	26.2	232	246	256	267
	5-16-55	74	26.6	29.4	246	260	270	279
	5-23-55	72	26.2	30.0	a			
50% Green immature + 50% White mature	5-13-55	83	25.6	29.2	236	250	263	272
	5-16-55	82	28.4	33.0	251	261	274	282
	5-23-55	80	27.4	31.2	256	273	280	293
25% Green immature + 75% White mature	5-13-55	89	27.4	32.2	241	255	266	276
	5-16-55	91	31.8	35.6	257	275	283	291
	5-23-55	90	32.2	36.4	a			
100% White mature	5-13-55	97	30.2	33.8	246	262	274	284
	5-16-55	97	33.4	37.6	267	277	289	300
	5-23-55	96	33.6	38.0	271	285	301	312

[a] Smple size, too small for determination.

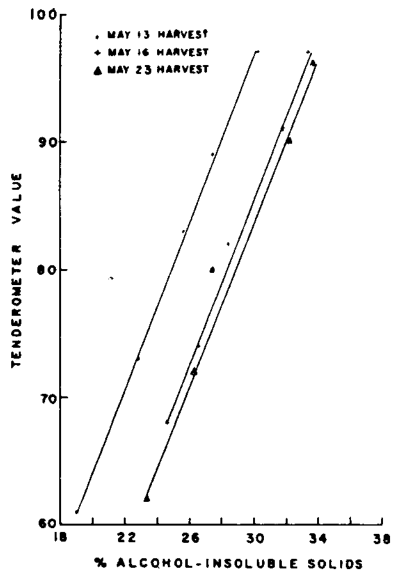

Figure 1. The relationship of tenderometer values to percent alcohol-insoluble solids of California Blackeye No. 5.

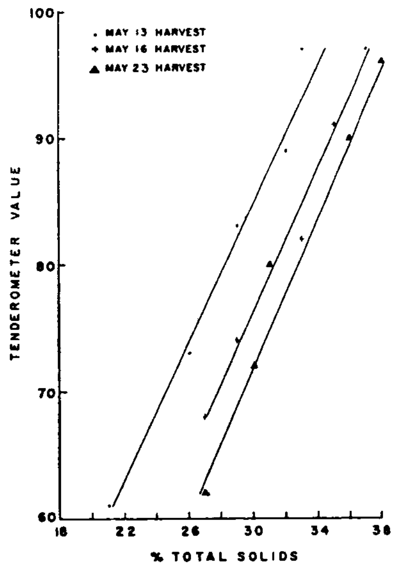

Figure 2. The relationship of tenderometer values to percent total solids of California Blackeye No. 5.

was 104, the alcohol-insoluble solids percentage was 26.8 and total solids percentage 31.4. (It is not shown in the results, but for comparison the alcohol-insoluble solids percentage of dried California Blackeye No. 5 peas is 82.5 and total solids percentage is 91.2.) The pods of yellow mature peas were plentiful for the May 13 harvest. For the May 16 harvest there were still sufficient pods but the tenderometer value of the peas increased to 129, alcohol-insoluble solids percentage to 35.0 and total solids percentage to 40.4, indicating the crew, although still picking what they considered yellow mature pods, were actually harvesting pods more mature than the May 13 harvest. Pods were harvested again on May 23, but during this harvest it was more difficult to find pods of the desired yellow maturity. Evidence of this is shown in Table 1 because the tenderometer value changed to 119, the alcohol-insoluble solids percentage to 32.4 and total solids percentage to 37.8. This could mean the picking crew either picked more pods which were a little greener in color than the desired yellow mature color, or they picked a few very green pods and a few which would be considered dry pods along with the yellow mature pods.

Another reason the maturity level coordinates did not fall along the same line may be due to the difficulty encountered in brine separating the peas at each harvest into identical proportions of immature and mature peas. During separation in the brine solution some white mature peas floated with the green immature fraction and some green immature peas sank with the white mature fraction. As many as possible of the white mature peas that floated and the green immature peas that sank were picked by hand from each fraction and discarded. At the time the experiment was outlined it seemed this procedure would give a very immature fraction and a very mature fraction. Therefore, when the fractions of peas were remixed to give the various maturity levels desired, the resulting coordinates from tenderometer values, alcohol-insoluble solids percentages or total solids percentages plotted on graph paper would be far enough apart to cover the full range of seasonal pea maturities that might be encountered at a canning plant. The peas discarded after brine separation could possibly have influenced the tenderometer values, alcohol-insoluble solids percentages and total solids percentages which would aid in causing the coordinates plotted in Figures 1 and 2 to fall along different lines. Although the coordinates did not occur on the graphs where anticipated the results obtained indicate the tenderometer as calibrated and used in this series of tests could be considered reliable in detecting different percentages of green immature peas and white mature peas which had been mixed to make the maturity levels.

The last objective of this investigation is presented in Figures 3, 4 and 5. It was designed to see if the drained weights of cans of field-run peas would coincide with the drained weights predicted from a graph prepared from tenderometer values, can fill-in weights and drained weights of mixtures of immature and mature peas. Again, it was anticipated that all coordinates would plot on the graph along the same line, irrespective of the dates the pods were harvested. This did not occur, pos-

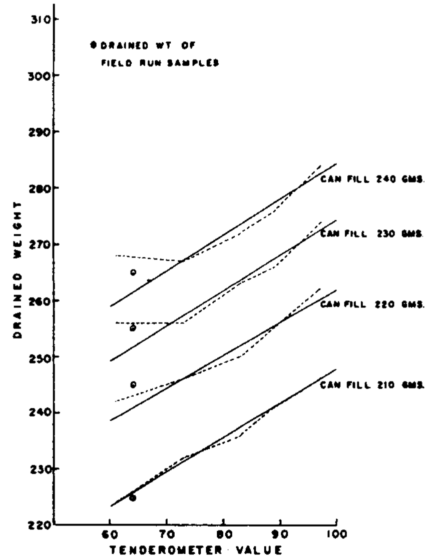

Figure 3. May 13 harvest. The relationship of tenderometer values to drained weight of canned California Blackeye No. 5 peas. The dotted lines connect experimental coordinates representing the mean of 6 cans of peas for each of the 5 maturity levels.

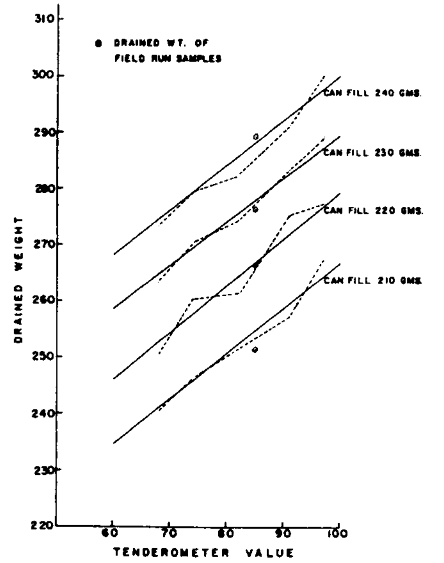

Figure 4. May 16 harvest. The relationship of tenderometer values to drained weight of canned California Blackeye No. 5 peas. The dotted lines connect experimental coordinates representing the mean of 6 cans of peas for each of the 5 maturity levels.

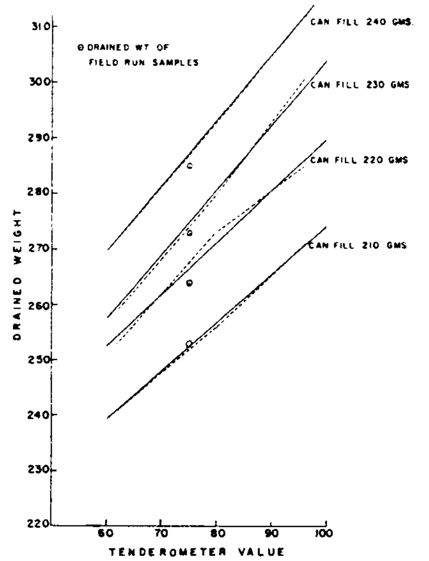

Figure 5. May 23 harvest. The relationship of tenderometer values to drained weight of canned California Blackeye No. 5 peas. The dotted lines connect experimental coordinates representing the mean of 6 cans of peas for each of the 5 maturity levels.

sibly for the same reasons the coordinates plotted in Figures 1 and 2 did not occur as expected. However, when data obtained was plotted on independent graphs, according to the dates the pods were harvested, the actual drained weights from the cans filled with field-run peas were within 4 grams, approximately 1.5 percent, of the drained weights predicted from the prepared graphs. In Figure 3 the tenderometer value of the blanched field-run peas harvested May 13 was 64. The predicted drained weights of the cans filled with 210, 220, 230 and 240 gms. of peas were 226, 241, 252 and 261 gms. The actual drained weights of the samples of field-run peas were 225, 245, 255 and 265 gms., or a maximum of 4 gms. difference between the predicted drained weights and the actual drained weights. The field-run peas harvested May 16, Figure 4, had a tenderometer value of 84. The predicted drained weights of the cans filled with 210, 220, 230 and 240 gms. of peas were 254, 267, 278 and 288. The actual drained weights of field-run peas were 251, 266, 276 and 289, or a maximum of 3 gms. difference between the predicted and actual drained weight. A like relationship exists between the predicted drained weights and the actual drained weights for peas harvested May 23 and shown in Figure 5. The predicted drained weights were 252, 267, 275 and 287 and the actual drained weights were 253, 264, 273 and 285, or a maximum difference of 3 gms.

The information presented cannot, in its present form, be used by a canning plant operator to estimate can fill of peas. Only one variety of peas has been used in this investigation. A processing plant which cans blackeye, purple hull or cream type peas would need to obtain tenderometer values and drained weights for a season or more on each type. The values obtained could be used to construct graphs or charts indicative of the average maturity level of those loads of peas delivered to the plant. Subsequent loads of peas could be measured with the tenderometer and by referring to the previously constructed graphs or charts, estimations made as to the approximate maturity and can fill-in weight necessary to obtain a final drained weight.

SUMMARY

The separate harvests of California Blackeye No. 5 peas were evaluated for the effect of blanching on tenderometer values, alcohol-insoluble solids percentages and total solids percentages. Field-run and 5 levels of maturity of peas from each harvest were used to compare tenderometer values with alcohol-insoluble solids percentages and total solids percentages. And, canned samples of the field-run and 5 levels of maturity of peas were used to find out if tenderometer values could be used to estimate the can fill-in weight of the peas.

The results from each of the 3 harvests show there was a consistent and uniform decrease in tenderometer values, alcohol-insoluble solids percentages and total solids percentages between fresh field-run peas (unblanched) and blanched field-run peas.

The tenderometer values determined on the maturity levels of peas, independently for each harvest, and plotted with alcohol-insoluble solids or total solids increased uniformly as the maturity increased from green immature to white mature peas.

The predicted drained weights for cans of field-run peas did not exactly coincide with the actual drained weights calculated from graphs which had been prepared from determinations made on the 5 levels of immature and mature peas. However, for the 3 harvests, the predicted drained weights of the canned peas were within 4 grams, approximately 1.5 percent, of the actual drained weights.

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Heat-Evolution Rates of Some Texas-Grown Fruits and Vegetables

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INTRODUCTION

In order to maintain horticultural products at the optimum temperatures for shipment or storage, refrigeration must be designed according to the specific requirements of the commodity. Refrigeration requirements of fresh produce following harvest vary and depend in part upon the rate at which heat is given off by the living plant tissue through respiration.

Previous investigators have determined respiration rates for many horticultural crops. Many of the figures now in use were compiled by Wright et al. (1954). Through necessity, many of the determinations were made with market produce of unknown post-harvest history. Respiration rates of highly perishable commodities such as sweet corn, broccoli, or spinach may fall rapidly during the first few days after harvest. Therefore, the authors tried to obtain samples for measurement with no greater delay between field and laboratory than would normally be encountered, in commercial practice, between field and storage or shipment.

Information on rates of respiration is lacking for certain crops grown in the Rio Grande Valley of Texas, and some crops grown in this area are subjected to higher temperatures after harvest than previous data cover. Data presented here will supplement those already published.

MATERIALS AND METHODS

Values for the heat produced by fruits and vegetables are generally obtained indirectly by calculations based on the production of CO_2 rather than by direct calorimetric measurements, which are more difficult to make. Green et al. (1941) found that calculating the heat of respiration of fresh plant material from the rate of CO_2 evolution gives values that are satisfactory for most practical purposes.

Carbon dioxide evolution was measured by the gas-stream method as outlined by Loomis and Shull (1937); 6 such units were set up in controlled-temperature rooms. Wide-mouth respiration chambers were constructed from 13-liter buckets which can hold about 20 sweet peppers, 2 small heads of cabbage, or 1 icebox-size watermelon. After the chambers were loaded and sealed, and before the actual determination was made, the air pump was started, the absorption columns bypassed, and the system equilibrated by pulling air through it for 3 to 5 hours at the rate of ½ liter per minute per unit. Determinations were run in quintuplicate at each temperature, and at least 2 runs were made, using different lots of each product for each run. A blank or check determination was made with each run to estimate the amount of CO_2 incident to, or entering, the system, but not associated with the actual respiration of the commodity. When required, a period of 16 to 48 hours was allowed to permit the product to come to equilibrium with the temperature at which the determination was to be made.

Heat evolution in B.t.u. per ton per day (24 hours) was computed by multiplying the rates of respiration in mg. of CO_2 per kg. per hour by a factor of 220. This factor is derived from the 2.55 calories of heat generated for each mg. of CO_2 produced by the combustion of sucrose, times the factor 86.4 to convert calories/kg./hour to B.t.u. per ton per day. Although this method falsely indicates an oversimple respiratory process, heat-of-respiration values calculated by this method agree fairly well with values computed from measurements of O_2 uptake as reported by Haller et al. (1945) and with values determined directly from calorimetric determinations at moderate temperatures up to 65° to 80° F. (Green et al. 1941). Considerable discrepancy may result at higher temperatures according to Haller et al. (1945), but even so, these calculated values have been used satisfactorily to establish practical ice requirements for transit cooling of several commodities.

Data were compiled from fruits and vegetables directly from the field, or collected from packing houses soon after harvest. Whenever conditions permitted, determinations were made on each commodity during two or more harvest seasons.

RESULTS AND DISCUSSION

Rates of carbon dioxide evolution in mg. of CO_2/kg./hr. were determined, and from this, the heats of respiration in B.t.u. per ton per day were calculated for each lot of produce tested. The averages of the heat of respiration values are listed in Table 1. Each number represents the testing of 5 to 200 kg. of plant material. The coefficients of variation, therefore, are given for each commodity in the final column of the table. An approximate standard deviation may be calculated by multiplying the respiration value by the coefficient of variation.

Measurements were not made at temperatures higher than the produce would ordinarily encounter during or after harvesting. For example, broccoli, carrots, cauliflower, lettuce, and spinach are grown in the winter in Texas and are harvested in cool periods or are precooled before loading for shipment. Some commodities, such as muskmelons, honeydew melons, grapefruit, okra, sweet peppers, mature-green tomatoes, and mature-green pineapples may be injured by low, but above freezing, temperatures. Symptoms of chilling injury include external and

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Table 1. Approximate heat of respiration of certain fresh commodities at the temperatures indicated (B.t.u. per ton per 24 hours)

	B.t.u. per ton per 24 hours at indicated temperatures for indicated commodity							*Coefficient of Variation (Percent)*
	90° F.	*80° F.*	*70° F.*	*60° F.*	*50° F.*	*40° F.*	*34° F.*	
Broccoli	....	....	65,850	38,190	17,830	7,640	4,400	7
Cabbage	....	12,350	9,510	5,000	3,970	2,420	....	13
Carrots, Imperator, roots	....	....	15,510	8,710	6,900	4,320	3,370	35
" " roots & tops	....	....	19,130	12,090	10,290	5,510	4,000	32
Cauliflower	....	....	17,640	10,130	7,440	4,480	3,930	7
Corn, Calumet, sweet, with husks	105,540	89,530	63,400	35,800	24,610	17,060	9,360	7
Grapefruit, Ruby Red	6,760	4,000	2,910	2,190	1,560	1,050	....	22
Honeydew melons	7,160	6,710	5,160	3,040	1,750	810	....	14
Lettuce, head	....	18,120	12,540	7,860	4,850	2,950	2,310	11
" leaf	....	32,200	22,090	13,830	8,650	6,450	5,060	18
Muskmelons (cantaloupe)	19,470	14,680	10,570	7,910	3,390	2,040	1,180	7
Okra, Clemson Spineless	104,780	75,900	57,400	32,080	19,910	12,240	....	5
Onions, White Bermuda, dry	....	6,200	3,700	2,440	1,590	750	640	4
Onions, green	....	....	....	....	....	14,030	....	7
Oranges, Valencia	....	7,150	4,930	2,750	1,630	1,080	890	25
Peppers, sweet	....	....	9,650	5,040	3,170	2,170	....	48
Pineapples, mature-green	....	7,800	5,320	2,850	1,240	430	....	21
" ripening	....	13,760	8,790	3,990	1,660	....	....	10
Romaine	....	23,820	15,060	9,760	7,800	4,550	....	12
Spinach	....	....	50,590	39,340	24,340	10,120	....	25
Tomatoes, mature-green	10,380	9,390	7,630	4,490	3,300	1,540	....	19
" ripening	14,850	10,590	8,910	5,870	3,140	....	....	9
Turnips, roots	....	....	5,390	4,770	3,590	2,100	....	2
Watermelons, Market Midget & Sugar Baby	9,780	....	4,680	....	1,650	800	....	18

internal physiological breakdown, failure to ripen properly, or increased susceptibility to decay. Since these fruits may be cooled below their chilling temperatures for short periods without apparent harm, they are often subjected to low temperatures during short transit periods or in mixed loads. To supply information for such shipments, the respiration rate of muskmelons was measured at 34° and 40° F. and the rates of the other products listed above were measured at 40°.

The higher the rate of respiration the more rapidly will a commodity ripen, age, and perish. For this reason, all factors which tend to increase the respiration rate should be minimized wherever feasible if food value is to be preserved and fresh appearance is to be maintained until the fruit or vegetable is consumed. Since temperature is the most important single factor affecting respiration rate, fresh fruits and vegetables should be cooled quickly after harvesting, transported with minimum delay, and kept at recommended temperatures until used (Redit and Hamer, 1961).

The use of heat of respiration data in estimating the refrigeration requirements to cool and maintain products at the optimum temperatures for shipment is discussed by Redit and Hamer (1961) and Barger et al. (1952).

The following example of the application of heat of respiration data to actual estimation of refrigeration requirements is taken from the Agricultural Marketing Service Bulletin, AMS-118, Transit Refrigeration of Mature-Green Tomatoes Shipped by Rail from the Lower Rio Grande Valley of Texas, by H. B. Johnson and D. W. Newsom (1957):

The ideal temperature range for mature-green tomatoes in transit is 55° to 65° F.

Estimation of Ice Requirement

In cooling a carload of tomatoes it is necessary to remove (1) field (sensible) heat from the fruit, boxes, and car structure; (2) the vital heat, or heat of respiration of the product; and (3) the heat leakage into the car when the outside temperature is greater than the inside of the car. Estimates of the amounts of heat from these sources for a closed carload of 700 lugs of tomatoes and the ice meltage required to absorb this heat are as follows:

Source of heat to be removed	*Amount*	*Ice Requirement*
Sensible:		
Fruits (23,000 lb.; specific heat = 0.95)	21,850 B.t.u.	152 lb./degree cooled
Lugs and strips (3,500 lb.; specific heat = 0.33)	1,155 B.t.u.	8 lb./degree cooled
Car interior (8,820 lb.; specific heat = 0.33)	2,910 B.t.u.	20 lb./degree cooled

Vital heat:		
At 90° F. (11.5 tons × 10,384 B.t.u./ton/day)	119,416 B.t.u.	829 lb./day
At 80° F. (11.5 tons × 9,394 B.t.u./ton/day)	108,031 B.t.u.	750 lb./day
At 70° F. (11.5 tons × 7,634 B.t.u./ton/day)	87,791 B.t.u.	610 lb./day
At 60° F. (11.5 tons × 4,488 B.t.u./ton/day)	51,612 B.t.u.	358 lb./day
At 50° F. (11.5 tons × 3,300 B.t.u./ton/day)	37,950 B.t.u.	264 lb./day
Leakage through fan car structure (80° F. mean outside temperature)		[1]2,000 lb./day

For example, a 700-lug load of tomatoes, with fans operating, cooling 25 degrees from an initial temperature of 80° F. to a temperature of 55° during a 3-day period, with an 80° daily mean outside temperature, will require the following amount of ice:

Source of heat	*Ice required* (pounds)
Sensible heat	
Tomatoes (152 × 25)	3,800
Boxes and bracing (8 × 25)	200
Car interior (20 × 25)	500
Vital heat	
First day	643
Second day	358
Third day	311
Leakage into car	6,000
Total	11,812

The calculations for vital heat are based on the loading temperature of the tomatoes for the first 6 hours of the first day and for the remaining 18 hours are based on the average temperature to which the load had cooled. For the second and third days, calculations are based on the average temperature to which the load had cooled. These calculations assume that the load is to be cooled to 55° F. and that a mean outside temperature of 80° is encountered during the first 3 days of transit. Ventilators are assumed to be closed and fans to be in operation.

A large amount of ice is required during the first 3 days in order to reduce the load temperature to the desired level. After the temperature is lowered to 55° F. the ice requirement for maintaining this temperature is relatively low. The heat evolved by respiration of the tomatoes at 55° will melt only 311 pounds of ice per day. Assuming that after the first 3 days of transit the mean outside temperature has dropped to 70° heat, leakage into a refrigerator car with fans operating will melt about 1,500 pounds of ice per day. In order to maintain the load temperature at 55°, under these conditions, approximately 1,800 pounds of ice will be melted daily. By the time the amount of ice added at the initial icing and first reicing is melted, the load temperatures are in the desired range. This point is usually reached after 72 hours in transit. The addition of ice at this time would result in cooling some of the tomatoes below the desired range. For this reason the schedule provides for running without ice for approximately 36 hours. During this period the coldest part of the load may warm 5 to 6 degrees while the warmest part show little or no warming.

SUMMARY

Respiration rates were measured at several temperatures, and heat-evolution rates were calculated for the principal fruits and vegetable crops of the Lower Rio Grande Valley of Texas. Rates were determined also for certain horticultural specialty crops that are grown in, or shipped from, this area, and for which little information on heat evolution has been published.

Commodities with very high heat-evolution rates included sweet corn, green onions, okra, broccoli, and spinach. Lowest rates measured were those of pineapples, dry onions, watermelons, honeydew melons, oranges and grapefruit.

An example is given of the way in which heat of respiration data can be used in computing ice requirements for shipment of fresh produce.

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[1] This figure is based on actual ice meltage for a number of test cars, and takes into consideration heat leakage into the car and heat developed from operating the fans.

Poinsettias in Lower Rio Grande Valley Yards

VIRGINIA W. GAUNT[1]

Poinsettias lend distinction and vivid color to the landscape at minimal cost and effort. The horticultural requirements are not demanding but growing poinsettias in the Valley requires attention to several simple rules.

Massed planting produces the most dramatic results. Poinsettias may form the background for low-growing plants or the base planting for a tall hedge. A crescent planting of yew or other tall plants with compactly-planted red, white or pink poinsettias within the crescent is attractive. Poinsettias with their large, distinctively-shaped foliage and their bright blooms offer an interesting contrast to evergreens such as juniper.

The choice of colors: Other blooming plants should harmonize with the poinsettias. The so-called white poinsettia is actually a creamy-white color that combines well with yellow and orange flowers. Pink poinsettias vary in depth of color and the color will clash with many other shades of pink. There are variations in the reds, the Indianapolis Red having a definite orange cast. Drifts of color are effective. A bed of white poinsettias between beds of pink and red poinsettias is very dramatic. Again, massed plantings are more effective than spotty plantings.

Wind damage: Wind damage causes misshapen plants whose bracts will tear unless protected. The angle of the house, a hedge, or a fence will shelter the plants from the force of the wind.

Protection from artificial light: During the bloom-development period in autumn, the plant requires short days and long nights. A street light or a house light shining for long night-time hours on the plant will impair bloom development. Once in full bloom, poinsettias can be grown under spotlight in order to dramatize them.

Adverse weather conditions: A roof overhang, a hedge or trees, or a heated wall may protect the plants from frost damage. A tarpaulin can be attached to a roof overhang and anchored to the ground. Electric light or candles in deep cans under the covering will heat the air to save plants from severe frost.

The selection of cuttings: During the blooming season mark those plants with the finest blooms. Select mature wood for cuttings. Twelve-inch cuttings should be planted two-thirds under ground, one-third above. This provides enough length for root development and minimum exposure to frost damage. With only four inches of stem above ground, protection from late frost is easily managed with a light covering of soil. Should adverse weather be predicted early in the season, cuttings may be made and stored. Poinsettias do not transplant well and the cuttings should be planted where the plants are to grow.

Watering: Poinsettias should be well watered throughout the growing and blooming periods. They require good drainage. A balanced fertilizer and humus are needed, and super-phosphate should be added twice a year. Iron sulfate or chelates should be added when chlorosis is manifest. After August, fertilizer with nitrogen should be eliminated because nitrogen encourages new growth which is susceptible to damage by early frost. Use super-phosphate at the start of the blooming season to insure strong sturdy stems. When bracts start to color, stop fertilizing.

Pruning: Early in the spring cut the plants to within one foot of the ground, or even lower. Following a freeze, the plants pruned level with the ground developed into plants with strong, straight stems and luxurious foliage. Two months after the first pruning, prune the plants to a height of two feet or less. To insure Christmas bloom, the last pruning in the Valley should not be later than August 1. Unpruned plants tend to defoliate, leaving long, bare, unsightly stems.

The last pruning is the time to establish a banked effect, where the blooms nod forward and form a solid mass of color. Poinsettias are pruned for this effect according to the size of the bloom. They should be planted in three or four rows and staggered so that no plant is directly in front of another. At the time of the last pruning, the plants in the first row should be cut to two feet, those in the second row to three feet, and those in the third row to four feet.

Cut flowers: They will hold up well if the proper precautions are taken. A week or ten days before the blooms are to be used, water the plant well. At that time strip the foliage from those stems which are to be used. In most instances the foliage on cut stems will curl and drop, leaving bare stems in the flower arrangement. Stripping the foliage also strengthens and enlarges the blooms.

The day before the blooms are to be used, place four inches of rubbing alcohol in a quart can. As the stems are cut, place them immediately in the alcohol. Space the blooms around the rim of the can so as to prevent bruising or breaking the bracts. Allow the stems to remain in the alcohol for eight to ten minutes, then immerse the stems and blooms in deep cool water for at least five or six hours, preferably overnight. When placed in a flower arrangement, the unconditioned portion of the stems must be in water.

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The Recurrent Threat of Cold to Crops in the Lower Rio Grande Valley: An Interpretation of Weather Records

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Agricultural meteorology is the study of weather affecting agricultural production. Weather records can be analyzed to show how often critical weather periods affect crops and livestock. In the Lower Rio Grande Valley of Texas (Cameron, Willacy, Hidalgo and Starr Counties), analyzed weather records provide growers with a useful tool for making long-range plans for producing citrus, vegetables, cotton and other weather-sensitive crops.

Low temperatures during the winter pose an important threat to many Valley crops. The severe freezes of 1949, 1951 and 1962 are prime examples. The purpose of this article is to show growers and related industries dependent upon Valley agriculture the probability of occurrences of certain temperature patterns that damage various Valley crops. By understanding the probability of occurrence of critical weather conditions, growers are able to change a "blind risk" to a "calculated risk."

Frequently used terms in this article are defined as follows:

1. Severe freeze – this condition exists when the temperature at or near the ground remains below freezing (32°F) for a sufficient time to destroy staple vegetation. The time period necessary is usually two or more days, but may be shorter with extremely frigid air masses. In the Lower Rio Grande Valley, a freeze is generally considered severe when citrus fruit, leaves, twigs, and a considerable amount of the one- to two-inch-diameter citrus wood is damaged in most of the citrus-growing districts.
2. Winter extreme minimum temperature – this is the coldest temperature during each winter season. It is a representative air temperature at the standard five-foot height.

NUMBER OF YEARS BETWEEN SEVERE FREEZES

Knowing the expected number of years between severe freezes for certain probability levels of occurrence is important to Valley growers in deciding upon the establishment or rehabilitation of citrus groves. This information is summarized in Table 1 for the 50- and 63-per cent probability levels for freezes of different severity at five stations.

The observed Valley-wide extreme minimum temperatures (Newton 1949, 1951; Jensen 1962) shown in Table 2 may be helpful in selecting the hypothetical low temperature for use in Table 1 that would likely result in a severe freeze for a particular district. If cold-sensitive plants can withstand the winter extreme minimum temperature, they can then probably withstand the other low temperatures during the year, depending upon other factors mentioned later.

The extreme minimum temperatures at Weslaco during the severe freezes of 1949, 1951 and 1962 were 20, 19 and 16 °F, respectively (Table 2). These temperatures are summarized as 20° or lower, which may be used as the general temperature criteria for obtaining the expected interval between severe freezes in the Weslaco area. According to Table 1, there is a 50 per cent chance that the winter extreme minimum temperature of 20° or lower at Weslaco will occur within 10 years. There is a 63 per cent chance that this same temperature will occur within 15 years, or only a 37 per cent chance (100% – 63% = 37%) that this event will *not* occur within 15 years.

The extreme minimum temperature distribution is skewed (not normal) and has some interesting peculiarities. According to Vestal (1961), the median is considerably smaller than the mean. The number of years indicated by the 63 per cent level of occurrence corresponds to the average interval between freezes (return period). Data in Table 1 was obtained by using the Fisher-Tippett Type I extreme value distribution and the Lieblein fitting procedure as described by Vestal (1961).

A large part of the data shown in Table 1 was obtained from Webb (1963) who has also prepared monthly extreme-minimum-temperature probability graphs for November through March.

No cycles are implied for the interval between freezes. In fact, the interval between the severe freezes of the past 33 years, 1930, 1949, 1951 and 1962, has ranged from two to 19 years.

DURATION OF CRITICAL TEMPERATURES

Cold injury to citrus and other Valley crops also depends upon the duration of critical temperatures. In some cases, information on the expected duration of critical temperatures during the night may be more important to agriculturists than the minimum temperature forecast. This is especially true when growers are deciding upon how much fuel oil, labor, and other items will be needed to adequately protect their crops during the forecast freeze period.

For the severe freezes of 1949, 1951 and 1962, the duration in hours of some critical temperatures in reference to the extreme minimum temperature is presented in Table 3. This shows the general relationship, but more data are needed than these three severe-freeze cases to estimate duration of critical temperatures in future severe freezes.

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Table 1. Interval (number of years) between freezes of different severity for two probability levels of occurrence.

Lower Rio Grande Valley Stations	*Probability Level*	*Winter extreme minimum temperature (°F) equal to or lower than:* 32	30	28	26	24	22	21	20	19	18	16
Brownsville	50%	1	2	3	5	7	12	15	19	24	32	----
	63%	2	3	4	7	11	17	22	28	35	46	----
Harlingen	50%	1	1	2	3	4	7	9	11	14	17	28
	63%	1	2	3	4	6	10	12	16	20	25	40
Weslaco	50%	1	1	2	2	4	6	8	10	14	18	30
	63%	1	2	2	3	5	9	11	15	20	26	44
Raymondville	50%	1	1	1	2	3	6	8	12	15	22	39
	63%	1	1	2	3	5	9	12	17	22	32	56
Rio Grande City	50%	1	1	1	2	3	4	5	7	8	11	17
	63%	1	1	2	3	4	6	8	10	12	15	25

NOTE: Values listed at the 63% probability level of occurrence are the average return periods (number of years) because of the peculiarity of the extreme value distribution. Temperatures are for the five-foot height. Temperature data used in this study was for the 30-year period, November through March, 1933-34 through 1962-63; except for Raymondville, which was for the 24-year period, 1939-40 through 1962-63.

Damage to cold-sensitive crops will increase proportionately with longer duration of the same critical temperature, or with colder temperatures at constant duration. Young and Peynado (1961a,b) reported on the temperature duration effect of artificially frozen 10-year-old Red Blush grapefruit trees. A temperature exposure to 23°F for four hours

Table 2. The observed extreme minimum temperatures during three severe freezes.

Station	*Jan. 29 - 31 1949*	*Jan. 29 - Feb. 3 1951*	*Jan. 9 -12 1962*
Baker Potts	21	20	----
Brownsville	23	22	19
Donna	19	20	----
Edcouch	21	21	----
Edinburg	20	19	16
Elsa	----	----	13
Engelman Gardens	19	20	14
Goodwin Tract	21	18	----
Hargill	----	----	14
Harlingen	21	21	14
Harlingen 6 NE	----	19	----
La Sara	20	19	----
Los Fresnos	21	20	13
McAllen	22	19	17
McCook	18	16	10
Mercedes 7 S	----	----	17
Mission	20	19	18
Mission 7 N	----	18	----
Mission 10 N	20	----	----
Monte Alto	20	20	12
Pharr	21	19	----
Pride O' Texas	21	19	14
Raymondville	20	19	14
Rio Grande City	17	15	10
Rio Hondo 5 E	----	19	----
Rio Hondo 7 NE	----	----	15
San Benito	----	----	16
Santa Rosa	----	----	12
Schuster Farms	----	----	12
Sebastian	19	17	----
Weslaco	20	19	16

in January, 1961, resulted in 14 per cent leaf defoliation, 0 per cent twig injury, an average of 0.4 injured segments of exterior fruit, and 0.2 injured segments of interior fruit. Exposure to 23° for six hours resulted in 63 per cent leaf defoliation, 1 per cent twig injury, 2.8 injured segments of exterior fruit, and 1.9 injured segments of interior fruit. Exposure to 21° for four hours resulted in 90 per cent defoliation, 20 per cent twig injury, 4.7 injured segments of exterior fruit, and 2.6 injured segments of interior fruit.

Table 3. Critical temperature – duration relationship for severe freezes (1949, 1951, and 1962) in the Lower Rio Grande Valley of Texas[1].

Critical Temperature (°F)		*Duration (Hours)*
Extreme Minimum	+0	0.9
" "	+1	2.5
" "	+2	4.1
" "	+3	5.7
" "	+4	7.3
" "	+5	8.9
" "	+6	10.5

[1] Data in this table were obtained by a linear regression analysis of 366 duration obervations of freezing temperatures ranging from the extreme minimum temperature to six degrees higher. Temperature records used were from 15 climatological stations in the Valley in the 1949 severe freeze, 20 in 1951, and 18 in 1962. The correlation coefficient is +.78. The regression equation is $y = .9 + 1.6x$ where y is the duration in hours and x is the difference between the observed and the extreme minimum temperature.

FACTORS RELATED TO COLD INJURY IN CROPS

Many factors influence the degree of cold damage to plants. Minimum temperature is most frequently mentioned, but other factors sometimes have equal or greater influence. Some other factors may be duration of critical temperatures, moisture of the air, freezing and thawing rates of the plant, and degree of cold-hardiness of the plant. Cold-hardiness in plants varies with prior climatic conditioning, present state of growth, size or age, specie, variety, plant part, etc. Young and Peynado (1963) found that a high water table was associated with a large number of freeze-killed trees in certain locations in the Lower Rio Grande Valley after the severe freeze of 1962.

SPRING AND FALL FREEZES

In making long-range general plans for planting cotton, vegetables, grain sorghum and other crops sensitive to light freezes, Valley growers can use average freeze dates as an aid. The freeze data and length of growing seasons in Table 4 were obtained from Hildreth and Orton (1963). They are averages for stations which have at least 15 years continuous temperature records. Minimum temperatures in some years remained above freezing (32°F). The longest data series used are 30-year records. Tender plants emerging near the average dates given in Table 4 would be exposed to freezes one year in two. This is a 50 per cent probability and quite risky. Probability data from Hildreth and Orton (1963) indicate that the chance of a spring freeze in the Valley is reduced to 20 per cent (one year in five) after approximately 24 days following the average date of the last spring freeze. It is reduced to five per cent (one year in 20) after 44 days following the average last spring freeze date.

For fall freezes in the Valley, the chance is 20 per cent prior to 12 days before the average date of the first fall freeze. The chance is five per cent prior to 23 days before the average date of the first fall freeze.

Risk-taking is an integral part of farming vegetables and other crops in the Valley. From the standpoint of dollar returns from a crop, it is sometimes profitable to take high risks in order to have crops for sale when their market value is correspondingly high.

Table 4. Average freeze dates and growing seasons.

Valley Stations	*Average Dates of 32° F Minimum Temperature*		*Average Growing Seasons (No. of days)*
	Last in Spring	*First in Fall*	
Harlingen	January 30	December 25	329
Raymondville	January 30	December 22	327
Mission	January 30	December 21	325
Rio Grande City	February 15	December 16	305

THE GROWING SEASON

The growing season (Table 4) for tender crops such as many spring vegetables, is the number of days between average dates of last 32°F freeze in the spring and first in the fall. It varies with location. Each Valley crop, as well as varieties of the same crop, has its own requirement for the number of days needed between planting and harvesting. By knowing the crop requirements and average length of growing seasons of their area, Valley growers can adjust farm crop calendars and operation schedules accordingly.

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