JOURNAL

OF THE

RIO GRANDE VALLEY HORTICULTURAL SOCIETY

Volume 13, 1959

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RIO GRANDE VALLEY HORTICULTURAL SOCIETY
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Editor, Edward O. Olson

Associate Editor, Bailey Sleeth

Aims and Objectives of the Society

The Rio Grande Valley Horticultural Society represents an amalgamation of the former Valley Horticultural Club, the Texas Avocado Society, and the Valley Grape Association.

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 13 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 the Journal of the Society, 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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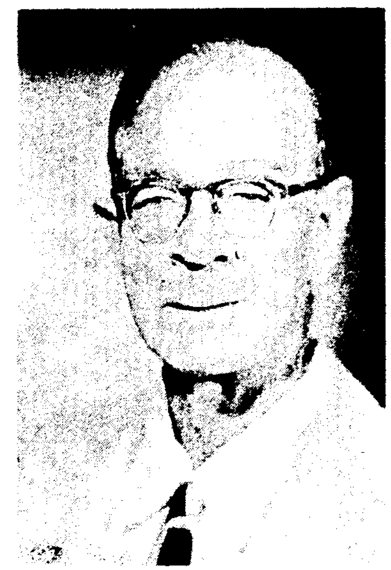
The Arthur T. Potts Award

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

Arthur T. Potts	(1955)
Dr. Wilson Popenoe	(1956)
E. M. Goodwin	(1957)
Dr. J. B. Webb	(1958)
Dr. G. H. Godfrey	(1959)



Dr. G. H. Godfrey

Dr. G. H. Godfrey
Recipient of the Arthur T. Potts Award
January 27, 1959

The Arthur T. Potts Award gives recognition for outstanding contributions in the field of horticulture in the Lower Rio Grande Valley. It is a fitting tribute to a man who has served as a leader in his field and who has gone beyond the second mile in his contributions in the betterment of horticulture.

Dr. G. H. Godfrey, the man chosen this year, was born in Madison, Kansas, received his B. S. degree from State College of Washington, his M. S. degree from Iowa State College, and his PhD. degree from the University of Wisconsin. His major field of work was Plant Pathology.

During his life-time he has held very responsible positions in the United States and in Hawaii. These positions include: Plant Pathologist, Bureau of Plant Industry, U.S.D.A.; Plant Pathologist, Bayer & Co., New York; Nematologist, Hawaiian Pineapple Canners Assn.; Nematologist and Pathologist, Spray Chemical Co., California; and Plant Pathologist, Texas Agricultural Experiment Station.

He is the author of numerous articles on diseases of castor beans, rice, vegetable crops, citrus and cotton. He has also published many articles on nematodes and their control.

Dr. Godfrey came to the Valley in January, 1937 and served as Plant Pathologist at the Texas Agricultural Experiment Station, Weslaco, until his retirement in 1958. He rendered an excellent service to fruit and vegetable growers with disease problems. Some of his principal work has been on the diseases of citrus, including melanose, psorosis, and Rio Grande gummosis. He worked with the Valley Nurserymen's Association on a tree certification program.

During the past fifteen years he has spent much of his time on the development of a downy-mildew-resistant cantaloupe. He developed the Rio Gold cantaloupe which has attracted much attention in all producing areas where downy mildew is a problem. Since his retirement he is serving as a commercial pathologist and is commercializing on his own creation, Rio Gold cantaloupe.

He is a member of the Horticultural Society, having served as Secretary-Treasurer and Proceedings Editor, and has been a regular contributor to the Journal of the Society.

Program of the Thirteenth Annual Institute of the Rio Grande Valley Horticultural Society
January 27, 1959

Institute Chairman – Dr. George R. Schulz

MORNING PROGRAM

FIRST SESSION

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President, A&I College, Kingsville

Address of Welcome .... Dr. J. B. Corns
President, Rio Grande Valley Horticultural Society,
Horticulturist, Pan American College, Edinburg

Consumer Preferences of Fruits and Vegetables ... Dr. R. E. Branson
Agricultural Economist, Texas A&M, College Station

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Horticulturist, Texas A&M, College Station

New Tangerines Developed in Florida .... Dr. Phillip Reece
Plant Breeder, USDA Horticultural Lab, Orlando, Fla.

Advances in Citrus Through Nucellar-line Trees .... Dr. W. P. Bitters
Horticulturist, Citrus Experiment Station, Riverside, Cal.

Cultural Practices in Arizona Citrus Orchards .. Dr. Robert Hilgeman
Horticulturist, University of Arizona, Tempe

AFTERNOON PROGRAM

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President, Pan American College, Edinburg

Arthur T. Potts Award Presentation .... Dr. J. B. Corns
President, Rio Grande Valley Horticultural Society

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and Dr. H. A. Thomas
Entomologists, Texas A&M and A&I, Weslaco

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Tree Planting .... A. H. Karcher, County Agent, Edinburg
Irrigation .... Gene Goodwin, Goodwin, Inc., Mission
Pruning .... W. H. Friend, Extension Service, Weslaco
Frost Protection .... Dr. P. W. Rohrbaugh, A&I, Weslaco
Cultivation .... Art Shull, Rio Farms, Inc., Monte Alto
Caretaking Programs .... H. J. Tanner, Edinburg Citrus Association

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Address At Dedication of New Laboratory At Weslaco[1]

BYRON T. SHAW
Administrator, Agricultural Research Service,
U. S. Department of Agriculture

I first want to congratulate all of you who have had a hand in making possible this fine new laboratory. To the scientists located here, it means up-to-date research facilities that will help them do a better job. To the farmers of the Valley, it means an intensified effort on their behalf in the improvement of farm efficiency and farm living. And to consumers throughout the Nation, it will mean a more abundant supply of high-quality fruits and vegetables.

These new facilities have been built because you people—who constitute the agricultural industry of the Valley—were able to convince your State and Federal legislators of your needs. And I'm sure your cooperation with this station through the years was a telling point in your favor. You've contributed thousands of dollars for research expenses. And you've furnished equipment, labor, and land for field tests of many kinds. That is the type of cooperation that gives convincing proof that you believe in research as a guiding force in your agricultural advancement.

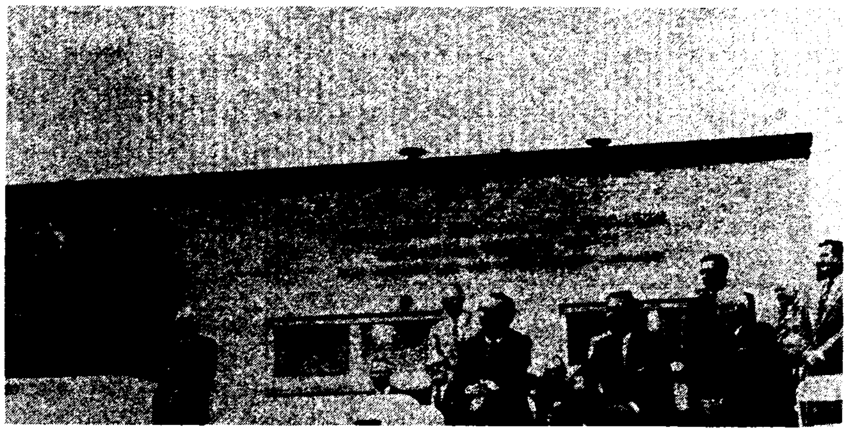
Today, as a result of your combined efforts, you have this modern laboratory, built by the Federal Government, on a site provided by your State, with additional land provided by Valley farmers for field-scale research. This 3-way approach provides an ideal environment for moving ahead rapidly in research on soils and water conservation and on fruit and vegetable production here in the Valley.

I know you're also looking forward to the new State experiment station facilities that will soon be under construction here. All these improvements will certainly heighten the effectiveness of research in seeking solutions to your more serious production problems.

I'm especially pleased that increased Federal operating funds have made it possible for us to strengthen our personnel at this station. This fiscal year, for example, we're increasing the professional staff at this laboratory to 14 men—7 for work on soil and water problems and 7 on various phases of fruit and vegetable production.

In spite of the limited facilities for research here at Weslaco, I believe you'll agree that State and Federal scientists have made important contributions to farming in this area. Thirty-five years ago, when this station was established, less than 5,000 acres in the Valley were planted to citrus. In 1948, your peak year before the two big freezes, citrus plantings had increased to more than 122,000 acres. Commercial vegetable pro-

[1] At the dedication of the Fruit, Vegetable, Soil and Water Laboratory, Weslaco, Texas, October 27, 1958.



Congressman Joe Kilgore makes a comment to Senator Lyndon Johnson and other distinguished guests during the Laboratory dedication ceremonies.

duction has grown from some 12,000 acres in 1923 to approximately 110,000 acres last year.

Today, the lower Rio Grande Valley is recognized as vitally important to the nutritional health of people throughout the Nation. Although the Valley is a major producer of vegetables throughout the year, your great variety of fresh produce during the winter and early spring fills a need that would not otherwise be met. Texas leads the Nation, for example, in the production of spinach, cauliflower, carrots, broccoli, brussels sprouts, and beets, for the winter fresh market. A number of our first spring vegetables, as well as the famous Texas pink grapefruit, come from this area.

Many things have contributed to your progress in fruit and vegetable production of course. Among them are your favorable climate and naturally productive soils. But along with these has been research, done here and elsewhere, that has resulted in better soil and water management . . . higher yielding varieties . . . better disease, insect, and weed control . . . and more efficient cultural and harvesting methods.

The level border system of irrigation developed here for example, is rapidly changing the face of irrigated farms throughout the Valley. Some 25 per cent of the irrigated land in the Valley has already been leveled, and at the present rate of development, it looks as if the other 75 per cent will be under level border irrigation within the next 10 to 15 years. Farmers prefer this system, because it means more efficient and uniform application of water, lower operating costs, and higher yields. It has made possible better land-management practices and contributed considerably to the permanency of irrigated agriculture in the Valley through better salinity and water-table control.

Level irrigation is becoming popular in other Western valleys, too. I understand the system is already being adopted in Gila Valley in California. In fact, the Technical Standards prepared by SCS for level irrigation in the Western States are based largely on the research done here at Weslaco. This is a fine example of how research conducted for one area becomes applicable in many others—of how the dividends from research repay many times over the original investment.

In the same way, benefits of research done elsewhere are being realized here in the Valley. As you are well aware, production of both onions and spinach was practically abandoned some years ago because of disease. New high-yielding varieties of onions—both open-pollinated and hybrids—with resistance to pink-root rot, developed at the USDA Research Center at Beltsville, Md., in cooperation with Texas, have largely restored your onion industry. Hybrid spinach varieties, with resistance to mosaic and blue mold, are doing the same thing for this crop.

Collaboration between Texas workers and our people in South Carolina and California has been stepped up in recent years, and increasing amounts of vegetable breeding materials that show promise are being brought here for adaptation and yield trials. New lines of lettuce, for example, are now undergoing seed increase in California, for commercial-size trials here in the Valley this winter.

We want to continue and expand this type of cooperative research. It has paid good returns for the money and labor invested. But it is not fully adequate for solving many of the production problems peculiar to the Valley.

You are all too familiar with these problems. Water is a big one—you either have too little or too much. High temperatures and humidity increase plant diseases, insects, and other pests. Sudden freezes can wipe out a crop—and an industry—almost overnight, as it did with your citrus 10 years ago. Salts are accumulating in some of your soils, cutting yields and, in some cases, completely preventing crop growth. Intensive cropping is increasing soil compaction, creating hardpan areas, and removing organic matter and soil nutrients. And many of your crop varieties were developed primarily for other areas and do not give maximum yields and quality under the climatic and growing conditions here in the Valley.

These are among the problems that will be attacked more vigorously in this new laboratory. Working with scientists here in Texas and in other States, we hope to develop soil and water management practices that will preserve soil fertility, reduce the salt problem, and make more efficient use of both irrigation water and natural rainfall. We want to learn more about crop rotation and fertilizer needs . . . disease, insect, and weed control . . . and other cultural practices that will cut the cost of production. And we want to develop varieties of fruits and vegetables that will stand up under the heat, cold, and winds of this area and still produce high yields of high-quality products both for the fresh market and for processing.

Some of these problems will yield only to basic research. And success will not come overnight. But I'm convinced that the rewards will be worth the effort.

If research can develop citrus stocks with disease resistance, cold hardiness, and salt tolerance, growers can go back into large-scale citrus production—a crop for which consumer demand is sure to increase. If research can obtain high yields and quality in vegetables, growers can change their present status of high vegetable acreage but lower yields and lower market returns, compared with other major producing areas. And if research can reverse the downward trend in soil productivity and available water, farmers of the Valley can look forward to sustained production in the years ahead.

Those are benefits worth striving for. And beyond them is the long-range benefit to people throughout the Nation. Our population is growing rapidly, and this in itself will mean an increasing need for more fruits and vegetables. But, in addition, many people even now are short in their consumption of some of the vitamins that are abundantly supplied in diets high in these protective foods. For example, nationwide nutrition surveys show that one family in four consumes less than recommended amounts of vitamin C, and one in six is short in vitamin A. These are among the vitamins absolutely essential to good nutritional health. And the Lower Rio Grande Valley has the potential for supplying them in ever-increasing quantities. It is the job of research to develop this potential.

Although knowing where we want to go in research is a prime requisite to success, it is not the only one by any means. As you well know, research is not something that just happens. First, it requires dedicated men and women with excellent scientific training. And, it requires adequately equipped laboratories and experimental greenhouses and field plots, such as the facilities being made available right here.

Although agriculture is concerned with surpluses of various kinds, it is certainly not burdened with a surplus of scientists—nor will it be in the foreseeable future. I want to say right here, however, that the scientists we've got are good. We need more like them. And we need to make the best possible use of the ones we have.

We can do this in two ways: First, by providing them with subprofessional assistants to take over the routine jobs, leaving them more time for creative thinking and planning; and, second, by providing them with modern facilities and equipment for putting their creative ideas to work.

Too many of our research facilities were built 20 to 40 years ago—some converted from houses, barns, and sheds. Some of them are overcrowded, have inadequate storage space for experimental materials, and contain obsolete research equipment. This is true throughout the country, at both Federal and State experiment stations.

The States have recognized the problems and have been expanding facilities at land grant colleges and experiment stations at the rate of 25 to 35 million dollars a year. But these funds have had to be distributed among research laboratories, class rooms, and other facilities needed to accommodate the terrific expansion in student enrollment. The Federal Government has also faced the need for more research facilities, and the Congress in recent years has provided funds for constructing a number of new laboratories in various areas of the country.

One of these laboratories we have the pleasure and satisfaction of dedicating today. And I am convinced that this Fruit, Vegetable, Soil, and Water laboratory—built and operated as a cooperative scientific endeavor—will give State and Federal scientists added incentive—and a greater determination—in helping farmers of the lower Rio Grande Valley meet the needs of our Nation.

CITRUS SECTION

Response of Marsh Grapefruit to Different Methods of Soil Tillage in the Salt River Valley of Arizona[1]

R. H. HILGEMAN,
University of Arizona Citrus Experiment Station, Tempe, Ariz.

Tillage practices in citrus groves in Arizona during the past 60 years have reflected the development of farm machinery. Forty years ago most groves were kept free of weeds by frequent shallow cultivation. This program was used because the small horse-drawn cultivators and disks were incapable of incorporating heavy cover crops deeply into the soil. With the advent of large tractors and disks, weeds were allowed to grow very large before incorporating them with the soil and tillage was changed to deep disking three or four times per year. Relatively recently the discovery of herbicides that kill weeds by spraying the material on the soil or on the small weeds have resulted in a non-tillage clean culture program in which the soil is not disturbed. This program has been supplemented in a few instances with permanent mulches. Weed cutters which effectively chop up the weeds and cut close to the ground, and rotary hoes which are capable of thoroughly incorporating weeds and cover crops with the surface soil have recently been developed. These suggest still further revisions in cultural procedures.

The selection of a tillage program depends upon the general climatic conditions and irrigation requirements of the region, the soil and topography of the particular grove and the economy of the operation.

Features which can be considered as fundamental in any tillage program are: (1) Moderation of climatic effects. (2) Maintenance of soil structure. (3) Prevention of excessive competition by cover crops and weeds for water and nutrients needed by the tree.

Under Arizona conditions the moderation of serious freezes is of primary importance in selecting winter tillage practices. Cold injury can be moderated by providing optimum conditions for heat transfer from the soil. Bare, firm soil absorbs and radiates heat better than loose disked soil or soil covered with heavy weed growth or mulch materials. Therefore, citrus groves should be cultivated thoroughly in the late fall and all weeds incorporated into the soil. By following this with a heavy irrigation to firm the soil, conditions are provided for the most efficient absorption of heat by the soil during the day and radiation of heat to the tree during the night.

The maintenance of soil structure is considered to be an important feature of grove management. The condition of the soil is partly reflected by the rate water enters. Any operation which compacts the soil reduces

[1] Talk presented January 27, 1959, before annual Institute of Rio Grande Valley Horticultural Society, Weslaco, Texas.

the rate water penetrates. If the rate is seriously reduced difficulty in wetting the soil develops and poor tree growth results. The surface soil is compacted by irrigation. Disking produces a layer of compacted soil in a zone below the disk level. Trucks and trailers cause compaction at variable depths depending upon the depth they sink into the soil. All traffic in a grove is harmful to the soil.

Cover crops utilize both water and plant nutrients and compete with the tree while they are growing. However, when the crop is incorporated with the soil the decaying plant material adds organic matter and thus improves soil structure and fertility. Thus, the benefits from the addition of organic matter and improved structure must be balanced against possible restricted tree growth and fruit production caused by competition.

Present tillage practices have been developed by growers as new equipment and materials became available. The value of these programs has usually not been established by experiments prior to their introduction into common usage. Since 1943 the University of Arizona Citrus Experiment Station near Tempe has conducted tillage tests to evaluate their effect on tree growth and yields.

METHODS AND MATERIALS

The experiments described herein were carried out at the Citrus Experiment Station in the Salt River Valley near Tempe. The soil at this location is a gravelly sandy loam underlain at about the 30 inch depth with a calcareous caliche. A 4.8 acre block of Marsh grapefruit trees on sour orange rootstock and planted 22 feet by 22 feet on the square system in 1931 was used. The trees were first grown uniformly under normal disk cultivation of 3 to 5 times per year with furrow irrigation. In 1943 the method of irrigation was changed to flooding and a large permanent border was placed near the tree row so that a modified contour system was evolved. The slope of the land was so slight that the irrigation program was essentially large basins containing 7 trees. Each tillage plot consisted of 3 rows of 7 trees separated by a single guard tree. Within each tillage plot equal numbers of trees were fertilized with 3 pounds of ammonium nitrate, 10 pounds of 11-48 ammonium phosphate or its equivalent and 200 pounds of dairy manure per tree. The tillage programs which were replicated 3 times are as follows:

1. Non cultivation with weeds killed with weed-oil sprays. Plots were sprayed 4-7 times per year when the weeds were usually less than 3 inches high.

2. Disk 5-6 inches deep in October, before spring growth in early March, late June after the fruit drop period and in some years also in August.

3. Disk 3-5 inches deep in October and late June. Mow or shred weeds with a stalk cutter in early April, May and August.

4. Permanent bermuda sod mowed about once per month between April and October.

Because of the permanent border, disking and mowing has been done in only one direction. Weeds on the border and in the tree rows have been controlled by weed-oil sprays and cutting above the soil level with a swing hoe.

The amount of water applied per irrigation has ranged from 4 to 7 acre inches. All plots received the same irrigation treatment. The average irrigation dates when the entire area was irrigated are as follows: Jan. 1, Mar. 13, Apr. 21, May 15, and Nov. 17. Between May 15 and Nov. 17 water was applied to alternate sides of the tree at 10 to 14-day intervals, and by wetting the entire area once in July and again in September. Fruit growth measurements indicated that slight moisture stresses developed during irrigation intervals during the summer and moderate stresses in October. This program was adopted in 1951 when it became evident that 20-24 day intervals during the summer allowed moderately severe stresses to develop and more frequent complete irrigations were known to produce iron chlorosis. From 4 to 5 acre feet of water were applied each year.

Concurrent with the above test, a similar test was conducted on Washington Navel trees. Because of the development of virus diseases this test was discontinued. However, data on the effect of tillage on growth of young replant trees were obtained. These trees, which were planted in 1948, 1949 and 1950, were commercial trees budded on sour orange and Rough lemon rootstock.

RESULTS

Effect of Tillage on Marsh Grapefruit

Yields and Tree Growth—Variations in fruit yields over a nine-year period from the bare untilled weed oil sprayed plots, the disked plots and the permanent bermuda sod plots are shown in Figure 1. The yields from the plot disked in June and October and mowed between diskings, were never significantly different from the disk plot, so the data has been omitted.

The average yields for the seven year period of 1942-48 prior to the initiation of this replicated test, showed that all plots had essentially the same yields. During the first two years after the experiment was started the yields of the bermuda grass plots were markedly lower than the others but wide variations between the replications kept these differences from being statistically significant. Thereafter, the yields from the non-tilled weed oil sprayed treatments and from the disked treatments were significantly higher than the yields from the bermuda grass treatments in the "on crop" years of 1952, 1954, 1955 and 1957. No significant differences existed in the "off crop" years of 1951, 1953 and 1956. Although the oil-spray-weed-control treatments produced more fruit than the disked plots, these differences were not statistically significant. Average yields

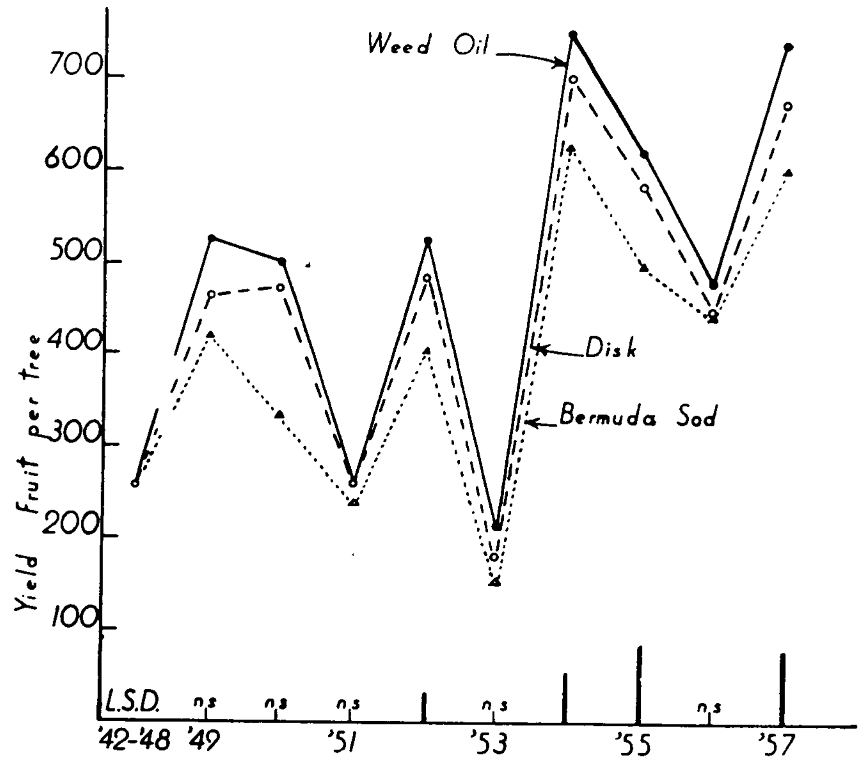


Figure 1. Variations in fruit yields over a 9-year period from oil-sprayed, disked and Bermuda-sod plots.

corrected for initial productive capacity indicate that the bermuda grass treatment produced 84 per cent as much fruit during the last four years as the oil-spray-weed-control treatment (Table 1).

Table 1. Effect of tillage on yield and tree growth.

	Average yield in truit/tree				*Trunk Growth in Sq. Cm.*			
	'42(a) '48	*'49 '57*	*'54 '57*	*(b) Rate*	*Trunk '49*	*Area '57*	*In-crease*	*Rate(d)*
Weed Oil	257	505	646	100	203	387	184	99
Disk	257	474	602	93	197	382	185	100
Mow & Disk	248	452	578	92	204	383	179	97
Bermuda	254	413	542	84	202	371	169	91
L.S.D. (c)		77	79				8	

(a) Yield before expt. started.
(b) Rate on ave. yields for '54 to '57 compared with original yields.
(c) Least significant difference between means at odds of 99:1.
(d) Area of trunk from circumference 10 inches above bud union.

Tree growth also reflected tillage practices. Trees growing in bermuda grass produced about 8 per cent less growth during the nine year period than those grown with disk tillage or with oil spray weed control.

Fruit size and quality—Tillage practices had no significant effect upon fruit sizes or grades between 1954 and 1957 when the fruit was graded on a grading belt and run over a sizer which separated it into four size groups (Table 2). Samples of fruit from the same 9 trees in each plot have been tested for quality each year. Data for 1956 and 1957, which have been combined and presented in Table 2, is typical of the type of variation which has occurred. There has been no evidence that tillage has affected the total dissolved solids, the amount of acid or juice content of the fruit. However, in the past two years the peel thickness has been slightly but significantly thinner on fruit from trees growing under bermuda grass culture.

The above effect on peel thickness may be related to nutritional conditions which apparently have been gradually changing during the experiment. The 1956 analyses of spring leaves sampled in October revealed that the percentage of phosphorous was higher in trees under bermuda grass culture than in trees under other treatments (Table 3). Neither the nitrogen nor the potassium were affected. This increase in phosphorous suggests that possibly the decomposition of the mowed

Table 2. Effect of tillage on fruit grade, size and quality.

	Grade and Size (a)			*Fruit Quality (c)*		
	% US No. 1	*% 27 & lgr. (b)*	*% T.S.S.*	*% Acid*	*% Juice Volume*	*Thickness Peel m.m.*
Weed Oil	56	8.6	12.1	1.73	35.7	9.0
Disk	63	12.0	12.1	1.80	36.6	8.8
Mow & Disk	56	8.8	12.0	1.77	36.0	8.9
Bermuda	55	13.3	11.9	1.74	36.3	8.6
L.S.D.	ns	ns	ns	ns	ns	.25

(a) Average values for grades and sizes '57 to '57 incl.
(b) No. of fruit per standard carton.
(c) Average values in Janu. '57 and '58.

Table 3. Effect of tillage on tree nutrition.

	Percentage in dry matter of leaf in Oct. '56		
Tillage	*N*	*P*	*K*
Weed Oil	2.11	.163	.88
Disk	1.99	.168	.92
Mow and Disk	2.21	.160	.96
Bermuda	2.00	.189	.92
L.S.D.*	–	.014	–

* Difference required for significance between means at 19:1.

grass on the soil surface or the larger root population of bermuda and citrus roots has made more phosphorous available. This soil contains a large amount of total phosphorous but available phosphorous appears to be low.

Effect of Tillage on Replant Washington Navel Trees

In a block nearby the tillage experiment on Marsh grapefruit trees, similar tillage treatments were applied to Washington Navel orange trees. In 1948, diseased trees were removed and a replant program initiated. Severe freezes on January 1949 and January 1950 killed trees so that additional replanting was required. Both sour orange and Rough lemon were used as rootstocks. Trees were located in all four tillage plots. Where permanent bermuda grass was grown the grass was hoed near the tree several times each year.

In 1954 the tree trunks were measured and all trees were rated as to vigor of growth. Trees growing under both the weed-oil-spray program and the disk program made similar growth. These trees were markedly superior to the trees growing in bermuda grass sod (Table 4). The trees growing on sour orange root planted in 1948 were frozen back to the trunk in both 1949 and 1950. In 1954 these trees were no larger than the trees on sour orange root planted in 1950. The trees growing under oil spray weed control and disk culture were larger and a higher percentage of them rated very good than occurred with the trees growing in bermuda sod.

Bermuda sod competition may have been primarily responsible for this reduction in growth. However, light freezes in 1951 and 1953 damaged leaves and small twigs more severely on trees growing with bermuda than they did on trees in the other treatments. This reduction in leaf area undoubtedly also reduced tree size and vigor.

Effect of Tillage on Water Infiltration

Beginning in 1950 the rate water entered the soil was measured in the large tree basins after they were filled with water. This method did not measure the initial rate of flow, but measured a stable rate of intake of the final 3 acre-inches of water applied.

Table 4. Effect of tillage on growth of young Washington navel trees interplanted in an old grove.

		Weed oil and Disk Culture			*Bermuda Sod Culture*		
Date Planted	*Root-stock*	*No. Trees*	*Ave. Trunk Area (Sq. cm.)*	*No. Very Good Trees*	*No. Trees*	*Ave. Trunk Area (Sq. cm.)*	*No. Very Good Trees*
Mar. '48	Sour org.	7	34	3	3	23	0
Mar. '50	Sour org.	4	31	1	5	27	1
Mar. '50	Rough lem.	9	34	6	3	24	0

Infiltration rates in the treatments were found to vary from 10 to 15 per cent from one irrigation to the next during any single year. Variations in rates between 1950 and 1957 were not greater than variations within a single year. Thus, there has been no significant change in infiltration rates in any treatment since the second year after the treatments were started (Table 5).

In all tests, beginning with the initial ones in 1950, the non-tillage weed-oil-spray plots have had an infiltration rate which was about one-half the rate in the disked plots. Factors causing these differences have not been established.

When fruit is harvested every fourth row is used as a road to haul fruit from the field. The same rows are used each year. Tests in 1957 showed that infiltration rates were slightly less in these road rows than in the adjacent rows not subjected to this traffic except in the oil spray non tillage and bermuda sod plots. In the latter plots, where the rate was initially law, traffic did not change the rate.

Soil Moisture Variations Between Treatments

In this experiment all plots received the same amount of water at the same intervals. Since cover crops and grasses were expected to use additional water, soil moisture changes were followed to determine the differences. In 1949, soil moisture changes were followed from oven-dry soil samples and from soil moisture tensions recorded on tensiometers at the drip of the trees. Rates of fruit growth were followed from fruit measurements.

During the summer it was found that during the first 3 to 5 days after irrigation the soil moisture tended to remain slightly higher under bermuda grass plots than under non-tillage bare soil. This apparently was caused by reduced evaporation from the soil under the bermuda sod. However, thereafter the rate was more rapid so that an average of 70 per cent more water was extracted from the bermuda plots than from the non tilled plots. These differences were reflected to a small degree in the fruit growth rates which were 5-15 per cent lower in the bermuda

Table 5. Effect of tillage on infiltration of water in the soil.

	Rate of infiltration in inches/hour			
	Time Effect		*Traffic Effect*	
Tillage	*Nov. 1950*	*Nov. 1956*	*Aug. 1957(a)*	*Aug. 1957(b)*
Weed oil	.26	.24	.26	.26
Disk	.48	.45	.49	.45
Mow and Disk	.45	.47	.56	.51
Bermuda	.44	.44	.43	.42

(a) Regular tillage rows.
(b) Rows used as roads for hauling fruit.

grass plots than in the bare soil plots during the 4 to 7 day interval prior to irrigation. This reduction was insufficient to significantly reduce the final size of all the fruit on the tree.

Fruit growth rates in the disked plots did not differ significantly from the non tillage plot. It appears that the annual weeds growing during the disk intervals did not produce a sufficiently extensive deep root system to provide measurable competition for water with the trees.

DISCUSSION

The question of the specific effect of the tillage practices upon trees cannot be entirely resolved. It is known that during the summer slightly greater water stresses have occurred between irrigations in the bermuda plots than in the others. These effects appear to be small since the average final size of the fruit has not been significantly changed. Furthermore, the soluble solids content of the fruit is increased if serious moisture stresses are allowed to develop (Hilgeman and Sharpless, 1957). Such increases have not occurred. However, moisture stresses do reduce trunk enlargement (Hilgeman and Sharples, 1957) and this situation has developed.

The nutritional levels in the leaves with respect to nitrogen show that weeds and bermuda grass have not influenced the supply of this nutrient. This may be explained in that all weed residues have been returned to the soil. After the experiment had been in effect for several years a balance could develop.

It appears that a possible explanation of the effect of bermuda may be simply a natural competition for space between the citrus and bermuda roots in the soil. Limited observations of root systems by washing roots has shown extensive development of bermuda roots which were intertwined with the citrus roots to a depth of 3 feet.

The failure of the non tillage trees to produce an increase in yields or tree growth is in agreement with the results of Patt with Marsh grapefruit in Israel, and Lombard (1951) with Valencia oranges at Rancho Sespe in California. It appears that if proper soil moisture is maintained with both disking of cover crops or non tillage practices little differences can be expected in tree growth and yield.

Infiltration rates were reduced under non tillage in this experiment, whereas rates have been markedly increased in California (Kimbel et al, 1950). Observations of soil compaction in this experiment (Karmeli, 1956) show that the surface 2-3 inches of soil has a higher apparent specific gravity in the non tilled plot than within the disked plot. Since this condition held true in areas where equipment has not operated for many years, it appears that the compaction must be related to some action of the irrigation water, possibly combined with the extremely high surface soil temperatures which are encountered in the desert area.

Much emphasis has been placed on the maintenance of proper soil tilth, and the addition of organic matter to soils to maintain maximum production in citrus groves (Schoonover and Batchelor, 1948). The high yields obtained from the non tillage plots tend to refute this theory. In these plots no organic matter has been incorporated into the soil and the soil is compacted so that water enters slowly. The soil structure and tilth is considered inferior to the tillage plots. Yet, high yields and good tree growth have been obtained. It appears probable that the condition of the surface few inches, where few roots are present, has little relation to tree performance. It should be pointed out that although the infiltration rate was low, ample water was supplied by holding the water in the basin until it moved into the soil.

SUMMARY

Marsh grapefruit trees planted in 1931 have been grown since 1949 under (1) non tillage with oil spray weed control (2) disking cover crops 4 times a year (3) disking cover crops 2 times a year with mowing between disking, (4) permanent bermuda grass sod mowed 8 times a year. Significant differences in yields between treatments 1, 2 and 3 have not occurred during 9 years of the test but significant reduction in yields developed in treatment 4 during four years. Tree growth in treatment 4 has been gradually reduced throughout the period. Treatment 4 has increased phosphorous uptake and reduced fruit acidity but has not improved U. S. grades or changed fruit size.

The performance of trees grown under treatment where water infiltration rates are reduced, no organic matter is added and soil structure is poor, suggests that these features of soil management may be overemphasized in citrus grove management.

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Problems and Progress in Breeding Citrus in Florida[1]

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Throughout the ages natural hybridization, occasional mutation and subsequent horticultural selection have produced most of the citrus varieties in existence today. Not until the pioneer systematic breeding experiments by W. T. Swingle and H. J. Webber is artificial hybridization of citrus recorded. The first cross-pollinations were made in Florida in 1893, but most of the seedlings were destroyed by the freeze during the winter of 1894-95. As a result of the freeze, hardiness became one of the principal objectives in the breeding work, and they used the cold-resistant trifoliate-orange, *Poncirus trifoliata,* as one of the parents. The cross-pollinations made in 1897-1899 produced the citranges, citrumelos, citrangors and others that have proved to be particularly valuable as rootstocks. In other crosses having loose-skinned fruit as an objective, grapefruit and mandarin varieties were hybridized to produce such commercially valuable varieties as the Orlando and Minneola tangelos.

Sporadic attempts to reactivate citrus breeding were made after the turn of the century by research workers in the U. S. Department of Agriculture, by H. B. Frost in 1914-15 at the California Citrus Experiment Station, and by Camp and Jefferies in 1924 at the Florida State Citrus Experiment Station, Lake Alfred. Citrus breeding, however, has always been hampered by inherent difficulties.

Every seedling plant of most species, generation after generation, begins the diploid phase of its life cycle as a fertilized egg cell. The diploid chromosome number is established by fusion of an egg and a sperm cell, each of which contributes half of the total chromosome complement carried by the individual. Thus the genetic inheritance is determined at the time of fertilization of the egg cell and various combinations of characters in the two parents may be obtained in progenies through controlled breeding. If this, the normal way, were the only way in which a citrus seedling could be formed, the problems of the citrus breeder would be relatively simple, and satisfactory combinations would be limited only by the land and funds available for his experiments. However, many citrus varieties produce few, if any, embryos of sexual origin. Hybridity often results in sexual sterility. In such a case the new type will become extinct unless it is propagated vegetatively or unless through some other phenomenon what is known as a "permanent hybrid" is established. "Permanent hybrids" may be produced by doubling of the chromosome number, which may occur by chance or may be induced by treatment with colchicine, by balanced lethal factors, or by a process known as apomixis.

Apomixis simply means reproduction is accomplished without sexual

[1] Paper given at the Annual Institute of the Rio Grande Valley Horticultural Society, January 27, 1959, Weslaco, Texas.

fusion, and it may be by one of three general types. The diploid, or sporophyte, individual may arise from an egg cell (female gamete) or possibly from a sperm (male gamete) without fusion with another sex cell. This type of apomixis is called parthenogenesis. The resulting individual may have only half the normal number (haploid) of chromosomes, or the chromosome number may become doubled as in the normal diploid. A seedling originating in this way may be correctly called a gametic seedling. Frost (1), however, refers to the hybrid individual produced sexually by the fusion of two gametes as a "gametic seedling." It is suggested that use of the term "gametic seedling" be discontinued and that the term "zygotic" seedling be substituted when the individual in question has arisen from a fertilized egg cell. The term zygote, or fertilized egg cell, has long been in use by both botanists and zoologists. Therefore, an individual that has arisen from such a cell may be correctly called zygotic. Furr, Reece and Hrnciar (2) have previously used this term in reference to the hybrid seedlings.

A second type of apomixis in which the new individual originates from a haploid cell or cells of the gametophyte (embryo sac) instead of from the egg or gamete is called apogamy. In a third type, the new seedling arises from the diploid cells of the female parent and is therefore genetically identical with the mother. The latter type is called sporophytic budding, or nucellar embryony and occurs in citrus, mangos, some roses, and at least five other genera of flowering plants. It is common in citrus that groves of seedling trees that will be largely true to type can be grown from seeds of known hybrid varieties.

Ample evidence leads us to think that citrus is exceedingly hybrid. This hybridity, or heterozygosity, has resulted in considerable sexual sterility. Types that otherwise would have failed to reproduce themselves by seeds have been perpetuated through nucellar embryos. If this had not been the case, or if sexual reproduction had been possible or frequent, the hybrid type would have been lost through segregation and recombination of genetic factors in a few generations.

Apomixis and frequent sexual sterility make citrus breeding very complicated because nucellar seedlings are often difficult to distinguish from hybrid seedlings until they produce fruit. In certain crosses all or nearly all the seedlings prove to be of nucellar origin. New hybrids are almost impossible to create from such highly nucellar parents.

In spite of these difficulties that have retarded citrus breeding, 35 crosses were made by John Bellows in 1942 at the U. S. Horticultural Field Station at Orlando, Florida. Shortly afterward, Bellows left the Department of Agriculture. Since that time the breeding work has been carried forward by remaining associates and scores of additional crosses have been made. At present their progeny are in various stages of development and citrus breeding is being expanded by the U. S. Department of Agriculture in both Florida and California.

Most citrus varieties have a diploid chromosome number of 18, or 9 pairs. Because of the heterozygous nature of citrus it is logical to assume, but hard to prove, that each chromosome pair carries at least one allelomorphic pair of genes and that there are 9 linkage groups. Therefore, for recombination of all the types of eggs and sperms the population from a single cross must consist of at least 184,320 individuals. In such a group, there will be 78,732 new genetic types and 768 will be visibly different.

A cross of Clementine tangerine x Orlando tangelo proved to be particularly fortuitous. The Clementine is one of a few citrus types that does not produce nucellar embryos. Therefore, all seedlings were hybrid. A population of only 327 produced a wide range of forms. Most of them are predominantly tangerine in type. Some resemble oranges and others tangelos. Most of them are early maturing, large and sweet, have red peel color and unfortunately are rather seedy. Prominent navels are characteristic of many of these F_1 hybrids.

Three promising Clementine tangerine x Orlando tangelo hybrids may be described, illustrated, named and released in the near future. They are outstanding because of their earliness. One, a tangerine type, sometimes breaks color by September 23. It reaches its prime eating condition by mid-October. Regular bearing in Florida is a habit, and fruits average 2¾ to 3 inches in diameter and are bright orange in color. Total soluble solids advance from 13.0 per cent in November to 14.75 per cent by December. Another somewhat later, exceptionally highly-colored hybrid tangerine is somewhat lower in solids but is excellent by November. The third hybrid of the group resembles an orange, although it is three-fourths tangerine and one-fourth grapefruit in its inheritance. This variety is lower in solids and in acids than the previously mentioned hybrids. Solids in early October average 10.0 per cent and acids 0.9 per cent. During November solids increase to 12 per cent while the acids remain about the same; but in some seasons the acids declined to 0.6 per cent. Average fruit size is 3¼ inches.

Preliminary rootstock tests indicate that these new varieties should not be propagated on Rough lemon, because quality is seriously reduced by that stock.

At the time these hybrids are mature most Dancy tangerines in Florida are still small and green. In "Seasonal Changes in Florida Tangerines," Harding and Sunday (3) say that "Dancy Tangerines reached the minimum standard of consumer acceptance about the middle of November. Prime eating condition was reached in January and February." The new tangerine hybrid varieties soon to be released will enable the grower to supply the public with larger, sweeter, more highly colored mandarin fruit at least 6 weeks ahead of the Dancy tangerines.

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Virus-free Seedling-line and Old-line Selections of Citrus Varieties in Texas[1]

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Many well-established commercial citrus varieties (old-line varieties) propagated in Texas (Olson et al, 1958), Florida (Childs et al, 1955) and California (Bitters et al, 1954) are symptomless carriers of one or more viruses; others are apparently virus-free. Seedlings of virus-infected trees are believed to be initially free of viruses. When these seedlings produce fruit apparently identical with that of the seed parent, they are considered nucellar seedlings. In the present paper these fruiting seedlings will be referred to as seedling lines, since some trees may be hybrids.

The performance of seedling lines in other citrus areas has aroused interest in seedling lines available in Texas. Tests are now underway in Texas to compare the productiveness of old-line and seedling-line grapefruit (Cooper et al, 1958) and Valencia orange trees. Data on orchard performance of these seedling lines are not yet adequate for them to be recommended for commercial planting in Texas. Many Texas seedling lines are young and show such juvenile characters as shy-flowering, excessive thorniness, and extreme vigor of growth. These juvenile characters disappear as the tree grows older. In contrast with the Texas seedling lines, some seedling lines used in California date back to 1917 and their budded progeny flower prolifically, are relatively thornless, and are not extremely vigorous but have retained some of the vigor associated with young nucellars. The present paper has the following objectives:

(a) To describe methods used to obtain seedling lines in Texas.

(b) To show that some seedling lines in Texas are virus-free, while others are not. (Seedling-line trees, like old-line trees, may become virus-infected by grafting them with virus-carrying buds.)

(c) To list varieties of seedling-line and old-line trees considered to be virus-free.

METHODS OF OBTAINING SEEDLING-LINES

Three different methods are being used to obtain seedling lines. One method is to grow seedlings of varieties known to produce a high proportion of nucellar seedlings; these seedlings, either on their own roots or on sour orange rootstock, are grown some distance from virus-infected plants. Since some varieties are either not present in Texas or, if present, carry one or more viruses, seedlings of such varieties are raised to obtain virus-free plants. A second method is to search for fruiting seedlings among back-yard plantings and variety collections made by individuals or organizations. Since such seedlings may have been infected inadvertently by budding from diseased trees, they are being indexed for viruses by grafting them on plants which express symptoms of virus infections. A third method is to introduce budwood believed to be virus-free from promising seedling-line selections in California. New hybrids from Florida are also being introduced as budwood. Such introductions are made through the cooperation of the Texas Department of Agriculture. This material is tested in accordance with state quarantine regulations before being planted in the field.

VIRUS SPREAD TO SEEDLING-LINE TREES

Seedlings are believed to be initially virus-free, but the progeny may become virus-infected as individual trees before, during, or after propagation. The infection may be spread by insects, inadvertently by budding the seedlings with virus-carrying buds, or by propagating the seedlings onto rootstocks that had been budded earlier with virus-infected buds. While examples of virus spread have been reported by citrus pathologists in other areas, a few local examples illustrate how this can happen.

A collection of seedlings of different varieties was set out in an orchard planting near Monte Alto, Texas, in November 1953. The collection comprised 2 different kinds of material: Group A, seedlings grown separately in a nursery, never budded, and considered virus-free; Group B, seedlings grown in an experimental rootstock nursery; some of these seedlings were budded with old-line virus-carrying buds which subsequently died. These seedlings, now 5 years old, bear fruit apparently true to variety and most of them are considered nucellar seedlings. Some trees in Group B are not virus-free because they show symptoms of virus-caused disorders; others show no visible symptoms of virus.

To locate virus-infected seedling trees among the apparently healthy trees in Group B, buds from individual trees were grafted to Orlando tangelo seedlings, which express specific symptoms if cachexia virus is present. Bud inoculations from 8 different seedling trees in Group B caused cachexia symptoms on Orlando tangelo seedlings 2 years after they were budded. These symptoms indicate that the 8 trees were inadvertently infected by virus-carrying buds in the rootstock nursery before they were set out in 1953. Other apparently healthy seedling trees in the same planting or in another planting near Weslaco have been shown to carry other viruses. Thus, seedling-line trees of uncertain or unknown origin are not necessarily free of bud-transmitted viruses, particularly if old-line buds have been grafted to them.

In areas where insect-transmitted viruses occur, some seedling-line trees may become infected with virus. Some mandarin-hybrid introduc-

[1] Part of the cooperative Citrus Rootstock Investigations conducted by the Texas Agricultural Experiment Station and the U. S. Department of Agriculture, Weslaco. Rio Farms, Inc., also cooperates in these studies.

tions to Texas from Florida were destroyed after they were found to carry a mild strain of insect-transmitted tristeza virus. This experience indicates the importance of indexing for viruses all budwood introductions from areas where tristeza virus is insect-spread.

APPARENTLY VIRUS-FREE SELECTIONS OF SEEDLING-LINE AND OLD-LINE VARIETIES

Virus-free selections of most of the major citrus varieties in Texas are listed in Table 1. These are not necessarily selections of the best strains of these varieties. Commercial varieties missing from the list are Pineapple, Jaffa and Joppa sweet oranges, Temple "orange," and Clementine mandarin. However, a seedling-line Pineapple orange has been introduced from California, and Joppa and Jaffa seedlings have been planted but have not flowered. Since Temple and Clementine seedlings are all hybrids, not nucellars, planting seedlings of these 2 varieties will not produce lines identical with the parental type. However, progeny of 28 new Clementine-hybrid selections from Florida and California may include one or more varieties equal to or better than either Clementine or Temple variety. Seedlings of varieties of importance in other countries—including the Shamouti orange of Palestine, the Ellendale mandarin of Australia, the blood oranges of Sicily and the Salustiana orange of Spain—have also been planted but have not yet fruited. Many of these foreign varieties are unknown in Texas, but some may be adapted to citrus culture in this state. Backyard seedlings, mostly of standard commercial sweet orange varieties from the United States and Mexico, are also being located and propagated. Many of these backyard seedlings occur outside the commercial areas.

In addition to the varieties listed in Table 1, seedling lines of other varieties will become available from other research groups in Texas also seeking virus-free varieties. There are other varieties available but not listed, such as the sour mandarins, which are of interest only to research groups. Other varieties introduced from other areas are in quarantine, prior to field testing.

Listing selections as virus-free does not automatically mean that they are ready for planting in commercial groves. The relative performance of old-line and seedling-line varieties in Texas is still unknown. The old seedling-line introductions from California have not yet borne fruit in Texas; their performance in comparison with that of local selections is unknown; and indexing is not complete. Thus, the virus-free seedling lines listed in Table 1 represent trees with potential merit to the Texas citrus industry rather than trees with proved superiority over selections now being propagated by local nurserymen. Most of the virus-free old-line selections in Table 1 are already registered as budwood-source trees by the Texas Department of Agriculture; some old-line selections are already being propagated and planted in commercial groves.

Table 1. Seedling-line and old-line selections of different varieties of citrus apparently virus-free in Texas in January 1959.

			Basis for considering clone probably virus-free	
Group and variety	*Relative age of line*	*Source of clone*	*No budding (NB) with old-line clones*	*Indexing begun in indicated year*
Grapefruit:				
Duncan	Juvenile seedling	Texas	NB	
Foster	Juvenile seedling	Texas	NB	
Henninger Ruby	Juvenile seedling	Texas	NB	1954
Marsh (Frost)	Adult seedling	Calif.		1956
Marsh (Garner)	Adult seedling	Texas		1955
Red Blush	Juvenile seedling	Texas	NB	1954
Red Blush	Adult seedling	Calif.		1956
Lemon-limes:				
Eureka (Frost) lemon	Adult seedling	Calif.		1956
Eustis limequat	Adult seedling	Texas		1955
Kusaie lime	Juvenile seedling	Texas	NB	
Meyer lemon	Old-line	Texas		1954
Mexican lime	Juvenile seedling	Texas	NB	
Rangpur lime	Juvenile seedling	Texas	NB	1954
Mandarin:				
Dancy (Frost)	Adult seedling	Calif.		1956
False Hybrid satsuma	Adult seedling	Texas		1955
Murcott Honey	Juvenile seedling	Texas	NB	
Ponkan	Juvenile seedling	Texas	NB	
Sweet orange:				
Hamlin	Old-line	Texas		1955
Marrs	Old-line	Texas		1954
Ruby	Adult seedling	Texas		1954
Valencia	Old-line	Texas		1952
Valencia	Juvenile seedling	Texas		1954
Valencia (Cutter)	Adult seedling	Calif.		1956
Valencia (Campbell)	Adult seedling	Calif.		1956
Valencia (Frost)	Adult seedling	Calif.		1956
Valencia (Olinda)	Adult seedling	Calif.		1956
Washington Navel	Old-line	Texas		1954
Washington Navel	Adult seedling	Calif.		1956
Tangelo:				
Minneola	Juvenile seedling	Texas	NB	
Orlando	Adult seedling	Texas		1954
Pearl	Juvenile seedling	Texas	NB	
Pina	Juvenile seedling	Texas	NB	
Suwannee	Juvenile seedling	Texas	NB	

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Tristeza Virus in Meyer Lemon and Other Citrus Varieties in the Upper Gulf Coast Area of Texas

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While the major citrus area in Texas is the Lower Rio Grande Valley, scattered plantings, mostly in backyards, occur all along the Gulf Coast. The common rootstock in the Valley is sour orange; many satsuma trees along the Gulf Coast are grown on trifoliate orange rootstock. Surveys in the Valley have indicated that Meyer lemon trees on their own roots and satsumas on various rootstocks may be symptomless carriers of tristeza virus (Olson and Sleeth, 1954; Olson and McDonald, 1954; Olson, 1955).

Tristeza-infected Meyer lemons have been spread throughout many citrus-growing areas of the world. Tristeza virus occurs in Meyer lemons in the Rio Grande Valley of Texas, Florida (Grant, 1953), California (Wallace and Drake, 1955), Arizona (Carpenter, 1956), Israel (Wallace et al, 1956), Algeria (Frezal, 1957) and Sicily (Russo, 1956).

The purpose of this survey reported herein was to determine whether tristeza virus also occurred in citrus along the Upper Gulf Coast. Tristeza virus is a hazard to grapefruit and orange trees grown on sour orange rootstock, the most common rootstock in Texas. Infected plants of satsuma and of Meyer lemon, although showing no visible symptoms of tristeza virus, may constitute a reservoir of infection from which tristeza virus may spread to other varieties.

PROCEDURE

Budwood was collected from individual trees of different varieties in the area between Victoria and Beaumont, Texas. The buds were grafted to Mexican lime seedlings grown in gallon cans under greenhouse conditions. This test for tristeza virus is in common use in Texas, Florida, California, Brazil, South Africa, Australia, Israel and other places where tristeza virus surveys have been conducted. If the budwood carries tristeza virus, the grafted lime seedlings show specific symptoms, including vein clearing of the leaves and stem pitting, in the new growth.

RESULTS AND DISCUSSION

On 78 trees tested, 14 carried tristeza virus (Table 1). Tristeza occurred in Meyer lemon, satsuma and grapefruit. These results demonstrate that tristeza virus is present in the Upper Gulf Coast area.

Table 1. Occurrence of tristeza virus in trees of indicated varieties in Upper Gulf Coast.

Scion Variety	*Number trees tested*	*No. trees carrying Tristeza virus*[*]
Satsuma	21	1
Meyer lemon	21	12
Grapefruit	12	1
Sweet orange	11	0
Kumquat	6	0
Tangerine	2	0
Tangelo	2	0
Kumquat sour	1	0
Limequat	1	0
Lime	1	0

[*] As shown by grafting scions to Mexican lime seedlings.

The occurrence of relatively high proportion of tristeza-infected Meyer lemon is in agreement with studies in the Lower Rio Grande Valley. The occurrence of tristeza-free Meyer lemon is probably due to propagation of the Ricketts strain, originally from the Valley (Olson and Sleeth, 1954).

At present, however, there is no evidence of insect spread of virus from infected Meyer lemon trees to adjacent trees of other varieties in Texas (Dean and Olson, 1956). However, Norman and Grant (1956) report virus transmission from Meyer lemon to Key lime seedlings in 2 of 107 tests where the green aphid was used.

Grapefruit buds from an old tree grown at Sinton, Texas caused tristeza symptoms on lime seedlings. This grapefruit tree was brought from a commercial nursery in the Rio Grande Valley where tristeza-infected trees have been found.

Although insect vectors have not been found in Texas, these tristeza-infected trees are a hazard due to the fact that insect vectors may come to this area in the future. Nurserymen should avoid use of infected Meyer lemon trees in propagation since virus-free trees occur in the Upper Gulf Coast area and in the Valley.

SUMMARY

Tristeza-infected trees of Meyer lemon and other citrus occur along the Upper Gulf Coast of Texas.

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Pigmentation, Pigment Analyses and Processing of Colored Grapefruit[1]

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Ruby red grapefruit is a bud sport or mutation of the Thompson or pink Marsh grapefruit, which in turn originated as a mutation of the white Marsh variety (Webber, 1946). Because of the attractive appearance of the flesh of the colored fruit a comparatively large proportion of trees of this type have been planted in the Lower Rio Grande Valley of Texas, since the freezes of 1949 and 1951 destroyed the older orchards. Smaller acreages are in bearing in the Coachella Valley of California and in Florida. Replantings in the Texas citrus area since 1951 have averaged between .5 and 1.5 million trees a year, approximately 75 per cent of new trees being red grapefruit. As these trees come into production, certain utilization problems arise because of the pigments present in the flesh of these fruit. White grapefruit contain very little, if any, pigment. When processed the canned juice has an "oyster white" appearance, to which the trade has become accustomed. Colored grapefruit when processed by conventional methods, yield a juice which has a reddish grey tinge. Under certain conditions of storage an objectionable dullness or "muddiness" develops in the canned juice.

Prior to 1949 the proportion of red fruit canned was too small, in relation to the white fruit with which it was blended, to seriously affect the juice color. With the larger quantities of red fruit now produced, a different solution than blending juice from white and colored fruit is necessary.

The major pigments of colored fruit are water-insoluble carotene and lycopene (Curl and Bailey, 1957; Khan and MacKinney, 1953; Matlack, 1928, 1935). These pigments occur in the cell wall and solids of the fruit, and are not present in the juice in appreciable quantities if it is filtered to remove suspended material. This characteristic permits two approaches to the problem of improving the color of canned juice from colored grapefruit. It is possible to entirely remove all the suspended solids from the juice and then to add a proportion of pulp or juice containing suspended solids from white grapefruit. Another possibility is to intensify the red tinge of canned juice by addition of colored pulp. The carotenoid pigments in finely comminuted pulp are relatively stable and, if present in sufficient amounts, mask any tendency of the juice to turn grey or develop the so-called "muddiness" (Huffman, Lime and Scott, 1953).

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[2] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture.

Because of the importance of the problem of satisfactory utilization of red grapefruit, color and processing of colored grapefruit have been studied for the past five years. Methods for the removal of color as well as color intensification have been investigated. Because of the superior appearance of juice containing a maximum of colored pulp, as well as its higher nutritional value, special attention has been given to the preparation and properties of pulp-fortified single strength canned juice. This paper reviews information on pigmentation of colored grapefruit and methods of color measurement.

Pigments of grapefruit. Matlack (1928, 1935) identified the major pigments of the pink grapefruit as lycopene and carotene. Khan and MacKinney (1953) studied the carotenoids of several varieties of grapefruit, including the Ruby Red, and determined the relative concentration of lycopene, beta carotene, zeta carotene, and phytofluene. They showed the major pigments of Ruby grapefruit to be lycopene and beta carotene present in the ratio of 1.14:1.00. They found approximately 9 per cent of the total pigments to be zeta carotene and phytofluene.

More recently Curl and Bailey (1957) have used counter current distributions to separate the pigments of Ruby Red grapefruit pulp into three fractions. Carotene and lycopene were the major pigments of fraction 1 and totaled 67 per cent of all pigments. Fraction 2, amounting to 2.6 per cent of the total pigments, consisted of monohydroxy carotenoids; fraction 3, 3.2 per cent of the total pigments, was composed of polyhydroxy pigments. They further differentiated these fractions by column chromatography into approximately 20 pigments.

It has been recognized that the intensity of fruit coloration varies from a medium red early in the fruit season, to a light salmon pink in late-season fruit. Investigations have shown this change to be largely due to a decrease in the amount of red lycopene pigment present in the pulp. Carotene content of pulp reaches a maximum a little later than lycopene and decreases at a somewhat slower rate as the season advances.

The correlation between fruit color as measured visually or by reflectance, and analytical measurements of pigments, has been reported by Lime, Stephens and Griffiths (1954, 1956).

Methods of measuring fruit color and pigmentation. Much of the demand for colored fruit is due to its attractive appearance. If processed products are to take advantage of the natural color of the fruit, methods of measuring pigmentation and standardizing the color of canned juice must be available. Research on factors influencing the formation and decline of pigments in grapefruit is dependent on accurate methods of separating and measuring the amounts of pigments and pigment precursors present in the fruit.

Lime et al (1954), in their study of color development in relation to fruit maturity, used a modified chromatographic technic for separating and measuring carotene and lycopene. Reflectance of cut fruit was determined using a Photovolt Reflectance Meter[3] with amber, blue, and green filters. Color of fruit was also rated visually as excellent, good, fair, or poor. An "Index of Fading" (Nickerson, 1946) was obtained by calculation from the reflectance measurement. Analytical values for carotene and lycopene were not in close agreement with reflectance measurements. The results of this study are summarized in Figure 1.

In a continuation of their study of color development in Ruby Red grapefruit, Lime et al (1956) report a simplified procedure for extracting the total carotenoid pigments from the fruit pulp and calculating color in terms of carotene and lycopene content. Reflectance measurements of the blended pulp were made with a Gardner Automatic Color Difference Meter[3] and color was expressed as a ratio a/b where a is a measure of redness and b of yellowness. This a/b ratio was found to agree closely with the ratio obtained if lycopene content is divided by twice the carotene content (L/2C), as shown in Table 1. Measurements on fruit from four groves showed nearly identical seasonal trends in color maxima and disappearance.

Table 1. Seasonal Reflectance Measurements,[1] a/b Ratio and Pigment Ratio, L/2C, of Pureed Edible Portion of Ruby Red Grapefruit.

Date	*a (red)*	*b (yellow)*	*a/b*	*L/2C*[2]
10/25	12.4	13.4	.925	.941
11/8	9.5	13.5	.704	.763
11/22	8.1	13.5	.630	.598
12/6	8.7	14.7	.592	.464
12/20	7.1	15.1	.467	.402
1/3	6.2	14.4	.431	.369
1/17	6.7	15.7	.427	.345
1/31	6.4	15.7	.408	.313
2/14	5.7	16.2	.352	.284
2/28	6.0	16.2	370	.261
3/14	4.8	17.3	.277	.262
3/28	6.7	17.3	.387	.267
4/11	5.6	17.4	.322	.256
4/25	4.6	17.1	.269	.250
5/9	3.9	17.6	.222	.265

[1] Measurements made with Gardner Automatic Color Difference Meter, using 2½ inch opening and LR1 plate as reference. Puree consisted of blended and deaerated composite sample of four segments from each of 30 fruit.

[2] Values for lycopene and carotene obtained by Method B.
L = Lycopene
C = Carotene

[3] It is not the policy of the Department to recommend the products of one company over those of any others engaged in the same business.

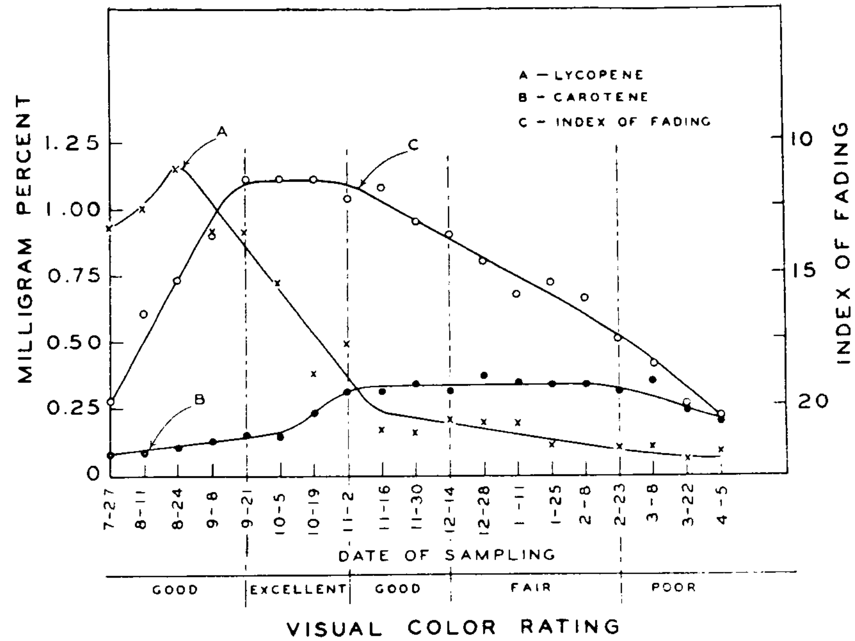

Figure 1. Relationship between index of fading, visual color, and lycopene and carotene content of Ruby Red grapefruit during growth and maturity. [From Food Technology 8(12): 566 (1954)].

Work on color measurements and pigment analysis was continued in cooperation with R. T. O'Connor and associates of the Analytical, Physical-Chemical and Physics Section, Southern Utilization Research and Development Division (Lime et al 1957). A study was made of the reproducibility and correlation of two procedures, a chromatographic method (Lime et al 1954) and a binary analysis method (Lime et al 1956). Both procedures are useful in a study of fruit pigmentation. The longer chromatographic procedure, Method A, quantitatively determines the amounts of lycopene and carotene in the hexane extract of the fruit pulp. Method B, the binary procedure, provides an index of total carotenoid pigmentation in terms of carotene and lycopene. The latter method, because it measures total pigments rather than purified lycopene and carotene, gives values which average 10.3 per cent higher for lycopene and 16.2 per cent higher for carotene. Reflectance measurements of comminuted pulp correlate with measurements of total pigment.

A brief outline of these methods may be of interest. For both procedures samples are prepared by halving several fruits and removing the meat and juice, being careful to exclude rag and seeds. After blending the sample in a Waring Blendor[3] for 3 minutes, 100 gram portions are removed by pipette while the blendor is operated at moderate speed. One hundred ml. of methanol are added to each sample and the mixture allowed to stand for approximately 30 minutes. Two grams of Hyflo Super-Cel[3] are then added to each portion and the samples filtered through a pad of this same filter aid on a Buchner funnel. The filtrate containing the methanol-water soluble substances is discarded.

The pigments are removed from the pulp by blending the filter cake in a micro blender cup with 50 ml. of 50 per cent acetone-hexane solution for one minute, filtering and washing with 20 ml. of extracting solution. The pulp and pad are blended, filtered, and washed twice more in the same manner; and the combined extracts are placed in a 500 ml. separatory funnel, 100 ml. of water are added, and the aqueous layer is removed and re-extracted with hexane until the hexane extract is colorless. The combined hexane extracts are washed three times with 100 ml. of water, care being taken to prevent emulsification. After washing, the hexane extract is filtered through a pad of sodium sulfate on a medium porosity fritted glass funnel and made to 250 ml. with hexane. Portions of the extract are used in making the analysis for carotene and lycopene by either the chromatographic procedure A or the binary procedure B.

Method A. In Method A a 100 ml. aliquot of the above extract plus 10 ml. of acetone is chromatographed on a 1:1 magnesia-celite column. Carotene is eluted from the column with 100 ml. of 10 per cent acetone in hexane. After removal of the carotene, a faint middle band of minor pigments is washed from the column with 100 ml. of 0.5 per cent methanol in hexane and this eluate discarded. Lycopene is removed from the column with 200 ml. of 5 per cent methanol in hexane. The carotene and lycopene eluates are transferred to separatory funnels and washed with 100 ml. portions of water (carotene twice and lycopene once) to remove acetone and methanol. Each portion is then filtered through sodium sulfate on a fritted glass funnel to remove water and made to 200 ml. with hexane. Concentrations of the pigments are determined by reading portions of the respective carotene and lycopene portions in a Beckman D. U. Spectrophotometer[3] at a wave length of 451 mu for carotene and 471 mu for lycopene. Purified lycopene and carotene in hexane are used to prepare standards for comparison.

Method B. The absorption of a portion of the unchromatographed hexane extract is determined at 451 mu (a maximum for carotene and a near minimum for lycopene), and at 503 mu (a maximum for lycopene and a low absorption value for carotene). By means of simultaneous equations a measure of the total pigments present is obtained in terms of lycopene and carotene content. The pigment concentrations of the sample are calculated as follows:

$$\text{mg.\% carotene} = 462a_{451} - 309a_{503}$$
$$\text{mg.\% lycopene} = 395a_{503} - 80.5a_{451}$$

Where a is the absorbtivity of the extract at the designated wave lengths.

The constants in the above were calculated using the specific absorption of carotene at 451 and 503 mu as 205.3 and 51.0 and lycopene at 451 and 503 mu as 195.5 and 292.7.

Factors affecting degree of pigmentation in colored grapefruit. The most obvious variable of colored grapefruit is that pigmentation develops in the small immature fruit, reaches a maximum before the fruit reach full size and acceptable maturity and proceed to fade. At the end of the season little red and only 2/3 of the yellow pigment remain in the pulp of the fruit. Table 2 presents the seasonal variations of pigment in the pulp of Ruby Red grapefruit. After lycopene formation stops, a part of the decline in its concentration can be explained by the dilution caused by continued growth of the fruit. Carotene formation continues as the fruit size increases, the concentration remaining relatively constant. Near the end of the season the concentrations of both pigments decline. The precursors of lycopene and carotene in grapefruit are not known. It is also not known whether the formation of the two pigments is related or what happens when the pigments decline in concentration.

Other factors which may influence fruit pigmentation are: source of budwood or parentage of the tree; soil characteristics of the individual grove; cultural practices such as sod or clean tillage; fertilization and water and climatic conditions.

Effect of colored grapefruit on commercial processing procedures and products. When processed by conventional methods which eliminate most of the pulp, juice from colored fruit lacks definite color and may become dull or muddy on storage. Huffman et al (1953) proposed pigment fortifications of the juice by additions of comminuted colored grapefruit pulp. Much of this pulp is screened from the juice and discarded

Table 2. Seasonal Weights of Ruby Red Grapefruit and Lycopene and Carotene Content of Edible Portion.

Date	Av. Wt. Grams	Lycopene mg.%[1]	Carotene mg.%[1]	Mgs. of Pigment per fruit Lycopene	Mgs. of Pigment per fruit Carotene	Total L & C mgs.
10-25	363	.64	.34	2.32	1.23	3.55
11-8	371	.58	.38	2.15	1.41	3.56
11-22	398	.49	.41	1.95	1.63	3.58
12-6	405	.39	.42	1.58	1.70	3.28
12-20	386	.33	.41	1.27	1.58	2.85
1-3	426	.31	.42	1.32	1.79	3.11
1-17	502	.29	.42	1.46	2.11	3.57
1-31	518	.25	.40	1.27	2.08	3.35
2-14	454	.25	.44	1.14	2.00	3.14
2-28	485	.23	.44	1.13	2.13	3.26
3-14	448	.22	.42	.99	1.88	2.87
3-28	464	.24	.45	1.11	2.08	3.19
4-11	438	.22	.43	.96	1.88	2.84
4-25	446	.18	.36	.80	1.60	2.40
5-9	457	.18	.34	.82	1.55	2.37

[1] Data obtained by Method B using a Cenco Sheard Spectrophotelometer, 1955-56 season.

by usual canning procedures. Investigations have shown pulp fortification to be entirely feasible. Pilot plant packs during the 1955-56 season demonstrated that pulp fortification enhanced the color, added substantial amounts of provitamin A (beta carotene) and increased the yield of juice about 1½ to 2 cases per ton of fruit. If all of the edible portion of grapefruit is removed without including septums or seeds and this material blended or run through a comminuting mill, juice containing 22-26 per cent suspended solids is obtained. This represents the maximum suspended solids ordinarily obtainable. The influence of increased pulp content on color is shown in Table 3. The increase in a/b ratio (red/yellow) correlates well with increased pulp content. Most reamers do not obtain all of the pulp and when seeds and rag are removed from the juice by finishing, an additional quantity is lost. Commercially prepared juice usually contains 6 to 10 per cent suspended solids. Ten per cent is the maximum suspended solids permitted by present standards for single strength canned grapefruit juice (U.S.D.A. 1954). In experimental packs this amount was raised to 14 per cent. Although the naringen content was increased, the added bitterness was not sufficient to be objectionable. Color and provitamin A, Table 4, were substantially raised. Removal of suspended solids by centrifuging or settling leaves an appreciable amount of pigment in the cloud as shown by the 0.07 mg. % lycopene and 0.12 mg. % carotene in juice 2A.

Storage tests on canned pulp-fortified grapefruit juice over a period of one year at 70-95° F. have shown that color is relatively stable and the added comminuted pulp effectively masks any tendency toward the formation of a brown or muddy color.

Table 3. Influence of Increased Suspended Solids Caused by Added Pulp on Color of Ruby Red Grapefruit Juice.

Suspended Solids	*Rd*[1]	*a (red)*[1]	*b (yellow)*[1]	*a/b*
		Sample 1		
8	13.5	-0.2	9.2	-.022
10	14.4	3.2	10.6	.302
14	15.0	6.2	11.8	.525
18	15.6	9.0	12.6	.714
20	16.0	10.8	13.1	.824
22	16.3	12.2	13.3	.917
		Sample 2		
9	13.0	0.0	9.1	.000
13	13.9	3.5	10.4	.337
16	14.5	7.0	11.7	.598
18	15.4	8.9	12.5	.712
20	15.6	10.2	13.0	.785
22	16.9	12.2	13.5	.904

[1] Rd = Reflectance
Reflectance and a and b readings made with Hunter Automatic Color Difference Meter, using plate LR1 for setting instrument.

Table 4. Influence of Pulp Variation on Pigment, Provitamin A, and Color Ratio a/b of Commercially Canned Single Strength Ruby Red Grapefruit Juice.

Sample	*Suspended Solids*	*Lycopene mg.%*	*Carotene mg.%*	*Provitamin A Per Ounce*	*a/b*[1]
1A	7.0	.13	.18	89	.000
1B	8.0	.15	.19	94	.006
2A	1.0	.07	.12	59	-.363
2B	14.0	.16	.25	124	.125

A major limitation of pulp fortification is that pulp in late season fruit contains too little lycopene to give effective coloration. Storage of highly colored early season pulp to add in late season juice may be one solution for this problem. A limitation is that excessive bitterness may be imparted to the juice by early season pulp. Another possibility is to remove all of the suspended material from colored juice and blend the clear juice with juice and pulp from white grapefruit. By this procedure an acceptable white product can be obtained.

There is considerable interest in the preparation of frozen grapefruit juice concentrate prepared from Ruby Red fruit. Preliminary investigations indicate difficulty in concentrating juice containing high proportions of suspended solids. An attractive red concentrate can be prepared by concentrating juice of 4 to 6 per cent suspended solids content to 56° Brix and cutting back to 41° Brix with comminuted pulp instead of fresh juice. More work needs to be done on details of this process before it is undertaken on a commercial scale.

The attractive coloration of the flesh of Ruby Red grapefruit offers inducements for the preparation of specialty products such as canned or frozen grapefruit segments and canned salad mixtures. Relatively little has been published on problems associated with the preparation of such items. When sufficient red fruit is available and high quality juice and frozen concentrate are available on the market, serious attention will be given to preparing such specialty products.

SUMMARY

Coloration of Ruby Red grapefruit flesh is due primarily to two pigments, lycopene (red) and carotene (butter yellow). Lycopene is formed early in development of the fruit, reaches a maximum, and starts to disappear before the fruit reaches optimum maturity. Carotene increases as lycopene decreases and remains near the maximum until late in the season. A number of other pigments occur in colored grapefruit.

[1] Reflectance measurements of blended pulp made with Gardner Automatic Color Difference Meter using plate LR1 for reference setting. Concentrations of lycopene and carotene were obtained by Method B.

cedure (Method A) giving only carotene and lycopene content, and a short procedure, (Method B) which gives a measure of total pigments as carotene and lycopene. The ratios of lycopene content over twice the carotene content, L/2C as obtained by Method B, correlate with Hunter reflectance measurement ratios a/b (red/yellow).

Two methods for pigment analyses are outlined: An analytical pro-

Besides seasonal variation, a number of other factors may influence color. Rootstock, budwood inheritance, soil, water, and cultural practices need to be evaluated to determine their influence.

A distinctive color is imparted to canned grapefruit juice from Ruby Red fruit if all or most of the pigmented pulp is added to the juice. Commercial preparation of pulp-fortified canned juice from colored grapefruit results in a superior product.

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Carotenoid Pigment Formation in Colored Grapefruit

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Fresh red and pink Texas grapefruit usually receive a premium market price. The canned juice of the colored varieties has not received a premium since the juice did not have a distinctive or pleasing color. Modification of the processing by pulp fortification yields a more acceptable juice (Lime *et al,* 1958). Further improvement of juice color is not expected until the color of the fruit to be processed is improved. The present report covers part of the study of the chemical steps involved in biosynthesis and degradation of the carotenoid pigments and the factors controlling the biosynthesis and degradation.

SEASONAL DEVELOPMENT OF THE CAROTENOIDS

The major pigments of Foster and Marsh pink grapefruit are lycopene and beta carotene (Matlack, 1935). Lycopene and beta carotene are also the major pigments of the Ruby Red variety (Khan and MacKinney, 1952).

Lycopene (red pigment) concentration of the Ruby Red fruit reaches a maximum near the end of August and begins a sharp decline while the carotene (yellow pigment) concentration continues to increase until much later (Lime *et al,* 1954). Purcell (1959) followed the development of the pigments in the Ruby Red varieties for three years and found that the maximum lycopene concentration occurred within a 26-day period from August 15 to September 10, although the maximum carotene concentration occurred over a wider period of time.

The lycopene and carotene concentrations of the fruit from a single Ruby Red tree near Weslaco, Texas, were determined at two or three day intervals from August 11 to September 24, 1958. The maximum lycopene concentration occurred in fruit collected August 27. (Figure 1).

An attempt was made to correlate the decline of lycopene concentration with daily maximum and minimum temperatures. Including the report of Lime *et al,* (1954) data are available for five years. During each year a decrease of temperatures occurred at about the same time the decline of lycopene concentration began, but unfortunately other factors, e.g., time since fruit set and change of day length, could not be excluded as possible causes of decline of pigment content.

By the time the processing season has started (generally after November 1) the lycopene concentration of the fruit has dropped to less than one-half of its maximum concentration which occurred in late August. The continued increase of carotene during this period results in

[1] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

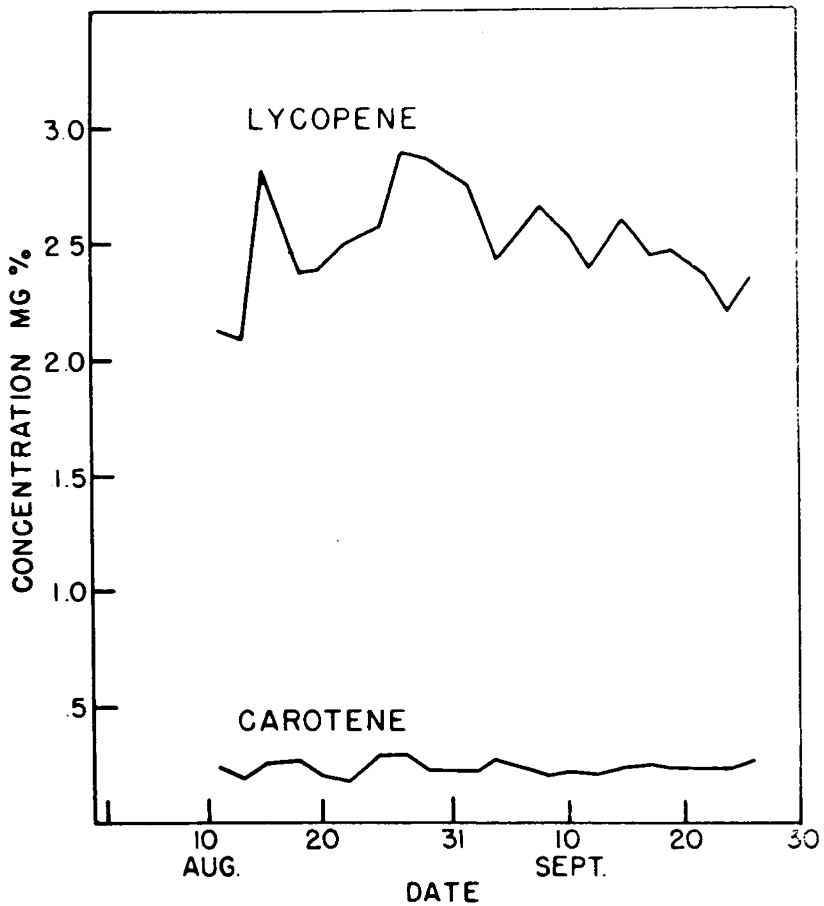

Figure 1. Changes of lycopene and carotene concentration in Ruby Red grapefruit from August to November, 1958.

a definite yellowing of the fruit. Nearing the end of the processing season (in late February) the lycopene concentration has decreased to about one-sixth of its maximum (Lime *et al*, 1954) (Purcell, 1959). This decrease cannot be accounted for by dilution resulting from a halt of lycopene synthesis and continued sizing of the fruit. If some means could be found to retain the lycopene which is in the fruit at the end of August, the pigment content of the juice could be at least doubled.

The same seasonal trends for lycopene and carotene concentrations appear to exist in the pink varieties as exist in the red. The pigment content of white fruit is too low to establish seasonal trends, but small quantities of lycopene are found in white grapefruit during development of the fruit (Purcell, 1959).

SEASONAL DISTRIBUTION OF THE CAROTENOIDS

The various tissues of white, pink and red varieties of grapefruit were separated and assayed for carotene and lycopene by the method previously reported (Purcell, 1959). During the development of the fruit lycopene appears first in the albedo of the red fruit. Traces were detected as early as May 15. The concentration of lycopene in the albedo increases quite rapidly (Table 1). By June 6 traces of lycopene were found in the carpels of the red and pink fruit. Later as the lycopene content increased in the carpels of the red and pink fruit, traces of it were found in the albedo of the pink and white and also in the carpels of the white. The concentration of lycopene in the albedo of the pink and white fruit did not increase as it did in the red. The maximum concentration measured was less than .01 mg. per cent.

Table 1. Seasonal trends of lycopene and carotene concentration in the various tissues of Ruby Red grapefruit (1957).

Date	*Tissue*	*Lycopene* mg. %	*Carotene* mg. %
June 6	Albedo	.74	.22
	Carpel walls	.21	.06
	Juice sacs	.02	.05
June 26	Albedo	2.03	.35
	Carpel walls	2.74	.43
	Juice sacs	.17	.08
July 12	Albedo	3.99	.61
	Carpel walls	4.78	.96
	Juice sacs	.62	.19
August 6	Albedo	4.42	.84
	Carpel walls	8.18	2.38
	Juice sacs	1.18	.23
August 28	Albedo	4.92	.90
	Carpel walls	7.17	1.22
	Juice sacs	1.82	.38
September 20	Albedo	3.65	1.08
	Carpel walls	7.06	1.42
	Juice sacs	1.74	.49

When a red fruit in the early stages of development (June) was quartered and examined visually, it appeared that the lycopene came into the fruit from the stem, spread evenly through the albedo into the carpel walls and into the juice sacs. Assay of the pigments in the albedo, carpel walls and juice sacs showed that in early season the concentration was highest in the albedo, less in the carpel walls and least in the juice sacs. As the season progressed the lycopene in the carpel walls increased more rapidly than in the juice sacs. It increased least in the albedo (Table 1). There was no apparent difference in the concentration of lycopene from stem end to blossom end of the fruit.

The appearance of the fruit early in its development (June), suggested a distribution of precursors along a well-defined pathway. A fruit was cut from a tree with about eight inches of stem and several leaves attached to the fruit. The cut end of the stem was placed in a dilute solution of eosine and allowed to stand for several days. When the fruit was cut the appearance was similar to that of an early season red fruit except that the dye was found in thin lines, indicating that it had entered the vascular system of the fruit but had not diffused out. The eosine was extracted and measured spectrophotometrically. The highest concentration was found in the albedo, (6.68 mg. per cent) less in the carpel walls (3.87 mg. per cent) and least in the juice sacs (.09 mg. per cent). From these observations it appears that the lycopene in the red fruit is formed along the route of distribution of water-soluble nutrients.

SITE OF THE CHEMICAL DIFFERENCE LEADING TO AN ACCUMULATION OF CAROTENOIDS IN THE COLORED FRUIT

It was considered possible that the red fruit received more specific precursors from the tree than the white, the chemical difference leading to an accumulation of pigment in the red fruit being in the tree. Another possibility was that the red and white fruit received the same nutrients from the tree but the chemistry of the red fruit was such as to cause an accumulation of the pigments in the red fruit. Purcell and Stephens (1959) grafted white fruit onto trees of a red variety and red fruit onto trees of a white variety. The fruit did not change its characteristics when grafted onto a tree of a different variety, and they therefore concluded that the chemical difference leading to the accumulation of pigments in the colored varieties is in the fruit.

STUDIES OF THE BIOCHEMICAL MECHANISM OF CAROTENOID FORMATION USING RADIOACTIVE TRACERS

If the chemical differences between varieties and the effects of other seasonal changes were known, it is possible that color formation in the fruit could be controlled. A number of investigators have used radioactive materials for investigating the physiological changes involved in color formation. Mevalonic acid has been reported to be a precursor for the sterols and squalene (Amdur *et al*, 1957, Dituri *et al*, 1957, Rilling *et al*, 1958, Tavormina *et al*, 1956, Tavormina and Gibbs, 1956). The chemical structure of these compounds indicates they may be built from the same metabolic building blocks as the carotenoids.

Braitwaite and Goodwin (1957) have concluded that mevalonic acid is not effectively incorporated into beta carotene by *Phycomyces blakesleanus*. This may be in part due to impermeability of the fungi to the metabolite. Purcell, Thompson and Bonner (1959) reported that mevalonic acid is rapidly incorporated into the carotenoids of tomatoes as well

as into colorless materials which may be intermediates in carotene synthesis.

The development and accumulation of carotenoids in the grapefruit are slow, requiring about six months to build up to their maximum. The grapefruit apparently does not undergo significant metabolic changes when detached from the tree. Considering these two factors it is more difficult to study the chemical changes in the grapefruit which lead to an accumulation of the carotenoids than in the tomato. The tomato is an excellent model system for the study of carotenoid formation from radioactive precursors. The same carotenoid pigments are found in the tomato as are found in the grapefruit. The concentration of the carotenoids in the tomato is about 3-4 times as high in the grapefruit. The synthesis of the carotenoids in the tomato is rapid, under ideal conditions a tomato will change from green to red within 48 hours. These pigment changes occur in detached fruit, permitting easy control of external conditions.

There is no reason to believe that the chemical steps in the synthesis of carotenoids in the grapefruit and the tomato are different, although the factors which control the various steps are perhaps different.
It is believed that once the major chemical changes are known, the factors which control color formation can be studied with greater ease.

INTERPRETATION OF THE REPORTED OBSERVATIONS

Several interpretations of the reported data may be made, but the one favored at present is that a water-soluble precursor for the carotenoids, perhaps mevalonic acid, is manufactured by the leaves of grapefruit trees. The precursor moves into the fruit through the vascular system. In the white fruit sufficient carotenoids are made to satisfy the fruit's physiological needs and the remainder of the precursor is used in some other way. In the colored fruit the precursor is not used efficiently for other purposes and is converted into the carotenoids which accumulate. The difference between red and pink fruit may be explained on the basis that the normal utilization of the precursor by pink fruit is more efficient than that of red fruit. The albedo of the pink fruit uses more of the precursor in the normal metabolic path and this more efficient use of the precursor by the pink albedo does not allow as much precursor to reach the carpels as in the case of the red fruit; consequently the carpels of the pink fruit accumulate less pigments than the carpels of the red.

No suitable explanation is known at present for the decline of content of carotenoid pigments in grapefruit after the maximum color is reached.

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Seasonal Development of Carotene and Lycopene in Grapefruit

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INTRODUCTION

The colored grapefruit of Texas appear to have a market advantage over white grapefruit. This advantage does not extend to juice prepared from the colored fruit. Juice prepared from colored fruit by conventional methods yields a product with a color which is neither distinctive nor pleasing. Modification of the processing by pulp fortification yields a more acceptable juice (Lime, Stephens and Griffiths, 1958). It is believed that greater progress might be made in the utilization of colored grapefruit if more were known about the development and chemical nature of the pigments in the fruit. The study reported here is one phase of a broader investigation of the pigments in grapefruit. Data are presented on the development of carotene and lycopene in white, pink and red grapefruit from the time the fruit is first formed until it is well along in its maturity.

The present report is part of a study to determine the mechanism involved in the bio-synthesis and degradation of the carotenoid pigments and the factors controlling these mechanisms. The study covered by this report was begun to follow the development of the carotenoids from the time the fruit formed and to compare the pigment content of the red, pink and white varieties of grapefruit.

Matlack (1935) isolated and identified the pigments of Foster and Marsh pink grapefruit. Khan and MacKinney (1952) and Huffman, Lime and Scott (1953), have identified those of the Ruby Red variety. In all three varieties the principal pigments were found to be lycopene and beta-carotene.

The grapefruit in Texas generally flower from March through early April. Fruit first becomes mature (marketable) during the month of October. Lime, Stephens and Griffiths (1954), found that the lycopene content of Ruby Red fruit reached a maximum near the end of August and began a sharp decline. The carotene content continued to increase until near the first of February and began a more gradual decline.

EXPERIMENT

Fruit were selected from trees and groves of known history in the Lower Rio Grande Valley of Texas during the seasons of 1955-56, 1956-57

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and 1957-58. Sampling was done on the dates indicated in Tables 1, 2 and 3. Samples were generally taken between 8:00 A.M. and 10:00 A.M. The fruit were prepared for assay without delay.

When the fruit were less than 40 mm. in diameter, sufficient fruit were picked at random to provide at least a 200-gram sample of peeled fruit. As the fruit became larger than 40 mm. diameter, the diameters of 10 randomly selected fruit were measured with a caliper and an average diameter was calculated. A sufficient number of fruit (2 or more) of average diameter to provide at least a 200-gram sample were harvested.

The fruit less than 25 mm. diameter were peeled with boiling 10 per cent NaOH for 1 minute to remove all material containing chlorophyl and most of the albedo. It was rinsed and dried with paper towels. Fruit larger than 25 mm. were peeled with a knife so as to leave the small carpels relatively free of albedo.

When the fruit were less than 70 mm. diameter the entire sample (about 200 grams) was assayed for pigment content. By the time the fruit were 70 mm. in diameter the pigment content had increased so that it was not necessary to extract the entire sample. The entire sample of peeled fruit was cut into sections of about one cubic inch and 200-gram portions were blended at high speed in a Waring Blendor[2] with 400 grams of water. It was necessary to add water with the immature fruit before it would blend. When the fruit was mature enough to drip juice freely when cut, it was not necessary to add water. When the slurry appeared homogeneous the blendor was run at low speed and a pipette with the constricted tip broken off was used to remove a sample. A weighed amount of the slurry (3-40 gram) of colored fruit, estimated to contain about 0.1 to 0.2 mg. total pigment was taken for extraction. The estimate of the amount of pigment was based on the previous sampling period. The sample of white fruit taken was twice the weight of the colored fruit sample.

Until the fruit reached 70 mm. the fruit were assayed as a single sample. When the fruit were larger than 70 mm. diameter, duplicate samples were taken from the blended slurry.

ASSAY OF PIGMENTS

The samples were blended with sufficient methanol to produce 50 percent (W/W) of methanol. Hyflo-Supercel[2] (2 per cent of sample weight) was stirred into the slurry at low blendor speed. The slurry was filtered through a filter paper, Whatman No. 1,[2] in a Buchner funnel with suction. The suction-dried mat was extracted by blending in a Waring Blendor at high speed with a sufficient amount of acetone-hexane (50-50) to give smooth blending. (Approximately twice the volume of the original sample.) The mixture was filtered and the mat

[2] The mention of trade products or companies does not imply that they are endorsed or recommended by the U. S. Department of Agriculture over other similar products or companies not mentioned.

extracted the second time by the same procedure. The filtrates were transferred to a separatory funnel. After standing a short time, distinct phases formed and the hypophase was drawn off and discarded. The epiphase was washed three times with an equal volume of water. The water was drained off as completely as possible and the hexane extract remaining was saponified by shaking for two minutes with one-eighth volume of methanol saturated with potassium hydroxide. The mixture was again allowed to stand until two distinct phases formed and the hypophase withdrawn and discarded. The epiphase was washed three

Table 1. Seasonal concentration of carotene and lycopene in peeled grapefruit—1955-56.

Date	Fruit Color	Carpel wt./fruit grams	mg. %		mg. per fruit	
			Carotene	Lycopene	Carotene	Lycopene
23 June	White	60	.02	Trace	.01	—
	Pink	70	.02	.12	.01	.08
	Red	68	.05	.44	—	—
5 July	White	—[1]	.02	Trace	—	—
	Pink	—	.05	.41	—	—
	Red	—	.07	.37	—	—
13 July	White	95	.03	.01	.03	.01
	Pink	88	.06	.42	.05	.07
	Red	98	.12	1.06	.12	1.04
26 July	White	138	.02	.01	.03	.01
	Pink	112	.06	.59	.07	.66
	Red	112	.11	1.29	.12	1.44
9 Aug.	White	144	.02	.02	.03	.03
	Pink	145	.09	.79	.13	1.14
	Red	146	.21	1.82	.31	2.66
24 Aug.	White	152	.02	.02	.03	.03
	Pink	185	.18	1.27	.33	2.35
	Red	186	.28	2.50	.52	4.65
6 Sept.	White	158	.02	.03	.03	.05
	Pink	198	.14	1.13	.18	2.24
	Red	171	.28	2.41	.48	4.12
19 Sept.	White	223	.02	.02	.05	.05
	Pink	228	.20	1.06	.46	2.42
	Red	208	.34	2.36	.71	4.91
3 Oct.	White	307	.03	.01	.09	.03
	Pink	227	.24	1.03	.55	2.34
	Red	237	.40	2.15	.95	5.10
20 Oct.	White	362	.05	.01	.18	.04
	Pink	272	.28	.78	.76	2.12
	Red	268	.49	1.91	1.31	5.12
31 Oct.	White	385	.02	0	.08	—
	Pink	280	.33	.70	.93	1.96
	Red	298	.48	1.70	1.43	5.06

Date	Fruit Color	Carpel wt./fruit grams	mg.% Carotene	mg.% Lycopene	mg. per fruit Carotene	mg. per fruit Lycopene
15 Nov.	White	337	.04	0	.14	0
	Pink	277	.30	.43	.83	1.19
	Red	268	.55	1.67	1.47	4.47
29 Nov.	White	356	.02	0	.07	0
	Pink	305	.37	.42	1.13	1.28
	Red	309	.59	.99	1.82	3.06
12 Dec.	White	383	.01	0	.04	0
	Pink	323	.33	.29	1.07	.94
	Red	313	.50	.77	1.56	2.41
27 Dec.	White	420	.02	0	.08	0
	Pink	317	.35	.19	1.11	6.02
	Red	310	.52	.40	1.61	1.24
9 Jan.	White	402	.02	0	.08	0
	Pink	359	.36	.21	1.29	.75
	Red	341	.55	.71	1.88	2.42
13 Feb.	White	275	.03	0	.08	0
	Pink	272	.30	.13	.82	.35
	Red	281	.48	.52	1.35	1.46
28 Feb.	White	347	.01	0	.04	0
	Pink	341	.29	.11	.99	.38
	Red	391	.44	.46	1.72	1.80
12 March	White	373	.02	0	.08	0
	Pink	368	.41	.18	1.10	.66
	Red	364	.45	.41	1.64	1.49

[1] Indicates no data.

Table 2. Seasonal concentration of carotene and lycopene in peeled Ruby Red grapefruit—1956.

Date	Carotene mg.%	Lycopene mg.%
11 April	.45	0
15 May	.12	0
25 June	.06	.17
20 July	.28	1.39
5 August	.32	1.49
14 August	.24	1.61
21 August	.36	2.42
4 September	.39	2.32
12 September	.45	2.33
26 September	.33	1.47

Table 3. Seasonal concentration of carotene and lycopene in peeled grapefruit—1957.

Date	Size	Carpel wt./fruit grams[1]	Fruit Color	mg.% Carotene	mg.% Lycopene	mg. per fruit Carotene	mg. per fruit Lycopene
3 April	10-20 mm.	—[2]	White	.35	0	—	—
			Red	.44	0	—	—
11 April	20-25	—	White	.30	0	—	—
			Pink	.26	0	—	—
			Red	.26	0	—	—
22 April	30-35	—	White	.20	0	—	—
			Pink	.17	0	—	—
			Red	.14	0	—	—
7 May	40	22	White	.04	0	.01	0
			Pink	.02	0	.00	0
			Red	.03	0	.01	0
3 June	50	43	White	.01	0	.00	0
			Pink	.02	0	.01	0
			Red	.13	.38	.06	.16
17 June	66	95	White	.04	0	.04	0
			Pink	.02	.06	.02	.06
			Red	.14	.46	.13	.44
9 July	70	113	White	.03	.01	.03	.01
			Pink	.09	.37	.10	.42
			Red	.21	1.38	.24	1.56
9 Aug.	78	154	White	.03	.01	.05	.02
			Pink	.18	.71	.28	1.09
			Red	.49	1.88	.75	2.90
19 Sept.	81	175	White	.11	.04	.19	.07
			Pink	.33	.96	.58	1.68
			Red	.73	2.62	1.28	4.59
24 Sept.	81	175	White	.09	.07	.17	.12
			Pink	.30	.93	.53	1.63
			Red	.73	2.42	1.28	4.24
3 Oct.	83	189	White	.05	.04	.10	.08
			Pink	.22	.82	.42	1.55
			Red	.59	2.33	1.12	4.38
8 Oct.	81	175	White	.05	.03	.09	.05
			Pink	.29	.93	.51	1.63
15 Oct.	85	206	White	.06	.03	.12	.06
			Pink	.38	.90	.78	1.86
			Red	.65	2.04	1.34	4.20

[1] Calculated from Pi R^3 – times constant 0.84.
[2] —Indicates no data.

times with water, dried by filtering through sodium sulfate and made to volume.

The spectral transmittancy of the hexane solution was determined at 452 and 502 millimicrons with a Cenco Sheard Spectrophotelometer.[2] The concentration of the total pigment expressed as beta-carotene and lycopene was calculated from a modification of the formula given by Lime, *et al* (1957). The following simultaneous equations based on measurements of isolated lycopene (Davis, 1949) and crystalline beta-carotene were used.

$$\text{Concentration of carotene mg/1} = 4.95\ a\ (452) - 3.45\ a\ (502)$$

$$\text{Concentration of lycopene mg/1} = 4.29\ a\ (502) - 1.14\ a\ (452)$$

$$a = \log_{10} \frac{100}{\%\ \text{Transmittance}}$$

RESULTS AND DISCUSSION

Tables 1, 2 and 3 show the seasonal trends of the carotene and lycopene concentration in the white, pink and red fruit. The development of the lycopene and carotene in the red fruit follows a pattern similar to that reported by Lime, *et al* (1954). The lower values for pigment concentration reported by Lime, *et al* (1954), is attributed to their use of only the edible portion of the fruit. Apparently the pigments in the pink fruit follow the same pattern. The pigment content of the white fruit is so low that experimental error might obscure the seasonal maximum. The difference between duplicate samples at this low concentration was as great as plus or minus 20 per cent.

The maximum lycopene content of the red fruit appears to occur during the period of August 15 to September 10 each year. From the data of Lime, *et al* (1954), it appears the maximum was reached between August 8 and September 9 in 1953. In 1955 the maximum occurred between August 9 and September 6. In 1956 it occurred between August 14 and September 4. In 1957 it occurred between August 9 and September 24.

The maximum which was measured may not have been the true maximum which actually occurred in the fruit. The true maximum may have occurred in the fruit sometime before or sometime after the measurement of the maximum was made.

It is not known what factors initiate the decline of lycopene concentration. It may be that the decline is a function of time after the fruit are formed, or of temperatures or a photoperiodic effect based on decreased daylight. During each period in which the maximum lycopene concentration was found there was a slight decrease in temperatures.

The time from fruit set to the period of decline of lycopene concentration was the same for all years. The length of day and night was the same during the period of decline in all years.

The beginning of the decline of carotene concentration is not so definite as the decline of lycopene and does not appear to occur during the same period each year.

Lycopene had not previously been reported in white grapefruit. The lycopene was identified by spectral absorption and chromato-

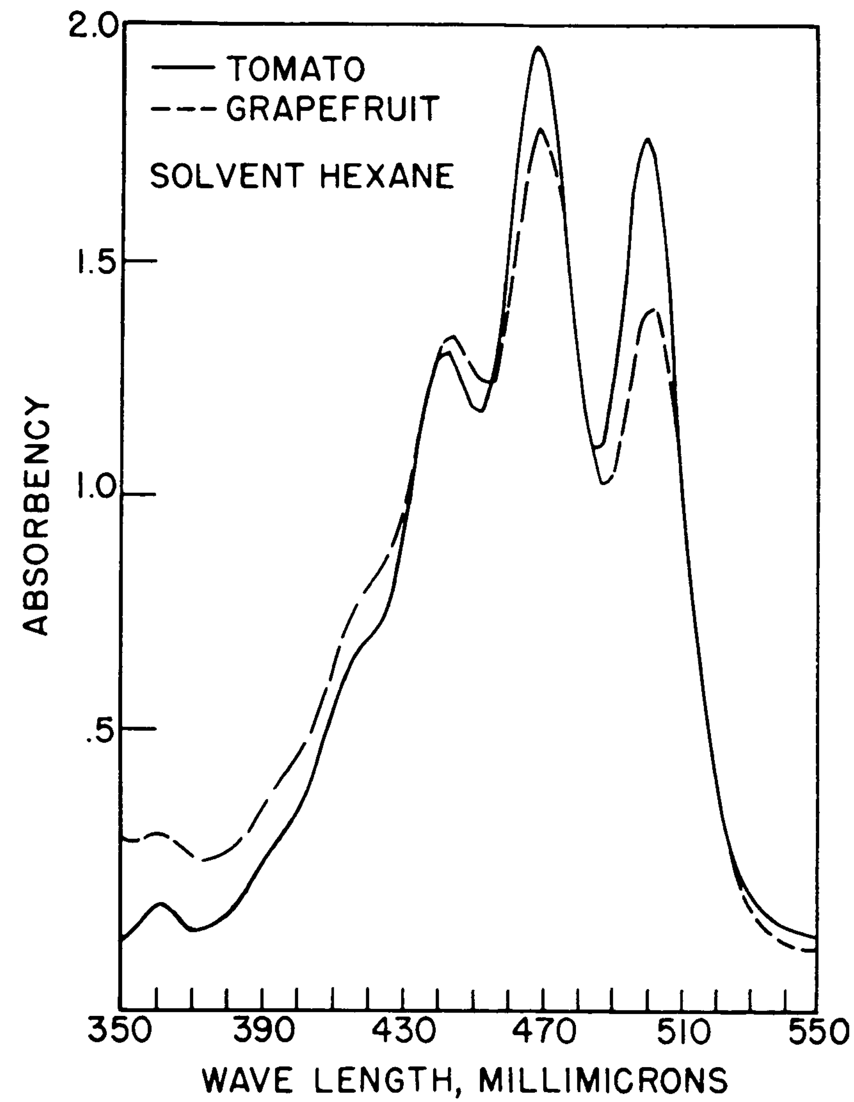

Figure 1. Spectral curves of lycopene isolated from tomatoes and Marsh white grapefruit.

graphic behavior. Spectral curves of lycopene isolated from tomatoes and Marsh white grapefruit are shown in Figure 1. The lycopene isolated from white grapefruit was chromatographically homogeneous on magnesia super-cel columns with that isolated from red grapefruit.

The Thompson pink grapefrruit is a mutant of the Marsh white (Webber, 1946) which in turn is probably a mutant of the Duncan white. A sample of Duncan white fruit was analyzed August 19, 1957, and found to contain significantly less pigment than the Marsh white picked at about the same time, i.e., .008 mg. per cent lycopene and .020 mg. per cent carotene. A sample of Duncan white fruit obtained from Florida at about the same stage of maturity was found to contain .0009 mg. per cent lycopene and .015 mg. per cent carotene.

The finding of lycopene in the white fruit during this period of development does not disagree with the report of Khan and MacKinney (1952) who found no lycopene in mature white fruit, since the lycopene content apparently decreases to zero as the fruit mature.

The finding of lycopene in white fruit indicates that the mechanism for lycopene formation was not created by the mutation which resulted in colored fruit. It cannot be said with certainty that the colored fruit have an increased ability to produce the carotenoid pigments, since the accumulation of pigments might just as well be explained by a decreased ability to convert the carotenoids or carotenoid precursors to other compounds.

SUMMARY

Data are presented to show that the maximum lycopene content of Ruby Red grapefruit occurred during the same 26-day period (August 15 to September 10) in four years for which data are available. The seasonal development and decline of lycopene in the Thompson pink grapefruit parallels that of the Ruby Red.

The seasonal development and decline of carotene is similar in red, pink and white fruit. In all years studied the decline of carotene content began after the decline of lycopene had begun, but the beginning was not uniform from year to year.

Lycopene has been found in immature white grapefruit (Texas and Florida) indicating the grapefruit had the ability to synthesize lycopene before mutation to the colored varieties. The seasonal change of lycopene concentration in the white fruit are similar to those of the red and pink varieties.

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Fruit Quality Studies of Eight Strains of Red Fleshed Grapefruit on Two Rootstocks

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The development of new varieties through the selection of mutants or bud sports is fairly commonplace in the citrus areas of the world. Such mutants as Pink Marsh, Henninger Ruby Red, and Webb Redblush have been landmarks in the development of the Texas citrus industry. Fruits of these mutants differ so drastically in appearance from those of the parent trees that mere observance is sufficient to establish their identity as distinct varieties. Less obvious are the possible differences in fruit quality and yield. Since the introduction of the red-fleshed varieties of grapefruit there have been claims of numerous further mutations that differ, if at all, but slightly from the original Henninger Ruby Red and Webb Redblush. An excellent account of the derivation of these strains has been given by Waibel (1953).

In order to make a close comparison of their characteristics a planting of these different strains on 2 rootstocks was set out at the Texas Agricultural Experiment Station at Weslaco in 1951. This paper presents the results of fruit quality studies during the first 3 years of fruiting.

Materials and Methods

The experimental design was a randomized block consisting of 2-tree plots of each of 8 strains on each of 2 rootstocks (sour orange and Cleopatra mandarin), replicated 4 times.

The 8 strains included were Webb Redblush, Henninger Ruby Red, Goodwin, Shary, Ballard, Riddle, Fawcett, and Curry. All are red fleshed and have a red peel blush. The trees were obtained from the nursery of the State budwood certification program at the Experiment Station and were certified as free of psorosis.

In 1954 a sample of random-sized fruits was taken from the periphery of each tree, 8 fruit per 2-tree plot, for quality analysis. In 1955-56 samples were taken on 2 sampling dates and in 1956-57 on 3 sampling dates; these fruits were of uniform size for any given date.

All samples were transported to the laboratories of the Department of Horticulture at College Station for analysis.

The equatorial diameter and the height (distance from the stem end to the apex) of each fruit were measured and the D/H index (an estimate of the flatness or roundness) was calculated by dividing the diameter by the height. A D/H of 1.00 indicates the fruit is relatively round or spherical. A D/H of less than 1.00 indicates the fruit is oblong and is undesirable. A D/H of greater than 1.00 indicates it is oblate or flattened at the poles and is normal for seedless red-fleshed grapefruit.

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The fruits were then juiced and the Brix (per cent total soluble solids), the per cent total titratable acid (expressed as citric), the Brix/acid ratio, and the percentage of juice on a weight basis determined.

Data for the 1954-55 season were not analyzed statistically because of the number of plots which did not have fruit. Data for each sampling date during the next 2 seasons were analyzed statistically by analysis of variance. A few plots in the latter 2 seasons did not have fruit and yields were somewhat reduced due to excessive fruit drop resulting from cold winds during the blossom period.

Results and Discussion

The results of these studies are not presented as conclusive but as a progress report of the performance of the 8 strains of red-fleshed grape-

Table 1. Fruit quality analyses of 8 strains of red-fleshed grapefruit.

Year	Strain							
	Ballard	Curry	Fawcett	Goodwin	Henninger	Riddle	Shary	Webb
				% Total Soluble Solids (Brix)				
1954-55	8.0	7.9	7.9	7.6	7.9	7.9	7.6	7.7
1955-56	8.2	8.2	8.2	8.2	8.1	8.2	8.2	8.2
1956-57	10.0	10.0	10.1	10.0	9.7	10.1	9.8	9.9
Mean[1]	9.3	9.3	9.3	9.3	9.1	9.3	9.2	9.3
				% Total Titratable Acid				
1954-55	0.87	0.89	0.88	0.85	0.86	0.87	0.86	0.89
1955-56	0.86	0.86	0.86	0.87	0.88	0.86	0.86	0.86
1956-57	1.08	1.08	1.07	1.08	1.04	1.07	1.08	1.08
Mean[1]	0.99	0.99	0.99	1.00	0.98	0.99	0.99	0.99
				Ratio				
1954-55	9.12	8.90	8.93	8.86	9.17	9.05	8.86	8.76
1955-56	9.38	9.66	9.54	9.18	9.22	9.60	9.58	9.68
1956-57	9.36	9.38	9.54	9.34	9.03	9.53	9.22	9.35
Mean[1]	9.37	9.50	9.54	9.29	9.10	9.56	9.37	9.48
				% Juice by Weight				
1954-55	56.8	55.5	56.7	56.7	58.2	56.0	56.7	56.5
1955-56	53.8	52.8	52.0	52.0	51.8	53.1	53.0	52.6
1956-57	54.2	54.7	54.5	55.0	54.8	55.2	54.4	54.8
Mean[1]	51.5	51.2	54.1	51.3	54.4	54.6	54.3	54.4
				D/H Index				
1954-55		not determined						
1955-56	1.12	1.12	1.12	1.12	1.12	1.11	1.12	1.12
1956-57	1.11	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Mean[1]	1.12	1.11	1.11	1.11	1.11	1.10	1.11	1.11

[1] The average or mean of the mean values for 5 sampling dates, 2 in 1955-56 and 3 in 1956-57.

fruit during their first years of bearing. Table 1 presents the average or mean values of the various analyses for each year for all plots of a given strain. In the 1954-55 season the mean represents only one set of analyses, but in 1955-56 and 1956-57 it represents the mean of the mean values for 2 and 3 sampling dates respectively. Also, the averages or means of all 5 sampling dates are included.

The 1955-56 data show appreciable variation but considering the small amount of fruit produced that season and the large variation in sizes the values of the various analyses are quite similar.

The data for each of the 5 dates during the next 2 seasons were analyzed statistically and no significant differences indicative of a relationship between strain and the criteria of quality studied or the D/H index were found. The D/H indices indicate that the fruits were oblate or slightly flattened, which is desirable.

Data in Table 2 indicate that in the 1954-55 season the fruit from the trees on sour orange were slightly higher in total soluble solids, acidity and percentage of juice; however, this was the first year of bearing and yields were small.

During the next 2 seasons no statistically significant differences attributable to rootstocks were found for any given date. There does appear to be a tendency for the fruit from the trees on Cleopatra to have slightly higher acid values, resulting in lower ratios, and slightly higher percentages of juice. These differences are very small and would be of little practical significance.

Table 2. The relation of rootstock to the fruit quality of red-fleshed strains of grapefruit.[1]

Sampling Date	% Soluble Solids (Brix)		% Total Titratable Acid		Ratio		% Juice by Weight		D/H Index	
	Sour	Cleo	Sour	Cleo	Sour	Cleo	Sour	Cleo	Sour	Cleo
1954-55										
12/4	7.9	7.5	0.88	0.87	9.02	8.73	57.0	56.0	....	....
1955-56										
11/11	8.2[1]	8.0	0.89	0.93	8.75	8.64	46.3	49.1	1.12	1.12
1/25	8.2	8.2	0.80	0.81	10.28	10.24	55.4	57.8	1.13	1.10
1956-57										
11/16	9.8	10.1	1.15	1.22	8.58	8.28	52.7	53.2	1.09	1.08
1/13	10.2	10.2	1.08	1.14	9.35	8.98	54.9	56.4	1.11	1.10
3/3	9.7	9.8	0.92	0.96	10.66	10.24	54.9	55.8	1.12	1.12
Mean[2]	9.2	9.3	0.97	1.01	9.52	9.28	52.8	54.5	1.11	1.10

[1] Each figure in the main body of the table is the mean of the analyses from 32 plots, except where fruit was lacking.

[2] The average or mean of the mean values for the 5 sampling dates in the 1955-56 and 1956-57 seasons.

It is conceded in the case of the rootstock data that had samples of random-sized fruits been taken results different than those presented might have been found. This is because Brix, acid, and juice values are generally related to fruit size (Hilgeman, 1941; Sites, 1953; Sites and Deszyck, 1952), and the sizes of fruits from trees on Cleopatra are generally smaller than those from trees on sour orange.

Obviously, the best procedure would be to take both samples of uniform and random sizes, but because of the limited crops on the young trees and the need for considerably larger samples of fruit when random sizes are used this was not done. Moreover, the primary value of Texas grapefruit is as a fresh fruit and size is an important factor in the price structure. Sizes 96 and 80 (the sizes sampled) are a more important segment of the crop than the smaller sizes and it was felt that information concerning these sizes would be of greater practical significance.

Of additional interest are the appreciable increases in Brix and acid values as the age of the trees increased (Table 2). This fact has been previously reported in Arizona (Hilgeman, 1941). It explains in large part the lower values presented here as compared to the general high Brix values previously reported for Texas red grapefruit (Krezdorn and Cain, 1952). However, the ratio values were always high and by the end of the third bearing season the Brix values were approaching the high level for which Texas grapefruit is noted. The rather large increases in certain of the criteria of quality as the trees aged is indicative of the rapidly changing physiological status of these trees. It is possible that at some age level differences in quality will become evident that were not present in fruit from the young trees.

Summary

1. Standard criteria of quality and the D/H indices of 8 strains of red-fleshed grapefruit on 2 rootstocks were determined for the first 3 fruiting years.

2. No statistically significant differences attributable to either strain or rootstock were found.

3. When the data were viewed in their entirety a slight tendency toward higher acid and juice values was noted in the fruit from trees on Cleopatra mandarin rootstock, but these differences were small and of no practical significance.

4. As the trees aged appreciable increases in the Brix and acid values were noted.

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Control of *Eutetranychus banksi* McG. on Citrus with Dusts During 1957, with Residue Analysis

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Few growers have used sprays during the past 20 years in the Lower Rio Grande Valley area for the control of various citrus pests. The tetranychid spider mite, *Eutetranychus banksi* McG., is an important pest of citrus in this area, second only to the citrus rust mite, *Phyllocoptruta oleivora* Ashm. Sulphur dust used with varying degrees of success has been the principal control material. Oil spray has been used in a few instances with success. An experiment was begun in May 1957 to test certain dusts for the control of this mite and at the same time reduce the citrus rust mite to very low populations.

Some chemical control information and certain increase periods of *banksi* mite have been reported by this station. Dean (1952) found high populations of *banksi* mites difficult to control with one application of various dusts. Population studies by Dean (1959) showed the greatest increase of *banksi* mites during the year to be in the May-July period under no miticidal treatment. Such information suggested the possibility of a May or June application for the particular reduction of *banksi* mites during this potential increase period. Increases of *banksi* mites were found to occur during other periods when weather conditions were favorable but not to the extent of the May-July increase period.

METHODS

Dusts were applied in June and September from the east and west sides of 7-year-old Ruby red grapefruit trees during the early morning hours with a Root duster mounted on the back of an Army truck. All trees in the experimental block had been sprayed at post-bloom in early April with a copper-sulphur mixture. Plots were 6 rows wide.

The third leaf from the apical end of the terminal flush of growth was used for sampling mite populations. Five leaves were taken from each quadrant around 2 trees for a composite 40-leaf sample for each replication with 5 replications for each treatment. Mites were counted on the leaf under the microscope for the initial count. Subsequent counts were made by counting the mites on 1/2 the plate used with the mite-brushing machine.

Fruit samples were taken by selecting one uniform-sized fruit from each quadrant for residue analysis.

RESULTS AND DISCUSSION

Rain occurred just prior to the June 8 application and caused some delay in treatment. *E. banksi* populations were higher at the outset in the sulphur plots and the early damage from the mite may have been responsible for a somewhat smaller build-up later in the year. Also, following the June application, an increase of the predaceous mites, *Typhlodromus spp.*, was considered a possible factor in the maintenance of low populations during the summer. Population data of spider and citrus rust mites are shown in table 1.

Control of spider mites was erratic following rainfall and miticidal applications. Following the June application and the 4-6 inch rains on June 18, a somewhat higher population was found in the sulphur plots. Spider mites in these plots then remained in low numbers until September. In the chlorobenzilate-sulphur plots, a lower initial count was reduced proportionately less, but higher populations remained throughout the summer period than in the other plots. Spider mites in the aramite-sulphur plots were about equal in numbers during the summer as in the sulphur plots but showed a somewhat larger increase during the September-October period. Hygrothermograph records showed temperatures of 90° F. or higher to range from 6-9 hours per day while relative humidity was somewhat lower than normal during the summer period. Such conditions were more favorable for the development of higher spider mite populations during the summer. The mite-feeding beetles, *Stethorus spp.*, increased during late September and appeared to be a very important factor for the lower numbers of spider mites in November.

Table 1. Populations of *Eutetranychus banksi* McG. mites and eggs and citrus rust mites in miticide (dust) tests conducted at the Crockett Grove near Harlingen, Texas during 1957.

	Sulphur[1]			*3% Chlorobenzilate-Sulphur*[1]			*3% Aramite-sulphur*[1]		
Date	*MPL*[2]	*EPL*[2]	*RML*[2]	*MPL*	*EPL*	*RMPL*	*MPL*	*EPL*	*RMPL*
6-4	18.3	18.9	18.0	5.0	3.9	.8	6.3	5.4	25.9
6-8[3] 6-24	2.8	1.7	.9	1.2	1.4	.3	.8	.4	.8
7-18	.8	.3	.1	1.2	1.4	.01	.2	.1	.1
8-1	.6	.9	.02	2.2	3.2	.02	.8	.8	.02
8-19	.8	1.0	.1	4.3	4.7	.03	1.2	1.0	.1
9-4	1.4	1.4	.1	9.2	9.0	.1	2.6	2.6	.1
9-18	3.3	3.6	.1	10.3	13.0	.6	9.2	14.1	.1
9-20[4] 10-21	10.9	24.0	.03	27.7	29.0	.02	14.2	33.0	.7
11-25	3.4	3.8	.1	.4	.5	.03	3.1	4.0	.04

[1] 93% dusting sulphur, 3% Chlorobenzilate (52% sulphur in 1st application, 42% sulphur in 2nd application), and 3% Aramite-sulphur.

[2] MPL, *E. banksi* mites per leaf; EPL, *E. banksi* eggs per leaf; RMPL, citrus rust mites per leaf.

[3] .65, .8, and .6 pound per tree of each material, respectively.

[4] .75, .7, and .8 pound per tree of each material, respectively. On 6-18-57, 4-6" rain; on 9-22-57, 2-3" rain.

Citrus rust mites were increasing at the beginning of the test in the sulphur and aramite-sulphur plots. A rather dry summer followed, with no rainfall from June 24 to August 20. Citrus rust mites remained in very low numbers for the duration of the test period in all treatments.

False spider mites, *Brevipalpus* spp., began to increase after the middle of August. Populations of these mites on 1800 leaves for 9 samples over the season were 515 in the sulphur, 345 in the aramite-sulphur and 219 in the chlorobenzilate-sulphur plots. A large portion of these mites was found in the two samples in September just prior to treatment.

Tydeid mites, mainly *Pronematus ubiquitus* (McG.), were about evenly distributed in all plots. Populations on 1800 leaves were 219 in the sulphur, 171 in the aramite-sulphur and 200 in the chlorobenzilate-sulphur plots. *P. ubiquitus* has been considered as a beneficial mite.

Residue analysis, as shown in Table 2, showed a low amount of chlorobenzilate in the peel of the fruit in 3 samples. It is possible that the higher amount of chlorobenzilate in the November sample may be explained by the difference in the absorption rate of the chlorobenzilate. No chlorobenzilate was found in the pulp of the sample taken December 13.

SUMMARY

Citrus rust mites remained at low levels following applications of sulphur, 3 per cent chlorobenzilate-sulphur and 3 per cent aramite-sulphur dusts applied on June 8 and September 20.

Table 2. Chlorobenzilate residues in grapefruit.[1]

Sample date	*Stripping date*	*Chlorobenzilate peel, ppm*	*Chlorobenzilate pulp, ppm*
10-14-57	10-22-57	0.816	
11-13-57	11-28-57	2.19, 2.65	
12-13-57	12-23-57	0.56	0.00

[1] Last dust application on 9-20-57. Residue based on fresh weight of part concerned. Pulp refers to juice and portion of fruit remaining after peel is removed. Analysis for residues were made by the Ultraviolet method under the supervision of Dr. R. F. Gigger, Geigy Laboratories.

The thoroughness of application and the heavy rains in June were considered important factors for the low population levels of the spider mite, *Eutetranychus banksi*, during this particular increase period. The population-increase period (September-November) was considered to have resulted from favorable weather conditions for mite development and rather poor conditions for miticidal effectiveness. Little to no benefit was found with the addition of chlorobenzilate or aramite to sulphur dust under the conditions of this experiment where erratic control of this mite occurred.

Residue analysis showed a low amount of chlorobenzilate in the peel while the analysis on December 23 showed none in the pulp.

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Control of Fruit Russeting in Citrus[1]

H. A. Dean and Bailey Sleeth[2]

The production of high external quality fruit is a major citrus problem in the Lower Rio Grande Valley where fresh market outlets provide for maximum grower returns. Clean, bright and unscarred fruit is a prime prerequisite for the successful marketing of fresh citrus.

Fruit russeting, the cause of which is not clearly understood, is a major defect of external quality of Texas citrus. Russet has been described by Fisher (1958) as an external blemish of citrus fruit which causes the fruit to appear from bronze through shades of brown to black. Russeting has been associated with high infestations of the citrus rust mite, *Phyllocoptruta oleivora* Ashm. The highest citrus rust mite populations were associated with high relative humidity, according to Dean (1959), and the period of most rapid increase and maximum populations of the Texas citrus spider mite, *Eutetranychus banksi* McG., was found to be during May-July. False spider mites, *Brevipalpus* spp., poised as a potential pest during the June-December period but particularly when the fruit was approaching mature size. A program of mite control should therefore consider these 3 mite species.

Melanose, caused by the fungus, *Phomopsis citri*, has been very prevalent in some years, particularly in the eastern part of the Valley. Melanose-infected fruits have substandard appearance for fresh market grades and must be sold for juice (processing) prices. Godfrey (1950) reported that post-bloom copper sprays would control sandy melanose in the Lower Rio Grande Valley. He also reported that a 5 per cent copper dust with a dust sticker would give some control, but was not nearly as effective as sprays, probably due to the small amount of copper deposited.

With the development of the newer fungicides, zineb has become an important consideration in the control program in citrus. Johnson *et al.* (1958) reported zineb controls citrus rust mites but does not control *banksi* mites. Fisher (1958) reported zineb controls fruit russet and that a fungus may be the primary *cause* of the blemish instead of the citrus rust mite.

Research was initiated in 1958 for the development of the most economical program of control of the various mites and diseases. Special emphasis was given the possible selectivity of the materials to control these pests without the disruption of the beneficial insect relation to scale insects. Such consideration was given due to the cost of scale control measures and the upsets that are known to occur with the various scale control materials.

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PROCEDURE

Sprays were applied by conventional sprayer with 2, 6-nozzle broom guns at 600 pounds pressure in grove A and with 2, 4-nozzle broom guns at 500 pounds pressure in grove B. In grove C, 375 gallons per acre were applied to 9-10 foot grapefruit trees with a speed sprayer. Dusts were applied by conventional dusters in groves A and B at the rate of 60 and 75 pounds per acre, respectively. In grove D, dusts were applied by airplane at 50 pounds per acre.

Dosages are given as follows:

Sprays: Amount per 100 gallons (except as noted)
- a. Zineb—1 pound
- b. Kelthane—1 quart emulsifiable concentrate
- c. Tedion—1 pound 25% wettable powder
- d. Copper—1¾ pounds 48% copper
- e. Oil—9 gallons 84% oil per 500 gallons
- f. Wettable sulphur—10 pounds

Dusts: Amount per acre
- a. Conditioned sulphur—50-75 pounds
- b. 5.2% zineb plus 3% kelthane plus dust sticker—50 pounds
- c. 5.2% zineb plus dust sticker—50 pounds

Effectiveness of the various treatments was determined by taking mite counts before and after applications and by the percentage of clean or bright fruit produced. Mite populations were sampled from terminal flush leaves taken 2-7 feet from the ground around the tree. Five leaves were taken from each quadrant for a total of 40 leaves per sample. A mite-brushing machine was used to brush the mites from the leaves onto a sticky plate. Mites on ½ of this plate were counted under 20X magnification of the microscope. The percentage of bright fruit was obtained by rating on its external appearance a box or more of mature fruit from each plot. Wind or mechanical scars on fruit were discounted because they were not controllable in these tests. Fruits free of typical russet damage were placed in the clean fruit class. Results are given in the tables 1, 2, 3 and 4.

RESULTS AND DISCUSSION

Weather conditions, pesticide materials, timeliness and thoroughness of applications are important factors in the effective and economical control of various mites and diseases affecting fruit quality. As previously observed, citrus rust mites increased in numbers during periods of high relative humidity, while spider mites decreased in numbers under rainy conditions. Spider mite populations were unusually low following the 1958 September-October rainy period. These factors greatly influenced the results of mite control and amount of clean fruit produced in the different groves.

Citrus rust mite.—Citrus rust mites were increasing prior to post-bloom treatment, particularly in groves A and D. An unusually long

period of bloom in grove A made the post-bloom period difficult to determine. A particularly high population was found in grove D (Table 4) before the first application of dust was applied on May 6th. The May-June application was directed against spider mites; however, citrus rust mite control materials were added even though their numbers were exceedingly low.

Residual control with sulphur dust following mid-June varied from 1½ to 3 months, depending on thoroughness of application. Timing was apparently good in groves A and B (Tables 1 and 2), particularly in regard to the reduced numbers in August before the ensuing September-October rains. Afterwards, control measures were again necessary. Control with wettable sulphur applied by speed sprayer in grove C (Table 3) lasted about 1½ months. The lack of control in the zineb-dusted plots in grove D (Table 4) leading into the rainy, September-October period may account for some of the difference in percentage of bright fruit. The residual control apparently broke in this test in 3 months, and the extra application of sulphur in treatment 1 should be noted. However, examination of fruit for rust mites following the October and November applications showed a great number on fruit in zineb plots which would

Table 1. Spray and dust treatments applied in grove A during 1958 and their effect on rust and Texas citrus mite populations and fruit russet control.

	Treatment 1		*Treatment 2*		*Treatment 3*	
Date	*RM*[1]	*TCM*[2]	*RM*	*TCM*	*RM*	*TCM*
March 24	15.2	.6	21.1	.4	50.6	.8
April 25	Copper-sulphur		Copper-sulphur		Zineb	
May 7	—	1.7	—	.2	—	3.8
May 27	—	.4	—	6.3	—	3.8
May 30	Sulphur dust					
June 12			Zineb-Kelthane		Zineb-Kelthane	
June 19	.4°	2.8	.9°	—	.9°	—
July 21	.4	12.5	.6	.6	.6	.4
August 4	Sulphur dust					
August 14	.1	.9	.1	4.5	.1	1.4
September 15	.04	2.6	.2	8.9	.1	4.2
October 29	1.2	.1	.9	.1	.8	.1
November 21	Sulphur dust		Zineb		Zineb	
December 5	1.0	.1	.3	.04	.5	.1
January 19	.4	.01	.1	.01	.1	.02
	Per Cent Bright Fruit					
December	88.5		92.0		94.5	

[1] Citrus rust mites per leaf.
[2] *E. banksi* mites per leaf.
° Unreliable, difficult to distinguish whether dead or alive.

indicate that coverage is probably more important with zineb than with sulphur when fruit is almost mature.

Residual control with summer applications of zineb spray varied from 1½ to 6 months. Following the June application in grove A, residual control extended for 4 months (Table 1), while in grove B citrus rust mites were in very low numbers from June to December following zineb-oil spray (Table 2). In grove C, plots receiving zineb in June were again treated in late July with zineb-oil with a resulting 4 months control (Table 3). After this period, a winter application was required in the latter grove.

Zineb spray, at the dosages used, gave longer residual control of citrus rust mites than sulphur when applied either as a spray or a dust. These findings are in agreement with those reported from Florida (Johnson *et al.*, 1958). There was a higher percentage of clean fruit (Tables 1, 2 and 3) in the zineb sprayed plots than those sprayed or dusted with sulphur. However, the yearly variation in the pattern of increase of citrus rust mite throughout the year makes continuous examination of populations necessary. Retreatment was considered necessary when the populations averaged 1-3 mites per leaf.

Texas Citrus Spider Mite.—Attention was given to the control of this mite during its greatest increase period, May-July. Populations were

Table 2. Spray and dust treatments applied in grove B and their effect on citrus rust and Texas citrus mite populations and fruit russet control.

	Treatment 1		*Treatment 2*		*Treatment 3*	
Date	*RM*[1]	*TCM*[2]	*RM*	*TCM*	*RM*	*TCM*
March 17	.3	.6	.5	.2	.5	.3
April 18	Copper-Sulphur		Copper-Sulphur		Zineb	
May 12	—	3.7	—	3.2	—	11.1
May 23	Sulphur dust					
June 9	—	.9	—	14.1	—	23.8
June 12			Zineb-Oil		Zineb-Oil	
June 26	—	3.0	—	.02	—	.06
July 31	.1	22.2	—	.4	—	.8
August 4	Sulphur dust					
August 18	—	.6	—	.2	—	.2
September 22	.02	.5	—	3.1	.01	4.8
October 7	—	.5	.1	3.0	—	3.7
November 10	.1	.2	—	.8	.1	.7
November 25	Sulphur dust					
December 15	—	.1	.1	.3	—	.1
	Per Cent Bright Fruit					
December	82.1		93.0		88.7	

[1] Citrus rust mites per leaf
[2] *E. banksi* mites per leaf

higher by the last of May in the zineb plots than in the sulphur plots (Table 2). This was expected, since zineb is specific for rust mite control only. Numbers were relatively low for a month or longer in groves A and B following sulphur dust in May and August. Considerably longer residual control was found in grove D with kelthane dust than with sulphur dust (Table 4). Kelthane, as a 3 per cent dust with a dust sticker, showed promise of control of high populations when applied to 3-year-old grapefruit trees. An application on May 30 reduced mites from 7.4 mites per leaf on May 13 to .4 on June 17, while an application on August 28 reduced mites from 62.4 on August 5 to .2 on September 12.

Duration of residual control of Texas citrus mites varied somewhat with the materials applied as sprays. In grove A, kelthane gave almost 2 months residual control (Table 1) during this potential increase period. In grove B, oil applied to higher initial infestation, 14 to 23 mites per leaf, gave control from early June to mid August (Table 2). Tedion gave better residual control of lower initial infestations than kelthane applied by speed sprayer in grove C (Table 3). However, oil was applied in late July and rather low populations were somewhat erratic until the September-October rainy period when infestations became very low in all treatments.

False spider mites, Brevipalpus spp.—False spider mites were found to be more numerous in plots treated with zineb than with either sulphur or copper-sulphur following the post-bloom period. These mites were

Table 3. Spray treatments applied in grove C during 1958 and their effect on citrus rust and Texas citrus mite populations and fruit russet control.

	Treatment No. 1		*Treatment No. 2*		*Treatment No. 3*		*Treatment No. 4*	
Date	*RM*[1]	*TCM*[2]	*RM*	*TCM*	*RM*	*TCM*	*RM*	*TCM*
Mar. 19	.4	—	.4	—			.4	—
Apr. 16	Copper-sulphur		Copper-sulphur		Copper-sulphur		Zineb	
May 6	—	—	—	—			—	—
May 29	.1	.5	.2	1.5	.2	1.6	.1	2.6
June 4	Sulphur		Zineb-Kelthane		Tedion-sulphur		Zineb-kelthane	
June 24	—	.4	—	—	—	—	—	—
July 23	12.8	6.1	.9	2.0	18.4	.1	.4	2.7
July 26	Oil-zineb		Oil-zineb		Oil-zineb		Oil-zineb	
Sept. 17	.1	3.8	.01	9.2	.1	5.0	.04	2.1
Oct. 8	.3	1.9	.2	2.1	.6	3.4	.1	1.9
Nov. 5	2.2	.2	.8	.4	.5	.4	1.8	.3
Dec. 16	7.8	.1	1.1	.3	2.1	.1	2.1	.1
Jan. 10	Zineb		Zineb		Zineb		Zineb	
	Per Cent Bright Fruit							
Dec.	90		96		86		96	

[1] Citrus rust mites per leaf
[2] *E. banksi* mites per leaf

very scarce following kelthane treatment in June and very few were found in the sulphur plots in grove A. These mites were very scarce in the sulphur plots in grove B while 50 and 202 were found in the copper-sulphur followed by oil-zineb and the all-zineb plots, respectively (Table 2). The plots treated with sulphur in grove C had 3 to 4 times the number of false spider mites as those treated with kelthane. These mites were more numerous in the zineb plots in grove D before kelthane was applied; however, numbers were very low in both treatments thereafter.

Predaceous mites, Typhlodromus spp.—*Typhlodromus* mites were more numerous in the sulphur plots than in the all-zineb plots. Very few were found in the all-zineb plots before September. Comparative mite numbers were 258 in the sulphur, 138 in the copper-sulphur followed by zineb and 84 in the all zineb plots in grove A and 588, 350 and 115 in the sulphur, copper-sulphur followed by oil-zineb and the all-zineb plots, respectively, in grove B. In grove C, these mites were somewhat more numerous in treatment 1 and the least numbers were found in treatment 4 where zineb was applied at each application. These predaceous mites were more than 5 times as numerous in the sulphur-dusted plots as in the zineb-dusted plots in grove D.

The reason for the low numbers of these mites in the all-zineb plots is not understood. Citrus rust mites may be required in the diet of these mites and zineb may indirectly affect their presence by *killing* off this food supply and causing them to migrate elsewhere for food. It is possible that zineb may be toxic to these mites.

SUMMARY

Zineb applied as a spray, gave longer residual control of citrus rust mites than either sulphur spray or dust. Following the post-bloom application, more frequent applications of sulphur than zineb were necessary for citrus rust mite control, but a high percentage of bright fruit resulted where timely applications were made.

Longer residual control of the spider mite, *Eutetranychus banksi*, resulted from applications of tedion, kelthane and oil than with sulphur. Tedion spray in one test appeared to give very long residual control. Kelthane gave better control either as a dust (with dust sticker) or spray than did sulphur. These mites were more numerous in May following zineb-alone than where sulphur was applied at post-bloom.

Kelthane showed considerable promise as a controlling agent for false spider mites, *Brevipalpus* spp. These mites were controlled by sulphur dust and zineb gave little or no control.

The predaceous mites, *Typhlodromus* spp., were almost absent from zineb-treated trees until September while being more prevalent in the sulphur treated trees.

Russet of fruit was controlled by timely applications of zineb or sulphur, producing 82 to 96 per cent bright fruit compared to less than 20 per cent in untreated groves.

Table 4. Dust treatments applied by airplane in grove D during 1958 and the effect on citrus rust and Texas citrus mite populations and fruit russet control.

	Treatment 1		*Treatment 2*	
Date	*RM*[1]	*TCM*[2]	*RM*	*TCM*
March 13	1.8	—	1.8	—
April 24	16.2	.4	16.2	.5
May 6	Sulphur		Zineb	
May 20	—	.9	—	.6
May 30	Sulphur		Zineb-Kelthane	
June 16	—	.4	—	—
July 9	.6	2.4	.5	.2
July 17	Sulphur			
August 4	.4	8.7	.3	1.4
September 2	.01	19.9	.9	14.7
September 29	5.7	4.0	19.6	14.0
October 8*	Sulphur		Zineb-Kelthane	
October 21	1.3	.2	.3	.04
November 12**	Sulphur		Zineb	
November 18	.9	.1	1.2	.04
December 12	.5	—	.8	.1
January 15	.5	.01	1.04	—
	Per Cent Bright Fruit			
January	69.3		57.7	

[1] Citrus rust mites per leaf
[2] *E. banksi* mites per leaf

* Rained off within 8 hours
** Rained off within 30 hours

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Pruning Wound Paint for Citrus

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It has been a common practice to paint cuts and wounds on fruit, shade and ornamental trees. The purpose of applying paints to wounds, especially pruning wounds, is to prevent drying out and dying of the exposed tissues; to hasten the initiation of callus and healing of the wound; and to prevent the entry of decay causing organisms. A good wound paint should protect the tree against infection until the wound is completely healed—callused over. This is of particular importance in citrus groves, which may require drastic pruning because of severe freeze or wind damage.

A considerable amount of work has been done at this Station over the past several years on developing an effective low cost pruning wound paint. The basic ingredient in the paints was asphalt dissolved in naptha, kerosene or carbolineum with addition of a fungicide. Over 60 formulations were tried of which the 5 reported in this paper are considered to best fit the objectives of a low-cost and effective paint.

In the asphalt wound-paint formula given by Fawcett (1936) no fungicide or disinfectant is incorporated. He suggested that large wounds should first be carefully disinfected and allowed to thoroughly dry before applying the paint. A safe and efficient pruning wound compound combining a disinfectant and a residual fungicide was developed by Dr. G. H. Godfrey of this Station. Information on how to prepare the paint was made available in a mimeograph release in 1951. The ingredients to make about 2 gallons of the paint is as follows:

Asphalt	8	pounds
Carbolineum	1	gallon
Phenol	5.75	ounces
Cuprous oxide	3	ounces

(Note: 1.5 ounces of pentachloorophenol may be substituted for the phenol.)

Godfrey's paint mixture specified solid asphalt with a melting point around 170° F.; this material is obtainable from most lumber yards. The carbolineum should be plant-safe; the phenol content below 2 per cent and a density of about 1.12. This mixture has been a very satisfactory wound paint. It is, however, moderately high in cost and the ingredients may not be readily obtainable. Asphalt paints containing one per cent pentachlorophenol in which either kerosene, naphtha or carbolineum were used as the solvent were found to give satisfactory results (Sleeth, 1955) when used to paint citrus nursery stock wounds. None of the paints delayed callus initiation.

PROCEDURE

A row of young citrus trees were pruned rather heavily in March 1955 and the wounds painted immediately with one of the following paints:

# 62	Asphalt	11	pounds
	Naptha	1	gallon
	Penta 40%	0.5	pint
# 63	Asphalt	11	pounds
	Kerosene	1	gallon
	Penta 40%	0.5	pint
# 64	Asphalt	11	pounds
	Kerosene	3	quarts
	Carbolineum	1	quart
	Penta 40%	0.5	pint
# 65	Asphalt	11	pounds
	Kerosene	2	quarts
	Naphtha	2	quarts
# 66	Asphalt	11	pounds
	Kerosene	2	quarts
	Naphtha	1	quart
	Carbolineum	1	quart
	Penta 40%	0.5	pint

Penta 40%, a commercial product consisting of 40 per cent pentachlorophenol, 43 per cent aromatic hydrocarbons and 17 per cent inert ingredients, supplied the disinfectant and residual fungicide in the paints, except #65, which contained none.

The paints were made by melting the solid asphalt in a metal container, allowed to cool slightly, and then the other ingredients were added, stirring constantly. The melting and mixing was done in a well ventilated room or in the open to avoid inhaling noxious fumes and to minimize the fire hazard. The cooled paints were thick and usually the desired consistency for use. However, if needed, a small amount of naphtha was used as a thinner. The paint was applied with a one-inch paint brush to the pruning wounds immediately after the cut was made to prevent drying out. The paint was thick enough so as not to run off the cut surface and down onto the bark below the wound.

The pruning was done with a Swedish-type saw blade, which left a smooth cut. The wounds were measured before painting and wound width or horizontal diameter was used in establishing the 2 wound classes, 1 to 1.5 inches and 1.6 to 2.5 inches, given in Table 1. The width of a wound is considered to be a more important factor than vertical length in determining the time required to heal, since wounds tend to heal or close over from the sides rather than from the top and lower edges.

RESULTS AND DISCUSSION

Four months after pruning, 16 painted stub wounds, 1.25 to 2.75 inches in diameter were examined to ascertain if any of the paints had caused noticeable injury to the live bark. None was observed. The bark die-back was negligible, less than that of the unpainted wounds, and in three-fourths of the cases healing of the cut surfaces had started. Also, drying out of the live wood beneath the painted wound surfaces was limited to 0.1 inch or less.

A final examination of the pruning wounds was made in December 1958, 3¾ years after treatment. The results obtained on the flush or branch type wounds are given in Table 1. The asphalt paints were effective in protecting the wounds against drying out and decay, Figure 1. In only 3 instances out of 60 had decay developed in the wood under the painted surface. On the other hand decay had developed in all of the unpainted wounds. Also, the painted wounds were free of borer or worm damage, which was common in the unpainted wounds.

In both wound classes, small and large, over 80 per cent of the painted wounds had healed over compared to slightly over 50 per cent of the unpainted wounds. This indicated that the wound paints did not retard healing and may have speeded up the healing process.

Table 1. Comparative effectiveness of wound paints in protecting citrus wounds against decay for 3¾ years.

Solvents and disinfectant in asphalt paint	*Wound size[1] classes*	*Number and condition of pruning wounds*			
		Total	*Callused over*	*Decay entered*	
				Wounds	*Penetration*
	Inches	*Number*	*Number*	*Number*	*Inches*
#62 Naptha	1 -1.5	5	4	0	....
Penta, 40%	1.6-2.5	10	9	1	1.1
#63 Kerosene	1.0-1.5	4	1	0	....
Penta, 40%	1.6-2.5	3	1	0	....
#64 Kerosene	1.0-1.5	8	8	0	....
Carbolenium	1.6-2.5	2	1	0	....
Penta, 40%					
#65 Kerosene	1.0-1.5	9	8	0	....
Naphtha	1.6-2.5	4	4	1	0.8
#66 Kerosene	1.0-1.5	9	9	0	....
Naphtha					
Carbolineum	1.6-2.5	6	6	1	1.7
Penta, 40%					
Control,	1.0-1.5	6	5	6	0.4-1.0
unpainted					
wounds	1.6-2.5	11	4	11	0.4-2.0

[1] Size of wound is given as width rather than vertical length.

Figure 1. Healed over citrus wounds nearly 4 years after pruning. Drying out and decay was prevented in the large wound on the left by a protective layer of an asphalt fungicidal paint. Decay and incipient gummosis have developed in the unpainted wound on the right.

The data in Table 1 do not indicate which of the 5 paints used is the best pruning paint. Based on these trials and subsequent observations the writer has a preference for a modified formulation of numbers 62 and 63. The formula would be as follows:

Kerosene, high grade commercial	3 quarts
Asphalt, good grade	11 pounds
Naphtha (Mineral spirits)	1 quart
Penta, 40% penthachlorophenol	0.5 pint

The naphtha is added to cause the paint to set or surface dry quickly. Also, it should be used to thin the paint if too thick. The pentachlorophenol disinfects the wound surface, provides fungicidal protection and gives added protection against borers and worms. A paint made according to this formula is low in cost and effective in protecting wounds while healing. However, anyone using this formula or any other should observe certain precautions; (1) use only good grade materials; (2) exercise caution in preparing the paint to prevent fires or chemical injury; and (3) test each batch of paint for plant toxicity by painting a few green citrus shoots and mature leaves. It will be plant safe if no injury occurs in 3 to 5 days.

SUMMARY

Five asphalt wound paints were found to be effective in preventing drying out and decay in citrus pruning wounds. Nearly 4 years after pruning and painting the cut surfaces, over 80 per cent of the wounds had healed over and 95 pe rcent of these were decay free. Decay had developed in all of the unpainted wounds. A modified formulation of two of the paints is low in cost and effective in protecting the wound surface from drying out and from decay. The formula is as follows: eleven pounds of a good grade asphalt, 1 gallon of a high grade kerosene (coal oil), 1 quart of naphtha (mineral spirits) and 0.5 pint penta (40 per cent pentachlorophenol).

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Experimental Control in Citrus Trees of Iron Chlorosis Associated with the Virus Disease Cachexia and High Soil Salinity by Applications of Iron Chelate

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INTRODUCTION

Iron chelates corrected iron chlorosis of citrus growing in calcareous soils in the Rio Grande Valley (Cooper, 1957; Cooper and Peynado, 1954, 1955 and 1956). Sequestrine 138-Fe was the most effective iron chelate tested (Cooper, 1957).

Rootstock influenced the incidence of iron chlorosis symptoms on grapefruit trees growing in calcareous soils (Cooper, and Olson, 1951). In their tests, many of the trees affected with iron chlorosis were on rootstocks affected with cachexia disease. It was not known what role the cachexia virus played in the development of iron chlorosis on trees on cachexia-intolerant rootstocks. It was likewise not known whether iron chelates were equally effective in correcting iron chlorosis on trees affected with cachexia and on those not affected with the disease.

Work by Cooper, Gorton and Edwards (1951) indicated that the usual symptoms of excess salt on citrus were bronzing and necrosis of the foliage and defoliation. In experiments conducted on grapefruit in the Rio Grande Valley during 1947 to 1957, such symptoms usually characterized damage from excess salt. However, during 1958 iron chlorosis developed on many trees in experimental plots irrigated with water containing 4000 ppm of sodium chloride. Similar iron-chlorosis symptoms were also reported under excess-salt conditions by Chapman and Kelly (1943). However, there has been no work reported on the effect of iron chelates on salt-induced iron chlorosis. The present paper explores the effect of Sequestrine 138-Fe on citrus showing iron-chlorosis symptoms associated with cachexia on various rootstocks, and high soil salinity.

METHODS

The first experiments were concerned with effect of iron chelate on iron-chlorotic cachexia-infected trees growing in calcareous soil. The trees were 12-year-old Red Blush grapefruit on Pina, Suwannee, Sunshine and Sampson tangelos and citrumelo No. 4475 rootstocks growing in the citrus rootstock orchard at the Texas Agricultural Experiment Station, Weslaco. The characteristics of the soil and the design of this orchard were described previously (Cooper and Olson, 1951). All the trees in this orchard carried the cachexia virus (Olson, 1954). The trees on Pina, Suwannee and Sunshine tangelo rootstocks were affected by cachexia, as indicated by pitting and gumming of the rootstock, and showed iron chlorosis in the scion top. The trees on Sampson tangelo and citrumelo No. 4475 rootstocks, although carrying cachexia virus, did not show any rootstock symptoms. The scion tops, however, showed iron chlorosis.

All the trees on a single rootstock variety in this orchard were not uniformly affected with iron chlorosis. Three grapefruit trees on each rootstock variety relatively uniformly affected with iron chlorosis were selected for one experiment. One tree was treated with ½ lb. of Sequestrine 138-Fe and another with 1 lb. and a third was left untreated. Only one chlorotic grapefruit tree on citrumelo No. 4475 rootstock was available, and a 1 lb. application of Sequestrine 138-Fe was used for it. The material was sprinkled over the surface of the ground at the drip line of the tree and chopped into the soil with a hoe.

The second experiment, concerned with salt-induced iron chlorosis, was conducted on 6-month-old sour orange seedlings growing in Crockett's nursery at Weslaco. The soil was slightly calcareous and contained excess salts resulting from irrigating the nursery with well water containing 2800 ppm of total soluble salts. Sour orange seedlings growing in a calcareous soil normally do not show iron chlorosis, but approximately 50% of the leaves on these seedlings showed iron chlorosis on July 14, 1958. The seedlings were spaced 3 in. apart in the nursery row. The Sequestrine 138-Fe was applied in a furrow 6 in. from the seedlings at rates varying from 8 to 170 grams per linear foot of the nursery row.

Table 1. Correction of iron chlorosis in 12-year-old Red Blush grapefruit trees on apparently healthy and cachexia-affected rootstocks by a single application of Sequestrine 138-Fe[a] on April 7, 1958.

Kind of rootstock	Amount of Sequestrine 138-Fe (lbs)	Iron-chlorosis score[b] April 7 1958	May 7 1958	July 15 1958	Feb. 7 1959
Cachexia-affected:					
Pina tangelo	0	3	3	4	5
	½	3	2	0	0
	1	3	2	0	0
Suwannee tangelo	0	5	5	5	5
	½	5	5	5	3
	1	5	3	0	1
Sunshine tangelo	0	5	4	3	3
	½	5	1	1	1
	1	5	3	0	1
Non-affected:					
Sampson tangelo	0	5	3	4	4
	½	3	1	1	1
	1	5	2	0	0
Citrumelo, No. 4475	1	5	3	0	0

[a] Sequestrine 138-Fe contained 6% metallic iron.
[b] Key for scoring iron chlorosis: 0, no iron chlorosis; 1, less than one-fourth of leaves chlorotic; 2, about one-third of leaves chlorotic; 3, about half of leaves chlorotic; 4, about three-fourths of leaves chlorotic; 5, all leaves chlorotic.

Figure 1. Two cachexia-affected Red Blush grapefruit trees on Suwannee tangelo. Tree at top was treated with 1 pound of Sequestrine 138-Fe on April 7, 1958, while tree at bottom was untreated. Photograph taken February 7, 1959.

RESULTS AND DISCUSSION

Sequestrine 138-Fe corrected iron chlorosis on Red Blush grapefruit trees on cachexia-infected rootstock varieties, some of which showed cachexia symptoms and some of which did not (Table 1). This beneficial effect of the iron chelate treatment lasted from April 7, 1958, to February 7, 1959; it is not known how much longer the beneficial effect of the iron chelate will continue. The results shown in Figure 1 are examples of the high degree of the effectiveness of the treatment on February 7, 1959. At this time, the treated trees had two extra flushes of growth and the whole periphery of the tree was luxuriantly green. The untreated trees, on the other hand, were almost completely defoliated from iron chlorosis and had not put out a flush of new growth since April 7, 1958. The trees shown in Figure 1 were on Suwannee tangelo rootstock and were affected with gumming and pitting, characteristic of rootstocks affected with cachexia.

All the trees in this planting, including those on Sampson tangelo and citrumelo No. 4475 rootstocks, were infected with the cachexia virus, but the two latter varieties were tolerant and showed no visible symptoms of the disease. Nonetheless, all the trees of these particular rootstocks in the planting showed iron chlorosis. It is assumed, but not definitely known, that the iron chlorosis on the rootstocks tolerant to cachexia was due primarily to the calcareous soil, while that on the trees affected with cachexia may possibly have been the result of the combined effect of cachexia and the calcareous soil. The results clearly

Table 2. Effect of Sequestrine 138-Fe applied on July 14, 1958, on salt-induced[a] iron chlorosis in 6-month-old sour orange seedlings in nursery row.

Amount of Sequestrine 138-Fe (grams per linear foot of nursery row)	*Iron-chlorosis score[b] on*	
	July 14, 1958[c]	*September 9, 1958[d]*
None	3.5	3.0[e]
Sequestrine 138-Fe:		
½	3.8	1.2[f]
1	3.2	1.5
2½	3.8	1.0
5	3.5	1.5
10	3.2	1.5

[a] Electrical conductivity of solution from saturated soil in the root zone was 3.64 millimohos/cm on July 14, 1958, and 3.03 millimohos/cm on September 9, 1958.

[b] Key to scoring for iron chlorosis: 0, no iron chlorosis; 1, less than one-fourth of leaves chlorotic; 2, about one-third of leave chlorotic; 3, about half of leaves chlorotic; 4, about three-fourths of leaves chlorotic; 5, all leaves chlorotic.

[c] Plants not growing.

[d] Plants with new flush of growth.

[e] Both new and old leaves chlorotic.

[f] New leaves free of chlorosis; old leaves showing some.

indicate, however, that regardless of the cause of the iron chlorosis in this planting, Sequestrine 138-Fe was effective in correcting the disorder.

Results shown in Table 2 indicate that Sequestrine 138-Fe partially corrected iron chlorosis in sour orange seedlings associated with high soil salinity. Presumably, since viruses are rarely shown to be seed transmitted in citrus, no virus was involved in this case. In this experiment, the plants were kept under observation for only 2 months. At the end of the 2-month period, iron chlorosis in the treated plants was greatly reduced as compared with that in the untreated plants. The new flush on the untreated seedlings still showed iron chlorosis, while that of the treated seedlings was free of iron chlorosis. However, some iron chlorosis persisted in the old foliage on the treated seedlings and it is not known whether these leaves completely regreened later.

Although iron chelate may correct or partially correct salt-induced iron chlorosis, iron chlorosis is only one symptom of excess salt. Analysis of the saturated extract of the soil at the end of the 2-month observation period showed an electrical conductivity of 3.03 millimohos per cm., and sour orange seedlings showed 1.2 per cent chloride on a dry weight basis. Thus a salt-excess condition which could injure the plants besides inducing iron chlorosis existed. The recommended procedure for correcting high soil salinity is leaching the soil with water of a low salt content. The partial correction of iron chlorosis in such plants is only of academic interest and has no practical application.

The results of these experiments clearly indicate that Sequestrine 138-Fe is highly effective in correcting iron chlorosis whether the iron chlorosis is associated with cachexia, high soil salinity, calcareous soil, or rootstocks particularly sensitive to iron chlorosis. It appears that iron chelates would be an effective treatment for chlorotic cachexia-affected trees and probably would greatly prolong the productive life of such experimental trees. Iron chlorosis in these experiments, regardless of cause, appears to be basically the result of iron deficiency.

SUMMARY

Twelve-year-old Red Blush grapefruit trees on several rootstock varieties, some of which were affected with cachexia and some not, but all of which showed severe iron chlorosis, were regreened by soil applications of Sequestrine 138-Fe. The regreening persisted for 10 months. Observations have not been made on the trees for a period longer than 10 months.

Iron chlorosis on sour orange seedlings associated with high soil salinity was partially corrected by application of Sequestrine 138-Fe, but toxic effects of excess salts other than iron chlorosis make it necessary to use procedures other than application of iron chelate for the control of high soil salinity.

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Yellow-vein Chlorosis of Old-line and Young-line Red Grapefruit Trees on Various Rootstocks

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INTRODUCTION

Yellow-vein leaf patterns often occur when a branch is partially or entirely girdled, or when roots are injured by foot rot and high water table (Pratt, 1958). Sometimes they are seen also on foliage of uninjured young trees during cool weather, especially in Arizona and California.

In yellow-vein chlorosis the midrib and main lateral veins and a band of leaf tissue bordering them become yellow and the rest of the leaf remains normal green. In iron chlorosis the midrib and veins remain green, and the interveinal areas are yellow. In zinc deficiency the midrib and veins also remain green, whereas irregular areas between the veins are light green to yellow, making a sharp contrast in color. Also, the leaves are often small and narrow. In nitrogen starvation, the entire leaf becomes pale green or yellow. Thus, yellow-vein chlorosis is readily distinguishable from chloroses associated with common nutritional disorders.

The present paper presents some observations on the incidence of yellow-vein chlorosis caused by cool weather and high water table as related to rootstock and to old-line versus young-line red grapefruit trees. In this paper trees that are descended by vegetative propagation from a recently produced nucellar seedling are called young-line, while those that are many years removed from gametic or nucellar seed reproduction are called old-line. The red grapefruit strains now propagated commercially in the Rio Grande Valley were initiated by bud variation on old-line Thompson and Marsh grapefruit trees in the early thirties (Fawcett, 1948) and are herein designated as old-line.

METHODS AND MATERIALS

The chlorosis observations described in this paper were found on grapefruit trees on various rootstocks in 3 different orchards. The first orchard consisted of 12-year-old old-line Red Blush grapefruit trees on 36 kinds of rootstock growing in calcareous soil at the Texas Agricultural Experiment Station, Weslaco. Another old-line orchard consisted of 9-year-old Shary Red grapefruit trees on 69 kinds of rootstock growing in non-calcareous soil at Rio Farms. Monte Alto. The third orchard consisted of 3-year-old trees of both old-line and young-line Red Blush grapefruit trees on 11 kinds of rootstock growing in non-calcareous soil at Rio

Farms. The trees in all 3 orchards were planted in groups of 3 trees of each scion-rootstock variety, the 3-tree groups being randomized in each of 4 blocks. The planting distance was 25 x 25 feet. The characteristics of the soil and the growth and production performance of the trees were described elsewhere (Cooper and Olson, 1951; Cooper, et al, 1957; Cooper and Olson, 1958).

The water-table and winter temperature conditions associated with yellow-vein chlorosis in Texas were described elsewhere in this paper. Some trees in the Experiment Station orchard showed symptoms of both iron chlorosis and yellow-vein chlorosis in the foliage, but they were readily distinguished and both were recorded. Midrib necrosis resulting from freeze injury was also recorded. In the young-line versus old-line orchard, symptoms of zinc deficiency and yellow-vein chlorosis were readily distinguished and recorded.

RESULTS

Yellow-vein chlorosis was observed on trees in the Experiment Station orchard late in 1957 after a 2-week period of cool weather in early December. The minimum temperatures during the 2-week period were generally in the forties, but light frosts occurred on December 1 (minimum temperature 28° F) and December 12 (minimum temperature 26° F). There was no evidence of leaf necrosis in this orchard, but considerable yellow-vein chlorosis occurred on trees on certain rootstocks.

In early January 1958 all trees in the Experiment Station orchard were inspected for yellow-vein chlorosis and iron chlorosis. Eighteen of the 36 kinds of rootstock in this orchard are classified in Table 1 as to their apparent tolerance to conditions inducing these disorders when they are used as rootstocks for virus-infected Red Blush grapefruit. These 18 kinds of rootstock showed no symptoms of virus disorders or were heavily affected. The 18 kinds not shown in Table 1 were only partially affected and did not adequately represent either a clear-cut affected or non-affected population. Most of the rootstock varieties listed in Table 1 showing apparently poor and moderate tolerance to conditions favoring yellow-vein chlorosis are affected with cachexia and exocortis, while most of the varieties showing good tolerance to conditions favoring yellow-vein chlorosis are not affected with the diseases. However, since two cachexia-affected varieties showed good tolerance and the two non-affected varieties showed moderate tolerance, there was no consistent association between virus disease symptoms and severity of yellow-vein chlorosis.

The classification of rootstocks as to tolerance to conditions favoring iron chlorosis showed a greater scattering of affected and non-affected kinds of rootstock in the 3 tolerance groups than occurred for yellow-vein chlorosis. Also, except for the Cleopatra mandarin, rootstocks with good yellow-vein tolerance showed poor iron-chlorosis tolerance and vice versa. The Cleopatra mandarin rootstock showed good tolerance to both disorders.

During December 1958 minimum temperatures in the Experiment Station orchard were generally above 50° F, except for 8 days during the middle of the month when temperatures dropped to 26° F and were accompanied by a light frost. Very little yellow-vein chlorosis was observed following this cold spell, but some leaf injury, especially at and

Table 1. Classification of 18 kinds of citrus used as rootstocks for Red Blush grapefruit trees[a] (carrying cachexia and exocortis viruses) as to tolerance to conditions inducing yellow-vein chlorosis, iron chlorosis and midrib necrosis.

Kind of disorder	*Group I (good tolerance)*	*Group II (moderate tolerance)*	*Group III (poor tolerance)*
Yellow-vein chlorosis[b] 1958	Cleopatra mandarin Citrumelo No. 4475 Sampson tangelo Suwannee tangelo (C)[c] Watt tangelo Pina tangelo (C)	Williams tangelo (E)[c] Minneola tangelo (C) Sour orange Lempum (E) Yalaha tangelo (C) Siamese pummelo Sunshine tangelo (C) Thong dee pummelo	Rangpur lime (E) Satsuma mandarin (C) Sunki mandarin (E) Rough lemon (C)
Iron chlorosis[d] 1958	Sour orange Cleopatra mandarin Lempum (E) Rough lemon (C) Sunki mandarin (E) Thong dee pummelo	Rangpur lime (E) Siamese pummelo Williams tangelo (E) Satsuma mandarin (C) Yalaha tangelo (C)	Sunshine tangelo (C) Citrumelo No. 4475 Minneola tangelo (C) Sampson tangelo Suwannee tangelo (C) Pina tangelo (C) Watt tangelo
Midrib necrosis[e] 1959	Cleopatra mandarin Citrumelo No. 4475 Minneola tangelo (C) Pina tangelo (C) Thong dee pummelo	Sour orange Sampson tangelo Watt tangelo Sunshine tangelo (C) Williams tangelo (E) Suwannee tangelo (C) Lempum (E)	Rough lemon (C) Sunki mandarin (E) Yalaha tangelo (C) Rangpur lime (E) Siamese pummelo Satsuma mandarin (C)

[a] Trees were 12 years old and were growing in calcareous soil at the Texas Agricultural Experiment Station, Weslaco. Some of the rootstocks were affected with symptoms of cachexia and exocortis and others showed no symptoms.

[b] The range in percentage of trees showing yellow-vein chlorosis is 0 to 6 for varieties in Group I, 7 to 31 for Group II, and 32 to 54 for Group III.

[c] The letter C in parenthesis indicates that symptoms of cachexia disease were evident on the rootstock. The letter E in parenthesis indicates that symptoms of exocortis disease were evident on the rootstock.

[d] The range in percentage of trees showing iron chlorosis is 0 to 12 for varieties in Group I, 13 to 62 for Group II, and 63 to 100 for Group III.

[e] The midrib necrosis on each tree was scored from 0 to 5, 0 indicating no freeze injury and 5 indicating nearly all leaves on the tree showing necrosis. The range in score of trees for varieties in Group I was 1.0 to 1.7; Group II, 1.8 to 2.7; and Group III, 2.8 to 3.3.

near the midrib, was observed. The relative severity of this midrib necrosis was scored for each Red Blush grapefruit tree and the citrus rootstock varieties were classified for tolerance to the low-temperature conditions associated with midrib necrosis. Although there are some discrepancies, the rootstock listings for the 3 tolerance groups closely parallel those shown for yellow-vein chlorosis.

Table 2. Incidence of yellow-vein chlorosis in cachexia-, xyloporosis- and exocortis-infected old-line Shary grapefruit trees on various rootstocks (some rootstocks being affected with symptoms of cachexia, xyloporosis, and exocortis diseases, and others showing no symptoms) in an orchard with a water table 40 to 50 inches below the surface during November 1958.

Rootstock group and variety	*Yellow-vein chlorosis score*[a]	*Rootstock group and variety*	*Yellow-vein chlorosis score*[a]
Mandarin:			
Cleopatra	0	Trifoliate orange hybrids:	
Calashu No. 50309	0	Troyer citrange (E)[b]	0
Pong Koa (C)	0.1	Thomasville citrangequat	0
Dancy (C)[b]	0.2	Citrangeor No. 43301	0
Changsha (C)	0.2	Rusk citrange	0.1
No. 117477	0.2	Savage citrange	0.2
Lau Chang	0.3	Citremon No. 46216	0.4
Ponkan	0.4	Citrumelo No. 4475	0.6
Suenkat (C)	0.6	Uvalde citrange	0.6
Oneco (C)	0.8	Rustic citrange	1.1
Sanguinea (C)	1.1	Sanders citrange	2.4
Choa Chou Tien Chieh (C)	1.8		
Tangelo:	0.1	Miscellaneous:	
San Jacinto	0.2	Sour orange	0.1
Webber	0.5	Bergaldin	0.1
Thornton (C)	0.6	Red Blush grapefruit	0.3
Watt	0.6	African pummelo	0.5
Minneola (C)		Rough lemon (C)	1.3
		Kusaie lime (E)	1.4
Sweet orange:		Rangpur lime (E)	1.5
Precoce de valence	0.1	Palestine sweet lime (X)[b]	2.7
Weldon	0.3	Columbian sweet lime (X)	3.1
Pineapple	1.2	Butwal sweet lime (X)	3.1
Cadena de panchosa	1.2		
Hamlin	1.9		

[a] The mean value for 4 replicates. The key to rating the severity of yellow-vein chlorosis was 0, none; 1, limb with chlorosis; 2, approximately one-fourth of tree chlorotic; 3, half of tree chlorotic; 4, neearly all of tree chlorotic.

[b] The letters C, E, and X in parenthesis indicates that symptoms of cachexia, exocortis and xyloporosis diseases, respectively, were evident on the rootstock.

Rainfall from September 6 through November 7, 1958, amounted to 23 inches at the Rio Farms rootstock orchard and was probably nearly the same at the Experiment Station orchard. However, because of certain physical conditions of soil peculiar to the area, a high water table developed in the old-line Shary Red grapefruit rootstock orchard at Rio Farms. The water table in the orchard ranged from 27 to 58 inches on November 11 and continued near this high level for about 1 month and gradually receded to a depth of 72 inches by January 9, 1959. The electrical conductivity of this water averaged about 4 millim-hos per cm.

Yellow-vein chlorosis, identical in appearance with the yellow-vein chlorosis associated with cool weather in the Experiment Station orchard in December 1957, developed in some trees in the Shary Red orchard during November 1958. The average water table reading for the 4 replicates of most of the rootstocks ranged from 40 to 50 inches. The rootstocks which showed an average water-table reading of less than 40 inches or more than 50 inches were eliminated from the data given in Table 2. The yellow-vein symptoms were generally most severe on trees affected with virus diseases. The disorder was especially severe on trees on sweet lime rootstocks affeced with xyloporosis. Trees on Rangpur lime and Kusaie lime rootstocks affected with exocortis and on 5 mandarin varieties and Rough lemon rootstocks affected with cachexia also showed yellow-vein chlorosis. Trees on only 3 of 10 cachexia-affected rootstocks failed to show much yellow-vein chlorosis. Most of the rootstock varieties not affected with virus failed to show yellow-vein chlorosis, but there were some exceptions.

The third rootstock orchard consisted of both young-line and old-line Red Blush grapefruit trees on various rootstocks; it was adjacent to the old-line Shary Red rootstock orchard. The average height of the water table during November 1958 in this orchard was 36 inches. Yellow-vein chlorosis did not occur on the young-line trees even when grown on Columbian sweet lime and Rangpur lime rootstocks. On the other hand, the disorder did occur on adjacent virus-affected old-line trees of the same variety on the same rootstocks (Table 3).

Zinc-deficiency symptoms were evident on most of the trees in this orchard. Although the zinc-deficiency symptoms were more severe on trees on some rootstocks than on others, there was no indication that trees on virus-affected rootstocks are more susceptible to the disorder. There was less zinc-deficiency on trees affected with exocortis and xyloporosis than on virus-free nucellar trees on the same rootstocks. The average score for zinc deficiency for young-line trees on all rootstocks was the same as that for old-line trees.

The leaves on all trees in the young-line versus old-line rootstock orchard were analyzed for chlorides in early January 1959. The chloride data, presented elsewhere (Cooper and Peynado, 1959), did not show any evidence that chlorides accumulated in these trees during the high-water-table period.

Table 3. Incidence of zinc-chlorosis and yellow-vein chlorosis in young-line and old-line[a] Red Blush grapefruit trees[b] on various rootstocks in an orchard with a water table 36 inches below the surface during November 1958.

Rootstock and Red Blush line	*Zinc chlorosis score[c] Nov. 30, 1958*	*Yellow-vein chlorosis score[c] Nov. 30, 1958*
Sour orange: young line	1.2	0
old line	1.0	0.5
Cleopratra mandarin: young line	0.6	0
old line	0.3	0
Dancy mandarin: young line	0.8	0
old line	0.8	0
Suenkat mandarin: young line	0.4	0
old line	0.7	0.3
Sunki mandarin: young line	0.2	0
old line	0.8	0
Taiwanica: young line	0	0
old line	1.3	0
Sunshine tangelo: young line	0.6	0
old line[e]	1.3	0
Rangpur lime: young line	1.8	0
old line[d]	0.5	1.9
Columbian sweet lime: young line	1.2	0
old line[e]	0.6	1.7
Rough lemon: young line	0.2	0
old line	0.2	0
Carrizo citrange: young line	2.8	0
old line	2.4	0.1
Mean: young line	0.9	0
old line	0.9	0.4

[a] Carries cachexia and exocortis viruses.
[b] Trees planted January 4, 1956.
[c] Mean value for 4 replicates. The key to rating severity of zinc and vein-chloroses was: 0, no chlorosis; 1, one limb shows chlorosis; 2, approximately one-fourth of tree chlorotic; 3, half of tree chlorotic; 4, whole tree chlorotic; 5, some defoliation.
[d] Bark exfoliation of rootstock characteristic of exocortis disease.
[e] Pitted and gummiferous rootstock characteristic of cachexia disease.

DISCUSSION

Cold-weather-induced yellow-vein chlorosis seems to be closely related to midrib necrosis; neither are associated with iron chlorosis. While the data are inadequate to indicate the exact climatic conditions which favor yellow-vein chlorosis rather than midrib necrosis, it seems probable that a prolonged cool spell in early December favors the development of yellow-vein chlorosis.

There also appears to be a close similarity between high-water-table-induced and cold-weather-induced yellow-vein chlorosis. In both instances the disorder was generally more severe on trees on virus-affected rootstocks. Since all trees in the two old-line orchards carried viruses, it does not appear that the presence of the viruses was a major contributing factor. In these experiments the trees that show yellow-vein chlorosis are principally those on virus-intolerant rootstocks affected with exfoliation symptoms of exocortis, pitting symptoms of xyloporosis, and pitting and gumming symptoms of cachexia. The sweet lime and Rangpur line strains of rootstocks budded with old-line virus-containing scions were the most severely affected with yellow-vein chlorosis in these experiments. The root systems of such virus-infected trees were probably weaker than those of the more tolerant rootstocks, and the weak root system may be the basic cause of yellow-vein chlorosis rather than the virus itself. The striking absence of yellow-vein symptoms on virus-free young-line trees on the same sweet lime and Rangpur lime strains is evidence that the rootstock itself is not at fault. However, the weak virus-affected rootstocks were susceptible. Probably a tree on any rootstock affected with either a virus or a fungus disease may be potentially susceptible. The high incidence of yellow-vein chlorosis on trees on Hamlin and Cadena de panchosa sweet orange rootstocks illustrates the susceptibility of foot-rot-affected but not virus-affected trees to yellow-vein chlorosis. The trees on Precoce de valence sweet orange rootstock are apparently free of foot rot in this particular orchard and did not show the yellow-vein disorder.

SUMMARY

The incidence of yellow-vein chlorosis, midrib necrosis, iron chlorosis, and zinc-deficiency chlorosis in red grapefruit foliage was observed in 3 different rootstock orchards. Some of the trees were on rootstocks affected with viruses; others carried viruses but showed no disease symptoms, while other trees in one orchard were virus-free young-line trees. Yellow-vein chlorosis associated with cool weather in early December was generally more severe on trees affected with virus diseases, but there were some exceptions. Yellow-vein chlorosis associated with a high water table was generally most severe on trees affected with virus diseases, while it did not occur on virus-free young-line trees and on some virus-infected trees showing no disease symptoms. The cause of the yellow-vein symptom in these experiments is believed to be the weak root systems resulting from the virus infection of intolerant rootstocks.

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Chloride and Boron Tolerance of Young-line Citrus Trees on Various Rootstocks

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Accumulation of chloride and boron in the leaves of grapefruit and orange trees is conditioned by the rootstock (Cooper et al, 1951; 1952; 1955; Cooper and Gorton, 1952). In these experiments old-line (many years removed from gametic or nucellar seed reproduction) Red Blush grapefruit and Valencia orange were used as scions. Recent studies showed that young-line (descended by vegetative reproduction from a recently produced nucellar seedling) trees have greater vigor than old-line trees (Bitters et al, 1956; Cooper et al, 1958) and that after the first 10 years the young-line trees may produce larger yields of fruit. Also yellow-vein chlorosis induced by a high water table was associated with old-line trees on virus-affected rootstocks and did not occur on young-line trees on the same rootstocks (Cooper et al, 1959).

Most of the old-line commercial citrus varieties originated as seedlings and have been vegetatively propagated for many years. During this vegetative propagation, usually by budding, an assortment of viruses have been introduced into old-line varieties. These viruses in trees on non-virus-tolerant rootstocks cause exfoliation, gumming and wood pitting of the rootstock and decline in tree vigor (Olson and Shull, 1956). There is also evidence that the presence of viruses in lemon trees on a so-called tolerant rootstock decreases the vigor of growth and productiveness of the tree even though there is no evidence of exfoliation (Calavan and Weathers, 1959). Since the growth habits of the young-line grapefruit trees and old-line trees of the same varieties are different, it seemed desirable to determine whether certain characteristics of rootstocks with old-line tops are the same if young-line tops are used. The present paper is concerned with a comparison of the toxicity and accumulation of chloride salts in young-line and old-line Red Blush grapefruit trees on various rootstocks. In one experiment the toxicity of and accumulation of boron as well as chloride salts in young-line Red Blush grapefruit trees on various rootstocks were investigated.

METHODS AND MATERIALS

The present study was concerned with 3 citrus plantings. One consisted of a 3-year-old orchard of young-line and old-line Red Blush grapefruit trees on 11 kinds of rootstock planted at 25- x 25-foot spacing in 3-tree plots of 4 replicates of each rootstock. This orchards was irrigated 6 times annually with Rio Grande river water. A 36-inch water table occurred in this orchard during November and December 1958 following 23 inches of rain in September and October 1958. The water in the water table contained approximately 3000 ppm of total salts and 3 ppm of boron and had a sodium percentage of 60.

In another experiment, 1-year-old young-line Red Blush grapefruit trees on 13 kinds of rootstock were planted at a 10- x 10-foot spacing and were irrigated with Rio Farms well water 7 times between March and September 1958. Control trees irrigated with river water were not included in this experiment. There were four 1-tree replicates of each rootstock.

In a third experiment, 1-year-old exocortis- and cachexia-free old-line and young-line Valencia orange trees on sour orange rootstock were planted 5 feet apart in single-tree, 36-inch diameter, circular plots bounded by galvanized iron 30 inches deep in the soil. The irrigation treatments consisted of river water alone or with added sodium chloride. The mechanics of preparing the salt solutions and method of applications to the soil are described elsewhere (Cooper et al, 1951). The plots were irrigated 4 times from June 24 to September 3, 1958, with 4 acre-inches of the various salt solutions at each irrigation.

The river water used in these experiments contained approximately 700 ppm of total soluble salts and 0.2 ppm of boron and had a sodium percentage of 50. The Rio Farms well water contained 3300 ppm of total soluble salts and 5.5 ppm boron and had a sodium percentage of 85. The sodium chloride solutions used in the third experiment just described contained 3000, 4000, and 5000 ppm of total salts, respectively; all the salt except the 700 ppm of salt in the base water supply, which was approximately 50 per cent sodium chloride, was sodium chloride.

Leaf samples were collected from the trees at times indicated in Tables 1 to 3. The samples consisted of 10 spring-flush leaves from each tree. The leaves of all trees of each replicate were lumped into a composite sample. Leaf preparation and analysis for chloride and boron were described elsewhere (Cooper et al, 1952).

Circumferences of the tree trunks of 4 inches above the bud-union were measured at the beginning and the end of the various salinization periods. These measurements were converted to area of cross-section, and these values were used as an index of the size of the tree.

RESULTS AND DISCUSSION

The high water table in the young-line versus old-line Red Blush rootstock orchard during November and December 1958 was not accompanied by excessive chloride accumulation in the trees (Table 1). The maximum concentration of chloride found in the foliage was .21 per cent for old-line trees on Columbian sweet lime rootstock. There was no evidence of bronzing and necrosis on the leaves of any trees; usually concentrations near 1 per cent are required for necrosis. The generally cool weather during this period probably accounts for the lack of excessive chloride accumulation. The mean minimum and mean maximum air temperature for November 1958 were 60° and 77° F, respectively, and

Table 1. Effect of rootstock on chloride accumulation in and growth of 3-year-old young-line and old-line Red Blush grapefruit trees in an orchard with a high water table during November and December 1958.

Rootstock and Red Blush line	*Chloride content of dried leaves, (%) Jan. 9, 1959*	*Cross-sectional area of trunk, (cm²) Nov. 18, 1958*
Texas sour orange:		
young line	.08	9.6
old line	.07	8.6
Taiwanica sour orange:		
young line	.06	10.4
old line	.06	8.6
Cleopatra mandarin:		
young line	.06	10.4
old line	.07	8.2
Dancy mandarin:		
young line	.08	9.5
old line	.08	7.0
Suenkat mandarin:		
young line	.06	10.0
old line	.07	7.8
Sunki mandarin:		
young line	.06	10.0
old line	.07	7.5
Sunshine tangelo:		
young line	.09	11.6
old line	.09	8.2
Rangpur lime:		
young line	.07	13.9
old line	.10	7.9
Columbian sweet lime:		
young line	.09	14.8
old line	.21	6.4
Rough lemon:		
young line	.09	10.3
old line	.11	7.9
Carrizo citrange:		
young line	.18	12.2
old line	.20	6.8
Mean:		
young line	.08	11.2
old line	.10	7.7

for December 1958 were 48° and 67° F, respectively.

There was generally about 20% more chloride in the foliage of old-line trees than in that of young-line trees; more chloride accumulated in the foliage of trees on Columbian sweet lime and Carrizo citrange rootstocks than in the foliage of trees on other rootstocks. In general the lower chloride content of leaves on young-line trees is correlated with the increased size of the young-line trees. The vigorous young-line trees, which average 32 per cent larger than old-line trees, had more foliage than the old-line trees; probably the total chloride accumulation per tree may have been even greater for the young-line trees.

The data in Table 2 illustrate more clearly the relative chloride and boron tolerance of young nucellar-line grapefruit trees on various rootstocks. In this experiment the trees were irrigated all summer with a saline water contaminated with boron. There were no old-line control trees, but the effect of rootstock in conditioning the chloride and boron tolerance is striking and is similar to that reported earlier (Cooper et al, 1951) for the old-line trees on the same rootstock varieties. The trees on the Carrizo, Savage and Troyer citranges and *Citrus moi* rootstocks accumulated excessive amounts of both chloride and boron. Leaf necrosis and defoliation occurred in late August and appeared to be caused primarily by the high cloride content of the leaves; foliage on other trees on other rootstocks containing equal amounts of boron but little chloride did not defoliate until several months later. Thus, though excessive boron accumulation occurred in the foliage of these trees, the early toxic symptoms observed on the foliage were probably caused by chloride ions.

The foliage of trees on sour orange, Ponkan mandarin, citrumelo No. 4475, and Columbian sweet lime accumulated a moderate amount of chloride and an excessive amount of boron; defoliation occurred late in the fall and was probably caused primarily by boron accumulation. Foliage of trees on Cleopatra, Timkat and Sunki mandarins and Rangpur lime accumulated little chloride and excessive amounts of boron; the toxic symptoms were those of boron injury.

The foliage of trees on *Citrus macrophylla* showed no toxic symptoms of either excess boron or chloride. The data given in Table 2 show relatively little boron accumulation but moderate chloride accumulation in the foliage of trees on this rootstock; the chloride content of the leaves was near the point (about 1 per cent) at which chloride toxicity is expected. It therefore appears that *Citrus macrophylla* has good boron tolerance but only moderate chloride tolerance. Bitters (1958) also reports superior boron tolerance for *Citrus macrophylla* as a rootstock for citrus.

It is obvious from these data that a tree on a certain rootstock may be an accumulator of chloride, but not of boron, and vice versa. Since tolerance of the tree to these constituents is related to the amount of the constituents accumulated, chloride and boron tolerance of a given rootstock are not necessarily concomittant. None of the rootstocks in-

Table 2. Effect of rootstock on growth, toxicity symptoms of chlorides and boron in young-line Red Blush grapefruit trees planted February 18, 1958 and irrigated with 28-acre-inches of Rio Farms well water between March and September 1958[a].

Kind of rootstock	*Cross-sectional area of trunk on 4/24/58 (cm²)*	*Increase in cross-sectional area of trunk from 4/24 to 11/19/58 (cm²)*	*Boron content of leaves (8/6/58) (ppm)*	*Chloride content of leaves (8/6/58) (%)*	*Severity of toxicity symptoms (12/19/58) and apparent cause[b]*	
Sour orange	174[c]	105[c]	786	.46[c]	3.3[c]	Boron
Cleopatra mandarin	194	66	1134	.22	4.0	Boron
Timkat mandarin	950	26	899	.12	4.5	Boron
Ponkan mandarin	406	20	1174	.66	4.5	Boron
Sunki mandarin	1825	81	787	.10	4.0	Boron
Carrizo citrange	140	33	742	2.11	4.0	Chloride
Savage citrange	652	31	939	1.34	4.5	Chloride
Troyer citrange	364	32	873	2.43	4.5	Chloride
Citrumelo No. 4475	121	158	904	.83	4.5	Boron
Citrus macrophylla	35	92	282	.67	0	....
Citrus moi	361	168	521	1.69	1.3	Chloride
Columbian sweet lime	2987	123	762	.79	3.3	Boron
Rangpur lime	2819	95	854	.40	4.3	Boron

[a] Twenty-four inches of rain fell during September, October, and November, 1958.

[b] Most of the trees showed combined boron and chloride toxicity symptoms. However, where chlorides were accumulated in excess, the leaves burned and dropped off by mid-summer. Boron toxicity, on the other hand, was a slower process. The leaves first showed yellow dots, then orange-mottling and tip burn and finally defoliation in late fall and winter. Where chloride accumulation was only moderately high, bronzing was frequently the only symptom that developed; but when boron mottling was superimposed on bronzing, it was difficult to distinguish the two symptoms. The key used for scoring of severity of toxicity symptoms was as follows: 1, some yellow dots and/or slight bronzing; 2, numerous yellow dots, orange-mottling of leaf tip and/or moderate bronzing; 3, prominent orange-mottling and/or bronzing; 4, leaf necrosis; 5, defoliation and twig necrosis.

[c] The values given represent the mean of 4 single-tree replicates.

Table 3. Effect of NaCl additions to irrigation water (16 acre-inches applied between June and September, 1958)[a] on growth, chloride accumulation and chloride-toxicity symptoms on young-line and old-line Valencia orange trees planted February 18, 1958.

NaCl treatment and Valencia orange line	*Cross-sectional area of trunk on 6/24/58 (cm^2)*	*Increase in cross-sectional area of trunk from 6/24 to 11/19/58 (cm^2)*	*Chloride content of leaves 8/15 1958*	*Chloride content of leaves 11/13 1958*	*Severity of chloride toxicity symptoms[b] (12/19/58)*
Base river water control:					
young line	162	258	.07	.12	0
old line	163	151	.18	.13	0
3000 ppm NaCl:					
young line	174	213	1.10	1.06	.8
old line	155	131	1.24	1.02	.5
4000 ppm Nacl:					
young line	200	184	1.06	.86	.8
old line	188	120	1.30	1.27	1.2
5000 ppm NaCl:					
young line	176	182	1.68	1.44	3.0
old line	180	96	1.87	1.69	2.2
Mean:					
young line	180	209	.98	.87	1.2
old line	171	125	1.14	1.03	1.0

[a] Twenty-four inches of rain fell during September, October, and November, 1958.

[b] Key for scoring chloride-toxicity symptoms: 0, no symptoms; 1, slight bronzing; 2, moderate bronzing; 3, severe bronzing and slight necrosis; 4, severe necrosis.

cluded in this experiment appeared to be able to exclude from the tree excessive amounts of both chloride and boron. The *Citrus macrophylla* rootstock excluded boron, while Cleopatra mandarin rootstock excluded chloride, but *Citrus macrophylla* took up moderate amounts of chloride while Cleopatra mandarin took up large amounts of boron. Of the two rootstocks, *Citrus macrophylla* was the most tolerant to the Rio Farms well water.

Toxicity and accumulation of chloride salts in the foliage of young-line and virus-free old-line Valencia orange trees on sour orange rootstock are shown in Table 3. In general, chloride accumulation in the leaves was proportional to the sodium chloride content of the irrigation water. Chloride accumulation was less in the young-line trees than in the old-line trees, but as in the first experiment (Table 1) this lower chloride content of the leaves is associated with a larger tree size and a larger leaf area; the actual chloride accumulation per tree probably is greater in the young-line trees. Leaf necrosis as a result of chloride accumulation was not severe except on trees in the 5000 ppm NaCl treatment and was slightly more severe for the young-line trees than the old-line trees. The young-line trees in all treatments grew more than the old-line trees, but the difference was approximately the same for control and salt treatments. The higher salt treatments, however, decreased growth of both old-line and young-line trees in direct proportion to the concentration of salt in the water.

These data indicate that under the conditions of these tests there is no appreciable difference in the effect of salt on old-line and young-line trees. However, the inherent vigor of the young-line trees might possibly give greater salt tolerance under more severe salt conditions. The present experiment was halted by rains after only 3 months (June, July and August) of salt treatment.

SUMMARY

In general chloride accumulation in the leaves was of the same relative magnitude as the salt content of the irrigation water. Chloride accumulation was less in the young-line trees than in the old-line trees, but this lower chloride content of the leaves of young-line trees was associated with a larger tree size and a larger leaf area.

Salt treatments decreased growth of both young-line and old-line trees in the same relative magnitude as the concentration of salt in the irrigation water; the decreased growth of young-line and old-line trees was approximately the same.

Trees on certain rootstocks may be accumulators of chloride, but not of boron, and vice versa. Since the tolerance of the tree to these constituents is related to the amount of the constituents accumulated, salt and boron tolerance of a given rootstock are not necessarily concomitant. The Cleopatra, Timkat and Sunki mandarin rootstocks excluded chloride but accumulated boron; the citranges accumulated both chloride and boron; and *Citrus macrophylla* excluded boron but accumulated chloride. None

of the rootstocks included in these experiments appeared to be able to exclude both chloride and boron.

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Effect of Grasses and Mulches on Soil Moisture Losses and Soil Temperature Changes in the Lower Rio Grande Valley of Texas

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Conservation of moisture is important to farmers throughout the United States because available soil moisture and supplies of water for supplemental irrigation are often limited. A major portion of crop production in the Lower Rio Grande Valley of Texas is dependent upon supplemental irrigation. Because water for irrigation is often scarce, citrus growers are especially interested in the influence of various covers on the water requirements of their orchards.

In the spring of 1955 an experiment was initiated on a Willacy fine sandy loam soil to study the influence of tillage, a straw mulch and grass upon soil moisture losses and/or utilization and upon soil temperature changes. Penman (1948) and Hyde (1954) have studied and discussed the mechanisms of evaporation and evapo-transpiration. Russell (1950) gives an excellent review of the influence of soil covers on soil temperatures.

The soil and straw mulches were kept approximately 3 inches thick. These plots were kept relatively clean of vegetation. In the fall of 1958 the dust-mulched plots were split to include both mulched and unmulched soil surfaces.

Common bermuda grass (*Cyanadon dactylon*) is the predominant grass on these plots. In the fall of 1958 the grass plots were split to include a non-fertilized and fertilized treatment. Half of the plots were fertilized with 90 pounds of nitrogen per acre 4 to 6 times a year. These grass plots were mowed 4 to 6 times a year.

Soil thermographs were installed at 3- and 9-inch depths under the various covers to determine the effect of covers on soil temperatures. A soil thermograph was also installed at 1-inch depth in the dust-mulched plots. An air thermograph was used also at the site to measure air temperature changes.

Average soil moisture losses and/or utilization in inches per day from March, 1955, through February, 1958, are indicated in Table 1. The results indicate that soil-mulched plots lost slightly more moisture than the straw-mulched plots. Results from November, 1957, through December, 1958, show that the soil-mulch plots lost slightly less moisture than the straw-mulch plots. Variations in climatic conditions no doubt influence which mulch is most effective in conserving moisture. Moisture losses and/or utilization from the grass plots were significantly higher than from the straw- and soil-mulch plots as indicated in Tables 1 and 2. Fertiliza-

Table 1. Soil moisture losses under soil mulch, straw organic, mulch and grass cover during different months at Weslaco, Texas.[1]

	Moisture losses – Inches/day			
	Type of Cover			*Evaporation from an open pan*[2]
Months	*Soil Mulch*	*Straw Mulch*	*Grass*	
January	0.08	0.08	0.08	0.10
February	0.13	0.10	0.11	0.12
March	0.12	0.09	0.12	0.16
April	0.07	0.08	0.11	0.18
May	0.10	0.10	0.14	0.20
June	0.11	0.10	0.19	0.23
July	0.11	0.10	0.20	0.27
August	0.11	0.14	0.21	0.28
September	0.12	0.10	0.16	0.17
October	0.10	0.12	0.13	0.17
November	0.10	0.09	0.11	0.15
December	0.07	0.06	0.06	0.10
AVERAGE	0.11	0.10	0.14	0.18
Average total loss/year—Inches	40.2	36.5	51.1	65.7

[1] Average of three replications and four years data.
[2] From a Class A standard Weather Bureau type pan (average of three years).

tion of the grass caused a substantial increase in moisture utilization as indicated in Table 2. Excessive rainfall during the month of February in 1958 made it impossible to determine moisture losses and/or utilization. Excessive rainfall during the months of September and October caused moisture losses under the mulched plots to be higher than normal. Some of the losses reported (particularly under the mulched plots) were due to water movement below 5 feet. The results in Tables 1 and 2 indicate that soil mulching was effective in conserving soil moisture.

In areas where supplemental irrigation is often limited (or lacking), it is important to consider trends in moisture losses and/or utilization. These data are particularly pertinent with respect to orchard management in the Rio Grande Valley. Many farmers have a limited supply of water with which to maintain productive orchards. It is important, therefore, to understand what effect different management practices will have on moisture requirements of citrus trees. It is apparent from evapotranspiration[1] results that grass-covered orchards will require more water for continued production. Fertilization of grass-covered orchard would also increase moisture utilization. Grass-covered orchards will probably require more frequent irrigation and fertilization to maintain top produc-

[1] Evapo-transpiration refers to total moisture used in evaporation and transpiration.

tion. On the other hand, a soil-mulch system would require frequent cultivation to maintain an adequate mulch. The best management from the standpoint of the grower will depend upon: (1) the availability of good quality water, and (2) the cost of upkeep of the orchard cover. Obviously, the importance that must be attached to the above factors will depend upon whether an ample supply of irrigation water is available.

Average soil temperatures for the various months under the different soil covers at 3 and 9 inches are indicated in Table 3. A soil mulch tended to cause higher average soil temperatures during the summer months. Grass covers (bermuda) resulted in lower average soil temperatures during the summer and resulted in higher average soil temperature during the winter months. The greatest daily fluctuation in soil temperatures occurred at 3 inches under the soil-mulched plots with very small variations occurring under grass. The greatest fluctuations in soil temperatures during the day occurred at the 1-inch depth under the soil-mulched plots. Soil temperatures at the 1-inch depth were not determined under the straw-mulched and grass-covered plots. The straw-mulched plots were intermediate with respect to high temperatures and temperatures fluctuation during the day. Only slight fluctuations in soil temperatures oc-

Table 2. Soil moisture losses at Weslaco, Texas, during different months as influenced by soil surface treatments and fertilization of grass cover.[1]

	Moisture losses—Inches/day				
	Soil Surface			*Grass*	
Month	*Mulched*	*Not-mulched*	*Straw mulch*	*Non-fertilized*	*Fertilized*[2]
1957					
November	0.18	0.20	0.17	0.18	0.21
December	0.08	0.04	0.05	0.06	0.10
1958					
January	0.08	0.11	0.11	0.13	0.15
March	0.07	0.06	0.03	0.10	0.09
April	0.06	0.09	0.10	0.14	0.18
May	0.14	0.19	0.19	0.16	0.17
June	0.04	0.11	0.10	0.18	0.20
July	0.14	0.12	0.08	0.21	0.20
August	0.04	0.11	0.17	0.21	0.22
September	0.18	0.18	0.20	0.22	0.23
October	0.20	0.21	0.16	0.15	0.18
November	0.02	0.03	0.04	0.07	0.07
December	0.05	0.04	0.05	0.06	0.06
AVERAGE	0.10	0.11	0.11	0.14	0.16

[1] Average of three replications.
[2] Fertilized plots received 90 pounds of N acre 3 to 4 times a year.

Table 3. Average daily soil temperature at different depths as influenced by soil mulch, straw organic mulch, grass cover and time of year.

	Temperature °F							
	Soil Mulch			Straw Mulch		Grass		
	Soil depths			Soil depths		Soil depths		
Months	1"[1]	3"[2]	9"[2]	3"[3]	9"[3]	3"[3]	9"[3]	Air temperature[2]
January	61.0	63.1	61.7	60.1	60.2	62.0	61.9	61.1
February	63.7	63.8	63.1	61.7	60.4	64.4	64.5	66.9
March	69.9	68.3	67.3	63.8	63.0	65.6	65.7	71.7
April	79.8	77.5	76.8	75.2	70.3	71.7	71.0	76.3
May	87.3	84.6	82.4	78.7	72.8	77.7	76.7	77.7
June	89.5	89.9	86.3	82.9	75.6	79.7	79.1	82.4
July	90.2	91.1	87.8	84.8	79.3	78.1	81.0	84.8
August	90.5	91.7	88.5	83.9	79.1	81.5	80.8	83.4
September	85.1	83.8	82.0	82.2	77.0	79.6	78.9	81.8
October	78.8	76.4	75.6	75.2	70.7	73.7	73.4	76.4
November	69.9	67.6	68.3	67.9	62.3	69.1	68.6	69.4
December	63.2	60.7	60.8	60.4	58.1	63.8	63.8	62.7

[1] Average of 3 years
[2] Average of 4 years
[3] Average of 3 years

curred at soil depths of 9 inches under all covers. However, the grass cover showed the least daily fluctuations and the soil-mulch cover the greatest.

The influence of soil temperatures upon citrus growth and development have not been fully evaluated. However, from the soil temperature data, speculative influences may be as follows: (1) higher average soil temperatures during the spring and summer under the soil mulch plots may cause the citrus trees to start growing earlier in the spring and summer; (2) higher (average) soil temperature under grass sod (bermuda) during the winter may be helpful in minimizing freeze damage.

The data presented show that mulched irrigated sandy loam soils in the Lower Rio Grande Valley of Texas lost less soil moisture than irrigated soils which had a grass cover. A four-year average showed that a grass cover required over 20 per cent more moisture than the soil mulched surface and over 30 per cent more than the straw mulched surfaces. This is particularly pertinent concerning the influence of covers on moisture requirement of fruit orchards. Moisture loss and/or utilization under the various mulches may vary somewhat differently under other soil types.

Soil covers had a definite influence on soil temperature and may have an important influence on the growth and development of citrus trees in the Lower Rio Grande Valley.

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Relation of Cultural Practices to Soil Moisture Depletion In a Young Citrus Orchard

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Three general systems of cultural management are used in orchards: cultivation, non-cultivation, and organic mulching. Each is subject to a number of modifications. Cultivation may vary from repeated diskings, in which no weed growth is permitted, to disking once or twice a year. Non-cultivation may include a system of sod culture with the grass being mowed regularly throughout the growing season or being mowed only when necessary to facilitate other orchard operations. Non-cultivation may also be combined with chemical weed control in which the surface is kept bare through the use of chemicals but is otherwise undisturbed. Mulching may be accomplished by the addition of material brought in from elsewhere or by the use of crop residues grown in the orchard.

Many studies deal with cultural practices and soil moisture in deciduous orchards in non-irrigated areas. References to such work in irrigated citrus orchards are less numerous. In Arizona chemical weed control reduced the permeability of the surface soil in citrus orchards while continuous cultivation resulted in the development of a plow sole 6 to 10 inches below the surface which retarded the movement of water into the soil (Hilgeman and Van Horn 1955). Reducing tillage operations from 12 diskings a year to only 2 diskings a year has increased the infiltration rate twelvefold in Orange County, California citrus groves (Schoonover and Batchelor 1948). Under Lower Rio Grande Valley conditions trees and cover crops or weeds may compete for moisture (Friend, 1956).

The work reported here was undertaken to evaluate the relationship between cultural practices and the depletion of soil moisture in a young citrus grove under Lower Rio Grande Valley conditions. Soil moisture levels during May to September, a critical period during the irrigation season, are reported.

METHODS

Four cultural practices are being compared in a block of Webb Redblush grapefruit on a Hidalgo clay loam soil at the Texas A&I College Citrus Center, Weslaco. Individual plots are 4 rows wide with 30 trees in each row. The practices, in effect since 1953, are:

1. non-cultivation with cover crop (cover mowed or shredded as needed)
2. mulch of cotton gin trash with no cultivation (weeds mowed or shredded as needed)

3. chemical weed control with no cultivation (weeds killed by oil spray)
4. cultivation (weeds disked under 6 to 8 times a year)

From 1953 to 1956 a surface mulch of cotton gin trash at the rate of 20 tons an acre a year was applied to one plot. In the spring of 1957 a nutritional imbalance, which has increased in severity with time, became evident on this plot. Data from the gin-trash plot has therefore not been included in this report since the trees are not comparable to trees on the other plots.

The non-cultivated plot was originally seeded to Hubam clover. By permitting the clover to go to seed each year the stand has been maintained. Five years of mowing clover and weeds has resulted in this plot being covered with a 2 to 3 inch mulch of plant residues in various stages of decomposition.

The cultivated plot is usually disked just prior to irrigation and at any time during the winter months when the size of the weed cover indicates the need.

To achieve effective chemical weed control it has been necessary to spray about one week after irrigation or heavy rain.

Trunk-diameter measurements of 2-year-old trees in 1955 revealed a maximum difference of 9 per cent. Presently tree size is believed to be correspondingly uniform on the 3 plots. On the basis of foliar analysis the plots are nutritionally uniform.

An overhead-sprinkler system provided all plots with an equal amount of water. Initially it was desired to supply irrigation when available soil moisture had been reduced to 30 per cent at the 18 to 24 inch depth in any plot. The local water situation has not permitted scheduling the plots on an individual basis. In practice it has been necessary to irrigate all plots when the driest plot needed water.

Soil samples were taken at 6 to 12 and 18 to 24 inch depth for the gravimetric determination of soil moisture. The sampling area consisted of sub-plots of 400 square feet located in the same relative position in each of the main plots. Triplicate samples were taken from both depths at weekly intervals from May to September.

RESULTS

Tables 1 and 2 present the per cent soil moisture (oven-dry basis) at the 6 to 12 and 18 to 24 inch depths respectively on the sampling date following and prior to each irrigation or effective precipitation.

Following irrigation on April 28 the non-cultivated plot had a vigorously growing stand of Hubam clover and the cultivated plot an active stand of careless weed (Amaranthus sps). On May 2 at the 6 to 12 inch depth the lowest per cent soil moisture was found on the non-cultivated plot. At 18 to 24 inches the non-cultivated and the chemical-weed-control

Table 1. Per cent soil moisture (oven-dry wgt.) at the 6 to 12 inch depth in plots under various cultural practices in a young citrus grove on Hidalgo clay loam soil May through September 1958.

Sampling Date	No cultivation plus cover crop	Chemical weed control with no cultivation	Cultivation
	Percent soil moisture (oven-dry wgt.)		
4-28-58		Irrigated	
5-2-58	18.4	18.9	19.4
5-27-58	15.3	14.3	14.5
6-2-58		Irrigated	
6-9-58	22.2	16.4	17.7
6-20-58	19.0	14.6	15.4
6-27-58		4" Precipitation	
7-1-58	25.1	17.8	21.0
7-28-58	16.9	14.6	14.1
7-30-58		Irrigated	
8-5-58	21.6	17.8	19.2
9-1-58	16.1	13.0	13.5

Table 2. Per cent soil moisture (oven-dry wgt.) at the 18 to 24 inch depth in plots under various cultural practices in a young citrus grove on Hidalgo clay loam soil May through September 1958.

Sampling Date	No Cultivation plus cover crop	Chemical weed control with no cultivation	Cultivation
	Percent soil moisture (oven-dry wgt.)		
4-28-58		Irrigated	
5-2-58	17.4	17.1	18.9
5-27-58	13.3	15.9	14.7
6-2-58		Irrigated	
6-9-58	18.3	16.0	16.6
6-20-58	16.9	14.1	14.0
6-27-58		4" Precipitation	
7-1-58	22.3	16.2	19.3
7-28-58	15.8	15.0	14.6
7-30-58		Irrigated	
8-5-58	20.5	18.2	18.5
9-1-58	14.3	13.0	12.9

plots contained nearly the same per cent soil moisture while the cultivated plot was at a considerably higher value. During May at the 6 to 12 inch depth the non-cultivated plot seemed to show the least soil-moisture depletion. At 18 to 24 inches both the non-cultivated and cultivated plots showed considerable moisture depletion while the chemical-weed-control plot showed very little depletion.

On May 29 weeds in the chemical-weed-control plot were sprayed and weeds in the cultivated plot disked under. The non-cultivated plot was not mowed as it was desired to permit the clover to go to seed. All plots were irrigated on June 2.

Samples taken one week after this irrigation suggest that soil moisture was restored to a higher level on the non-cultivated plot than on either of the others at both depths. One June 20, eighteen days after irrigation, the non-cultivated plot still had a higher per cent soil moisture than did the others in spite of the heavy stand of clover.

On June 27 a 4-inch rain occurred. The sampling of July 1 reveals large differences in the per cent soil moisture at both depths on the various plots. Again the non-cultivated plot contained the highest per cent soil moisture and the chemical-weed-control plot the lowest.

All plots were moved, disked, or sprayed according to the differential treatments on July 7. The heavy mulch resulting from the mowing of the clover on the non-cultivated plot controlled weed growth and regrowth of clover for about two weeks. By mid-July the cultivated plot was supporting a stand of careless weed and grasses were invading the chemical-weed-control plot. On July 28 the most favorable moisture conditions at the 6 to 12 inch depth existed on the non-cultivated plot. At the 18 to 24 inch depth the differences between plots were small.

All plots were irrigated on July 30. Four days following irrigation the non-cultivated plot again had the highest per cent soil moisture and the chemical-weed-control plot the lowest at both depths. During August all plots were supporting actively growing weed cover: Johnson grass on the non-cultivated and chemical-weed-control plots; careless weed on the cultivated plot. On August 20 weeds were mowed, disked, or sprayed according to the differential treatments. On September 1 the non-cultivated plot still had the highest per cent soil moisture of the three plots at either depth. The chemical-weed-control and cultivated plots were both at about the same moisture content.

Differences in the rate of water infiltration into the soil under the various practices have become increasingly apparent with time. On cover-cropped non-cultivated plots infiltration is rapid. Within 12 hours after an irrigation such plots are in condition to take foot traffic. The chemical-weed-control plot, after a like time, has an inch or more of water ponded on the surface, much of which is lost by evaporation and does not penetrate into the soil. Chemical-weed-control, where the surface is kept bare and undisturbed, combined with sprinkler irrigation, has resulted in a gradual sealing of the soil surface to a point where infiltration has been seriously reduced. On the cultivated plot 12 hours after an irrigation the soil is saturated through a depth of 8 to 10 inches where a plow sole is encountered. Further downward movement is extremely slow.

DISCUSSION

The reduced infiltration rate after several years of chemical-weed-control is in accord with the results of Hilgeman and Van Horn in Arizona. They further observed that continued cultivation on the finer textured soils can lead to the development of a plow sole which retards movement of water into the soil. In the present study after five years of continuous cultivation a plow sole, which retards the movement of water, exists at a depth of 8 to 10 inches. Under the system of a cover crop with no cultivation no slowly permeable layer is encountered in the profile.

By considering the per cent soil moisture before and after an irrigation or rain, as given in Tables 1 and 2, an estimate of the effectiveness of recharge of soil moisture under the various practices can be made. It is evident that the greatest recharge occurred under the system of a cover crop with no cultivation. The least recharge was under the system of chemical weed control while cultivation was intermediate.

A consideration of the per cent soil moisture for the dates between irrigations gives an estimate of the amount of water used. It is apparent that the least water was used under the system of chemical weed control. Between the cover-cropped and cultivated systems differences in the amount of water used were small with the cover crop using the most water.

While the combination of cover crop with no cultivation did use the most water there was more water present to be used. Equal amounts of water were applied to all plots. The greater amount present under the non-cultivated cover crop can be attributed to the better physical condition of the soil with respect to entry and movement of water as compared with the other treatments where the retarded entry and movement resuled in excessive losses by evaporation.

During the 5 month period the non-cultivated cover-cropped plot reached a lower per cent soil moisture than the other plots only in May at the 18 to 24 inch depth. The most active growth stage of the clover crop also occurred in May. At all other sampling dates the highest per cent soil moisture was consistently found under the system of non-cultivation with a cover crop.

The importance of the competition for moisture between cover crop and trees has been referred to by Friend. The results reported here suggest that on the finer textured soils the maintenance or development of a physical condition that facilitates entry of water into and movement of water through the soil may be of greater importance.

Under the soil conditions existing on the experimental plots after 5 years of differential treatment soil moisture remained highest during the summer months where a system of cover cropping and no cultivation was followed.

SUMMARY

The per cent soil moisture at the 6 to 12 and 18 to 24 inch depths under various cultural practices in a sprinkler-irrigated young citrus grove on a Hidalgo clay loam soil is reported for the period May to September 1958.

Equal amounts of water were applied to all plots. A cover-cropped non-cultivated plot consistently had the highest per cent soil moisture during the sampling period. It had a higher water infiltration rate resulting from the better physical condition of the soil. While this plot used more water it also retained more water following rain or irrigation.

A chemical-weed-control plot had the lowest water usage and retained the least water following rain or irrigation due to a sealing of the soil surface.

A plot receiving frequent disking used almost as much water as did the cover-cropped non-cultivation plot but did not retain as much following rain or irrigation. Water infiltration was impeded by a plow sole 8 to 10 inches below the surface.

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Effect of Gibberellic Acid on Cambial Activity of Young Overwintering Grapefruit Trees

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INTRODUCTION

The period of quiescence in shoot growth between the fall and spring flushes of shoot growth in citrus is often referred to as winter dormancy. This winter dormant period occurs under short day conditions when night temperatures frequently drop below 50° F. When night temperatures almost always drop below 50° F., as in southern California, there is no activity of the cambium in the twigs, branches and trunk, nor is there shoot-growth activity (Schneider, 1952). However, in the Rio Grande Valley of Texas, where night temperatures drop below 50° F. only on an average of every other day, there may be some cambial activity in the twigs, branches and trunk of the trees even though there is not shoot-growth activity (Cooper and Peynado, 1959). Thus, though the buds are not actively elongating during the so-called winter dormancy period in the Rio Grande Valley, there may be some cambial activity.

Studies with gibberellic acid (Cooper and Peynado, 1958) indicated that gibberellic acid treatments to young grapefruit trees applied during November and December broke bud-dormancy and shortened the winter dormant period. These tests were conducted at Rio Farms, Monte Alto, and these experimental trees were made available to the writer for a study of the effects of the gibberellic acid treatment on cambial activity of the terminal twigs. The objective of the study was to determine the effect of the gibberellic acid treatment on cambial activity prior to any evidence of bud growth and after evidence of bud growth.

METHODS AND MATERIALS

The trees used in these studies included twelve 3-year-old Redblush grapefruit trees grown at 6 to 6 feet spacing and divided at random into 3 groups. One group of 4 trees was sprayed with 100 ppm gibberellic acid on November 18, 1957. A second group of 4 trees was sprayed with 100 ppm gibberellic acid on December 2, 1957. A third group of 4 trees was not sprayed and constituted a control plot.

The gibberellic acid solution was prepared by dissolving 1 g. of gibberellic acid in 10 ml of 95 per cent ethyl alcohol. One ml of Tween-20, a wetting agent, was added to the gibberellic acid and alcohol, and

[1] These studies herein reported represent part of a thesis by the author, presented to the faculty of the graduate school of Texas A & M College in partial fulfillment of the requirements for the degree of Master of Science. The writer is indebted to William C. Cooper, Ascension Peynado, Guy W. Adriance, F. R. Brison, H. T. Blackhurst, and Charles LaMotte for many helpful suggestions.

the mixture was made up to a volume of 1 liter by the addition of water. This solution was applied to the foliage with a portable electric sprayer. Muslin cloth was used as a shield to protect other trees from a spray drift.

In order to determine the cambial activity of treated and untreated trees, 5 terminal shoots were collected from each tree at 2-week intervals between November 18 and January 13. A section 1½ inches in length and about the same age and diameter was selected from the middle region of the terminal shoots. These sections were killed in a formalin-acetic acid solution and preserved in 70 per cent ethyl alcohol. Transverse sections cut on a microtome were stained with safranin, carried through the alcohol series, and stained in fast green, then carried through the xylol series, and mounted in Canada balsam, as suggested by Johansen (1940). To obtain a measurement of the activity of the cambium, the radial thickness of cambium plus undifferentiated cells of xylem was measured under the microscope. It was very difficult to distinguish the cambium cells from the newly-formed xylem tissue; therefore, the cambium zone was included in the measurements along with the undifferentiated xylem.

The bark-peeling test (Cooper, Tayloe, and Maxwell, 1955) was also used as an index to cambial activity. Two longitudinal cuts, 1 inch long and ⅛ inch apart were made in the bark and joined at the bottom by a transverse cut. A knife blade was inserted under the cut edge, and the bark peeled from the sapwood. Ease of bark peeling was indexed by the following numerical scores: O, no peeling; 1, bark barely peels; 2, bark peels easily; 3, bark peels easily and sap exudes.

RESULTS

The results for radial width of cambium plus undifferentiated xylem shown in Table 1 indicate that the gibberellic acid treatment increased cambial activity as compared with controls. In the case of the November 18 application, the gibberellic acid appeared to increase cambial activity as compared with control before there was any evidence of bud-breaking. After bud-breaking, there was a large increase in cambial activity. In the case of the December 2 applications, bud-breaking occurred so quickly that there was no apparent increase in cambial activity prior to bud-breaking. However, following bud-breaking, there was a rapid increase in cambial activity as with the November 18 treatment. These measurements were not continued long enough after bud-breaking for the control trees to determine if the increase in cambial activity following bud-breaking was greater on gibberellic acid trees than on control trees.

The data shown in Table 1 for condition of buds were taken from Cooper and Peynado (1958) and indicate that although both the November 18 and December 2 applications of gibberellic acid were effective. The November 18 application was much slower taking effect than the latter.

The bark-peeling data shown in Table 1 also indicate greater cambial activity for gibberellic-acid-treated trees than for untreated trees,

Table 1. Radial width of cambium plus undifferentiated xylem of unsprayed young grapefruit trees and trees sprayed with 100 ppm gibberellic acid on November 18 and December 2 as related to the breaking of bud-dormancy.

Treatment and type of observation	Sampling Dates				
	Nov. 18 1957	*Dec. 2 1957*	*Dec. 16 1957*	*Dec. 30 1957*	*Jan. 13 1958*
Unsprayed trees:					
Condition of buds	Dormant	Dormant	Dormant	Dormant	Breaking
Radial width of cambium plus undifferentiated xylem	33	33	33	33	44
Bark peeling score	2	2	1	2	2
Trees sprayed Nov. 18:					
Condition of buds	Dormant	Dormant	Breaking	3" new growth	3" new growth
Radial width of cambium plus undifferentiated xylem	....	56	72	82	....
Bark peeling score	2	2	2	2	2
Trees sprayed Dec. 2:					
Condition of buds	Dormant	Dormant	Breaking	3" new growth	6" new growth
Radial width of cambium plus undifferentiated xylem	....	46	47	89	92
Bark peeling score	2	2	2	3	3

but the data is not as clear-cut as that for the measurements of radial width of cambium plum undifferentiated xylem.

DISCUSSION

These studies indicate that gibberellic acid accelerates cambial activity in grapefruit trees. However, most of the acceleration may be due principally to bud-breaking and resulting shoot growth. Only in case of the trees sprayed on November 18 was there any indication of increased cambial activity by gibberellic acid treatment prior to bud-breaking. It is generally known that there is a great increase in cambial activity of terminal shoots following bud-breaking by many causes, whether naturally or chemically. Therefore, although the results in this paper show increased cambial activity from gibberellic acid treatment, it may not be caused so much by the gibberellic acid treatment per se but by the bud-breaking caused by the treatment.

Gibberellic acid has potentialities as a tool to use in future studies of cold hardiness of citrus. It can be used to break winter dormancy of

cold hardy material to be exposed to freezing temperatures. Thus, true cold hardiness can be separated from the dormancy effect. In the event that a dormancy promoting material is found, gibberellic acid may provide an antidote to break a chemically-induced dormancy after the danger of freeze is over.

SUMMARY

Grapefruit trees in tests conducted by Cooper and Peynado (1958) on the effect of gibberellic acid in breaking winter dormancy of grapefruit buds were made available to the writer for a study of the effect of gibberellic acid treatment on cambial activity in the terminal shoot. The gibberellic acid at a concentration of 100 ppm was applied to some trees on November 18, others on December 2, and others were left unsprayed. The gibberellic acid treatment applied on both November 18 and December 2 broke bud-dormancy and accelerated cambial activity, but the November 18 treatment was slower taking effect than the December 2 treatment. There was a slight indication that gibberellic acid accelerated cambial activity prior to bud-breaking, but most of the acceleration occurred following bud-breaking.

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Labor-saving Devices Aid Citrus Growers

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Labor is such an important item in the production of citrus fruit that many kinds of labor-saving devices have been invented and manufactured by Valley growers.

Starting with the laying-out of an orchard site, it is now customary to mark the tree locations with a square of paper (usually a fruit wrap) and a clod of soil. This eliminates the need for staking where a power-operated hole-digging auger is used to make the holes to receive the balled trees. Tree-balling devices are also in use by some Valley nurserymen.

After the trees are set, circular water basins can be made about trees with special attachments for small tractors.

Several types of attachments are available for making earthen banks of soil about young trees to protect the trunks against dangerously low temperatures.

Figure 1. **The check-closer is a great labor saver in orchards where basin irrigation is practiced.**

In older orchards, where basin or flood irrigation is practiced, the disk border-making machine is an essential piece of equipment, as poor borders waste a lot of labor. The first border makers were in use in Valley orchards long before any machinery manufacturing firm started making attachments for tractors.

The check-closer is an essential piece of equipment in orchards where basin irrigation is used. Orchardists who have used them would not be without one of these labor saving devices. Ridge-busters mounted in front of each front wheel of the tractor, used in making the irrigation basins, save a great deal of wear-and-tear on the tractor and driver. Special side-mounted disk plows are available for making circular basins around young trees that are to be tank watered.

Many machines have been invented by Valley growers to aid them in the battle against weeds. The first rotary weed chopper was invented and manufactured by an Edcouch blacksmith. Now there are many types

Figure 2. An off-set roto-tiller does the work of many hoers in controlling weeds under the skirts of citrus trees.

of rolling choppers, including tandem models, that are offered for sale by machinery manufacturers.

The first traction-driven rotary shredder was put into use by Mr. M. H. Held, Manager of the Pride O'Texas Citrus Association at Mission. Now there are many kinds of power driven shredders available that are in general use by orchardists who use permanent borders and flood irrigation. Many orchardists use shredders or mowing machines to control weeds during periods when it is desirable to have some kind of ground cover in the orchard (during the summer and fall seasons). Offset roto-tillers are especially useful for controlling weeds under the skirts of the trees. Several types of these laborsavers are made in the Valley.

Mechanical fertilizer distributors of several types have been used in Valley orchards for many years. The traction-driven whirl-wind type was invented by a Valley man.

The speed sprayer is proving to be a great labor saver, and results obtained have been satisfactory where sufficient material was used, and the spraying was done under the proper conditions.

Power pruners have been used in the Valley, and hedging and topping machines are used in other citrus fruit producing areas.

The so-called wind-machines eliminate much of the labor needed in protecting tree and fruit against dangerously low temperatures.

After the crop is ready for harvest, there is the bulk handling of the fruit to economize on labor. Fork lift trucks are used to lead and unload the large containers that hold many boxes of fruit.

The profit margin in citrus fruit production is narrow, and keen competition is likely to reduce that margin. The fruit growers and handlers who use the latest laborsaving machines and methods are the ones most likely to realize satisfactory profits from their fruit enterprises.

GRAPE SECTION

Effect of Gibberellin on Size of Thompson Seedless and Perlette Grapes in South Texas

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Thompson Seedless and Perlette are the two grape varieties grown in South Texas for the early fancy table grape market. Both varieties produce small, green, seedless berries that mature in most seasons from late May to June 20. In order to get a premium price, the grape berry size must be large. In both California and Texas, girdling the vines of seedless grapes when the berries are buckshot size increases the size of the berry. The method and its limitations were described in California by Jacob and Winkler (1950) and in Texas by Maxwell (1957).

Girdling grape vines is expensive and requires close supervision and careful workmanship to avoid injury or death to the vine. While girdling increases the berry size it also causes the bunch to become so tight that it must be berry-thinned to open the bunch for better appearance and to lessen possible disease damage.

In experiments at Davis, California on Thompson Seedless grapes, Robert J. Weaver (1958) found that plants sprayed with gibberellin produced berries as large or larger than obtained from girdled vines. Also, the use of gibberellin spray eliminated most of the expense of bunch thinning.

The only bunch thinning required was removal of the tail of the bunch. The Gibberel apparently not only increased berry size but increased the length of the pedicels and stems causing a more open bunch.

METHODS

In the spring of 1958, experiments were initiated on 3-year-old Thompson Seedless and 2-year-old Perlette grape vines in the Rio Grande City area of South Texas to determine the effect of Gibberellin sprays on size and solids of berries.

Four levels of Gibberel were applied on plots consisting of twenty vines each. A check plot and a girdled plot also were part of the test. The material was applied and the vines were girdled when the berries were from small pea to buckshot size. This same berry size was used for both Perlette and Thompson Seedless.

The bunches were berry thinned on the girdled vines, but on the Gibberel treatments only the tail was removed from the bunch. No berry thinning was done on the vines in the non-treated plots.

Sampling was done by taking bunches near the same maturity from the vines in the differential treatments and pulling 200 berries at random without regard to size. The berries were then weighed, crushed and per cent total solids were read with a Bausch and Lombe hand refractometer. Table 1 gives the comparative data of the effect of various treatments on both Thompson Seedless and Perlette.

Table 1. Effect of Gibberel on size and solids of Thompson Seedless and Perlette Grapes in Texas.[1]

Variety	*Treatment*	*Gram wt. 200 berries*	*Avg. wt. per berry*	*% Total Solids*
Thompson Seedless	None	282	1.41	16.1
Thompson Seedless	Girdled	428	2.11	17.1
Thompson Seedless	10 ppm Gibberel	341	1.70	15.8
Thompson Seedless	15 ppm Gibberel	412	2.06	15.6
Thompson Seedless	20 ppm Gibberel	396	1.98	17.8
Thompson Seedless	50 ppm Gibberel	385	1.93	15.3
Perlette	None	300	1.50	17.2
Perlette	10 ppm Gibberel	303	1.52	17.6
Perlette	20 ppm Gibberel	307	1.53	17.6
Perlette	50 ppm Gibberel	301	1.51	17.4

[1] Thompson Seedless Harvested June 19, 1958
Perlette Harvested June 13, 1958

RESULTS

Gibberel sprayed vines of Thompson Seedless showed a berry size increase over the non-treated vines. The 15, 20 and 50 ppm treatments gave an average berry size comparable with the girdled vines. Except for vines sprayed with 20 ppm gibberel, all Gibberel plots were slightly less in total solids than either the girdled or check plots.

The slight delay in maturity caused by gibberel spray is so small that it would not be a significant factor in a commercial vineyard in Texas. This is similar to results obtained in California during the 1957 season.

When Perlette grapes were sprayed with Gibberel, it did not affect either average berry size or per cent total solids. The girdling treatment was omitted on the 2-year-old vines of Perlette, considered to be too young to girdle safely.

It is suggested that growers having Thompson Seedless vineyards try the 20 ppm application on a portion of the vineyard.

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VEGETABLE SECTION

Consumer Preferences as Related to Texas Fruits and Vegetables

Dr. Robert E. Branson[1]

(Paper given at the Annual Institute of the Rio Grande Valley Horticultural Society, January 27, 1959, Weslaco, Texas.)

INTRODUCTION

The fruit and vegetable industry of Texas, not unlike that of any other industry, is always confronted with a number of major problems. My purpose here today is to discuss one of these major problem areas with you. It revolves around the question "What do consumers want?" The reason this question is assuming increasing importance for the fruit and vegetable industry lies largely in the marketing setting for these and other food products in the last few years.

THE SETTING OF MARKETING TODAY

In the 1920's and 1930's it was not unusual for producers of agricultural products to market them directly to consumers, or at least to retail stores selling to consumers, in neighboring towns and cities. Under the system there wasn't any particular problem in knowing what consumers want. If tomatoes delivered around the neighborhood were too ripe the housewife promptly told us about it. If they had been picked somewhat prematurely and the flavor was flat, this also was promptly brought to our attention. Perhaps you remember the hog-killing days on the farm when sausage was made and peddled from door to door or sold to neighborhood retail stores. In case the seasoning was too "hot" immediate information was available to guide the farmer in preparing the product next time. This constant flow of information from consumer back to producer served to guide production, handling, marketing and processing practices on the farm.

Today a quite different situation prevails in our agricultural economy. Our age of specialization has permeated the food industry because it offered great savings in food production and distribution costs. Producers are highly specialized. Also, food marketing agencies are highly specialized.

Tremendous innovations have been made by processors and retail food distributors in the handling of food products. As you know, the retail store of yesteryear has almost vanished. It has been replaced by the modern self-service chain or independent food store. However, this has introduced another unplanned change. The food retailer has little opportunity to discuss food likes and dislikes with his customers. He is

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conscious of whether a product sells or does not sell, but he seldom knows the reason why. In many cases products might have been sold in considerably larger volume had the consumers' attitudes toward the product only been known.

As in any case of specialization, where we divide activities into several parts, some or all of the cost efficiencies gained can be lost if there is not proper coordination of the activities of each. The present lack of coordination among producers, processors, retailers and consumers' desires is beginning to receive increasing attention from coast to coast.

Better coordination of food marketing activities can and is being obtained by the introduction of consumer market research designed to serve not only the producer but also the processor and retailer. After learning the needs and attitudes, and even fancies, of the consumer, the information is relayed by the marketing research department to the producers, processors, and retailers. Thus, proper coordination of the production and marketing system is again achieved.

You might ask, "Is this a problem of agriculture alone?" The answer is no. There have been tremendous problems in industry too. The president of a corporation manufacturing consumer goods—whether it be automobiles, furniture, or clothing—never has a real opportunity to meet the consumers that are his market. Consequently, he faces the same difficulty as the food producer and processor. Now let's take a brief look at what industry is doing to solve the problem.

INDUSTRY'S APPROACH TO THE MARKETING PROBLEM

Basically the approach of industrial corporations has been to set up either marketing research departments within the company or a top executive whose function it is to serve as marketing research director. This research director acts as a watch dog for possible problems in meeting consumer needs and contracts with private marketing research concerns or consultants to survey consumers' attitudes and opinions regarding their products.

The more progressive business corporations have been working on this problem for several years. One of the major factors behind the success of General Motors Corporation in the manufacture of automobiles has been their untiring efforts at consumer marketing research. Their decision was that consumers were interested in more than the functional design of the old Ford automobile which was the predominate car at that time. History has certainly proved them to be correct.

Some concept of the size and scope of consumer market research among American business was obtained by a survey in 1945 made by the American Marketing Association. The survey comprised 4,786 companies who were members of the National Association of Manufacturers. The specific purpose of the survey was to determine what plans were being made regarding the problem of war-to-peace conversion in industry. It was found that 38 per cent of the companies were doing marketing research of some kind.

Whether a company was engaged in market research depended somewhat upon its size. Twenty-three per cent of the firms marketing under $500,000 worth of products per year had marketing research activities. However, of those companies with a gross business volume of over $5,000,000, 72 per cent were conducting marketing research. Of the latter group two-thirds had their own marketing research department staffed with experts in either marketing, economics, statistics, psychology or sociology. One-third of these companies operated their marketing research through the function of a line executive charged with that responsibility. Such an executive generally contracted his marketing research with consultants and private research companies.

A more recent survey—June 1958—by Sales Management, one of the leading journals in the marketing fields, indicated that 80 per cent of the 500 largest firms in the United States reported marketing research as one of their standard operations. Therefore, it is evident that the amount of attention devoted to the problem of adequate knowledge of markets and what consumers want is steadily increasing.

Let's stop for a minute and make what I think is a very worthwhile comparison. If business firms with over $5,000,000 sales in the United States find it desirable to engage in marketing research as a matter of self-interest in the promotion of their own company's future welfare. it would seem that the Texas Citrus Industry, for example, which has sales of well over the $5,000,000 level per year would also do well to make adequate use of proper market research.

PRODUCTION VERSUS MARKETING

The United States is known the world over for its emphasis on production and the improvement of production techniques. Nonetheless, it has been pointed out recently that for the first time in history a major nation, the United States, now has more people employed in marketing and servicing the goods made by its industry than it has in the production of those goods in the first place. This change apparently occurred sometime between 1953 and 1955.

This switch in the relative importance of production versus marketing has given rise to a new concept of company organization called "marketing management." It has developed in realization of the fact that we must produce *for* the market, not *find* a market for something we happen to produce. The General Electric Company has been credited as the innovator of this new concept in business management.

Development of the marketing management concept is not to say that there is less need for emphasis upon production. Quite to the contrary. It does indicate, however, that we have moved sufficiently far enough with our production know-how that we can now devote more resources to the determining what the things are that our economy should produce in order to provide the consumer with the best possible standard of living.

This says to those engaged in research concerning better methods of producing horticultural crops that your activity is as important if not more important than it has been before. It also says that if you make a mistake and develop a product that does not fully meet consumer approval, there are hundreds of other products they can buy instead of it. It means that rather than guessing at what the market would like to have in a particular kind of product, you had best have intelligent information regarding consumers' wants and fancies to guide you in your research activities. It means that as new varieties of a product are developed, they need consumer testing before full-scale production is undertaken. This offers a tremendous advantage in guiding production research activities. Sizeable money losses, which might easily occur if large-scale production were undertaken before adequate consumer tests had been made, can thus be avoided.

THE NEW MARKETING CONCEPT – ITS OPERATIONAL FORM

In this age of researching the consumer, one notes that the activities generally take one of two forms. As indicated previously, consumer market research is one of the major areas that has been developed. Another not mentioned thus far, is new product development.

Consumer market research has as its objective not just finding out what the consumer wants, but why the individual wants this or that feature or characteristic in a product. It may be said that we are entering the age of "why" research.

Laborious and painstaking research over the past ten years in consumer marketing research has indicated that we can learn more about consumers' behavior in buying food and other products by applying techniques developed in the social sciences. Involved are techniques, tools, and theories developed in economics, psychology and sociology as well as statistics. Experience has shown, for example, that direct questioning of consumers as to why they act as they do often leads to erroneous results. Consequently, indirect approaches are necessary to find the true motivations behind the consumers' actions. It is from this particular development in marketing research that there has sprung up the general label of "motivational" research.

Oftentimes people accuse motivational research as being a term manufactured by Madison Avenue. The latter is the home of many of the national advertising and marketing research organizations. The truth of the matter is that motivational research was developed by social scientists and especially those in the fields of psychology and sociology. It is a by-word on Madison Avenue because it is at that point that it is being applied to the solution of marketing problems of United States industry.

Now let's look at new product development. In its current form it is, if anything, more recent than motivational research. It is estimated that the modern food supermarket has five to six thousand products on its shelves. Only a few years ago, the number was two to three thousand.

There are estimates that from 20 to 30 new products are introduced each day in the food marketing field alone. Some succeed; many do not. Whether they are successful oftentimes depends upon the degree of marketing research that went into the planning and development of the product from the outset.

What are some of the new products in the food field in relation to fruits and vegetables? Certainly, we are all familiar with frozen concentrated orange juice which was developed by the U. S. Department of Agriculture Research Laboratory. It has been a tremendous success. There is also frozen concentrated grapefruit juice. The latter, however, has not met with very good success. It is hoped that a better product can be produced. My own hope is that it will eventually be possible for us to market a frozen red grapefruit juice from our own Texas production. Some experimental work in this field by the USDA Laboratory at Weslaco has produced a very high-quality product.

Not all new products, however, are from usual natural sources. Perhaps some of you have noticed a recent introduction by General Foods Corporation of a product which they have called "Tang." Some consumers I have discussed this product with indicate that they think it is far from being one of desirable quality. On the other hand, others have told me that they think it is a highly acceptable one. This is a product which we and the citrus industry should watch with considerable care.

Whether the "Tang" is successful or not at the moment is perhaps not of major importance. The important fact is that the idea has been born and developed. Products, once introduced, can usually be improved if enough research is used. While I was in the Rio Grande Valley a few weeks ago, the comment was made that this may be the oleomargarine of the citrus industry. You all know the effect of the introduction of oleomargarine upon the dairy farmers.

SOME EXAMPLES OF RESULTS OF CONSUMER MARKET RESEARCH

A number of us have been surprised, intrigued, and yes, even amused, by the results that have been developed by researching the consumer. A large number of examples could be cited but look at only a few.

Take, for example, the information developed concerning the influences of color upon the individual's idea of the qualities of a product. Experiments have been conducted with coffee from a single brewing of a given quality of coffee. The result, of course, is a uniform quality coffee for all of the cups prepared. The cups of coffee were placed in front of coffee cans of different colors. The colors ranged from a dark brown color to a blue and a red and a yellow, for example. Consumers invited to test the coffees in the different cups indicated their own opinions about each. The result pointed out that the coffee by the dark brown can was considered by most of the testers as being too strong. Coffee by the yellow can was considered too weak. Here then is obviously a measure of the effect of color upon our conception of quality of a product.

A recent development some of you may have noticed was the full-page advertisements by Camel cigarettes indicating that they had put the pyramids back on the Camel cigarette package. If you were to examine the old package of Camels, and the new one, you would find only a slight difference. Nonetheless, the color of the Camel is of considerably lighter brown and the general design of the package might have somewhat of a more effeminate look. It might also be mistaken for a package of candy cigarettes. The old package has an old battered rugged camel of a rather dark brown color which suggests considerable amount of strength and endurance. This possibly suggests to the consumer a much stronger bodied tobacco. Consequently, even minor changes in packages can have tremendous effects upon consumers' ideas about your products.

Now let's take a look at some of the recent work at the Texas Agricultural Experiment Station with regard to Texas citrus products. Dr. Harold Sorensen has been engaged in a very important series of tests together with Dr. Burns in determining the loss of quality of fresh grapefruit in marketing channels. Heretofore, it has been assumed that grapefruit more or less retain quality through to the final consumer. The finding is that this certainly is not the case.

Grapefruit that are in marketing channels for over three weeks lost quality drastically compared to the quality at the time of picking from citrus groves in the Texas Valley. This means that consumer acceptance of Texas citrus may suffer in comparison with Florida or California fruit, where greater care is being exercised in the marketing of the product through federal marketing orders and other organizational devices to insure that a high-quality product is placed before the consumer.

Texas oranges reaching some consumers this year are far below the quality of the product that can be produced in the Valley. Here again there is critical need for further marketing research.

The U. S. Department of Agriculture Research Laboratory in Weslaco has recently developed what is known as Texas fortified red grapefruit juice. It was learned by these researchers that the color in red grapefruit is not in the juice. Rather, the color is in the pulp. Consequently, a method was devised for introducing additional pulp in the canned grapefruit juice as it was being processed. The reasons for research along this line was that red grapefruit juice marketed from the Valley in past years has been subjected to criticism because of the fact that the juice loses its color. It develops a rather off-color faded appearance that is far from appetizing to the housewife.

Samples of Texas fortified red grapefruit juice, together with those of Texas white grapefruit juice and Florida white grapefruit juice were presented to a taste panel at Texas A. & M. It was learned that when the

three juices were artificially colored to the same color, the taste panel was not able to distinguish among them. Having established this fact, we then took the three juices in their natural color and presented them again to the taste panel. Considerable preference was found for the red fortified grapefruit juice.

In the interest of having an available means of testing new food products, including varieties of fruits and vegetables, a consumer panel has been established by the Texas Agricultural Experiment Station in Dallas, Houston, and Waco. Each panel contains 300 families. With this number it is possible to conduct a single test in each of the cities or to combine parts of the panels in all the cities for a combined test. Using these panels, the three grapefruit juices mentioned above were presented to a panel of 150 families in Dallas and a corresponding size panel in Houston. The consumers were not told of the source of the grapefruit juice. They only knew that one was from pink or red grapefruit and the other two from white grapefruit. The results of the consumer panel were that 61 per cent preferred Texas fortified red grapefruit juice, approximately 26 per cent preferred Texas white grapefruit juice, and interestingly enough to the Rio Grande Valley, Florida white grapefruit juice was preferred by only 13 per cent. Identical preference indications, within one or two percentage points, were reported by the consumer panel in both cities.

These findings are of considerable importance to you as producers of Texas red grapefruit because a number of the retail stores in the past have been discounting the price of Texas red grapefruit juice under the false assumption that consumers did not like it as well as white grapefruit juice. Armed with better information on consumers' desires, Texas is now in a better position to bargain for higher prices for its red grapefruit juice.

WHAT ARE SOME OF THE ADDITIONAL THINGS THAT CAN BE DONE TO PROMOTE TEXAS CITRUS?

The application of motivation research to consumer research has indicated that consumers generally like big business. Big business is considered the same as a big brother. And, big brother usually looks out after little brother's interests. In view of this, it certainly seems desirable, as well as fortunate, that the Texas citrus is now beginning to organize itself into the Texas Citrus Mutual and the Texas Citrus Sales Corporation. Consumers of the nation need to be presented with the fact that the Texas Citrus Industry is a large and substantial industry, and one interested in the consumers' individual welfare in the form of providing him with a standard high-quality, healthful, and nutritious product.

Of course, most of us are acquainted with the fact that there is an inherent desire in many people to "keep up with the Joneses." Here again we can put this personal desire to work for our own interest. We can show to the American housewife that the use of Texas citrus products has been "keeping up with the Joneses" insofar as providing the best possible of nature's fruit products to her family and friends.

To accomplish the above program, however, we must be certain that we market only the best qualities of our product and distinguish them with a label which is readily identified and readily known by consumers everywhere.

There is increased interest in the production of oranges in the Valley at the present time. From some of my experience in working with the Florida industry, I know that the Hamlin and Pineapple oranges are not as good quality, at least in that area, as the Valencia oranges. The juice from these oranges is blended with juice from the later season Valencia oranges in order that a more uniform, better quality product can be presented to the food buyer. Consequently, we must constantly appraise the direction we are moving in our production program to see that it is adequately coordinated with possible advantages that we can obtain in the consumer market.

CONCLUSION

In conclusion may I say that the most dangerous statement and most dangerous attitude that we can take is that "I know what the market wants. I know what the consumer wants." Only by taking the advantage of the new concept of "marketing management" can we make the maximum progress for the fruit and vegetable industry of the Rio Grande Valley. We can always gamble on hunches and "go for broke," but I think it is preferable to develop scientific knowledge and go for progress instead.

Variety and Strain Evaluation of Southern Peas

THOMAS S. STEPHENS, *U. S. Fruit and Vegetable Products Laboratory*,[1] and R. T. CORREA, *Texas Agricultural Experiment Station, Weslaco*

Southern peas (edible varieties of cowpeas, *Vigna senensis*) has continued to be an important vegetable crop in the Southern States. The importance of this crop is evidenced by the report of the National Canners Association, 1956, that more than 1,000,000 cases (303's—24 units per case) have been canned annually since 1949 with more than 2,000,000 cases canned in 1950, 1953 and 1955. More Southern peas would possibly be canned if a more desirable variety were available. Brittingham and Mortensen (1951) point out that existing varieties do not mature evenly and must be harvested by hand several times during the season. Yields of fresh shelled peas are sometimes low and frequently disease and insect damage may be severe. Too often the processed peas are dark in color, with many mashed and broken pieces, resulting in an unattractive product.

Correa (1954) and Correa and Stephens (1956) reported on the yield, shellout percentage and canning quality of several varieties and strains of Southern peas grown in the Rio Grande Valley in the fall. This study presents additional information on several of these varieties and strains and in addition information on several new strains grown in the spring.

MATERIALS AND METHODS

Six varieties and 14 strains of Southern peas were grown in the spring of 1956, the spring of 1957 and the spring of 1958 at Substation 15, Texas Agricultural Experiment Station, Weslaco. The strains of Southern peas evaluated in this test were obtained through the breeding program conducted by the Texas Agricultural Experiment Station, College Station, Texas. A released strain normally becomes a variety. Purple Hull 49 and Cream 40 have been released to the seed companies for sale and have been given the same variety names as their strain designations.

The peas were planted in a randomized block with 4 replications, each plot consisting of 2 rows 30 feet long, and 38 inches apart. Irrigation and other cultural practices were applied as needed during the growing season.

The green pods of all varieties and strains were harvested twice during the season at a comparable stage of maturity. The pod maturity suggested by Brittingham and Mortensen (1951), was represented in the non-purple hull types by pods just beginning to turn yellow, and

[1] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

in the purple hull types by pods that were a bright reddish-purple. Calculated acre yields and shellout percentages given in table 1 include both harvests; however, the first harvest only was used for processing evaluations. Each variety or strain was shelled in a Sinclair-Scott[2] laboratory model pea sheller, operated at a paddle speed of 475 to 500 rpm, and cleaned by dropping through a blast of air. The seasonal shellout percentage was determined and recorded in table 1.

The peas were canned and the canned samples evaluated according to the procedures used by Correa and Stephens (1956). A shelled sample of peas from each replication was blanched in water for 4 minutes at 185° F. Four No. 300 (300x407) "C" enamel cans, as recommended by Cain and Brittingham (1950) were filled with 200 grams of blanched peas per can. Boiling 2% brine was then added to a constant headspace, and the cans closed while the center temperature was about 180° F. All these samples were cooked 35 minutes at 240° F. (10 psi) and water-cooled as quickly as possible.

Canned samples were examined for drained weight, defects, and splits, and a sensory evaluation made for color, flavor, and appearance after about 2 months storage at room temperature. Drained weight and defects were determined according to the U. S. Standards (1950) for Grades of Canned Field Peas and Canned Blackeye Peas. The term "defect" refers to the presence of extraneous vegetable matter, loose skins, parts of peas, mashed peas, or foreign material. A pea was considered to be split if the skin was separated to a width of 1/16 inch or more (Cain and Brittingham, 1950). The percentage of defects and splits in table 2 were calculated from duplicate 100-gram samples from each of four cans.

Sensory evaluations for color, flavor, and appearance were made by a panel of seven judges. The blackeye and purple hull peas were judged in one group, and the cream peas in another group. The numerical ratings shown in table 3 are averages of two separate evaluations of duplicate samples of four replications. A reference sample of commercially canned peas was used for each group. Judges rated appearance on the amount of loose skins, splits, broken and mashed peas visible in the sample.

RESULTS

Six varieties and 14 strains of Southern peas were evaluated for yield, shellout percentage and processing quality. There were 4 varieties and 11 strains evaluated for 2 or 3 seasons, and 2 varieties and 3 strains evaluated only one season. Comparative yields and shellout percentages are shown in Table 1. For the blackeye-purple hull pea group, California Blackeye No. 5 was the highest producer of green pod peas for the three seasons, and Cream 7 and Cream 20 were high for the cream group.

[2] The mention of trade products or companies does not imply that they are endorsed or recommended by the U. S. Department of Agriculture over similar products or companies not mentioned.

There were no significant differences between the higher yielding varieties and strains in average total yield of green pod peas for the 1956 season, but the varieties Extra Early Blackeye, Commercial Purple Hull, and Cream 40 were significantly lower. In 1957 the varieties Extra Early Blackeye, California Blackeye No. 5, and the strains Purple Hull 13, Cream 18 and Cream 20 were significantly higher in total yields, and in 1958 the variety California Blackeye No. 5 and strain Cream 7 were significantly higher in total yield.

The shellout percentage obtained for each variety or strain is given in table 1. Of those varieties and strains evaluated for two or three seasons, Purple Hull 13 had the highest average shellout percentage of the blackeye-purple hull pea group and Cream 10 strain had the highest average shellout percentage for the cream group. There were 2 varieties and 5 strains with a maximum shellout difference between years of over 8%. In the test conducted on peas grown during the fall of 1953 and 1954, Correa and Stephens (1956) reported, these 2 varieties

Table 1. Yield and percent shellout of Southern pea varieties and strains, Spring 1956, 1957 and 1958.

Variety or Strain	*Green pod peas (lbs./A)* 1956	1957	1958	*Seasonal shellout (%)* 1956	1957	1985
Calif. Blackeye No. 5	5278	4526	7546	51.3	59.3	54.3
Extra Early Blackeye	4108	4843	6575	55.4	—	53.4
Blackeye 53 Sp 2	5653	—	—	47.2	—	—
Comm. Purple Hull	4305	—	—	66.6	—	—
Purple Hull 49	5211	3976	5990	51.9	59.2	47.8
Purple Hull 3	—	—	5884	—	—	51.3
Purple Hull 4[a]	—	3195	5789	—	57.8	49.0
Purple Hull 5[a]	5040	3504	6337	50.1	57.9	44.6
Purple Hull 12[a]	5421	3625	6030	47.4	56.1	47.9
Purple Hull 13[a]	5015	4518	6525	55.3	61.9	52.2
Cream 7[a]	4856	3831	7322	50.0	60.0	54.6
Cream 8[a]	5297	3805	6265	43.8	54.3	46.1
Cream 9	—	4062	6481	—	52.0	50.2
Cream 10	—	3649	4807	—	63.4	47.1
Cream 14	—	3762	—	—	—	—
Cream 16[a]	5421	—	5897	37.8	—	42.7
Cream 18	5513	4423	—	47.0	46.8	—
Cream 20	5162	4346	6579	45.9	60.0	56.1
Cream 40	4305	3865	5984	46.3	57.3	50.5
Long Pod Cream	5445	—	—	47.9	—	—
Least significant difference						
.01 level	961	967	660			
.05 level	706	717	488			

(a) The designation "52 Sp" used to help identify the strains of peas in the fall of 1953 and 1954, and reported by Correa and Stephens (1956), has been eliminated by the plant breeder.

and one of these same strains had a maximum shellout difference between years of over 11.3%. Brittingham and Mortensen (1951) reported only 4 of the 16 varieties they studied showed a maximum shellout difference between years of over 8%. Although every effort was made each season to harvest the pods at the same stage of maturity, it is felt that the relatively large shellout differences obtained during the 5 seasons' work may be due, in part, to lack of uniformity in maturity. These differences emphasize the need for a more accurate method of determining field maturity.

In 1956 and 1957 the variety Cream 40 was significantly higher in average percentage of defective peas but in 1958 Purple Hull 3 and Cream 20 were significantly higher in defective peas. There were no highly significant differences obtained among the other varieties and strains.

The variety Cream 40 and strain Cream 8 were significantly higher in split peas for the 1956 season. The strains Cream 8 and Cream 9 were significantly higher in split peas for the 1957 season and strains Cream 9, Cream 20, Cream 7 and the variety California Blackeye No. 5 were significantly higher for the 1958 season. The high level of split peas in these varieties and strains resulted in unattractive products.

There was no relationship between drained weight and seasonal shellout percentage or between drained weight and split percentage among the varieties and strains tested.

The sensory evaluation ratings for color, flavor and appearance are presented in table 3. The purple hull varieties and strains received a higher rating for color than did the blackeye varieties and strain. The color in the hilum of the blackeye peas diffuses into the cotyledons and liquor during canning, causing a dark "muddy" canned product. The "buff" colored hilum of the Purple Hull peas do not cause as pronounced a discoloration. In 1956 the Purple Hull 12 strain again turned brown during canning (Correa and Stephens, 1956), but the same strain canned in 1958 did not discolor. The flavor of the varieties and strains of the blackeye-purple hull pea group received about the same rating and the flavor of the varieties and strains of the cream group were similar. The apperance rating given each variety or strain did not in all instances agree with the defect and split percentages of the same variety or strain.

Table 2. Processing quality of Southern pea varieties and strains. Spring 1956, 1957, 1958.

Variety or [illegible]	Drained weight (gms.) 1956	1957	1958	Defects (%) 1956	1957	1958	Splits (%) 1956	1957	1958
[illegible]keye	355	333	305	3.0	1.8	.9	54.8	62.8	47.7
[illegible]	346	—	316	.4	—	.0	24.2	—	13.9
[illegible]	[illegible]	—	—	.6	—	—	28.6	—	—
[illegible]		313	258	.4	.6	.5	22.4	25.3	5.2
[illegible]			299	—	—	2.8	—	—	15.9
[illegible]			317	—	.8	1.3	—	9.5	10.5
[illegible]				.5	.4	.5	13.0	7.8	4.9
[illegible]				.2	1.1	.3	18.6	13.5	5.8
[illegible]					1.5	1.2	36.2	36.0	17.7
[illegible]					1.5	.8	61.8	71.5	44.3
[illegible]						.1	65.4	78.3	43.1
[illegible]						8	—	76.3	54.9
[illegible]							—	37.3	18.3
[illegible]							23.4	—	16.5
[illegible]							41.0	66.8	—
[illegible]							42.6	57.8	49.5
[illegible]						4	69.8	63.3	31.7
[illegible]						—	22.2	—	—
[illegible]						1.5	7.1	7.6	14.5
[illegible]					.0	1.2	5.4	5.7	11.1

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[2] The mention of trade of peas in the fall of or recommended by the 1956), has been eliminated companies not mentioned

Table 3. Sensory evaluations of Southern pea varieties and strains. Spring 1956, 1957, 1958.

Variety or Strain	Color [a] 1956	1957	1958	Flavor [a] 1956	1957	1958	Appearance [a] 1956	1957	1958
Calif. Blackeye No. 5	6.3	6.8	6.0	6.1	7.2	6.6	3.7	5.6	6.6
Extra Early Blackeye	6.3	—	5.4	5.3	—	6.1	8.0	—	7.2
Blackeye 53 Sp 2	6.6	—	—	5.6	—	—	7.7	—	—
Purple Hull 49	6.9	7.4	6.9	7.1	7.3	6.6	8.0	7.7	7.4
Purple Hull 3	—	—	6.0	—	—	6.4	—	—	7.1
Purple Hull 4	—	7.1	6.6	—	6.7	6.5	—	7.6	7.1
Purple Hull 5	7.1	7.1	6.5	6.8	6.9	6.4	8.1	6.9	7.4
Purple Hull 12	6.2	—	6.7	6.4	—	6.9	7.3	—	7.3
Purple Hull 13	6.6	7.2	6.6	7.2	7.1	6.5	7.6	7.4	7.0
Cream 7	6.7	6.8	6.4	6.7	6.7	6.5	6.4	5.8	6.6
Cream 8	6.7	6.6	6.8	6.9	6.7	6.9	5.1	5.8	6.8
Cream 9	—	6.6	6.4	—	6.6	6.9	—	6.0	6.6
Cream 10	—	7.2	7.3	—	6.7	7.1	—	7.4	7.4
Cream 16	6.9	—	7.6	6.8	—	7.1	7.6	—	7.6
Cream 18	6.8	5.9	—	6.9	6.3	—	5.4	5.8	—
Cream 20	6.5	7.6	7.4	6.4	7.4	6.8	6.0	6.3	6.9
Cream 40	7.0	6.8	7.3	6.9	6.8	7.3	5.0	5.7	6.8
Long Pod Cream	7.0	—	—	6.5	—	—	7.2	—	—

[a] Numbers represent numerical opinions of the judges. The word description of each number in the scale is:

1	Very poor	4	Fair	7	Good	10	Ideal
2	Poor	5	Acceptable	8	Very good		
3	Fairly poor	6	Fairly good	9	Excellent		

However, in most instances when the defect and split percentages were high the appareance rating was lower. The California Blackeye No. 5 and Cream 40 varieties and the Cream 8 strain which have high defect and split percentages were given low appearance ratings.

SUMMARY AND CONCLUSIONS

The strain Purple Hull 13 and variety Purple Hull 49 are the most desirable of the blackeye-purple hull pea group and the strain Cream 16 is the best of the cream group. California Blackeye No. 5 produced more pounds of green pod peas than did either Purple Hull 13 or Purple Hull 49, but the number of split peas and the dark discoloration after canning resulted in an undesirable product. The strains Cream 7 and Cream 8 produced more pounds of green pod peas and had higher shellout percentages than did the strain Cream 16, but both strains after canning were very high in split peas, resulting in a "mealy" appearing canned product.

The relatively large differences in seasonal shellout percentages are partly attributable to differences in maturity of the pods when harvested. A more rapid, accurate method is needed to determine field maturity.

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Tomato Varieties for Greenhouse Production

AMON D. DACUS and PAUL W. LEEPER[1]

INTRODUCTION

For a number of years, the production of greenhouse vegetables in several Northeastern States has been a thriving industry of considerable proportions. The wholesale value of vegetables grown under glass in 1949 was more than 13 million dollars, of which about 10 million was accounted for by tomatoes. Ohio led the states with about 650 acres of vegetables under glass (Porte and Smith, 1955).

Development of the industry in the Lower Rio Grande Valley area would seem to be favored by the fact that a high quality vine-ripened tomato is not available on the market, even when the Valley and adjacent areas are producing tomatoes in the field. The use of plastics to cover greenhouses makes possible the use of low cost construction, which results in a lower initial investment on the part of a grower entering the greenhouse vegetable business.

MATERIALS AND METHODS

In August 1958, a 20'x80' greenhouse was constructed at Monte Alto, Texas, near the offices of Rio Farms, Inc. The house was covered with 4 mil polyethylene, and a pad and fan cooling system was installed for ventilation and for cooling when necessary. About two-thirds of the area was utilized for the production of tomatoes, while the remainder was used for the production of pot plants.

The greenhouse was located on a well drained sandy loam soil which for five years had not been cultivated. Before starting construction, the soil was chiseled to a depth of 14 inches and an application of approximately 10 tons per acre of steer manure was worked into the soil.

Two recently developed greenhouse tomato hybrids and two field varieties were selected for the trials. The varieties are described as follows:

1. Tuckcross "O" (Tucker's Forcing x Ohio WR3). Fruit large, scarlet red, meaty, mild flavor and very productive. Vigorous but open foliage, highly resistant to Cladosporium leaf mold disease (race 1). Plants resistant to Fusarium wilt (race 1). Indeterminate growth habit.

2. Tuckcross V (Tucker's Forcing x Valiant). Fruit large, red, flatened globe very similar to Valiant. Sets fruit well under adverse conditions, very few of which are parthenocarpic. Foliage open and highly resistant to Cladosporium leaf mold. Good resistance to Fusarium wilt.

[1] Head, Crops Research Department, Rio Farms, Inc., Edcouch, Texas, and Associate Horticulturist, T.A.E.S., Weslaco, Texas.

3. Rio Grande. Fruit very large, red, meaty and firm with mild flavor. Vigorous, large determinate plant with dense foliage. Resistant to gray leaf spot and Fusarium wilt.

4. W21-3. Fruit medium size, red, meaty and firm, with mild flavor. Small determinate plant with light green, sparse foliage. Resistant to gray leaf spot and Fusarium wilt.

Seed of the four varieties was planted July 23 in sterile soil contained in No. 303 tin cans. After establishment, the seedlings were thinned to one plant per can and grown to transplanting size under one-fourth to one-half shade. The plants were transplanted to the greenhouse soil September 8. At the time of transplanting, 400 pounds per acre of a 5-10-10 fertilizer were applied broadcast over the area.

Rows were 34 inches apart and the plants were 12 inches in the row provided 2.83 square feet per plant and a plant population of approximately 15,300 per acre. Recommendations for spacing vary from 3 to 4 square feet per plant (Campbell and Aultman, 1957) (Emmert, 1956) (Romshe, 1942), and there seems to be some advantage in yield by a square arrangement to provide the necessary area for each plant. For convenience in working the tomatoes and in harvesting, however, a wider row spacing is more desirable. Each plot consisted of 6 plants of a variety and 6 replications were supplied in a randomized block design. Buffer rows were provided both on the sides and ends of the replicated test.

The only insect pest encountered was the cabbage looper, and only one application of insecticide was necessary throughout the season. A regular program of fungicide application was necessary, however, to control foliage diseases. Three different fungicides were used in alternating fashion, and were applied as a spray on a 1 or 2 week schedule.

A portion of the plants were sprayed in the seedling stage with 200 ppm. N-M-Tolylphthalamic acid[2] according to a technique described by Wittwer and Teubner, 1956. By proper timing of application, the material is reported to increase the number of flowers per cluster and thereby increase yields. In this test, the application was timed to affect the first flower cluster only.

Pollination was accomplished by vibrating the flower clusters daily with an electric vibrator. Twenty-eight harvests were made from November 17, 1958 through March 23, 1959. Cracked, misshapen, undersized, and other undesirable fruit was culled out at harvesting. The remaining fruit was assumed to be marketable and, except for the fruit affected by gray wall disease, as described later, the assumption was valid.

RESULTS AND DISCUSSION

Data on the total and marketable yield and size distribution by va-

[2] U. S. Rubber Company's "Duraset-20W"

riety are presented in Table 1. The two hybrids Tuckcross "O" and "V" performed about equally well as far as total and marketable yield was concerned. In the first few weeks of harvesting, the W21-3 line produced well, but because of its determinate type of growth tended to top itself and subsequent production was very low. Although the final yield from the Rio Grande was somewhat below that of the two hybrids, production was sustained throughout the harvesting season.

Table 1. Yield and size of fruit.

	Lbs. Per Plant *Marketable*	*Total*	*Per Cent Marketable*	*Size - Per Cent 6-6 and Larger*
Tuckcross "O"	7.2	7.9	91	75.2
Tuckcross "V"	6.9	8.0	86	66.4
Rio Grande	4.5	5.9	76	87.2
W21-3	2.9	3.7	78	75.3
LSD (.05)	1.2	1.4	—	—

The variety Tuckcross "O" tended to puff early in the season, but was greatly improved later. The varieties Tuckcross "V" and Rio Grande produced some cracked fruit; however, losses were not great. The slightly lower percentage of marketable fruit with the variety Tuckcross "V" can be accounted for by the greater number of very small fruit produced.

The low percentage of marketable fruit of the varieties Rio Grande and W21-3 may be accounted for by the fact that some of the fruit was rough and misshapen.

The percentage of fruit size 6x6 and larger was highest for the Rio Grande; intermediate for the varieties Tuckcross "O" and W21-3; and lowest for the variety Tuckcross "V". The size of the fruit improved as the season progressed, probably because of high temperatures early which caused the fruit either to mature before attaining a good size or prevented proper pollination. This was more pronounced with variety Tuckcross "V" than with other varieties.

As indicated by early yields, the chemical spray treatment seemed to have been of some benefit on three of the varieties; however, with the fourth variety (Tuckcross "V") the reverse was true. Insufficient replications were supplied to determine if a real difference actually exists (Table 2).

Table 2. Early yield as influenced by chemical spray.[1]

	Lbs. Per Plant 1st Seven Harvests			
	Tuckcross "O"	*Tuckcross "V"*	*Rio Grande*	*W21-3*
Sprayed	2.1	1.3	1.6	2.0
Not Sprayed	1.8	1.8	1.1	1.7

[1] 200 ppm. in water

Under greenhouse conditions, the fruit of varieties Rio Grande and W21-3 was severely affected by gray wall disease; whereas the two hybrid varieties were only slightly affected. The fruit, although appearing normal in the pink stage of ripening, developed grayish-green blotches or streaks as ripening progressed. This resulted in a large percentage of the fruit of the two most severely affected varieties being culled at the time the fruit was packed for market. Under field conditions, gray wall has not been observed on these two varieties.

SUMMARY

Four varieties of tomatoes were grown to determine their suitability for greenhouse production. The Tuckcross hybrids were developed especially for greenhouse production, while the Rio Grande and W21-3 are field varieties.

Total, as well as per cent of marketable fruit produced and size of fruit, indicates that the Tuckcross hybrids are about equally desirable varieties for greenhouse production in the Valley area.

Additional variety trials, as well as economic and marketing studies on a larger scale operation, are some of the things which this study has indicated for future investigation.

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Developing Tomatoes with Multiple Disease Resistance

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The development of disease-resistant tomatoes in the United States received new meaning in the early 1930's with the introduction by the Bureau of Plant Exploration and Introduction of the U. S. Department of Agriculture of a large collection of tomatoes from different countries of the world. This collection contained selections with resistance to most of the common diseases of tomatoes. Early work on the tomato improvement program was summarized by Harrison (1941, 1948).

At the present time different states and federal tomato breeders are working on developing commercially-adapted types of tomatoes with resistance to one or more of the following diseases or disorders: Fusarium wilt, grey leaf spot, Alternaria collar rot and early blight, leaf mold, root knot, mosaic, tobacco etch, anthracnose, Phoma rot, late blight, Septoria leaf spot, nailhead spot, bacterial spot, bacterial wilt, bacterial canker, grey wall, curly top, Verticillium wilt, spotted wilt, southern blight, blossom end rot, puffing, catfacing, and fruit cracking.

In Texas the problem of developing tomatoes with multiple disease resistance did not get started until about 1939. However, it was not until 1950 that a concerted effort was started to develop disease-resistant tomatoes adapted to the Lower Rio Grande Valley. Personnel from the Texas Agricultural Experiment Station at Weslaco (Paul W. Leeper), Winter Haven (Bruce A. Perry), College Station (H. C. Mohr), and Yoakum (A. L. Harrison); and from the U. S. Department of Agriculture at Beltsville, Maryland (William S. Porte) and Charleston, South Carolina (C. F. Andrus) are now cooperating in the tomato-improvement program for the Lower Rio Grande Valley. Disease-resistant lines developed by the different cooperators are grown in the Valley for studies on adaptability and selections made from promising material. Some of the selections are screened for disease resistance under controlled conditions in greenhouses and some are used for hybridization with other disease-resistant lines to incorporate resistance to other diseases into the promising lines. It usually takes from six to ten generations of single plant selections to sufficiently stabilize a strain in order to enter it in replicated performance tests. Even then additional selections may be necessary before the strain can be released for commercial use.

A summary of the status of the improvement program with reference to the various diseases may be of interest:

Fusarium wilt:

With the introduction of Weshaven (Anon., 1955) and Rio Grande (Anon., 1958) by the Texas Agricultural Experiment Station and Homestead (Andrus, 1953) by the U. S. Department of Agriculture, the soil-borne disease, Fusarium wilt (*Fusarium lycopersici*), is no longer a

Figure 1. Tomato plants inoculated with the Fusarium wilt fungus. Plants on right and left are resistant; plants in center susceptible and dying from Fusarium wilt.

problem in the Lower Rio Grande Valley. These varieties, as well as most commercial introductions since 1950, have field immunity to the race of the Fusarium-wilt fungus that occurs in Texas. Most of the breeding lines now under observation have this same type of resistance to Fusarium wilt. The problem of screening for wilt resistance in segregating propulations is a simple procedure. The roots of young seedlings are dipped in a suspension of the wilt fungus and grown in greenhouse flats until ready for field setting. Only those plants that have a high level of resistance survive in the greenhouse flats if a virulent strain of the fungus has been used. This method of testing for wilt resistance is not only more rapid and requires less space, but is also more reliable than planting the segregating material in the field. (Figure 1).

Grey leaf spot:

Grey leaf spot (*Stemphylium solani*) frequently causes serious defoliation, especially during periods of prolonged high humidity. Resistance to this disease, as well as Fusarium wilt, occurs in the Weshaven and Rio Grande varieties, and in many of the advanced breeding lines. Selections for resistance sometimes are made under field conditions and sometimes in screening tests under controlled conditions in the greenhouse. The technique is to spray a spore suspension of the grey leaf spot fungus on to young plants, and then place them in a moist chamber under high humidity for 36 to 60 hours. In five to ten days disease resistance ratings can be made.

Alternaria collar rot:

Collar rot (*Alternaria solani*) is a phase of early blight in which cankers develop on the stems of the tomato plants. It is most serious in

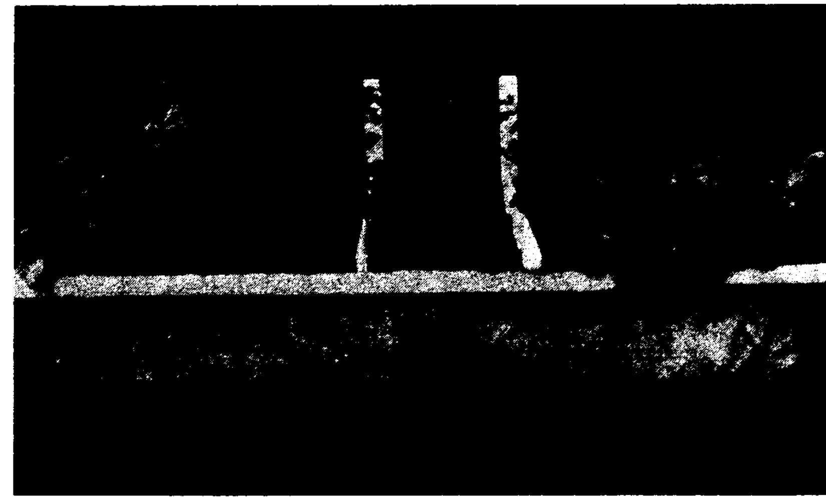

Figure 2. Tomato plants inoculated with the collar rot fungus. Plants on left and right resistant; plants in center susceptible and drying from collar rot.

the young-plant stage because then cankers may girdle the stem and actually kill the plant. Resistance to this disease occurs in many of the breeding lines in the tomato-improvement program for the Lower Rio Grande Valley. Screening for this disease is usually done under greenhouse conditions (Figure 2). The technique is similar to the one used in screening for Fusarium wilt resistance, and in fact may be combined with the wilt test. The roots and stems of the young plants, three to four weeks old, are dipped in a combined suspension of the fungi causing Fusarium wilt and collar rot and then set in greenhouse flats. Plants that are susceptible to wilt will die from wilt, those susceptible to collar rot will die of collar rot. Of course, if the seedling is susceptible to both it is sometimes difficult to tell which disease was the actual cause of death. Survivors may then be set in the field for further observation. There are commercial varieties available that have combined resistance to Fusarium wilt and collar rot but none that are adapted to the Lower Rio Grande Valley. Weshaven and Rio Grande have some tolerance to collar rot but are not as resistant as some of the breeding lines.

Early blight:

Early blight (*Alternaria solani*) frequently causes serious defoliation of tomatoes and occasionally a fruit rot. It is caused by the same fungus that causes collar rot. Resistance to the collar-rot and leaf-spotting phase does not necessarily go together. Selections for resistance to early blight are usually made under field conditions since the disease is generally more prevalent during harvest time. Tolerance to early blight occurs in some of the advanced breeding material.

Figure 3. Tomato plants growing in root-knot infested soil. Tray of plants on left resistant to the root knot nematode; tray of plants on the right susceptible to root knot.

Root knot:

Root knot is a soil-borne disease that causes galls on the roots of tomato plants. The vigor of the plants are greatly reduced, and may directly or indirectly be the cause of premature death. Resistance to the common species (*Meloidogyne* spp.) of the root-knot nematode is present in some of the advanced breeding lines. Progress has been slow but nevertheless definite. The original root-knot resistance was obtained from a wild Peruvianum tomato that has fruits more like small green grapes than tomatoes. During the initial stages of the program, many of the hybrids were very poor producers, and in fact some were self-sterile. However, after repeated backcrossing to commercial types, this factor for low-yielding ability has been overcome and at the same time, the original resistance to root knot has been maintained.

The screening tests for root-knot resistance have been carried on in the greenhouse. Soil thoroughly infested with root-knot nematodes has been used to grow the plants for field setting and only those plants free of root knot were set in the field (Figure 3). This phase of the tomato-improvement program has progressed to where lines resistant to root-knot are being tested for commercial acceptance. Some of the advanced root-knot-resistant lines also carry resistance to Fusarium wilt, grey leaf spot and Alternaria collar rot.

Leaf mold:

Leaf mold (*Cladosporium fulvum*) is a disease that is usually confined to greenhouse tomatoes, however, it has on several occasions caused serious defoliation not only in the Lower Rio Grande Valley but also in

areas of South-Central Texas. Because of this fact, a definite attempt to get leaf-mold resistance into the program was started in 1954 when crosses were made between Texto 2 (Anon., 1955) and a leaf-mold-resistant line from the Southeastern Vegetable Breeding Laboratory at Charleston, South Carolina. Selections from this cross also carry resistance to Fusarium wilt and grey leaf spot and a high level of resistance to the strains of the leaf-mold fungus occurring in Texas. However, they are not resistant to race 6 according to Dr. D. L. Bailey of the University of Toronto. Because of this fact new crosses have been made, using varieties resistant to race 6 as one parent. This program is still in its infancy and material adapted to the Lower Rio Grande Valley conditions and with resistance to all the known races of the leaf-mold fungus is not available.

Mosaic:

Mosaic is a serious virus disease of tomatoes and can cause losses in quality and production. There are many strains of mosaic which has increased the complexity of the program. Some attempts have been made to incorporate mosaic resistance into the tomato-improvement program, however, none of the material available has sufficient resistance to give satisfactory results.

Multiple disease resistance:

The main objective of the tomato-improvement program for the Lower Rio Grande Valley is to combine resistance to as many diseases as possible into one tomato. This coming season lines will be evaluated that have resistance to Fusarium wilt, Alternaria collar rot, grey leaf spot, root knot and leaf mold from one or both parents. The multiple disease resistance studies have been simplified by determining resistance to the first four diseases at the same time. The procedure is to dip the roots and stems of three- to four-week-old seedlings in a mixed suspension of the Fusarium-wilt and collar-rot fungi and set the plants in soil thoroughly infested with the root-knot nematode. When the seedlings are well established, the plants are sprayed with a suspension of spores of the grey-leaf-spot fungus and incubated for 36 to 60 hours in a moist chamber. Plants that survive this procedure usually carry high resistance to all four diseases. A number of breeding lines have this multiple-disease resistance, but do not have all the necessary horticultural characters needed for a commercial tomato. However, lines with multiple-disease resistance adapted to Lower Rio Grande Valley conditions should be available in the next few years.

Other diseases:

As time and facilities permit resistance to other pathogenic diseases of tomato will be added to the improvement program.

Resistance to blossom-end rot, puffing and fruit cracking are considered in the field evaluation studies made each crop season. Some material is available that has good resistance to all these physiogenic disorders.

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The Relative Efficiency of Liquid and Solid Forms of Fertilizers as Indicated by the Growth Response of Cabbage

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The use of liquid fertilizers has increased steadily in the Lower Rio Grande Valley over the past decade. From a very minor position as primarily a specialty product with limited use, the manufacture and marketing of liquid fertilizers now makes up a significant part of the commercial fertilizer industry.

Liquid fertilizers comprised only 0.3 per cent of the total quantity of primary nutrient fertilizers used in the United States in 1946-47. The proportion increased to 2.6 per cent in 1953-54 (Jacob and Scholl, 1955). This increase in the use of liquid fertilizers from 1947 to 1954 is shown in Table 1.

Very little data is available on the relative efficiency of liquid and solid fertilizers or on the efficiency of different methods of applying such materials. An experiment was initiated in 1956 at the Valley Experiment Station to obtain more information on crop response to such materials.

METHODS AND MATERIALS

Treatments used in the investigation are presented in Table 2.

The experimental design was a randomized block with four replications. Plot size was six rows (38 inches wide) fifty feet in length. Cabbage of the variety Gloria Enkhuizen was planted two rows to the bed and thinned to a spacing of 12 inches within and between rows on the bed. The soil was a Willacy loam.

Table 1. Consumption of Liquid Fertilizers in The United States and Territories (commercial Fertilizers and Plant Food Industry Yearbook—1955). (Short Tons of Material as Applied)

		Year Ended June 30	
Product		*1947*	*1954*
Anhydrous Ammonia		27,314	350,474
Nitrogen Solutions[1]		7,328	191,592
Phosphoric Acid		5,888	15,246
Mixed Fertilizer[2]		6,607[3]	27,548
	TOTAL	47,136	584,860

[1] Aqua ammonia and all other aqueous solutions supplying nitrogen as the only primary nutrient.

[2] Continental United States only. Includes ammonia phosphate solutions.

[3] California only.

Broadcast treatments were applied by hand. Dry materials were banded using a chisel applicator that applied the materials into the center of the beds 2-3 inches below the seed zone. Fertilizer solutions applied directly to the soil were banded with a chisel applicator equipped with an engine driven gear pump for metering fertilizer solutions. Soil-applied anhydrous ammonia was applied with a conventional chisel applicator previously calibrated for rate of application. All materials applied in the irrigation water were metered through gated, aluminum irrigation pipe onto the plots at the irrigation immediately after seeding. All other treatments were applied just prior to the seeding and irrigation operations. The total fertilizer treatment was applied at the beginning of the season.

Application efficiency of the fertilizer materials was considered to be excellent from the standpoint of uniform distribution of fertilizer materials.

RESULTS AND DISCUSSION

The yields of maketable cabbage in tons per acre by head sizes are given in Table 3. All sources of nitrogen regardless of method of application resulted in significantly higher yields. Under conditions of this experiment cabbage did not respond to applications of phosphate fertilizer of any kind. Size distribution was not appreciably influenced by source of material or method of application.

It is interesting to note that the method of fertilizer application or placement did not significantly affect yield response. This is probably best explained by the fact that the cabbage was planted at a very high

Table 2. Fertilizer treatments, source of materials and methods of application.

Treatment	*Source of material*	*Method of application*
120-0-0	Ammonium nitrate	Broadcast dry
120-0-0	Nitrogen solution (20-0-0)	Irrigation water
120-0-0	Anhydrous ammonia	Irrigation water
120-0-0	Ammonium nitrate	Banded in soil
120-0-0	Nitrogen solution (20-0-0)	Banded in soil
120-0-0	Anhydrous ammonia	Banded in soil
120-60-0	Ammonium nitrate & superphosphate	Broadcast dry
120-60-0	Fertlizer solutions (8-20-0 and 20-0-0)	Irrigation water
120-60-0	Anhydrous ammonia and superphosphate	Banded in soil
120-60-0	Ammonium nitrate and superphosphate	Banded in soil
120-60-0	Fertilizer solutions (8-20-0 and 20-0-0)	Banded in soil
120-60-0	Anhydrous ammonia and superphosphate	Irrigation water and broadcast dry

Table 3. Yield and size distribution of marketable cabbage as affected by different sources of fertilizer and different methods of application.

	Yields in tons/acre—1956				*Yields in tons/acre—1957*				*Avg. total yield tons/acre 1956 and 1957*
	*Sizes***				*Sizes*				
Fertilizer Treatment	*1*	*2*	*3*	*Total*	*1*	*2*	*3*	*Total*	
0-0-0					1.59	10.40	6.68	18.67	18.67*
120-0-0 Ammonium nitrate broadcast	5.37	14.55	2.68	22.60	2.69	13.00	9.97	25.66	24.13
120-0-0 Nitrogen solution in irrigation water	3.59	14.42	3.70	21.71	1.52	14.06	7.68	23.26	22.49
120-0-0 Anhydrous ammonia in irrigation water	3.28	15.27	5.21	23.76	1.49	12.65	7.90	22.04	22.90
120-0-0 Ammonium nitrate banded	4.87	15.01	2.34	22.22	2.39	14.10	10.52	27.01	24.61
120-0-0 Nitrogen solution banded	5.21	14.57	1.60	21.38	1.65	12.89	10.35	24.89	23.14
120-0-0 Anhydrous ammonia banded	6.10	13.76	1.55	21.41	1.85	14.07	7.92	23.84	22.63
120-60-0 Ammonium nitrate and superphosphate broadcast	5.51	15.68	2.71	23.90	1.39	12.53	6.41	20.33	22.12
120-60-0 Ammonia in irrigation water superphosphate broadcast	4.14	15.10	2.56	21.80	2.04	13.41	7.12	22.57	22.19
120-60-0 Fertilizer solution in irrigation water	4.50	15.09	1.20	20.79	3.23	13.06	6.23	22.52	21.66
120-60-0 Anhydrous ammonia and superphosphate banded	6.53	12.99	1.32	20.84	1.73	10.75	8.97	21.45	21.15
120-60-0 Ammonium nitrate and superphosphate banded	5.10	14.95	2.43	22.48	2.00	11.05	7.57	20.62	21.55
120-60-0 Fertilizer solutions banded	4.59	14.43	2.27	21.29	3.14	13.56	9.82	26.52	23.91

* 1957 Only
** Size 1 — under 1.5 lb.
Size 2 — 1.75 to 2.75 lb.
Size 3 — over 3.0 lb.

density stand which resulted in thorough root exploration of the fertilized zone of soil. Even under broadcast fertilizer application good utilization of fertilizer was obtained. It would be expected that with single row crops the banded fertilizer would be more effective than fertilizer applied broadcast or in irrigation water.

It should be pointed out that the application efficiency of fertilizers applied in irrigation water as far as uniform distribution is concerned was at a maximum under conditions of this experiment. Under field conditions the application of fertilizers through the irrigation system is likely to be far less efficient because of ditch losses, excessive leaching and uneven distribution of water on to the land.

It is significant to note that with good application efficiency one source of nitrogen was equally as effective as other sources tested.

SUMMARY

The yield response of cabbage to dry and liquid fertilizer treatments and to different methods of fertilizer application was checked.

All sources of nitrogen caused significant yield increases regardless of method of application. Different sources of nitrogen were equally effective.

Cabbage did not respond to phosphate fertilizers in this experiment.

Under high density plant population method of fertilizer application or fertilizer placement did not affect yields or head size distribution. Good application efficiency was obtained with all methods of application.

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Control of Onion Tip and Leaf Blight

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INTRODUCTION

The need for an effective method to control a severe outbreak of tip and leaf blight of onions became a matter of urgent importance in January through February and into March of 1959. The disease, which became epidemic by early February in the Lower Rio Grande Valley, affected onion fields in all stages of growth. It was more serious in young, thick stands than in older and thinner stands. The disease first developed as a tip blight and within a few days the infected leaves collapsed and died during wet weather periods which occurred frequently. The suspected causal fungus, *Botrytis squamosa*, and other fungi associated with the tip and leaf blight disorder are reported by McLean and Sleeth (1959).

Spray trials were initiated to find a fungicide or chemical and dosage that would control the tip and leaf blight disorder after it had become well established in an onion field. This approach was in striking contrast to a preventative control program and it was realized that different results might be obtained. Under the circumstances it was too late to follow a preventative program. The immediate need was a control program that would arrest the disease and minimize subsequent infections from the tremendous quantity of spore inoculum that already had been produced.

METHODS

Young onions, 3 to 6 leaf stage, severely diseased, were used in the spray trials. The spray materials were applied with a hand compressed air sprayer at an approximate rate of 100 gallons per acre. A commercial spray spreader-sticker was used at the rate of 4-6 ounces per 100 gallons. The results presented in Table 1 are based primarily upon the response observed 7 to 10 days after the first application. In case of the fungicides, additional sprayings did not change the comparative evaluations made following the first application.

RESULTS AND DISCUSSION

The most effective material and dosages was maneb at the rate of 4 pounds per 100 gallons. Maneb at the 2-pound rate and zineb at 2 and 4 pounds were only slightly effective. However, Parzate-C at the 2 pound rate in an early preliminary trial gave outstanding control. Two possible explanations for the response to the Parzate-C application may be (1) formulation and (2) it was applied while the disease was mostly in the tip blight stage and may have functioned as a preventative measure.

Table 1. Comparative effectiveness of sprays applied to control tip and leaf blight of onions in severely infected fields.

Fungicide or chemical	*Pounds per 100 gallons spray*	*Disease control*	*Further trial needed*	*Recommended for grower use*
Maneb	4 pounds	Good	Yes	Yes
Maneb	2 pounds	Fair	Yes	?
Zineb	4 pounds	Fair	Yes	?
Zineb	2 pounds	Fair	Yes	?
Captan	2 & 4 pounds	None	No	No
Copper A	2 & 4 pounds	None	No	No
Copper Sulfate	2 pounds	None	?	No
Iron Sulfate	16 pounds	None	?	No
Zinc Sulfate	2 & 4 pounds	None	?	No
Magnesium Sulfate	4 pounds	None	?	No
Manganese Sulfate	3 pounds	None	?	No
Manganese Sulfate	3 pounds	None	?	No
Mixture of Copper, Manganese and Zinc Sulfates		None	?	No

Copper A and Captan were ineffective in controlling top and leaf blight in severely infected onions. No favorable response was obtained from spray applications of copper, iron, magnesium, manganese or zinc sulfates, or a mixture of copper, manganese and zinc sulfates (Table 1). Further trials with minor element foliage sprays are desirable on Valley onions, but applications should be made early and before foliage diseases become a serious problem.

Based on the results obtained in these trials the use of maneb at the rate of 4 pounds per 100 gallons and 4-6 ounces of a commercial spray spreader-sticker applied at 7-day intervals was suggested to the onion growers. Parzate-C at the rate of 2-3 pounds per 100 gallons was suggested as an alternate spray material. In suggesting such a spray program it was realized that its effectiveness depended upon a number of factors, the principal ones being the weather and the spraying operation. It has been gratifying to receive reports from onion growers which attest to the effectiveness of maneb at the suggested dosage in bringing under control a serious disease situation. It is not unlikely than an effective preventative onion disease control program would be somewhat different from the one suggested for an epidemic situation.

SUMMARY

Of a number of fungicides and chemicals used as sprays, maneb at the rate of 4 pounds per 100 gallons water with 4-6 ounces of a commercial spreader-sticker was the most effective in controlling tip and leaf blight of onions. Parzate-C, a formulation of zineb developed for use on citrus, at 2 pounds per 100 gallons water plus a spreader-sticker gave very good control of onion tip and leaf blight in the early stage of the disease.

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Tip and Leaf Blight of Onions in the Lower Rio Grande Valley

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INTRODUCTION

A tip and leaf blight of onions (*Allium cepa* L.) was unusually severe during the 1958-59 winter growing season in the Lower Rio Grande Valley of Texas. Losses from the disease, which reached epidemic proportions, are estimated at 50 to 75 per cent reduction of expected yields from approximately 10,000 acres planted. Recurrent periods of excessive precipitation, high humidity, and cool, cloudy weather were favorable for the disease to develop. Similar tip-blight symptoms were observed in previous winters, but were much milder. Symptoms were somewhat similar to those described by Ivanoff (1938) in the Winter Garden region of Texas and referred to locally as "onion blight" or "onion wilt." The disease was observed on leaves of yellow, red and white bulbing onions and on early bunching onions. Plants of different sizes and ages were similarly affected.

SYMPTOMS

Early symptoms of the disease were firing or a light scorched appearance of the tips of older leaves which turned a tan to light brown color and died. As the disease progressed, infected leaves collapsed and looked wilted (Figure 1). Often the stem or the neck was invaded, killing the plant. The disease was more severe and losses greater in young, thickly planted onions than in older and wider-spaced ones. Several fields of young onions were abandoned because of severe loss.

Foliar lesions associated with the tip blight showed discrete, elliptical, greyish-white necrotic areas, approximately 0.5 x 0.1 mm. usually with sharply defined margins. These lesions were slightly sunken and elongated in the direction of the long axis of the leaf. Exposed portions of the inner leaves often showed spotting without the tip blight. The lesions bear some resemblance to those caused by thrip injury, but lack the cuticle injury and surface excrement characteristic of such injury.

CAUSAL AGENT

Repeated mycelial and conidial isolations were made from infected leaves, and the most commonly isolated organism fits the description of *Botrytis squamosa*. Spores of this organism, produced in great abundance on blighted and dead leaf tips, measured 15.0-25.0 x 10.0-19.0 microns. Septate conidiophores with typical accordion-like pleats or folds in degenerated side branches, a distinct characteristic of *Botrytis squamosa*, closely agreed with the description by Walker (1925). Formation of

abundant sclerotia on culture media, as well as on dead onion leaves and on unharvested onions, is a distinct characteristic of the fungus.

Purple Blotch (*Alternaria porri* (Ell.) Cif.), which is common most years, was not observed on young onions affected with tip and leaf blight. *Stemphylium* sp., *Alternaria* sp., and *Cladosporium* sp. were observed occasionally on dead blighted onion leaves.

DISCUSSION

In England, Hickman and Ashworth (1943) attributed similar disease symptoms on onions to three species of *Botrytis*. The predominant fungus isolated in their investigations was *Botrytis squamosa*. Similar symptoms were reported by Yarwood (1938), who demonstrated that *Botrytis cinerea* may infect onion leaves and seed stalks. Walker (1925) reported that *Botrytis allii* and *B. byssoidea* "may cause small, white, necrotic lesions on leaves and seed stalks." Viennot-Bourgin (1952), who observed a firing of the leaf tips on white onion in the winter of 1951-52 near Rennes, France, considered *Botrytis squamosa* to be the causal agent. Page (1953) considered *Botrytis squamosa* to be the causal agent of a foliage disease of onions in the Holland-Bradford Marsh, Ontario, during the 1952 and 1953 growing seasons. A similar leaf blight on Narcissus was described (Gould 1946) as caused by *Botrytis polyblastis*, and the disease is commonly referred to as "fire" (polyblastis).

Botrytis squamosa was described by Walker (1925) as producing numerous flat, scale-like sclerotia on infected white onion bulbs. In the reports cited (Page 1953, Hickman and Ashworth, 1943, Viennot-Bourgin 1952), the investigators failed to find sclerotia of *Botrytis squamosa* on infected foliage in the field; however, typical "squamosa" sclerotia were found occasionally on storage bulbs and were produced readily in culture. In these studies in Texas, numerous small, black sclerotia developed on diseased leaves and bulbs placed in moist chambers, and abundant sclerotia occurred on the necks of infected onions in the field.

Apothecial production from sclerotia of *Botrytis squamosa* was reported by Cronshey (1946). Apothecia, a perfect stage of this organism, were not observed in Texas. Sclerotia produced on infected onions in the field may well perpetuate this fungus in the Valley soils from year to year.

SUMMARY

A severe tip and leaf blight disease occurred on onions in the Lower Rio Grande Valley of Texas during the winter growing season of 1958-59. Symptoms of the disease are described. Losses are estimated at 50 to 75 per cent reduction of expected yields from approximately 10,000 acres planted. *Botrytis squamosa* was the most common fungus isolated from infected onion leaves, and this organism was usually associated with tip blighting. Abundant sclerotia of the organism were readily obtained in culture and were produced on infected onion leaves and bulbs in moist chambers. Sclerotia also were found on the necks of infected onions in the field.

Figure 1. Onions affected with tip and leaf blight, showing firing on tips of older leaves and the general wilted appearance of diseased plants.

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Demeton Residues on Tomatoes

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The tropical mite, *Tetranychus marianae* McG., is a very destructive pest of tomatoes in the Rio Grande Valley (Wene, 1957). Research work showed that demeton (Systox) was one of the few commercially available miticides that was effective in controlling the tropical mite (Wene, 1958). Even though demeton gave effective control its use could not be recommended until a determination was made showing the tomato fruit did not absorb dangerous amounts of demeton.

A hand garden sprayer, applying 100 gallons of water per acre, was used in spraying demeton at the rate of 0.25 pound per acre to a 0.02 acre plot of tomatoes. Care was taken to see that the fruit was also covered by the spray. Seven, 14 and 21 days after the treatment a 2-pound sample of tomatoes was picked and frozen. An equal-size sample was taken from an untreated portion of the field. The frozen tomato samples were analyzed by the chemists of Chemagro Corporation.

No detectable traces of demeton were found on any of the samples. These data indicate that demeton can be safely used for the control of the tropical mite, especially since applications are usually made before the plants start fruiting.

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Field Tests of Insecticidal Dusts For Control of the Cabbage Looper

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The cabbage looper *Trichoplusia ni* (Hbn.) is the most important insect pest affecting cabbage production in the Lower Rio Grande Valley of Texas. Considerable difficulty in controlling the cabbage looper by the use of insecticides has been reported by growers in the past.

Wene (1958) obtained poor control of the cabbage looper with the use of toxaphene at 1.5 pounds per acre applied as a spray or at 5.0 pounds per acre applied as a dust. Effective control was obtained by the addition of either .25 pound of parathion or methyl parathion. Applications of Phosdrin, endrin, parathion and methyl parathion also yielded commercial control. Bibby (1957) reported excellent control of the looper was obtained from the use of a malathion-Perthane combination at the rate of one pound per acre. Neither malathion at 2 pounds nor toxaphene at 4 pounds per acre gave satisfactory control. Brett *et al.* (1958) applied insecticide dusts to cabbage at the rate of 30 pounds per acre. Erratic control of loopers resulted from the use of 2.5 per cent Phosdrin, and 4.0 per cent Thiodan. Twenty per cent toxaphene was more consistently effective against the cabbage looper than the other insecticides tested.

MATERIALS AND METHODS

Dust formulations of malathion, malathion + toxaphene, cryolite, cryolite + DDT, cryolite + toxaphene, Dylox, Thiodan, Phosdrin, Sevin and toxaphene were evaluated in this investigation. Plots in all but the large scale experiment were .02 acre in size with each treatment replicated three times. The treatments shown in table one were applied with rotary hand dusters. In the large scale test the insecticide was applied with a Sterman airplane to single blocks two acres in size. The untreated control area was one-half acre in size.

The efficiency of each treatment in the small plot tests was determined by selecting 10 plants at random from each plot and counting the number of live loopers before treatment and at various time intervals after application. In the airplane treatment the live loopers were counted on 20 plants selected at random from each plot. The percentage control was calculated by Abbott's formula.

The minimum and maximum temperatures were 50-62° F., 50-86° F., 60-90° F., 48-60° F., respectively, for the periods of test one, two, three, and four. No rainfall occurred during the test periods.

Cabbage in the pre-head stage was the test plant used in tests 1 and 3, while test 2 was conducted on mature cabbage. Test four was conducted on mature lettuce. Third to fifth instar loopers predominated in all tests except in test three.

Table 1. Cabbage looper control with insecticidal dusts.

Treatment	*Lbs. per acre*	*Initial infestation*	*Looper per plant and per cent control on days after treatment*	
		Experiment 1 – January 13, 1958		
			7 days	
			LPP	%
10% malathion	2.0	1.04	.33	62.4
10% malathion + 20% toxaphene	2.0 4.0	1.21	.25	81.7
20% malathion	4.0	1.00	.33	62.7
20% Toxaphene	4.0	1.13	.21	85.2
Check	....	.92	.84	....
		Experiment 2 – April 10, 1958		
			7 days	
			LPP	%
30% cryolite + 15% DDT	9.0+ 3.5	4.26	.53	77.1
30% cryolite + 15% toxaphene	9.0+ 3.5	2.80	.60	64.9
72% cryolite	22.6	3.20	.20	87.5
20% toxaphene	4.0	3.60	.40	79.8
Check	....	3.67	2.10	–
		Experiment 3 – April 30, 1958		
			7 days	
			LPP	%
20% toxaphene + 10% malathion	4.0+ 2.0	2.20	.17	90.0
4% Thiodan	.8	1.90	.70	59.2
10% Dylox	4.0	2.23	.83	49.6
10% Sevin	4.0	3.73	.10	96.4
20% Toxaphene	4.0	2.73	.20	91.3
Check	....	2.50	2.37	....
		Experiment 4 – December 20, 1957		
			2 days	
			LPP	%
2% Phosdrin	.4	.7	.15	80.7
2% Phosdrin	.6	.6	.25	62.5
Check	....	.9	1.00	....

RESULTS

The data in Table 1 show that 20 per cent toxaphene consistently gave effective control of the cabbage looper when used alone. The addition of malathion or cryolite did not increase the degree of control over toxaphene alone. A mixture of 10 per cent malathion + 20 per cent toxaphene proved better than 10 per cent or 20 per cent malathion alone but not better than 20 per cent toxaphene used alone. Control with a mixture of 30 per cent cryolite + 15 per cent DDT was more effective than 30 per cent cryolite + 15 per cent toxaphene but not equal to 72 per cent cryolite. In test 3, 10 per cent Sevin, 20 per cent toxaphene, and 10 per cent malathion + 20 per cent toxaphene gave excellent control of first to third instar loopers. Ten per cent Dylox and 4.0 per cent Thiodan failed to give effective control. Phosdrin applied by airplane effectively reduced large loopers on lettuce.

SUMMARY

Control tests for the control of the cabbage looper *Trichoplusia ni* Hbn.) were conducted in the Lower Rio Grande Valley of Texas with dust formulations of 10 per cent and 20 per cent malathion, 10 per cent malathion + 20 per cent toxaphene, 72 per cent cryolite, 30 per cent cryolite + 15 per cent DDT, 30 per cent cryolite + 15 per cent toxaphene, 10 per cent Dylox, 4 per cent Thiodan, 2 per cent Phosdrin, 10 per cent Sevin, and 20 per cent toxaphene. Effective control was obtained with 20 per cent toxaphene, 10 per cent Sevin, 10 per cent malathion + 20 per cent Toxaphene, 72 per cent cryolite, 30 per cent cryolite + 15 per cent DDT, and 2 per cent Phosdrin. Ten per cent Dylox, 4 per cent Thiodan, 10 per cent and 20 per cent malathion and 30 per cent cryolite + 15 per cent toxaphene failed to give effective control.

LITERATURE CITED

Bibby, F. F. 1957. Field tests of insecticide sprays for control of cabbage loopers on lettuce. Jour. Econ. Ent. 50:101-2.

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The Control of Turnip Aphids and Flea Beetles with Di-Syston and Thimet

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Control of the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis), on turnips is an important problem in the Winter Garden area of Texas. Many insecticides must be excluded from the spray program to prevent excessive residues on the greens. In preliminary tests, Wilcox and Howland (1957) found that 4 pounds of actual Thimet per acre in granular form applied to turnips approximately 35 days before harvest gave excellent (100 per cent) aphid control and the plants retained only a trace of Thimet (less than 0.004 ppm). Costs of one treatment per crop would certainly be more economical than repeated treatments. Also included in the present study are data on control of the Western flea beetle, *Phyllotreta pusilla* (Horn.) which causes "shot-hole" feeding scars in the leaves, thus hindering the sale as greens. The object of the present study was to confirm previous work and secure data on the effect of the flea beetle and aphid infestations on yields.

MATERIALS AND METHODS

Purple top, white globe turnips were planted January 23, 1959 on beds with 36-inch centers to facilitate observations and minimize granule drift. The plants were treated while in the cotyledonary stage on February 5. Granular formulations of Di-Syston and Thimet, each at 2 rates, were applied by hand from weighed, prepared sacks. There was no wind movement and excellent placement was obtained. Light dews and moderate winds kept the materials in the plant furrow around the base of the plants in a swath 4 inches wide.

The design of the test was a randomized block in which each treatment was replicated five times on experimental plots 2 rows wide and 20 feet long. The effectiveness of the treatments was evaluated by recording flea beetle "shot-holes" on 5 consecutive plants at 5 random locations per plot. A beetle count was made but was not considered reliable due to the rapid movements of the insect. Thirty-nine days after treatment the aphids present on 6 random plants per plot were counted and 53 days after treatment the aphids on 10 random leaves per plot were counted. Green yields were taken 39 days after treatment, root yields were recorded 63 days after treatment. In both cases the yields were taken by harvesting 2 random 3-foot row areas per plot.

Data were evaluated statistically for sources of variance by use of the F-test and for differences between treatment means by Duncans' New Multiple Range test at the 5 per cent level of probability. Presenting differences between means by this method would be difficult in a table, so they are mentioned only in the text.

RESULTS

Flea beetle and aphid damage in relation to yields of greens are summarized in Table 1. No other insects were present in destructive numbers. Twelve days after treatment the plants averaged 3 true leaves with 8 holes per plants in the untreated plots. All treatments were very effective in protecting the greens. Twenty-five days after treatment Thimet at 2 pounds per acre was superior to the other treatments as shown by only 4.7 beetle feeding holes per plant (7 leaf stage) in contrast to 28.7 holes per plant in the check. All treatments increased the yields. It is important, however, when comparing the yields of greens, to note that only plots treated with 2 pounds of actual Thimet per acre were free enough from aphids to permit processing and marketing of the greens.

Table 1. Effect of systemic insecticides on flea beetle damage to turnip greens, 1959.

Treatment		*Mean number of shot-holes per 25 plants following treatment*		*Mean yield (grams/6 ft. of row)*
Material	*Pounds active/acre*	*12 days*	*25 days*	*39 days*
Thimet	1	16.2	200.6	1121.4
Thimet	2	11.8	117.4	1048.0
Di-Syston	1	38.0	526.4	944.4
Di-Syston	2	20.0	451.2	1030.0
Check	0	208.0	717.8	803.00

Results of aphid and flea beetle infestation levels on the root yields are shown in Table 2. All treatments were effective 39 days after treatment, but only Thimet at 2 pounds actual per acre, gave a commercial level of aphid control. Thirty-nine to 53 days after treatment, chemicals under test at all rates of application become relatively ineffective. No significant yield differences appeared due to insect control.

Table 2. Effect of systemic insecticides on the turnip aphid and on root yields, 1959.

Treatment		*Mean number of aphids per plot following treatment*		*Mean yield (grams/6 ft. of row)*
Material	*Pounds active/acre*	*39 days (6 plant)*	*53 days (10 leaves)*	*63 days*
Thimet	1	21.6	102.4	1201.0
Thimet	2	0.6	73.2	1079.4
Di-Syston	1	34.4	107.2	1099.0
Di-Syston	2	23.6	77.2	1045.8
Check	0	56.8	90.4	1080.0

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