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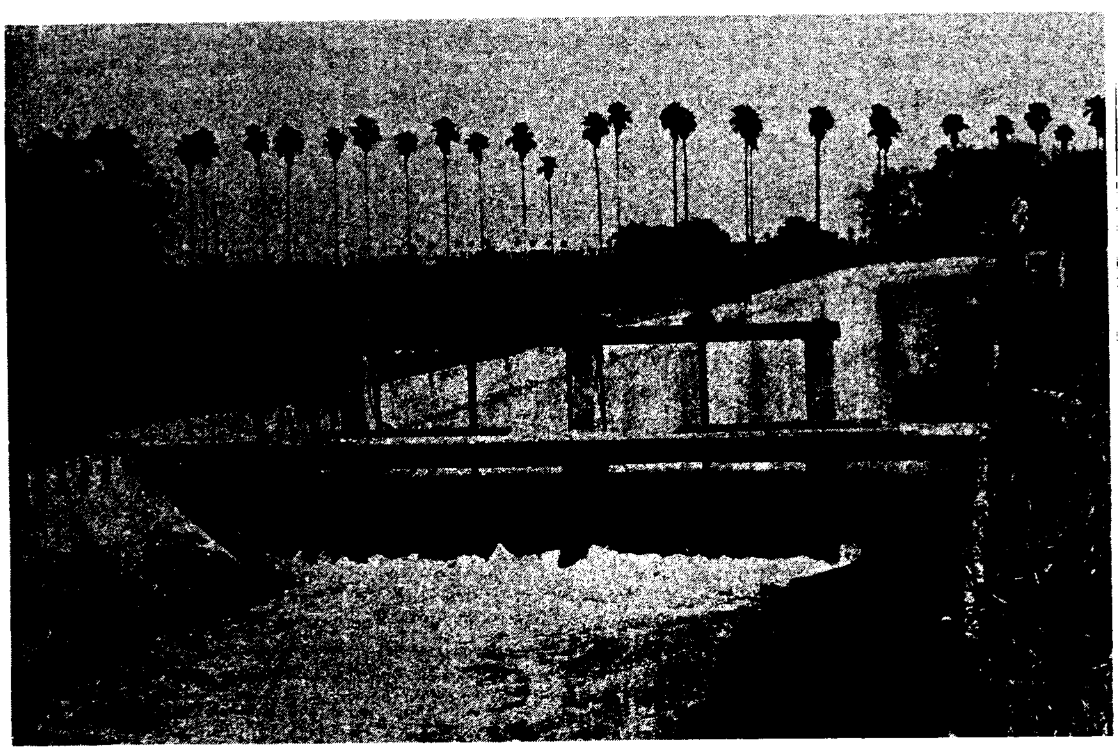

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Aims and Objectives of the Society

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

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

The Society has sponsored 19 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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HARRY FOEHNER, Recipient of the Arthur T. Potts Award for 1965

In 1955, the Rio Grande Valley Horticultural Society voted to present an award to one person each year, for outstanding work in horticulture.

The award was named after its first recipient, Arthur T. Potts. Beside Mr. Potts, the list of recipients includes such outstanding personages as Dr. William Popenoe, E. M. Goodwin, Dr. J. B. Webb, Dr. G. H. Godfrey, Dr. W. C. Cooper, Lon C. Hill, W. H. 'Bill" Friend, Paul W. Leeper, and Stanley Crockett.

Harry Foehner received the Arthur T. Potts award in 1965 "in recognition of his contributions to Valley horticulture through many years of meritorious reporting of farm news and as an active member and loyal officer of the Horticultural Society."

Harry Foehner has specialized in farm news for many years, as reporter and editor. He is editor of Texas Farming and Citriculture magazine; correspondent for agricultural publications outside the Valley, and public relations advisor for several Valley organizations. He is past president of the Horticultural Society. In recognition of his service to agriculture, he has received awards from the Soil Conservation Society of America, and the Southmost Soil Conservation District.

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*Honorary members of Rio Grande Valley Horticultural Society.

CITRUS AND SUBTROPICAL FRUIT SECTION

Effects of Several Oils and Influence of Deposit Rates on the Juice Quality and Maturity of Grapefruit in Texas[1]

H. A. DEAN, R. C. HALTER, CLIFFORD E. HOELSCHER and JACK C. BAILEY[2]

Factors which cause a delay in maturity of grapefruit may curtail shipment of fruits early in the season. Oil sprays have been reported to retard soluble solids development when applied during certain months. Oils were applied during the June-September period of 1960 and 1963 to determine the possible effect on maturity. Oil deposition on field trees was also determined for comparison with that on laboratory-sprayed grapefruit during 1963.

Several investigators have shown juice quality effects following the use of petroleum oil on oranges, but only a few reports were found which showed juice quality of grapefruit reduced following the use of oil in certain months. Total soluble solids were reduced in oranges treated with as little a dosage as 0.25% oil in California (Sinclair et al., 1941). The application of oil in August or September in accordance with procedures recommended for proper usage greatly increased the probability that reduction in solids of orange juice in California could be avoided (Riehl et al., 1957). In Florida oil sprays applied after August 1 either delayed or prevented the formation of maximum solids, especially during the early part of the picking season (Thompson and Sites, 1945). Grapefruit and pineapple oranges were affected more or less the same in regard to timing of oil sprays. Their work also indicated that the first part of November was the earliest time that the grapefruit samples reached minimum maturity standards. The soluble solids of fruits sprayed with a higher molecular weight paraffinic oil treatment in Texas were consistently lower when compared with the soluble solids of fruits sprayed with 3 other oil treatments or a non-oil treatment, applied in July (Dean and Bailey, 1963). Although the soluble solids were lower, the percentage acid was correspondingly lower so that ratios were not significantly different. A few samples made minimum legal maturity standards by early November.

Minimum maturity standards of grapefruit for intrastate movement under Texas law were issued by the Texas Department of Agriculture

[1] Technical contribution No. TA 5092, Texas A&M University, Texas Agricultural Experiment Station, Substation No. 15, Weslaco. These investigations were partially supported by Esso Research and Engineering Company, an affiliate of Humble Oil & Refining Co.

[2] Assoc. Entomologist, TAES, Weslaco; Research Associate, Baytown Research and Development Division, Esso Research and Engineering Company; Technician I (Entomology), TAES, Weslaco; Graduate Student, Mississippi State University of Applied Arts and Sciences.

(White, 1959). The minimum ratios required respectively for the following minimum percentage solids were: 7.2 to 1 for 9%; 7 to 1 for 10%; 6.8 to 1 for 11% and 6.5 to 1 for 11.5%.

Structural composition and deposition of various petroleum oil fractions have been related to insecticidal efficiency. Control of certain deciduous fruit tree pests in New York was reported in relation to the paraffinicity, molecular weight, density and deposition rate of the oils (Pearce et al., 1948). In Florida, 50-90 micrograms oil per square centimeter were considered necessary to obtain scale control on citrus while deposits greater than 90 micrograms gave significant leaf drop (Redd, 1945). However, spray oils in current usage are more-highly refined and contain higher unsulfonated residue percentages. Greater oil deposits are considered possible with these oils to achieve better pest control, and less tree responses are considered likely as a result of their usage. The oil-depositing efficiency of a quick-breaking spray is desirable, so an effective compromise must be found between oil-depositing efficiency and safety to the tree (Ebeling, 1959). In California, results showed that 120 micrograms oil per square centimenter would be necessary to control adults of California red scale, *Aonidiella aurantii* (Mask.), and eggs of citrus red mite, *Panonychus citri* (McG.) (Riehl et al., 1958). Consistent inhibition of photosynthesis did not occur at levels below 150 micrograms dosage (Riehl and Wedding, 1959). Therefore, an oil-deposition range between 120 and 150 with 1.75% oil in the diluted mixture was considered a desirable oil-deposit range in California. An oil deposit of approximately 140 micrograms for spray mixtures made with 1.6% oil was considered desirable for Texas citrus because of current usage of the more highly refined fractions (Dean et al., 1964).

MATERIALS AND METHODS

Physical properties of the spray oils are shown on Table 1. Oils A and C were derived from paraffinic crudes. Inspection characteristics of

Table 1. Summary of spray oil properties.

	Oil A	*Oil B*	*Oil C*
Gravity, °API at 60 F (ASTM D-287)	35.3	36.3	33.0
Molecular weight (Mills)	325	300	362
Viscosity, SSU @ 100F (ASTM D-445)	73.5	57.6	105.0
Oil, Vol. %	99.75	99.75	99.5
Unsulphonated residue, (ASTM D-483), Vol. %	96.3	96.1	90.0
Distillation at 10 millimeters pressure (ASTM D-1160) 50% point, °F	448	410	475
Maximum boiling range (10-90%)	65	47	55
Neutralization Number (ASTM D-974)	Neutral	Neutral	Neutral

Oil B compare favorably with inspection characteristics of comparable viscosity oils from paraffinic crudes. The oil-soluble surfactant, Sponto 200[3], was used at 0.5% (by volume) with Oil C, but this surfactant was later withdrawn from our program because of its oleic acid content and high acid number. The latter oil was used at only one field location for comparison with a non-oil, selective-miticide-control treatment. Oils A and B contained 0.25% Triton X-207[4] for field use. The latter surfactant was used at 3 dosages with Oil B in laboratory deposit studies. Blood albumin spreader[5] was used at 4 oz. per 100 gallons mixture with Oils A and B. All diluted oil mixtures contained 1.6% actual oil plus one pound 75% WP zineb per 100 gallons of spray mixture.

A colorimetric method was used for determination of oil deposit on grapefruit in the laboratory, except that Oil Red A dye was substituted (Riehl et al., 1953). A recently-described technique was used for determination of oil deposits on leaves and fruits in the field (Dean et al., 1964).

Each juice-quality sample was comprised of the juice from 16 grapefruit. Fruits of the same average diameters were picked randomly from the outer periphery and interior of the tree in each quadrant in a zone 2 to 6 feet above the ground. Fruits from the northwest and southeast trees were combined as were the fruits from the northeast and southwest trees of each plot at the Crockett experiment (near Harlingen) where plots were replicated 4 times. Scale insects were present in very small numbers throughout the period of testing. Single tree plots were replicated 3 times at the experiment station.

Juice was removed by a hand-extractor unit powered by a ¼ horsepower motor and screened through a 16 mesh stainless steel screen. Volume and weight of juice were determined.

Acid content was determined by titration with standard sodium hydroxide and is reported as anhydrous citric. A hand refractometer with temperature correction was used for determination of percentage soluble solids in accord with an established procedure (Sinclair et al., 1941).

RESULTS AND DISCUSSION

Juice quality analyses from the Crockett grove in which Oil C was used showed that none of the samples passed the minimum maturity standard by October 4. Although the minimum for soluble solids was found, as shown in Table 2, the acid had not dropped sufficiently to meet the required soluble solids to acid ratio. All samples met minimum maturity standards by November 2, while a much better soluble solids to acid ratio was found on December 2, even though the percentage soluble solids had dropped further.

[3] Sponto 200 manufactured by Retzloff Chemical Company, Houston, Texas.
[4] Triton X-207 manufactured by Rohm and Haas Company, Philadelphia, Pennsylvania.
[5] Blood albumin 25%; inert ingredients 75%.

Table 2. Effect of an experimental paraffinic Oil C spray applied on various dates on juice quality of red grapefruit on indicated dates during 1960 at the Crockett grove near Harlingen, Texas.

Date	Soluble Solids			Acids			Solids/Acid		
applied	10/4	11/2	12/2	10/4	11/2	12/2	10/4	11/2	12/2
7/1	9.60 b	9.60 b	9.38 bc	1.60 c	1.34 b	1.30 c	6.03 c	7.12 c	7.25 c
7/15	9.54 b	9.60 b	9.45 ab	1.57 bc	1.34 b	1.26 b	6.08 c	7.12 c	7.51 b
8/1	9.39 c	9.46 c	9.30 c	1.51 a	1.33 b	1.24 b	6.21 bc	7.11 c	7.50 b
9/1	9.46 bc	9.31 d	9.10 d	1.50 a	1.26 a	1.21 a	6.29 b	7.40 b	7.57 b
Non-oil	10.01 a	9.79 a	9.55 a	1.54 ab	1.29 a	1.23 ab	6.51 a	7.61 a	7.79 a

Values followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

The percentage of soluble solids for the non-oil treatment was significantly higher than for the oil treatments except that the July 15 oil C treatment was not significantly lower in the juice samples conducted on December 2. Percentage soluble solids of fruits from September 1-treated plots were significantly lower than in other plots except in the October 4 samples. In general July-treated plots showed consistently higher soluble solids in juice samples than did August and September-treated plots.

A tendency for higher acid percentages was found with samples from the early-treated plots. The September Oil C and the non-oil plots were not significantly different on either date examined. Percentage acid was consistently lower for samples from September 1-treated plots than other treatments. Percentage acid was particularly low in samples from the first replication of September 1-treated plots.

The soluble solids to acid ratio of the non-oil treatment was significantly higher than that of Oil C on each sampling date. Samples of all treatment plots made minimum legal maturity (7.2 to 1 ratio with 9-9.9% soluble solids) on December 2. Samples from September 1 Oil C plots and non-oil plots also made minimum maturity by November 2. The lower percentage acid in the fruits from September 1 plots resulted in a higher ratio than other oil treatment dates, even though the percentage soluble solids were lower.

Analyses of grapefruit samples taken at Weslaco, November 6, 1963, from Oil A and Oil B plots are shown in Table 3. Data from previous work (Dean and Bailey, 1963) had shown minimum maturity standards for grapefruit were not met in early October and all samples met minimum standards by early December.

The percentage juice by weight was significantly higher for Oil B. A highly significant difference in samples indicated that juice extraction was not as uniform as would be desired.

The soluble solids in September-treated plots at Weslaco were significantly less than in other plots while the soluble solids in the June-

Table 3. Effect of experimental Oils A and B applied in various months during 1963 on juice quality of red grapefruit November 6, 1963 at Weslaco, Texas.

Application	% juice by weight		Soluble Solids		Acids		Solids/Acid	
Date	Oil A	Oil B	Oil A	Oil B	Oil A	Oil B	Oil A	Oil B
June 14	50.90	51.24	11.00	11.20	1.57	1.57	7.04	7.16
July 11	52.97	52.04	10.13	10.43	1.38	1.40	7.32	7.45
August 15	50.67	52.55	10.77	10.10	1.42	1.51	7.58	6.72
September 16	49.40	53.40	9.23	9.90	1.30	1.49	7.11	6.72

treated plots were significantly higher than in other plots. No differences were found in soluble solids from the July and August-treated plots. No differences were found in the soluble solids samples from Oil A or Oil B plots.

June samples showed significantly higher acid content than July and September samples. No differences were found in acid percentages of fruits sprayed with Oil A or Oil B.

No significant differences were found in the analyses of soluble solids to acid ratio for oils or months. However, it is important that the juice from the September-oil-treated plots did not meet the minimum ratio required for maturity. The ratio with Oil B for August treatment was also too low for minimum maturity standards. The greater oil deposit with Oil B, as shown in Table 4, during August and September might be related to the lower soluble solids and ratio.

The greater oil deposit in the field during June 1963 (Table 4) was the result of over spraying. While preparations were being made for stripping the oil from leaves and fruits, the first tree received more oil than desired. The same spray pattern was used on the following 5 trees to maintain uniformity. Deposits did not differ significantly during the following 3 months except that deposit on leaves with Oil B during August was significantly greater than in July or September, as shown in Table 4. No significant differences in oil deposits were found among leaf samples (or fruit samples) from each tree or among samples of leaves (or of fruits) from the four quadrants. Deposits of oil on leaves (and on fruits) were significantly greater with Oil B than with Oil A.

An analysis was made of laboratory oil deposit data for each oil with the following variables: surfactants (2), samples (12) and months (4). Oil deposit with blood albumin did not differ significantly between months with either Oil A or B (Table 4). Significantly greater deposits of Oil A were found with blood albumin than with Triton X-207. No differences were found between the 2 surfactants with Oil B. Consistently greater deposits were found using blood albumin with Oil A than with Oil B in the various months. A diluted-treatment-mixture of 1,000 ml was prepared each time 9 fruits were sprayed on the turntable. Treatment mixtures were replicated 4 times. Each mixture provided 3 samples with stripping from 3 fruits each.

Analysis of the variables of surfactants, oils and months showed no significant difference for months with either oil with blood albumin. With Triton X-207, deposits with Oil B in July, August and September were significantly greater than in June. July deposits were significantly greater than in August and September. With Oil A, deposits were significantly greater in August and September.

Deposits of Oil B on grapefruit in the laboratory are shown in Table 4 for 3 concentrations of the surfactant, Triton X-207. Deposits decreased as the percentage (volume) of the surfactant increased. Deposits were 25-41% less with the greater dosage (0.68%) of Triton X-207 during

Table 4. Average micrograms of oil per square centimeter in field and laboratory experiments at Weslaco, Texas.

	Field				*Laboratory (fruit only)*					
	Oil A		*Oil B*		*Oil A with*		*Oil B with*			
Month	*Leaves*[a]	*Fruits*[a]	*Leaves*	*Fruits*	*Blood Albumin*	*TX 207*[b] *0.25%*	*Blood Albumin*	*TX 207 0.25%*	*TX 207 0.34%*	*TX 207 0.68%*
June, 1963	227.3 a	205.0 a	287.2 a	262.1 a	173.2	121.3 b	140.3	114.6 c	109.0	85.7
July	108.5 b	98.2 b	137.4 c	143.7 b	179.7	125.4 b	159.8	185.9 a	124.0	111.3
August	127.3 b	121.7 b	198.1 b	146.7 b	197.4	145.6 a	182.7	149.5 b	108.0	88.0
September	129.1 b	124.9 b	160.3 c	182.5 b	185.4	142.9 a	159.2	151.9 b	132.3	103.3
					NS		NS			
Aug., 1964					194.2	111.4	164.4	113.7	98.2	93.3

[a] Values followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.
[b] Triton X-207

1963. The water contained the following total soluble salts (ppm) during the indicated months of 1963: 768 in June; 700 in July; 800 in August; and 880 in September. In August 1964, the water contained 970 ppm total soluble salts.

Deposits of oil in the laboratory trials during August 1964 were somewhat smaller than in August 1963. Greater deposits were gain found with blood albumin spreader, particularly for its use with Oil A. Deposits for each oil with Triton X-207 were smaller than with blood albumin in the increased dosages of Triton X-207 with Oil B resulted in smaller deposits.

SUMMARY

Results indicate that application timing and choice of oil are important to fruit quality development of grapefruit in Texas following application for pest control. Significant interference with maturity development occurred for oil sprays applied in September. Increased effects of spray oil were found for the fraction with the highest distillation temperature values and for increases in rate of oil deposit. Legal maturity was not attained by October by fruit from either oil or non-oil treatments. Juice quality increased in the fall as percentage acid decreased.

Rate of oil deposit was consistently greater in the field with the lowest molecular weight oil, due perhaps to its composition difference that may require formulation adjustment. In the laboratory, oil deposit on grapefruit was greater for mixtures made with blood albumin than with Triton X-207. Increased concentrations of Triton X-207 decreased rate of oil deposit.

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Citrus Oil Deposit with an Aerosol Sprayer[1]

CLIFFORD E. HOELSCHER, RICHARD C. HALTER and H. A. DEAN[2]

The use of petroleum oils for insect control has created a need for better application methods on small numbers of trees. Commercial methods of application may be impractical or impossible for small or inaccessible grove areas. Selected oil formulations have been very beneficial in the Rio Grande Valley to citrus growers for tree protection against certain mites and scale insects in previous years (Dean and Bailey, 1962; Dean 1963; Reinking 1964). Currently oils are applied in a water emulsion (usually containing one to 1.6 gallons of oil per 100 gallons of water) and applied to trees as a recommended all coverage technique. It was anticipated that a more concentrated formulation might be used to achieve comparable results with respect to deposit, completeness of tree coverage, and ease of operation.

A compact simplified method of applying oils for a small operator or an isolated grove was investigated at the Texas Agricultural Experiment Station at Weslaco during July, 1964. The applicator used in these field evaluations was a German manufactured SOLO PORT sprayer. This applicator unit is a packback, motor driven, low velocity, large air volume sprayer.

METHODS AND MATERIALS

Deposit measurements were taken from grapefruit and orange trees ranging in height from twelve to fifteen feet. These dense regrowth trees were used in one tree plots and were replicated twice.

Four formulations of a narrow boiling paraffinic base stock were used and the physical properties of the oil are as follows:

Gravity °API at 60°F (ASTM D-287)	35.1
Specific Gravity, 60°/60°[3]	0.8493
Average Molecular Weight[4]	330.0
Viscosity at 100°F, SSU (ASTM D-445 & D-446)	74.6
Unsulfonated Residue, Vol. % (ASTM D-483)	96
Neutralization Number, Mg. of KOH/Gm (ASTM D-974)	Neutral
Distillation at 10 mm pressure, 50% point (D-1160)	450.
10% to 90% Range, °F	70.0

[1] Technical Contribution No. TA 5080 Texas A&M University, Texas Agricultural Experiment Station, Substation No. 15, Weslaco. These investigations were partially supported by ESSO Research and Engineering Co., an affiliate of Humble Oil & Refining Co.

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[3] Converted from API Gravity using Table 3 of Fisher/Tag Manual for Inspectors of Petroleum.

[4] Obtained from correlations by Mills, Herschler, and Kurtz, I. & E. C., Vol. 38, p. 442 (1946), using VIS at 100°F and sp. gr. at 60°F.

Four surfactant combinations were evaluated with the single oil. The composition and some properties of each formulation are shown in Table 1. Formulations A and B were "Mayonaise" type formulations and C and D were emulsive liquids. Water containing 830 total soluble salts ppm were used to prepare the formulations for application. The spray mixtures were formulated to contain ten percent oil by total weight.

Trees were sprayed with a modified total coverage spray technique (Riehl et al., 1959). This spraying technique is recommended to growers to achieve maximum results from an insecticide application to citrus trees. Essential total spray distribution and coverage were evaluated for completeness. Preliminary sprayings were made using mixtures containing 0.25 grams of Fluorescent Yellow C-4 dye per 100 ml of oil (Dean et al., 1961). The four quadrants of each tree were sprayed thoroughly from the inside with a sweeping motion from top to bottom and from far to near quadrants with careful attention to the inside skirt, branches and trunk. Outside coverage of the dome and skirt was obtained by using horizontal strokes from side to side of the full visible width of the foliage progressing downward to the bottom to cover each of the four quadrants. The spray was directed to the tree from each of eight different locations. The sprayer was operated at full throttle and settings of three and four were used at the liquid outlet. With these position settings, an output volume of approximately 0.26 or 0.42 U. S. gallons, respectively, of spray mixture per minute could be expected. The sprayer was equipped with a spray tank of two and one half gallon capacity. Spraying time varied from two minutes and 40 seconds to four minutes and 36 seconds depending on the size of the tree covered. Immediately following application, three leaves were taken at random from each quadrant of the tree at levels of three, six and eight feet. These samples were examined in darkness under ultraviolet light for dyed oil distribution.

Oil deposit measurements on the fruit and foliage were determined by the dyed-oil technique (Dean et al., 1964). Three fruit and three leaves were collected from each quadrant and stripped immediately with dioxane after each individual tree was sprayed. The quantity of oil deposited was calculated from spectrophotometric measurements of the dye content of the dioxane strippings. Oil Red A dye was used at a concentration of 0.25 grams for each 100 ml. of oil.

RESULTS AND DISCUSSION

Inspection of the leaves sprayed with Fluorescent Yellow C-4 dye under ultraviolet light indicated a need for better coverage at the top

Table 1. Analysis of spray oil formulations used in field oil-deposit experiment at Weslaco, Texas during July, 1964.

Formulation	*% Oil*	*% Water*	*% Inert Ingred-ients*	*Total Acid[1] %*	*Strong Acid[1]*	*Total Base[1] %*	*Strong Base[1]*	*Apparent PH[1]*	*Neutral Number[2]*
Emulsified oil A with 0.25% Yellow C-4 dye	80	19	1	0.64	0.0	2.83	0.0	9.2	Neut.
Emulsified oil A with oil Red A dye	80	19	1	0.11	0.0	0.0	0.0	9.5	Neut.
Emulsified oil B with oil Red A dye	85	12.5	2.5						Neut.
Emulsifiable oil C with oil Red A dye	98	—	2						Neut.
Emulsifiable oil D with oil Red A dye	98	—	2						0.75

[1] Potentiometric titrations method (ASTM D-664)
[2] Colormetric titration method (ASTM D-974).

of the tree. This may be overcome by spraying the top portion of the trees from a portable platform.

Formulation A (the term formulation in this discussion refers to diluted spray mixture) produced a significantly heavier deposit than the other formulations tested. Formulation D and B deposits were lighter than A but heavier than C formulation (Table 2). There was no significant difference in deposit among trees sprayed with the same formulations.

Formulation B was the most promising formulation tested. This formulation gave the most desirable amount of deposit and most uniform coverage deposit on both sides of the leaves and in all quadrants, with the exception of the top portion of the tree as previously mentioned. Formulation B also had good stability and remained in suspension satisfactorily to be applied.

In previous tests, the use of water containing a smaller amount of total soluble salts increased oil mixture suspension time. When using water conatining 300 to 500 total soluble salts ppm, all diluted spray formulations appeared satisfactorily suspended for application for a period of 24 hours. Formulation A and D separated noticeably in eight minutes and C and B formulations in 10 to 30 minutes, respectively, when water containing 800 to 1000 total soluble salts ppm was used. Standard deviations were higher in formulation A and D as shown in Table 2. This may be a result of the faster separation time of the oils. The coefficient of variation was also greater for these two formulations than B and C formulation. Formulation C has less deviation in deposit on the fruit than other formulations tested but the deposit was very light and was not expected to furnish sufficient insect control.

The most desirable deposit level approached 140 micrograms of oil per square centimeter with formulation B. This is in the desired deposit range with a 70 viscosity oil and is expected to furnish efficient insect control with a minimum amount of tree reaction effect (Riehl et al, 1958; Dean et al, 1964).

Table .2 Average micrograms of oil deposited per square centimeter on fruit and leaves and coefficients of variation in the field experiment at Weslaco, Texas during July, 1964.

	Fruit			*Leaves*		
Formulation	*Average*	*Standard Deviation*	*Coefficient of Variation*	*Average*	*Standard Deviation*	*Coefficient of Variation*
A	223.4	±55.5	24.8%	215.6	±40.3	18.7%
B	182.1	±42.4	23.3%	148.9	± 8.7	5.7%
C	84.3	± 4.1	4.8%	129.9	± 9.0	6.9%
D	201.6	±47.6	59.0%	162.8	±34.8	21.4%

Initial deposit efforts may be improved with minor changes made in formulations for an insecticidal efficiency study conducted for future field use of this form of application.

SUMMARY

A field evaluation was conducted with a SOLO PORT sprayer using concentrated oil formulations for oil deposit on citrus. The most desirable oil deposit level with the formulations tested was obtained by using an emulsified oil containing 85 percent oil, 12.5 percent water and 2.5 percent inert ingredients. A fluorescent dye technique with this formulation also indicated better spray distribution and uniform coverage.

Oil suspension time decreased when using water containing a greater amount of total soluble salts.

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Release to Texas Growers of Citrus Budwood of Virus-Indexed Selections of 11 Varieties

E. O. Olson and Bailey Sleeth[1]

The Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Texas Agricultural Experiment Station have jointly released for commercial propagation budwood of 11 selections indexed and found free of 4 viruses: psorosis, tristeza, exocortis, and xyloporosis. With the possible exception of 'Changsha' tangerine and 'lemonquat', these are well known to the citrus industry (Webber, 1946). They are released for commercial propagation because other selections of these varieties are either known to carry one or more viruses, or are of uncertain virus status. Available budwood is limited. *Budwood – not to exceed 50 buds – of indicated selections can be obtained by licensed nurserymen from Nursery Inspector, Texas Department of Agriculture, Pharr, Texas.* If orders should exceed the supply of budwood, individual orders will be pro-rated on the basis of numbers of orders received. Orders for fall budding will be accepted after September 1, 1965; for spring budding by January, 1966.

DESCRIPTION OF VARIETIES FROM WHICH SELECTIONS WERE MADE

'Summerfield' navel orange (TR 20) differs only in minor details from the 'Washington' navel, and is probably a nucellar seedling of Florida origin.

'Parson Brown' sweet orange (TR 21) is a standard early variety in Florida, and the trees are considered more cold hardy than the popular 'Pineapple' orange. In Texas, it develops a good juice color earlier in the season than other sweet oranges. Its seeds are big and numerous.

'Clementine' ('Algerian') tangerine (TR 22) is an early-season, sweet-fruited, cold-hardy tangerine of good quality. It has been notable for its cold hardiness in freezes in 1949, 1951, and 1962.

'Changsha' tangerine (TR 23) is an extremely cold-hardy, free-peeling tangerine introduced from China for use in breeding (Traub and Robinson, 1937). It has been exceptionally cold-hardy at Crystal City, Monte Alto, and College Station. The fruit has orange peel, numerous seeds, insipid flavor, and is extremely early. Growers may wish to try it as a backyard tree in areas where the cold hazard is too great for standard varieties of sweet oranges, grapefruit and tangerines.

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'Kinnow' mandarin (TR 24), a high-quality tangerine that fruits later than 'Clementine', is a hybrid of 'King' orange x 'Willowleaf' tangerine. It originated in California.

'Ponderosa' lemon (TR 25) is a popular backyard novelty in the Lower Rio Grande Valley. The fruit is extremely large (sometimes of football size), acid, and more susceptible to cold than the 'Meyer' lemon.

'Lemonquat' (TR 26) is a chance hybrid found at Beeville and tested at Crystal City, Texas. It has flowering habits like those of kumquat, and its fruits are round to pyriform, ranging from 1½ to 3 inches in diameter, and orange-yellow when ripe. The lemon-like interior of the fruit has a pleasant acidity, and becomes sweeter in March and April. The selection probably is a hybrid of 'Meyer' lemon and kumquat (Mortensen, 1954). The 'lemonquat' has value for backyard culture in areas where standard lemons are injured by cold, since it has acid fruit, is cold-hardy, and blooms several times a year. It can be propagated as cuttings.

Calamondin (TR 27) is a popular ornamental, with attractive foliage, numerous small orange-colored acid fruits, and the habit of blooming several times a year. The acid fruits are a good lime substitute, and the trees of the variety are more cold-hardy than the limes. It is propagated commercially as cuttings.

'Chinotto' sour orange (TR 28) is an ornamental variety, uncommon in Texas, and characterized by small, acid, ornamental orange fruit, and small leaves crowded closely together along the stem. The tree is small and thornless, and suited to landscape use.

'Meiwa' kumquat (TR 29) has broadly oval golden to red fruits, with edible thick peel. The tree is attractive, and blooms several times a year. Kumquats are recognized as one of the most frost-resistant of all citrus fruits, particularly when grown on *Poncirus trifoliata* rootstock. They flower late in spring when danger of frost has greatly decreased.

'Nagami' kumquat (TR 30) has fruit more elongated than the 'Meiwa'. Original trees of both kumquats were growing near Crystal City, Texas, on *P. trifoliata* rootstock.

Rootstocks for various selections are indicated in Table 1. Some varieties, especially kumquats, kumquat hybrids, and calamondin, are unsuccessful on sour orange rootstock. Outside the Lower Rio Grande Valley, they should be propagated on *P. trifoliata*. In the Valley, calamondin or 'Cleopatra' mandarin rootstocks should be used for kumquats and their hybrids.

Nurserymen should protect their budwood source of virus-indexed selections by budding only on trees which have never been budded before. In all cases, a scion grove should be situated at least 35 feet or more from non-indexed or old citrus trees.

Table 1. Selections of indicated variety, released to Texas citrus growers.

Selections	*Texas Release No.*	*Age of selections from seed*	*Recommended rootstocks*
COMMERCIAL VARIETIES			
'Summerfield' navel orange	20	more than 50 yrs.	Sour orange, 'Cleopatra' mandarin
'Parson Brown' sweet orange	21	16 years	Sour orange, 'Cleopatra' mandarin
'Clementine' tangerine	22	more than 50 yrs.	Sour orange, 'Cleopatra' mandarin
SPECIAL VARIETIES			
'Changsha' tangerine	23	16 years	Sour orange, 'Cleopatra' mandarin, *P. trifoliata*
'Kinnow' mandarin	24	14 years	Sour orange, 'Cleopatra' mandarin
'Ponderosa' lemon	25	more than 25 yrs.	Sour orange, 'Cleopatra' mandarin
'Lemonquat'	26	16 years	'Cleopatra' mandarin, calamondin
Calamondin	27	16 years	'Cleopatra' mandarin, *P. trifoliata*
'Chinotto' sour orange	28	16 years	Sour orange, 'Cleopatra' mandarin
'Meiwa' kumquat	29	more than 30 yrs.	'Cleopatra' mandarin, calamondin, *P. trifoliata*
'Nagami' kumquat	30	more than 30 yrs.	'Cleopatra' mandarin, calamondin, *P. trifoliata*

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Grafting Citrus Fruits to Small Potted Seedlings

E. O. Olson[1]

Reasonable success has been obtained in grafting grapefruit, some mandarins, and citrangequat fruits to sour orange and *Severinia buxifolia* seedlings in 6-inch pots (gallon cans) of soil. The process, described here, is illustrated in Fig. 1, A, B, C; the results are outlined in Tables 1 and 2.

Time to graft. Graft after June drop and while cambium of seedling is active, as indicated by ease of bark separation from xylem. Grapefruit fruits in Texas are about 1½ to 2½ inches in diameter at this time, usually mid-June. Grafts made in mid-June were more successful than those made in May.

Plant materials. Use vigorous seedlings with foliage all along the stem. Cut fruit with attached stem and twig of 2 inches or longer. Store in polyethylene bag in such a manner that the fruiting twig does not dry before grafting.

Making graft. Cut twig or stem attached to fruit so that the end can be inserted as a wedge or side-graft into cut surfaces on the side of the rootstock seedling. Exposed cambiums of rootstock and scion should fit together as closely as possible. Wrap the sidegraft with polyethylene tape.

Maintaining high humidity. Bend over the rootstock seedling on the side opposite the graft, and tie the doubled-back portion to the stem below the graft (Fig. 1 A). Do not prune off leaves above graft. Cover fruit, graft, and leafy doubled-back portion of the rootstock with a polyethylene bag. Tie bag at the same point where the doubled-back portion is tied to the stem (Fig. 1 B). The terminal foliage should not be enclosed in the bag. In trials in 1965, many fruits dropped off if all foliage was covered by the bag.

An alternative procedure to maintain high humidity was also used successfully in 1965. The bottom of a polyethylene bag was cut off, so the bag was open at both ends. The grafted branch of the rootstock seedling was passed through the open-ended bag, which then covered some leaves and the fruit grafted to the branch. The terminal leaves were not closed. The polyethylene bag was then tied at both ends.

Treatment after grafting. Place plants in half-shade. The polyethylene bag can be removed after 7 days. When there is a strong callous

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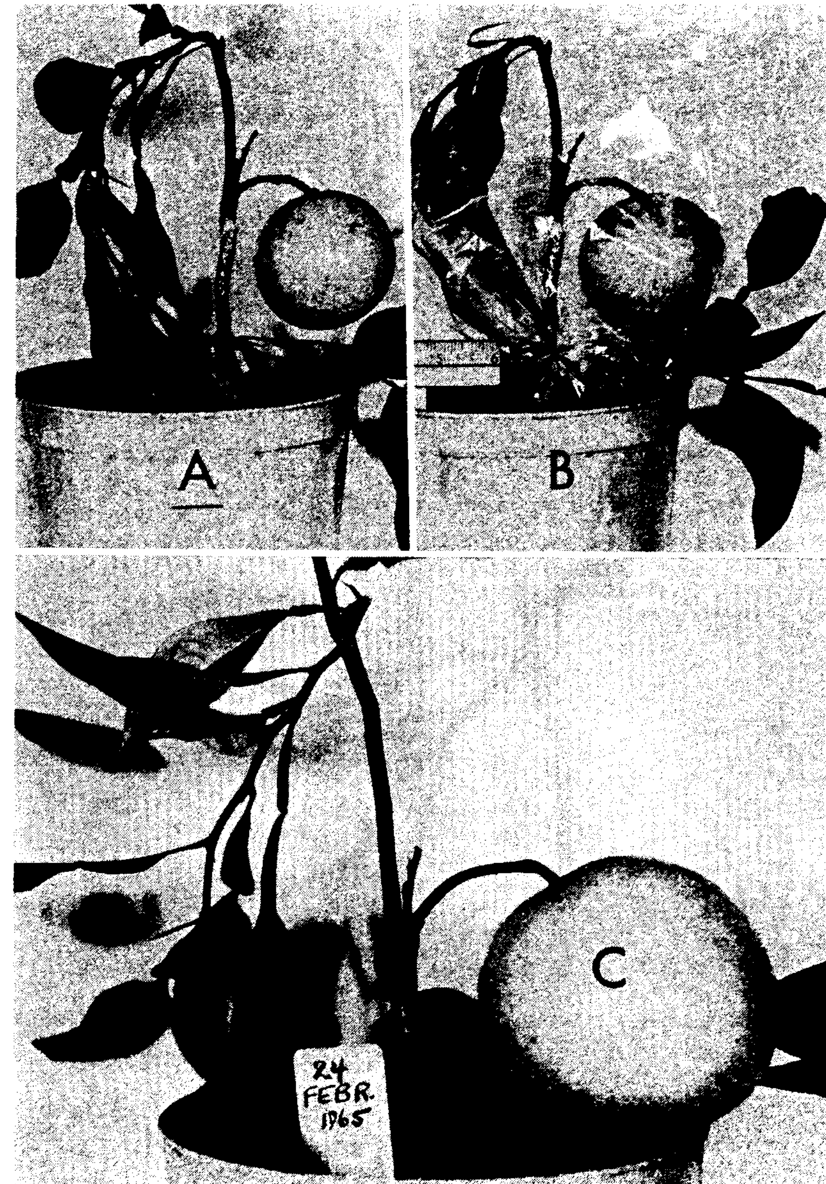

Figure 1. A technique for grafting citrus fruits to a sour orange seedling growing in a 6-inch pot of soil. A. Side-graft of a fruiting twig was wrapped with polyethylene tape and the rootstock seedling was bent over and tied to the stem. B. Graft, leafy doubled-over rootstock, and fruit were enclosed in a polyethylene bag, which was also tied at the rootstock stem. C. 'Redblush' grapefruit had increased in size 7 months after grafting, and callous tissue had developed on the edges of the side-graft.

around the graft, adequate to support the weight of fruit, the polyethylene tape around the graft may be removed. The tape can remain for several months, if considered necessary to support the grafted fruit, provided that the tape does not girdle the graft. In our trials, fruit has remained attached until the next summer. Fig. 1C shows fruit 7 months after grafting.

DISCUSSION

Other workers have grafted fruits to decapitated seedlings growing in the greenhouse or in high-humidity glass chambers. Nairn (1820) grafted oranges and lemons in this manner. Likewise, commercial nurserymen in Florida whip-grafted fruiting kumquat branches to *Severinia buxifolia* stumps (Norman, 1956). Erickson (1957) published a picture showing a fruiting lemon twig cleft-grafted onto a decapitated seedling.

In our trials in Texas, polyethylene bags were used as a substitute for greenhouse or humidity chambers. Grafts to decapitated seedlings were unsuccessful. In 1963, fruiting twigs were cleft-grafted onto decapitated seedlings and the graft and fruit were covered with a polyethylene bag. The twigs and even attached leaves survived, but almost every fruit fell off, with abscission layer forming between the base of the ovary and the disk, just as in June drop (Bartholomew and Reed, 1946). The same thing happened in early-season trials in 1964 (Table 1) and 1965 (Table 2).

Table 1. Percentage of successful grafts of fruit to citrus[1] seedlings in 1964.

Treatment of grafted seedling prior to bagging with polyethylene	*Fruit*	*Date grafted in 1964*	*Seedlings grafted (No.)*	*Successful grafts (%)*
Decapitated	'Sinton' citrangequat	May 30	26	4
Doubled	'Sinton' citrangequat	June 15	20	65
Doubled	'Sinton' citrangequat	June 27	36	46
Doubled	'Redblush' grapefruit	June 17	25	96
Doubled	'C53-4-7' mandarin	June 24	12	33
Doubled	'Fairchild' mandarin	June 24	12	58
Doubled	'Redblush' grapefruit	June 25	14	86
Doubled	'Redblush' grapefruit	July 2	22	100

[1] ***Severinia buxifolia*** and sour orange seedlings.
No rootstock effect on percentage of successful grafts with these scions was observed.

Table 2. Percentage of successful grafts of 'Redblush' grapefruit fruit to sour orange seedlings.

Location of polyethylene bag on rootstock seedling	*Fruit diameter (inches)*	*Date grafted in 1965*	*Seedlings grafted (No.)*	*Successful grafts (%)*
Entire top covered	½ to ¾	May 3-6	500	0
Entire top covered	¾ to 1	May 14	10	0
Double-back portion covered	¾ to 1	May 14	10	0
Entire top covered	1½ to 2[1]	May 25	12	25
Double-back portion covered; terminal leaves exposed	1½ to 2	May 25	12	92
Single branch covered; other branches exposed	1½ to 2	May 25	12	67
Portion of single branch; terminal leaves exposed	1½ to 2	May 25	12	58
Portion of single branch; terminal leaves exposed	1½ to 2	May 26	139	59
Portion of single branch; terminal leaves exposed	1½ to 2½	June 6-9	370	90
Portion of single branch; terminal leaves exposed	2 to 2½	June 21	120	95

[1] Rains during the period between May 14 and 25 caused the rapid size increase.

An important step in successful grafting in these trials was enclosing 3 to 5 or more rootstock leaves in the bag covering the grafted fruit. When leaves were enclosed in this manner, moisture collected and condensed on the sides of the bag. With grafted decapitated seedlings, moisture did not condense inside the bag, because there were no transpiring leaves to add moisture to air around the fruit. The use of polyethylene bags to enclose transpiring leaves provided the high humidity that was apparently necessary for fruit to remain attached to the grafted fruit stem.

USES OF FRUIT GRAFTED ON SMALL SEEDLINGS

Grafting fruit on small seedlings in 6-inch pots of soil can be a useful research technique. Erickson (1957) used it to study influence of leaves on fruit development and composition. He and an associate also used it to study color development in Valencia oranges grown in growth chambers (Erickson, 1960; Young and Erickson, 1961).

The technique is potentially useful in virology studies where significant disease symptoms occur on the fruit. Examples are "Stubborn" disease and "Impietratura" disease, both of which express symptoms on grapefruit fruit. The techniques may also be useful to study June drop.

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A Review of Citrus Research Activities of the U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas

ROGER F. ALBACH and FRANCIS P. GRIFFITHS[1]

In 1931 Congress authorized the establishment of a Citrus Products Station at Weslaco, Texas. Since the original appropriation provided only for the operation of the laboratory, a building was constructed from funds provided by Rio Grande Valley citizens; a site was provided by the Texas Agricultural Experiment Station at Substation No. 15.

The main objectives of the new laboratory were to determine the composition and characteristics of Texas citrus fruit and to develop methods for profitable use of citrus wastes. The laboratory's main research efforts have centered on grapefruit, the major citrus product of Texas.

The laboratory was established prior to the construction of the majority of citrus processing plants in Texas. It aided the establishment of new plant facilities and recommended equipment and methods for handling the Texas crop. Between 1933 and 1938, forty-five processing plants were established in the Lower Rio Grande Valley.

During the first decade, the laboratory developed or demonstrated established methods for preparing: flash-pasteurized, single-strength canned grapefruit juice (Heid and Scott, 1937[a]; Heid and Scott, 1937[b]; Heid and Scott, 1939; Scott, 1941), frozen orange and grapefruit juice (Heid, 1941), carbonated-beverage bases; marmalades and marmalade stocks (Scott and Heid, 1934); fruit butter and jams from excess pulp (Heid, 1938); and fermentation products such as wines and brandies. Analytical methods were developed for use in the citrus processing industry (Scott, 1941).

In the 1940's, the laboratory's interest broadened to include vegetable products. The main research on citrus during this period was devoted toward utilizing processing wastes for preparing commodities of industrial value, such as plastics and chemical by-products (Scott, 1946; Scott, 1948). Technical and economic problems prevented the successful commercial application of these processes. The utilization of dehydrated citrus pulp for cattle feed economically disposed of large amounts of cannery waste. The laboratory then concentrated on the task of increasing the quality of juice products.

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Since Texas red-fleshed grapefruit was extremely popular and profitable, extensive plantings were made during the replanting program which followed the freezes of 1949 and 1951. Initially, the red-fleshed grapefruit proved to be more a liability to the processor than an advantage. The juice from red-fleshed grapefruit was a weak pink color which became "muddy" after storage for several months. When there were few red-fleshed grapefruit, the processor diluted the juice from red grapefruit with sufficient white juice to yield a satisfactory product. An alternative was to remove the pulp, which contained most of the color, and add white grapefruit juice to the depulped juice. This would allow the use of up to 50% pink juice in the blend, as compared to 10-25% in full-pulp blends (Huffman, Lime and Scott, 1953[a]). Both methods were unsuited to the increasing ratio of red to white fruit and the second method was also too expensive.

Rather than remove the color from the juice, the Weslaco laboratory developed a method of enhancing the red color of the juice by pulp fortification and thus created a product which exploited the popularity of red-fleshed grapefruit and increased juice yield by 2-5% (Huffman, Lime and Scott, 1953[a]; Griffiths and Jones, 1954; Lime, Stephens and Griffiths, 1958; Lime and Griffiths, 1960; Tucker and Lime, 1962).

Although pulp fortification produced an acceptable product during part of the harvest season, the process was limited by two factors: the decrease of redness of the fruit as the season progressed (Lime, Stephens and Griffiths, 1954; Griffiths et al., 1959), and the bitterness associated with the pulp, especially in the early season.

The decrease in redness of fruit was caused by the loss of lycopene pigment (Lime, Stephens and Griffiths, 1956; Lime et al., 1957). It could be partially compensated for by adding well-colored canned or frozen pulp from the early season to the weak-colored late-season juice.

To understand physiological and biogenic changes which affect production of pigments, a basic study of carotenogenesis in grapefruit was begun. This work produced inforamtion on the biosynthesis of carotenoids (Purcell, 1958; Purcell and Thompson, 1958; Purcell, Thompson and Bonner, 1959; Thompson, Purcell and Bonner, 1960; Purcell and Thompson, 1961; Bennett et al., 1961), and the physiology (Purcell, 1959[a]; Purcell, 1959[b]; Purcell, deGruy and Carra, 1963; Purcell and Schultz, 1964) of the grapefruit. Purcell and Stephens (1959), by the use of reciprocal grafts of red- and white-fleshed young grapefruit onto trees of opposite type, showed that the ability of a fruit to produce color was dependent only on the fruit variety and not on the type of tree onto which it was grafted.

Recently, using radiocarbon-tracer techniques, Purcell obtained evidence in support of the parallel synthesis of the carotenes (Purcell, 1964[a]). Although phytoene may be a precursor for other carotenes, including lycopene, it is probably not a pool precursor. Fruit, *per se*, apparently are capable of total synthesis of carotenes from carbon dioxide,

and the fruit derives no carotene precursors from the rest of the tree. Data accumulated during these studies indicate that photosynthesis by the fruit may be the major source of carbon for growth of the fruit (Purcell, 1964[b]).

In a current cooperative study with personnel of the Crops Research Division of the Agricultural Research Service (Purcell et al., forthcoming), two-year-old, potted grapefruit trees bearing fruit were subjected to controlled climatic conditions. The variations of fruit size and lycopene content with different climatic conditions are being determined.

The laboratory has been engaged in similar cooperative citrus research activities in the past. Those with the Crops Research Division of the Agricultural Research Service include studies on the effect of rootstocks on grapefruit quality (Cooper and Lime, 1960), differences in orange varieties (Olson and Lime, 1963), and a means of assessing freeze damage (Purcell and Young, 1963); other cooperative studies have been conducted with the Texas College of Arts and Industries, Citrus and Vegetable Training Center (Purcell and Hensz, 1961); Texas Agricultural Experiment Station, Substation No. 15, and Rio Farms, Inc.

Although pulp-fortification improved the color of red-fleshed grapefruit juice, it also increased the bitterness of the processed juice. The Weslaco laboratory has investigated two methods of debittering juice; one is enzymatic (Griffiths and Lime, 1959), the other involves physical adsorption of the bitter compounds on selective resins (Griffiths, 1963).

A method was developed whereby the pulp used for fortification could be debittered by the use of the commercially available enzyme, naringinase (Griffiths and Lime, 1959). As a result of this laboratory scale development the U. S. Department of Agriculture approved a research contract with the Citrus Experiment Station, University of Florida, Lake Alfred, for "The development of a practical and efficient pilot plant process for the manufacture of enzymatically debittered grapefruit and products with improved flavor, product stability, and storage characteristics."

Polyamide and polyvinyl pyrrolidone resins have a high adsorptive capacity for polyphenolic compounds. F. P. Griffiths (1963) established that grapefruit juice of high bitterness can be easily debittered by treatment with these resins. The other aspects of taste as well as the vitamin C content are essentially unchanged. The insoluble resins which have been employed are capable of partial regeneration for recycling by treatment with hot water. It has not been determined for how many such cycles the resin would be useful. Some minor components of the juice appear to be irreversibly adsorbed, and accumulation of these compounds may eventually render the resin useless for further debittering. A public service patent application on the process has been applied for.

During the course of the work on pulp-fortification and debittering, it became clear that the established chemical methods of determining the principal bitter components of grapefruit gave results which did not correlate well with subjective taste evaluations. Because a more thorough understanding of the known flavonoid components of grapefruit was needed, a research contract was negotiated with the University of Oklahoma Research Institute, entitled, "Investigation of the effect of maturity of grapefruit on total flavonoids, naringin, and poncirin; and on the chemistry and nature of naringin and naringin-derived compounds, and their relationship to bitterness." S. H. Wender, assisted by W. J. Dunlap, R. E. Hagen, and J. W. Mizelle of the Institute, and in cooperation with the Weslaco laboratory staff, have successfully developed a method for quantitatively determining the flavanones present in grapefruit (Hagen et al., 1965). Their method is based on a column and thin-layer chromatographic separation of a flavonoid mixture isolated from the fruit, followed by fluorometric analysis of the individual components. The fluorometric readout is compared with standard solutions of known purity and from this the concentration of the individual components are determined.

They have confirmed (Mizelle et al, 1965) that the non-bitter flavanone rutinosides exist in grapefruit as well as the bitter flavanone neohesperidosides. They found both the 7-rutinosides and 7-neohesperidosides of naringenin, hesperetin, and isosakuranetin to be present in red-fleshed grapefruit.

The Oklahoma group also resolved each of the two naringenin derivatives, naringin and naringenin-7-rutinoside, into what are tentatively postulated to be sterioisomers which differ from each other only in the configuration of the asymmetric carbon of the aglycone. They are currently trying to confirm the identification of these isomers.

We are now investigating the sequence of flavonoid development in the grapefruit by exposing fruit-bearing, potted trees to carbon dioxide tagged with radioactive carbon-14. These exposures have been performed at monthly intervals from bloom until harvest. It is anticipated that analysis of the fruit will indicate the relative rates of flavonoid production during the growing season. In the future we hope to correlate these rates with cultural and climatic conditions. Information of this nature would allow a prediction of the fruit quality from groves having different cultural practices. An intelligent timing and selection of cultural practices relative to climatic conditions may allow the orchardist a greater degree of control over some aspects of fruit quality, involving more than just flavonoids.

Present plans call for a continuation and possible expansion of work on the influence of climatic and cultural factors on color and flavor of processed citrus products.

An outgrowth of the laboratory's interest in grapefruit flavonoids has been the examination of other citrus species and relatives for better sources of the minor flavonoids found in grapefruit. This survey, done in cooperation with E. O. Olson of the Crops Research Division of the Agricultural Research Service, shows promise of yielding results which

may aid taxonomists and citrus breeders in their work.

Citrus research of a practical nature has not been overlooked. In recent years such studies include the preparation of grapefruit, tangerine, lemon and lime concentrates or punch combinations (Huffman, Lime and Scott, 1953[b]; Veldhuis, Scott and Griffiths, 1955; Lime and Griffiths, 1957; Stephens, 1958; Lime and Griffiths, 1962), the processing characteristics of limes (Griffiths, Lime and Stephens, 1954), varietal differences in orange quality during the season (Lime and Tucker, 1961; Lime and Tucker, 1962), and the effect of processing variables on the shelf life of chilled citrus juices (Tucker, Lime and Griffiths, 1960).

Although the recent interests of the laboratory have tended toward basic research, the fundamental objectives have not changed. C. H. Fisher and J. R. Matchett (1952) have indicated the probable direction of future research of the laboratory. Citrus research is still directed ". . . at improvements in all stages of production, processing, marketing and use." "Future research on the utilization of citrus undoubtedly will continue to stress efforts to decrease the weight and bulk of processed products and to improve quality from the standpoint of flavor and storagability. Practical developments in some directions, however, may have to await more fundamental research on the chemical, enzymatic and microbiological changes that occur during the processing operations."

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Processing Procedure to Retain Vitamin C in Naranjilla, *Solanum Quitoense*, Products

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INTRODUCTION

Naranjilla is a fruit resembling a small orange in appearance. A native of Ecuador, the plant *(Solanum quitoense)* is now grown in Colombia and Peru. A few years ago, commercial plantings, 600 acres or more, were made in Costa Rica and a company formed to process and export the canned product. The company experienced difficulties in retaining the qualities of the fresh fruit in the canned puree, and in 1963 the writer was requested by A.I.D.[2] to visit Costa Rica and study this and other food processing problems.

PROCESSING INFORMATION

The following brief account relates only to information relative to processing. For a description of the plant, its history, cultivation and agricultural characteristics, the reader is referred to the article by Lehman et al., (1964). In areas where it is grown, the fruit, which is quite like a tomato in structure, is used to make a refreshing drink. It is cut in halves, the inside pulp scooped out of the skin, blended with sugar, water added, and the diluted sweetened juice served as is lemonade.

In the canning plant, the fruit was washed, run over a sorting table to remove overripe and blemished fruit, run through a fruit crusher, pumped to the first of three finishers connected in series. Juice from the third finisher flowed into a large tank where sugar was added to 32-33° Brix, the sweetened juice was pumped through a deaerator, then through a tubular pasteurizer and heated to 190-200° C., filled into No. 10 cans which were sealed and air-cooled. The same process, but without adding sugar, was used to produce a canned naranjilla puree for export.

COMPOSITION

According to information supplied by A.I.D., the edible pulp of fresh naranjilla has the following analysis (also reference Munsell et al., 1953).

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[2] Agency for International Development, U. S. Mission to Costa Rica.

Calories	28 per 100 grams	Calcium	14.0 mgs. per 100 g.
Water	91.8 grams per 100 g.	Iron	0.4 " "
Protein	0.7 " "	Thiamin	.06 " "
Fat	0.1 " "	Riboflavin	.04 " "
Carbohydrates	6.8 " "	Niacin	1.5 " "
Fiber	0.4 " "	Vitamin C	65 " "
Ash	0.6 mgs. "	Vitamin A	50 mcgms "

The total acid as citric is 2.5-3.0%, pH 3.2-3.6, Brix about 10°, total solids 10-12%. The color of fresh pulp is a greenish yellow and it has a characteristics exotic odor and a distinctive flavor.

Examination of the pulp canned (without sugar) in No. 10 cans showed it to be as follows: color, brownish yellow; Brix, 9.8°; acid, 2.45%; vitamin C, 5.35 mgs. per 100 grams; odor, slightly cooked, not distinctive; taste, highly acid; flavor, not aromatic; appearance upon diluting one part with two parts water, brownish yellow, numerous dark specks. The vitamin C content of the canned product was less than 10% of that reported for the edible portion of the fruit.

RETENTION OF VITAMIN C

The vitamin C contents of Costa Rican grown naranjilla were determined so that a better comparison of losses occurring during processing could be made. The amount of vitamin C, as determined by indophenol titration, (A.O.A.C., 1960) in the edible pulp of naranjilla varied considerably. Analyses are as follows:

Description	*Vitamin C per 100 grams*
Juice from very ripe fresh fruit	40 mg.
Fresh juice from slightly greener fruit	33 mg.
Juice from skins of fruit (outside of locules)	13.5 mg.
Fresh juice from fruit being canned	35 mg.
Fresh juice, after 6 hours in refrigerator	20 mg.
Fresh juice, after 24 hours in refrigerator	8 mg.
Fresh juice, after heating fruit to 80° C.	33 mg.
Heated juice, above, after 24 hours in refrigerator	29 mg.
Canned sweetened juice, 37° Brix less than	2.5 mg.

In order to determine at what stage of processing losses of vitamin C were occurring, samples were taken at the canning plant and after immediate removal to the laboratory, titrated for vitamin C. Results are as follows:

	Vitamin C per 100 grams
1. Fresh fruit	33-35 mgs.
2. Pulp after passing through hammer mill	6.5
3. Pulp after first finisher (3.0 mm. screen)	1.6
4. Pulp after second finisher (1.75 mm. screen)	1.4
5. Pulp after third finisher (0.75 mm. screen)	1.4
6. Puree after addition of sugar and deaeration	1.6
7. Canned product, 33° Brix less than	2.6

These analyses show a loss of 80% of the total vitamin content during the first grinding operation and a loss of 95% of vitamin C in the overall operation.

Studies in the laboratory show that vitamin C was lost very rapidly from fresh juice. Juice, on standing 24 hours in a refrigerator, retained only 25% of the original vitamin content. It is evident that naranjilla, like its relative, the tomato, contains an oxidase enzyme which permits very rapid decrease of vitamin C in fresh juice. Heating the fruit sufficiently to inactivate enzymes prevented large losses. Juice which had been heated to 80° C. lost only 12% of the vitamin C in 24 hours.

PILOT PLANT PROCESSING

Arrangements were made with a local Costa Rican cannery to put up an experimental pack of naranjilla puree (sweetened) and a "Tropical Fruit Blend" of naranjilla, papaya, pineapple and lime. This was prepared from fruit which was cooked before pureeing in order to preserve flavor and vitamin C. The process was as follows:

Two boxes (80 lbs.) of naranjilla fruit were washed, rubbed to remove dirt and fuzz, then *trimmed by hand to remove all black areas.* The fruit was cut in halves, placed in a stream kettle and stirred while the temperature was raised to 80-85° C. The naranjilla cooked in its own juice. After cooking 15 minutes at 80° C., the hot fruit was put through a finisher to remove the skins and seeds. The puree was sweetened with sugar to 33° Brix and one-half of the puree filled into No. 10 cans at 80-85° C. and processed 5 minutes at 98° C., then cooled in water as rapidly as possible.

The "Tropical Fruit Blend" was prepared from the remainder of the puree as follows:

5.5 gallons of 33° Brix naranjilla puree
2.75 gallons red papaya puree (8° Brix)
1.0 gallon pineapple juice
1.0 gallon lime juice
24 lbs. more sugar to 30° Brix

This blend was reheated to 80° C., filled into No. 1 cans, cans exhausted through a steam box for 3 minutes at 96-98° C., then processed 5 minutes in boiling water at 98° C., (altitude about 4000 feet) and water-cooled rapidly.

Analyses for vitamin C on juice and blend showed that vitamin C was very well stabilized by heating the fruit to 80° C. prior to pureeing. An additional advantage was that considerably more color (carotene) was obtained from the cooked skins and the puree was a bright orange rather than a greenish yellow. Careful trimming of the fruit prior to heating eliminated the problem of black specks in the final product. Analyses of the products showed 22 mgs. vitamin C per 100 grams in the sweetened naranjilla puree and 28 mgs. vitamin C in the Tropical Fruit Blend. For use, these products are diluted one part with two parts water. These drinks were well liked.

SUMMARY

Naranjilla rapidly loses vitamin C when the fruit is macerated. Heating the fruit to at least 80° C. to inactivate enzymes prior to pulping improves color and stabilizes the vitamin C. Because of the high acidity of 2.5 to 3.0%, short processing times at temperatures below 100° C. should be used, together with quick cooling of the product, if maximum retention of color and aroma is desired. A mixture of naranjilla puree, papaya puree, pineapple and lime juice makes a satisfactory "Tropical Fruit Blend."

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The Importance of Processing to the Lower Rio Grande Valley[1]

C. M. Sherrill[2]

First of all, processing is more important than most people think. Twenty years ago there were forty-seven canneries processing fruits and vegetables in the Valley. Today there are less than ten left. The average Valley resident could not care less how many processors went by the wayside. Other sections of the country feel differently about their processors. Valley processors pay the same for canning crops that other sections pay, but we are continually criticized for what the grower calls "robbing" the farmer.

If Florida did not process citrus fruit, they would have to dig up most of their fruit trees. It is estimated that 88 million boxes of oranges will come off the trees this year, just in Florida. Within five years the Florida orange crop is estimated to be 225 million boxes. It would be impossible to market all this fruit in fresh chanels. The same holds true in the Valley. If it were not for the processing plants we might just as well forget our citrus trees. If it were not for the canning and freezing of fruits and vegetables, most of California's production would have to be forgotten. Still, the average grower, here in the Valley, looks on the processor with a jaundiced eye. One of the officials of the J. J. Heinz Company was in the Valley recently. He stated that if his company had to pay more than $25.00 per ton for ripe tomatoes, they could not afford to put them in cans or bottles. Still my company (Knapp-Sherrill Company) paid $27.00 for ripe tomatoes this past season and in national shortages paid as high as $50.00 per ton for them. The beans we canned this last fall cost us an average of $93.50 per ton, while the canners of Wisconsin bought them for around $70.00 per ton.

The Valley canner and freezer spends hundreds of thousands of dollars in raw product, harvesting labor, plant labor, trucking labor, material purchasing, etc. All of this strengthens the economy of the Valley. When our plant is in operation we often have payrolls that total $18,000 to $20,000 per week. Take the two canning plants out of the City of Donna, and Donna would go a long way towards drying up. When a grower enters into a growing contract with a processor he has assurance that his crop will be harvested. In many instances that is not true when he tries to market through a shipper of fresh fruit or vegetables. This past fall the green-wrap tomato market collapsed. If it had not been for the canner, the tomatoes remaining on the vines would have rotted in the field. I know of two instances in which we salvaged the crop. One

[1] Past President, Texas Canners and Freezers, Weslaco, Texas.
[2] A portion of a talk given at 19th Annual Institute of Rio Grande Valley Horticultural Society, Weslaco, Texas, January 26, 1965.

brought the grower around $125 per acre and the other around $150 per acre. This happened after the growers had sold a heavy tonnage of green tomatoes.

What does the Valley processor mean to the Valley economy? He processes 2 million dollars of green beans; tomatoes and their products, 3.25 million dollars; carrots, 2.75 million dollars; beets, 2.25 million dollars; large quantities of spinach, greens, and miscellaneous vegetables, such as Alaska and cream peas, cabbage for sauerkraut, blackeye peas, lima beans, gabanzos, potatoes, etc. – or a total of all vegetables last years in excess of $15,000,000. At the height of the citrus-fruit canning, before the freeze, there was approximately 25 million dollars of canned juice sold. In the other phases of processing, namely freezing, which is fast growing, it is estimated that 10 million dollars is derived and another 6 million dollars in products not raised in the Valley but processed here. This gives a grand total in excess of 56 million dollars in canning and freezing operations.

The Valley must get off its haunches if it does not want the rest of the United States to run over us. I feel too much emphasis has been placed on crops that make you rich one year and break you the next three years. In my opinion, more research effort must be given to crops for freezing and canning. We have fine climate and fine soil. Most of the time we have water. Still we cannot produce enough tonnage or quality vegetables to compete with other sections.

I have just returned from California. They showed me a tomato which produces some 30 tons to the acre. It is coreless, deep dark red in color and is firm enough to harvest mechanically. Out there they know they MUST use mechanical harvest, for the bracero is gone. This tomato is being lye-peeled instead of being hand-peeled. How can the Valley canner compete with the California canner when the California canner can do away with high-priced field labor and minimum or union wages in the factory? He just cannot do it. The result is that we will go out of business, unless we have better raw stocks to work with. We, here, have done some work on trying to improve our raw stock but we are wav late and far behind other sections. The word BLUE LAKE on a can of beans is magic. With the exception of a few acres, the only Blue Lake bean that has been grown in the Valley is a pole bean and expensive to raise. The Pacific Northwest and Wisconsin have developed a bush Blue Lake bean that can be mechanically harvested. We sit here *hoping* some day to get the same type of bean that will be adapted to this section of the country. The blackeye pea we grow here is subject to weevils, the beans to wilt and disease, the tomatoes to light tonnage and sunburn. The processors of the Valley have the know-how but we cannot exist unless we have better raw stock, and insecticides that will kill insects but not human beings.

Between 50 and 75 million dollars of the Valley economy depend on the processor and freezer staying in business. The men here at the Experiment Station working on our problem are able and well-qualified,

but there are not enough of them. To those of you who carry on experimentation, I urge you to devote more time to canning and freezing crops. To those of you who have influence in higher places, I urge you to insist on more man-power and more money for experimentation. Our problems are big. Other parts of the country are ahead of us. Time is running out on the Rio Grande Valley. The canning and freezing industry of the Valley is too important to let it die.

Concepts of Tree Dormancy, Cold Hardiness, and Freeze Injury in Relation to Citrus[1]

William C. Cooper[2]

In subtropical climates such as Florida, Texas, and California, most citrus trees are exposed to temperatures below freezing at one or more times during their lifetime. Their ability to survive the "test winters," about 1 year in 10, depends upon their cold hardiness.

Citrus trees killed by cold generally look as if they had been scalded. The leaves lose their turgidity, and rapidly dry, and turn brown. Such injury to citrus, however, is not a uniform phenomenon. The symptoms and degree of injury vary, depending not only on temperature conditions of freezing, and possibly thawing, but also upon certain physiological conditions of the plant.

Based on the literature, this article presents an integrated hypothesis of the most plausible concepts of dormancy, cold hardiness, and freeze injury as related to citrus. Its aim is also to make more immediately recognizable the most profitable course for future research in this field.

TREE DORMANCY

By understanding the factors governing dormancy in citrus, we can hope to control cold hardiness.

Summer dormancy. The nature of shoot growth in citrus has been described by Schroeder (1953). Growth in length consists of a series of growth flushes. The buds formed at the axil of each leaf do not immediately grow out but remain inactive as long as the terminal bud of the shoot is present and actively growing. Upon completion of the growth flush, the apical portion of the stem abscises and the auxiliary buds on the shoots remain quiescent for 3 or 4 weeks or longer. Eventually, one of the axillary buds begins extension growth and takes over the function of the former apical bud in suppressing the growth of axillary buds below it.

The inhibition of bud development in the pea plant by physiological concentrations of indole acetic acid has been described by Wickson and Thimann (1958). That a similar simple system of bud inhibition by auxin may occur in the summer dormancy of citrus buds has been suggested by Cooper et al. (1964), who based their theory on the occurrence of large quantities of auxin in the young leaves of actively growing citrus shoots (Cooper, 1939). Sorokin and Thimann (1965) have presented anatomical data on bud development of the pea plant which show that during the sequence of events from the origin of the bud primordia until bud maturity, there is incomplete vascular contact between the bud and the vascular bundles of the stem. Auxin acts to inhibit xylem differentiation, while kinetin is effective in promoting xylem differentiation.

[1] Part of a talk given at the Regional Cold Protection and Cold Hardiness Conference April 28-30, 1965, Weslaco, Texas.

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Similarly, in the magnoliaceous plant *Michelia*, most of the dormant buds lack xylem and phloem connections (Tucker, 1963). Thus, morphological isolation of non-growing buds from the vascular transport system, which appears to be characteristic of inhibited buds in the pea plant, may be of general occurrence. The possible implications of these findings to a better understanding of bud-dormancy points to a need for an anatomical study of dormant buds in citrus.

Winter dormancy. The vegetative growth of most tree species is influenced by the photoperiod and by temperature. Short, warm days in the fall induce bud dormancy on some species; exposing these dormant plant to a long, warm day – with no other treatment – will cause bud growth to resume (Downs and Borthwick, 1956). Other species go dormant on short, warm days but to resume growth require a chilling period in addition to long, warm days. With citrus, short, warm days decrease shoot elongation but do not completely stop elongation and do not set dormant buds (Piringer et al., 1961; Young, 1961). Cool days and nights (60°F. day and 40°F. night) induce dormancy in citrus in the sense of cessation of growth in both short- and long-day photoperiods (Young, 1961). If the plant is returned to long, warm days, growth is resumed. There is no evidence that chilling is required for breaking this kind of dormancy in citrus. Appropriate treatments with gibberellic acid will break winter dormancy in citrus (Cooper and Peynado, 1958).

Cambial dormancy. With ample soil moisture during bud dormancy and bud growth in the late spring, summer, and fall, cambial activity in the twigs, branches, trunk, and roots appears to continue without interruption. Cameron and Schroeder (1945) found that cambial activity is first evident in the spring in twigs and small branches bearing new shoot growth. Cambial activity in other parts of the tree was very irregular but appeared to proceed slowly basipetally. Cooper et al. (1963) found that radial growth of 20-year-old Valencia orange tree trunks in Florida, Texas, Arizona, and California is almost continuous from late spring until late fall. Exceptions occurred when growth inactivity is imposed by drought, heat, or cold. Periods of cambial growth between late spring and fall are not as well defined as shoot-extension growth. Cambial growth appears to be largely mediated by soil moisture and soil or air temperature.

Cessation of cambial growth during the winter depends on the micro-climate of the tree. During the winter in California, the ambient air temperature usually falls below 40°F. every night, and soil temperatures range between 40 and 50°F. The temperature of the roots, trunk, and outer canopy of the tree falls below the minimum temperature for growth (about 50°F.); and buds, cambium, and roots of the entire tree cease growth (Cooper et al., 1963). On the other hand, in Florida and Texas during the winter season the ambient air temperature at night usually falls below 50°F. only about 15 times during the winter. Usually there are no prolonged periods below 50°F. Under these conditions there is usually no growth activity of buds and cambium in twigs of Valencia orange trees. There may be cambial activity in large limbs and trunks which have a temperature near 60°F.

COLD HARDINESS

Many factors vary directly with cold hardiness. There are so many exceptions to each factor that their causal relationships are uncertain. Some may merely be produced by the same environment.

Attempts to determine the influence of each factor in orchard-grown trees met with serious difficulties. While field observations are of value, the infrequent occurrence of "test winters" means infrequent observations and slower progress toward sound conclusions. Each natural freeze usually differs from preceding freezes in several significant aspects. These difficulties have been partially overcome by a variety of procedures: (1) freezing detached leaves and twigs at carefully controlled temperatures in a laboratory refrigeration chamber; (2) freezing the undisturbed tree in the orchard by means of a portable tree freezer; and (3) growing and hardening small plants in controlled temperature chambers. Problems occur with each procedure. Use of the portable tree freezer and the controlled temperature chamber does not duplicate cold conditions on a calm, clear night when the leaves and fruit are exposed to the cold sky. These chambers for freezing plants eliminate the cold sky from the freeze situation. The researcher who grows small plants in growth chambers can control growing and hardening conditions prior to freezing. He is, however, limited to small-sized trees which may differ physiologically from mature trees. Even so, much has been learned during the past decade by the use of these controlled conditions.

Investigators are in general agreement on the gross effects of the dormant condition in increasing cold hardiness of citrus. However, there are many discrepancies among the results reported by various workers in regard to the response. These differences are due, at least in part, to difficulties involved in classifying the degree and kind of dormancy. In a fully dormant tree stem elongation and leaf expansion cease. Cambial activity also ceases, bark is tightly attached to xylem, and twig and trunk circumference does not increase. By estimating the ease with which the bark peeled from the sapwood on the twigs, branches, and trunks of citrus trees, it has been possible to quantify roughly cambial activity.

The buds on 3-year-old Redblush grapefruit trees remained dormant all December and half of January. During this period there was a measurable lessening in the ease of bark peeling but not a complete cessation of bark peeling. Following a flush of bud growth in late January, the ease of bark peeling greatly increased. By mid-February the bark of the branches was quite succulent (Cooper et al., 1955). These trees were

tested for cold hardiness in a tree freezer. In early December the minimum temperature causing injury to the trees was 26°F. for 3 hours; in early January it was 23° for 3 hours; and in early February it was 26° for 3 hours. Thus, the increase in cambial dormancy of the trees in early January was associated with an increase in cold hardiness. During the winter of 1960-61, it was found that cambial dormancy (related to cool winter weather) was associated with increased cold hardiness with 10-year-old Redblush grapefruit trees (Young and Peynado, 1961).

In a series of growth-chamber tests, grapefruit seedlings were exposed to several successive day-night temperature treatments for 2 weeks prior to a freeze treatment (Young and Peynado, 1962). As the preconditioning temperatures were gradually lowered, twig cambial activity gradually decreased and leaf cold hardiness increased. In these tests the seedlings, as a result of exposure to low temperature, tolerated temperatures 7 degrees lower than the controls.

Under Rio Grande Valley conditions, it is possible to prolong winter dormancy and under some conditions increase it by withholding irrigation water. In the experiments with irrigated 3-year-old Redblush grapefruit trees described earlier (Cooper et al., 1955), bud growth associated with warm ambient air temperatures commenced in early February and the minimum temperature at which injury occurred rose to 26° as compared to 23° for early January. At the same time (early February), the minimum temperature for injury to Redblush grapefruit trees on dry soils remained at 23°, while that for Meyer lemon trees on dry soils was 20.5°. On February 12, all trees were irrigated and one week later the trees of both citrus varieties lost their cold hardiness. Thus, cambial dormancy induced by cold weather in December or by drought in January is directly related to cold hardiness. In other words, preconditioning of the trees with cold is not an absolute prerequisite for cold hardiness.

During 1942-43, the seasonal changes in the cold hardiness of citrus leaves in Florida was determined by freezing cut-up samples of the leaves (placed in stoppered test tubes) at carefully controlled temperatures and then allowing the electrolytes to exosmose into distilled water. The amount of exosmosis was used as a measure of tissue damage (Cooper, W. C., 1943, unpublished). The young leaves are at their most susceptible stage from the time they emerge until fully expanded. They are most resistant to low temperatures immediately after this growth period, when they assume their normal green color. Thereafter, with increasing age, they became progressively more tender to cold. Oddly enough, citrus leaves tolerated a lower temperature in May or June than in December or January. These results were based on the performance of detached leaves.

The cold hardiness of the tree stems is partly conditioned by cambial dormancy; and citrus trees in May and June, though they may possibly have cold-hardy leaves, have an actively growing cambium. If soil moisture is adequate, growth in diameter of the trunk, branches, and twigs is rapid and, consequently, these tissues are tender to cold.

FREEZE INJURY

The lethal temperature of a large citrus tree will vary greatly. Most studies on the lethal temperatures of citrus are concerned with the death of organs or their tissues.

In the study of death of citrus leaves caused by low temperatures, the term freezing point of the leaf has often been used synonymously with the death temperature. Under some situations these two values are not always identical. In fact, in many trials with the portable tree freezer on citrus in Texas, occasional "water-soaked" and stiff leaves completely recovered and showed no necrosis.

Ice formation in living plant cells causes changes in plant tissue temperatures during freezing. Luyet and Gehenio (1937) reported a characteristic rise in temperature before freezing in the freezing curve of tissues of potato tubers. Before this rise, the tissue temperature dropped below the freezing point. The minimum temperature before the rise was called the "subcooling point." Young and Peynado (1960) recorded changes in citrus leaf temperatures during freezing on small plants grown in pots and exposed to cold conditions in a "walk-in" freezer set at 33°F. The temperature was lowered to 20° at the rate of 2.5°F. per minute. A characteristic rise in leaf temperature, apparent as freezing was initiated, was followed by a reduction in temperature after the leaf was fully frozen. Freezing curve patterns for the leaves of 6 species of citrus tested were similar in shape. The freezing points ranged from 22° to 23°F. for the different varieties.

Jackson and Gerber (1963), using a different technique, obtained freezing curves on citrus leaves differing considerably from those described above. They used detached leaves placed in test tubes and they inserted the test tubes, in turn, in a −16.6°F. alcohol ice bath in a Dewar flask. The rate of cooling under these conditions was extremely rapid, approximately 7.5°F. per minute. The freezing curve was exceptionally steep on both sides of a freezing-point hump. The freezing points were generally about 3 degrees lower than those of Young and Peynado (1960); in all cases frozen leaves were killed.

Some investigators have considered the death point as a definite temperature at which tissue passes from the living to the dead state. At times, the results with the small portable tree freezers in Texas appeared to indicate the same conclusion (Cooper et al., 1955). Using a standard 3-hour freezing period. a tree would sometime show no injury at 23°F. but would show complete killing of leaves at 22.5°. However, if trees were exposed to 3- and 6-hour freezing periods at 23°, injury would occur at 6 hours but not at 3 hours. Thus, the time factor must be introduced into a definition of both freezing temperature and death temperature.

Luyet and Gehenio (1940) also reported that the apparent freezing point is greatly influenced by the rate of cooling. At rapid rates of cool-

ing, the true freezing point following subcooling is sometimes not reached. Freezing curves which show a plateau at the freezing point are more likely to give the true freezing point.

Ice crystals were abundant in the cambial area of split bark of tree trunks of citrus trees during the 1949 freeze in Texas. In some instances, the bark of such trees was not killed. Callus tissue developed rapidly and soon healed over the split bark lesions.

The histology and physiology of the ice formation in citrus tissue during freezing has not been reported on, but such information is available for frozen animal tissue. Merryman (1958) studied histological sections which were especially prepared to retain the tissue architecture as it existed while frozen. Ice crystals resulting from slow freezing may be many times the size of an individual cell, while the cells are compressed between them in indistinguishable bundles. The appearance of such a section suggested evidence for physical destruction of tissue through freezing, but such is not the case. Such freezing is not necessarily lethal to tissues provided exposure is not excessive. In his experiments, tissues which were frozen to only 3 or 4°F. below the freezing point had only 60 to 70% of their water changed to ice crystals. Although this necessarily resulted in an increase in the osmotic concentration of the cell sap, it was not rapidly lethal. At such low temperatures, cell destruction is not instantaneous and enough cells to permit tissue survival may recover following exposure at these temperatures for a period up to 30 minutes.

The cambial cells of citrus tree bark, though injured by freezing, generally do not show any discoloration. Very little information on tissue survival can be gleaned from microscopic observation of such tissue immediately following a freeze. The cambial cells of avocado shoots, branches, and trunks do show a brown discoloration following injury by freezing (Cooper et al., 1957). Such brown discoloration, however, does not preclude tissue survival. It has been observed that enough cells may recover to permit small areas of meristematic activity and this gradually produces a new and functioning cambium to replace the injured meristem. Similarly, the watersoaked appearance, the gray or milky color, and hesperidin crystals disappeared from all or part of Valencia orange fruit within 3 months after they were frozen (Bartholomew et al., 1950). This is also true of many of the gelatinized vesicles, although this usually does not happen in severely frozen fruit.

Thus, both the freezing point temperature and the death point temperature of a tissue, organ, or whole plant are not precise terms. Instead, one should use the notion of a lethal region–giving the time necessary for death as well as the rate of cooling and other conditions which hasten or delay it. In consideration of these facts, Young and Peynado (1961) have used the expression "L. T. 50." For slow cooling they defined it as the temperature at which the plant, after 4 hours' exposure, must be frozen to produce approximately 50% killing of the leaves.

SUMMARY

There appears to be two kinds of dormancy in citrus. Bud inhibition, or summer dormancy, occurs when environmental conditions are unfavorable for growth. There is no chilling requirement for breaking either kind of dormancy, but appropriate treatment with gibberellic acid will break both kinds. The winter-dormant condition is usually preceded by the bud-inhibited condition on the fall flush of growth. Thus the bud-inhibition and winter-dormant conditions overlap; it is difficult to establish when winter dormancy begins. A study of the early development of the xylem connections between the stem and the dormant buds (both during the summer and winter) is needed to clarify if there is a morphological isolation of dormant buds from the vascular system of the plant.

To distinguish between factors causally related to cold hardiness and those merely produced by the same environment, it would be profitable to explore, in more detail, effects of drought on cold hardiness and to expand cold-hardiness testing procedures to include the exosmosis technique.

The present published information on apparent freezing-point determinations of citrus tissue is not adequate. Additional studies at various rates of cooling and various lengths of exposure with companion studies on the histology of ice formation in the tissue is needed to clarify the significance of the frozen state in citrus tissue.

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Cultural Practices and Rootstocks in Relation to Citrus Yield, Freeze Injury, and Recovery[1-2]

R. F. Leyden[3]

A cultural practices demonstration orchard at the Texas College of Arts and Industries Citrus Center near Weslaco, has interested Valley growers since it was planted in the fall of 1952. The trees are Redblush grapefruit on sour orange and Cleopatra mandarin rootstocks, planted 20' x 22', at 100 trees to an acre. The cultural practices of chemical weed control with no tillage, clean cultivation, and sod culture, are in plots consisting of 4 rows with 28 trees each, an area of about 1 acre for each practice. Results of moisture studies conducted during the early years of this planting have been reported (Leyden 1959). Yield records before and after the freeze of January 1962 are considered here.

In Table 1 yield data, expressed as tons an acre, are presented. The first section lists yields at 7, 8, and 9 years-of-age, and the 3-year average. During the 7th and 8th year highest yields were harvested from the chemical weed control system regardless of rootstock. By the 9th year yields from clean cultivation and sod culture equalled or, on sour orange rootstock, slightly exceeded chemical weed control. The 3-year average yield, however, favors chemical weed control with both rootstocks.

With all other production factors equal, a partial explanation of the differences in favor of chemical weed control appears to lie in the microclimate of the 3 practices on nights of critically low temperatures. On 1 December 1957 an early-season light freeze caused wood damage to citrus trees at some of the colder locations in the Valley. At the Citrus Center, which is considered a naturally cold location, considerable wood damage was sustained by trees under sod culture, a lesser amount by trees under clean cultivation, and essentially none by trees under chemical weed control with no tillage. This differential loss of fruit bearing surface was reflected in yields through the 1960-61 crop year. Differences were not overcome until the fourth season after the injury. Similar detrimental effects of this light freeze on yields, in an experimental block at Monte Alto, have been reported by Maxwell (1961).

On nights of radiation cooling, the condition under which damaging cold occurs, plots under chemical weed control with no tillage have been found to be slightly warmer than plots under other cultural systems (Leyden and Rohrbaugh, 1963). This has been attributed to the firm,

[1] Cooperative citrus research of Texas College of Arts & Industries and Texas Agricultural Experiment Station of Texas A & M University, Weslaco.
[2] A part of a talk given at the Regional Cold Protection and Cold Hardiness Conference, April 28-30, 1965, Weslaco, Texas.
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bare surface being a good absorber of heat during the hours of sunlight and an equally good radiator of the stored heat on nights of radiation cooling. Similar reports which relate the condition of the soil surface and the presence or absence of cover to heat balance are in the literature (Gradwell, 1963; Young, 1925).

The temperature differences between cultural practices, though small, can be of economic importance as the yield data following the light freeze of 1957 indicate. Further emphasis is provided by the yield records for the 3 seasons since the 1962 freeze.

For the crop year 1962-63, the first season after the freeze, trees on sour orange rootstock produced 1000 lb of grapefruit to an acre on chemical-weed-control plots compared to 100 lb to an acre on clean-cultivated or sod-culture plots. No fruit was produced by trees on Cleopatra mandarin rootstock under any of the cultural practices.

In the second season after the freeze all cultural systems showed slight improvement, and in the third season marked improvement. Trees on sour orange rootstock showed the greatest increases. With Cleopatra mandarin rootstock, only trees under chemical weed control had substantial yields.

Table 1. Cultural practices and rootstocks in relation to yield before and after January 1962 freeze. Red grapefruit on sour orange and Cleopatra mandarin rootstock, planted 100 trees to an acre fall 1952, Weslaco, Texas.

Crop year	*Cultural Practice*					
	Chemical weed control with no tillage		*Clean cultivation*		*Sod culture*	
	(yield, tons/acre, pre-freeze)					
	Sour	*Cleo*	*Sour*	*Cleo*	*Sour*	*Cleo*
1959-60	21.6	10.8	18.6	9.6	14.1	5.7
1960-61	22.3	16.5	18.5	14.6	18.3	12.7
1961-62[a]	19.9	17.3	20.4	15.7	21.5	17.0
3 yr. ave.	21.2	14.8	19.1	13.3	17.9	11.8
	(yield, tons/acre, post-freeze)					
	Sour	*Cleo*	*Sour*	*Cleo*	*Sour*	*Cleo*
1962-63	0.5	0	0.1	0	0.1	0
1963-64	2.4	3.3	1.1	1.2	0.5	1.4
1964-65	17.0	11.0	11.0	2.7	8.9	4.7
	(yield as % of pre-freeze 3 yr. ave.)					
	Sour	*Cleo*	*Sour*	*Cleo*	*Sour*	*Cleo*
1962-63	2	0	½	0	½	0
1963-64	11	20	5	7	3	12
1964-65	80	74	57	20	50	40

[a] Fruit harvested one week after freeze.

In the last section of Table 1, as an indicator of degree of recovery from freeze damage, post-freeze yield has been calculated as a percent of the pre-freeze average. On plots under chemical weed control with no tillage trees on sour orange rootstock have shown an 80% recovery; trees on Cleopatra mandarin rootstock a 73% recovery. Trees on sour orange rootstock under chemical weed control averaged 21 tons to an acre at 7, 8, and 9 years of tree age, prior to the 1962 freeze. In the third season after the freeze these trees were yielding 17 tons to an acre.

Chemical weed control with no tillage is a cultural method which can favorably influence the microclimate in the orchard on nights of radiation cooling. It may be considered a first step in cold protection, one which involves no additional expense, and which may enhance the effectiveness of other protective measures.

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Heating Air, When Initial Temperatures Are Either 20° or 40° F, and Its Relation to Citrus-Grove Heating Research in Texas

DONALD J. HADDOCK[1]

Severe freezes, 50% probability of recurrence within 11 years, have plagued the Texas citrus industry. The climate is sufficiently warm though, that about one out of three years is freeze-free which makes it difficult to do continuous research on heating. As a result, Texas researchers have resorted to heating tests on cool (about 40°F.) nights. Some have questioned whether research with heaters can be done on cool nights, and suggest that heating research can be done only during a hard freeze.

The objective of this article is to present calculations showing air-temperature rise resulting from addition of the same amount of heat when initial temperatures are either 20°F. (a hard freeze) or 40°F. (a cool night).

A Method For Calculating Air-Temperature Rises Resulting From Addition Of Heat

The most rapid method utilizes a psychrometric chart, such as is available from Carrier Corporation (1960). Complex energy-balance studies of orchards containing heaters also furnish data for comparison. (Kepner, 1948; Crawford, 1964).

Heated air is visualized as being in a box or a greenhouse 20 feet high. It is assumed that heat is not transferred in or out. Therefore, the heat needed to produce an air-temperature rise is the difference between the initial and final heat of the air. Likewise, for the same amount of added heat, temperature rises can be calculated and compared for different initial temperatures.

These formulas involve terms not in common use among citrus growers. A *British Thermal Unit (BTU)* is the amount of heat required to raise one pound of water 1°F. The *specific volume* of air is the number of cubic feet per pound of air, or the reciprocal of density. *Enthalpy* designates the total heat in a substance. As used in the psychrometric chart, enthalpy is measured in BTU's per pound of dry air.

Let us assume a well-insulated enclosure has an acre base and is 20 feet high. Then calculate the heat required to produce a 10°F. air-temperature rise for air with the following cool night characteristics:

[1] Advisory Agricultural Meteorologist, Weather Bureau Agricultural Service Office, Weslaco, Texas.

initial dry-bulb temperature of 40°F., relative humidity of 80%, and pressure of 30.12 inches (1020 millibars) of mercury.

Average specific volume = 12.80 ft^3/lb dry air (from chart)
Initial enthalpy = 14.07 BTU/lb dry air (from chart)
Final enthalpy = 16.45 BTU/lb dry air (from chart)
Added enthalpy = 16.45 − 14.07 = 2.38 BTU/lb dry air
Enclosed volume (acre x 20 ft) = 43,560 ft^2 x 20 ft = 871,200 ft^3

$$\text{Added heat} = \frac{2.38\ \text{BTU/lb dry air} \times 871{,}200\ \text{ft}^3\text{/enclosure}}{12.80\ \text{ft}^3\text{/lb dry air}} = 161{,}989\ \text{BTU/enclosure}$$

For further comparison, let us calculate for the same enclosures the temperature rise which would result if *the same amount* of heat (161,989 BTU's) were added to air having hard freeze characteristics of: dry-bulb temperature of 20°F., relative humidity of 80%, and pressure of 30.56 inches (1035 millibars) of mercury.

Enclosure volume = 871,200 ft^3
Average specific volume = 12.25 ft^3/lb dry air (from chart)

$$\text{Added enthalpy} = \frac{161{,}989\ \text{BTU/enclosure} \times 12.25\ \text{ft}^3\text{/lb dry air}}{871{,}200\ \text{ft}^3\text{/enclosure}} = 2.28\ \text{BTU/lb dry air}$$

Initial enthalpy = 6.60 BTU/lb dry air (from chart)
Final enthalpy = 6.60 + 2.28 = 8.88 BTU/lb dry air
Final temperature = 29.5°F. (from chart)
Temperature rise = 29.5 − 20.0°F. = 9.5°F.

The heat which raised air temperatures 10°F. when the initial temperature was 40°F. was 161,989 BTU's. When the initial temperature was 20°F., 161,989 BTU's raised the air temperature 9.5°F. Under the conditions listed above, which were not uniform for two different initial temperatures, it essentially required the same amount of added heat to raise air temperature 10°F. whether at an initial temperature of 20° or 40°F.

DISCUSSION

This article deals only with calculated air-temperature rise in a theoretical well-insulated enclosure. It does not take into account the radiational flux, heat of the soil and trees, and other heat-balance variables. The net flow of heat out of an open grove on a cool night may be similar to heat flow on the coldest night during a hard freeze period, but only a heat-balance study can furnish the complete details.

SUMMARY

It is concluded that useful research evaluations of air-temperature rises can be obtained from studies of heaters on cool (about 40°F.) nights. However, the critical test will still be a heater's performance during a hard freeze.

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Under-the-tree Heating Tests in Citrus Orchards Using Petroleum Coke Fuel Blocks[1-2]

R. F. Leyden, R. A. Hensz, and J. E. Fucik[3]

Many citrus growers in the Lower Rio Grande Valley of Texas have been reluctant to make large capital investments in freeze protection systems because of the low frequency of severe tree-killing freezes. According to past weather records there is only a 50% chance of a severe freeze, 20 degrees or lower, occurring in the Valley every 11 years (Haddock 1965).

Any system giving even a few degrees temperature increase would reduce the duration of exposure to critical temperatures, thereby providing a measure of protection to the framework of the tree. A method wherein fuel represents the entire freeze protection investment would reduce the grower's capital outlay. Attempts are being made to develop such fuels.

The fuel should have a cost that is economically feasible. It should not require expensive burners or containers, be easily ignited, burn relatively flameless and smokeless, and be adaptable for use directly under the canopy of the tree.

Attempts at under-the-tree heating have been made elsewhere. In Russia a successful system, using peat briquettes, has been reported (Khidasheli, A. N. et al., 1959). In California small oil heaters, burned under the tree, were considered impractical, chiefly because of excessive flaming, soot deposit, and poor heat distribution. (Young and Harmon, 1948).

A preliminary report on under-the-tree heating tests in the Lower Rio Grande Valley, using various small sources of heat, was published in 1964 (Young, et al.). Tests conducted during the winter of 1964-65 at the Texas College of Arts and Industries Citrus Center, using an experimental fuel block are reported here.[4]

MATERIALS AND METHODS

The major component of the fuel block tested was petroleum coke, with other compounds incorporated to enhance the burning characteristics. An ignition layer on the top surface provided quick, easy lighting.

[1] Cooperative citrus research of Texas College of Arts & Industries and Texas Agricultural Experiment Station of Texas A & M University, Weslaco.
[2] Part of a talk given at the Regional Cold Protection and Cold Hardiness Conference, April 28-30, 1965, Weslaco, Texas.
[3] Assoc. Prof. of Agriculture; Director; and Ass't. Prof. of Agriculture, Texas College of Arts & Industries, Citrus Center, Weslaco.
[4] The fuel blocks, labeled "Tree Heet", were formulated by Mobil Oil Company.

Blocks were enclosed in polyethylene to prevent absorption of moisture. Blocks, ranging in weight from 2.7 to 3.5 lb were tested.

In formulating the petroleum coke fuel blocks the criterion was established that the bulk of the fuel be consumed in a 4 hour period. Under field conditions, blocks were burned on a balance to determine the rate of fuel consumption. Single blocks were found to be 50-60% consumed in 4 hours. However, burning 2 blocks side by side, about 1 inch apart, resulted in the generation of intense heat at the interface and more rapid combustion. The pairs of blocks were about 80% consumed in 4 hours.

In field scale tests burning single blocks, either one under each tree or 3 spaced equidistant around the trunk under each tree, the results were not satisfactory because of the slower rate of combustion. In all other tests fuel blocks were burned in pairs, as described above, so that the bulk of the fuel was consumed in 4 hours.

Fuel blocks were burned under the trees (100 trees to an acre) approximately 2 feet from the north side of the tree trunk. When burned in 2 locations under the tree they were placed to the north and south of the trunk.

Labor requirements for ignition, based on number of blocks and acreage, were determined in the field.

A network of temperature measuring equipment was installed in 2 test areas and at control points beyond the test areas at the Citrus Center. Equipment included copper-constantan thermocouples, multipoint switches, direct reading potentiometers, glass thermomenters in thermometer stands, and recording thermographs within standard Weather Bureau Cotton Region Shelters. The thermocouple set-up and the glass thermometers had an accuray of plus or minus 0.5 F, the thermographs plus or minus 1.0 F.

Test areas included 7 acres of ten-year-old and 3.5 acres of twelve-year-old grapefruit trees. Control points were located in orchards adjacent to the test areas. Thermocouples were placed, within the foliage, 8 to 10 inches from the periphery of the canopy. They were spaced 5 feet above ground, on the north, south, east, and west sides, and in the center, of individual trees. (Fig. 1). Thermocouples were also placed at the 10-foot level in the center of the trees. Eleven trees in the test areas and 7 trees in control areas were thus wired.

Glass thermometers, mounted 5 feet above ground in shielded thermometer stands, were located just outside the tree canopy in the tree row at 25 points in one test area and at 25 points outside of the test area. Thermocouples were mounted alongside the thermometers in the stands, and wired to a central location to permit rapid reading of all points.

Four thermographs were located in a test area, one in each quad-

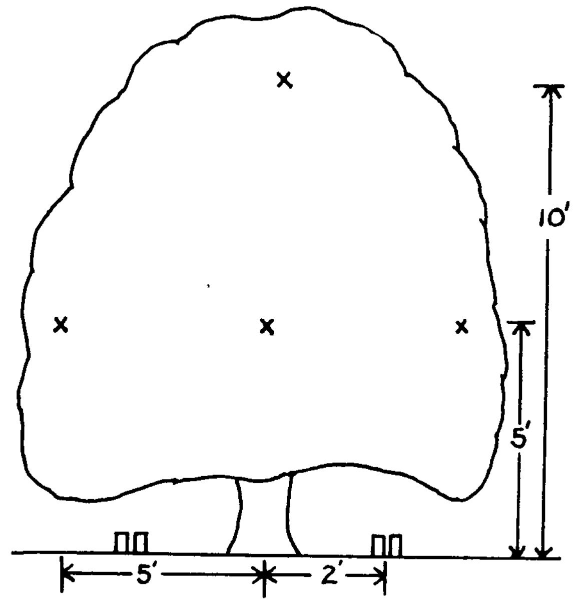

Figure 1. Location of thermocouples (X) and fuel blocks around typical heated tree.

rant. The other 4 thermographs were located outside of the test area, with one mounted atop a 30-foot tower.

On test nights temperatures of the thermocouples were obtained by means of the potentiometers. Glass thermometers were read by a crew walking the route. Typically, readings were obtained immediatelv before cold protection devices were put into use, with additional readings at hourly intervals for the duration of the test, usually 4 hours.

RESULTS AND DISCUSSION

Field scale tests were conducted with fuel blocks on 6 nights during the winter of 1964-65. Temperatures on 3 of these nights were in the 30's, but only on February 24 did weather conditions resemble those of a dry, radiation freeze. Dates and weather data for the test nights are given in Table 1.

Tests on the 3 most suitable nights, with respect to weather conditions are discussed. The amounts of fuel blocks used were:

December 14, 700 lb to an acre, 1 pair of blocks under each tree
January 17, 600 lb to an acre, 1 pair of blocks under each tree
February 24, 1200 lb to an acre, 2 pair of blocks under each tree

Table 1. Weather data during test periods 1964-65, Citrus Center, Weslaco, Texas.

Date	Cloud cover (tenths)	Wind speed (mph)	Wind direction (from)	Temperature[a] °F 5 ft	Temperature[a] °F 30 ft	Relative Humidity (percent)
14 Dec. '65	0	2-3	NE	41 to 38	45 to 41	70-80
5 Jan. '65	0-2	3-4	SE	65 to 62	66 to 63	75-80
17 Jan. '65	0	1-2	S	40 to 35	44 to 39	70-90
27 Jan. '65	0	3	NE	50 to 45	52 to 48	60-70
14 Feb. '65	2-4	3-4	NE to SE	47 to 44	47 to 46	75-90
24 Feb. '65	0	3	NW to SW	42 to 32	44 to 37	40-70

[a] Temperature within Cotton Region Shelter outside of heated area at start and end of test period.

The average temperature differences between heated and unheated trees at the 5-foot level within the canopy and the range of temperatures contributing to the average are presented in Table 2. The effectiveness of the fuel is indicated by the positive values after ignition. The narrow range of temperatures contributing to each average is evidence that no one thermocouple was in such position, in relation to the fuel blocks, as to be registering an unrealistic increase. When 1200 lb of fuel blocks were burned to an acre the average temperature increase over the 4-hour period was 5.6 F. Burning 600 or 700 lb of fuel blocks to an acre increased the average temperature 3.5 F over the 4-hour period.

Table 2. Average temperature difference[a] and range of differences, within the canopy 5 ft. above ground, during under-the-tree heating tests with 600, 700, and 1200 lb of petroleum coke fuel blocks.

Time after ignition	14 December 1964, 700 lb fuel/acre (7 lb/tree), 1 pr blocks/tree		17 January 1965, 600 lb fuel/acre (6 lb/tree), 1 pr blocks/tree		24 February 1965, 1200 lb fuel/acre (12 lb/tree), 2 pr blocks/tree	
	Temperature difference, degrees F					
	ave.	range	ave.	range	ave.	range
(hours)						
0	−0.1	−0.3 to +0.1	+2.5	−1.0 to +3.7	+0.3	−0.4 to +0.6
1	+3.8	+2.3 to +6.7	+4.3	+2.3 to +7.5	+5.6	+4.0 to +6.8
3	+3.1	+2.0 to +5.4	+3.6	+1.3 to +6.5	+6.7	+5.5 to +9.9
4	+4.0	+2.9 to +6.9	+3.8	+2.3 to +6.7	+4.4	+3.6 to +5.9
Ave of 1, 3, 4	+3.6		+3.4		+5.6	

[a] Average temperature difference = average of heated trees − average of unheated trees. Temperature measured at points in the foliage (north, south, east, and west) and in the center of the tree, 5 ft above ground.

A temperature increase at the 10-foot level within the canopy of the trees (Table 3) showed that the heat from the fuel blocks was not confined to the lower levels. The 12 lb of fuel blocks gave a 4.4 F average temperature increase over the 4-hour period. At the 10-foot level, heating may be influenced to a greater extent by weather conditions such as strength of the inversion, intensity of radiational cooling, and air movement.

Temperature increases such as those shown at the 5- and 10-foot level within the canopy would reduce the number of hours of critical temperatures and the associated damage under the conditions of a severe freeze.

Throughout 7 acres a mass heating effect was found when 2 pairs of 3 lb fuel blocks were burned under the trees (1200 lb of fuel blocks to an acre). Thermograph shelters were located in the open space bounded by 4 trees. The sensing element of the thermograph was about 16 feet from the nearest heat source with the shelter and the tree canopy intervening. Since the thermographs were sheltered from the direct radiation of the burning blocks, the increase in temperature was caused by convective currents resulting from temperature gradients produced by the burning fuel.

Thermograph records for the test using 1200 lb of fuel blocks to an acre, are reproduced in Fig. 2. The lower curve is the average of thermographs located in orchards 300 feet north and 300 feet south of the heated area. The upper curve is the average of thermographs located in each quadrant of the heated area. The increase in air temperature within the orchard resulting from burning fuel blocks under the trees is indicated by the space between the 2 curves. At hours 1 through 5 after ignition the heated area averaged 2.3, 4.5, 5.5, 6.0, and 5.3 degrees warmer than outside the heated area.

Less, but measurable, mass heating occurred over a 4-hour period when 700 lb of fuel blocks to the acre were burned. On December 14 temperatures measured by thermocouples in 25 thermometer stands averaged 3.2, 4.0, and 3.4 degrees warmer 1, 3, and 4 hours after igni-

Table 3. Average temperature difference[a] in the center of the tree 10 ft. above ground, during under-the-tree heating tests with various amounts of petroleum coke fuel blocks.

Date	lb fuel/acre	Hours after ignition of fuel		
		1	3	4
		(ave temperature difference F)		
14 Dec. '64	700	+1.0	+3.0	+1.2
17 Jan. '65	600	+3.3	+2.2	+2.7
24 Feb. '65	1200	+3.1	+5.8	+4.4

[a] Average temperature difference = ave. of heated trees — ave. of unheated trees.

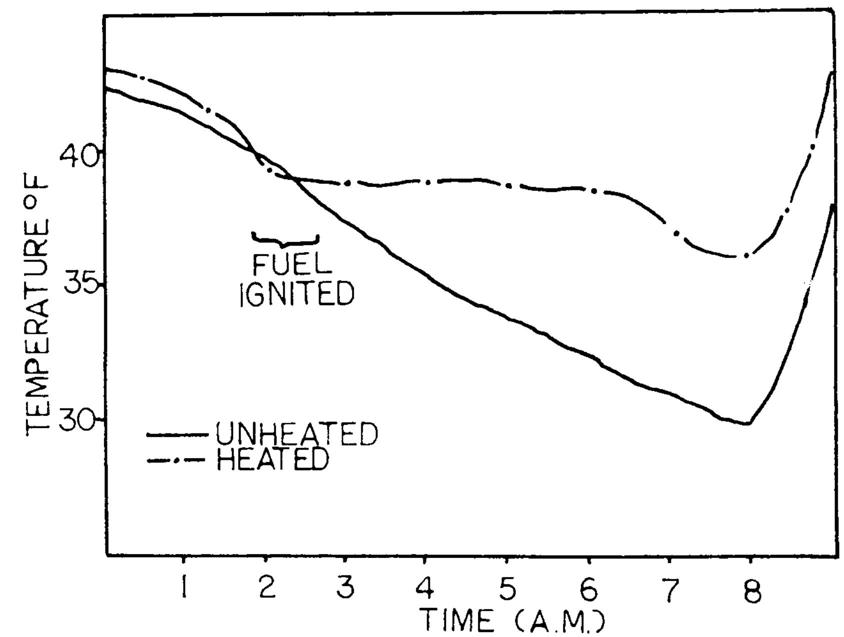

Figure 2. Thermograph records for test using 1200 lb fuel blocks/acre.

tion within the heated area than outside the heated area.

The labor requirement for igniting petroleum coke fuel blocks averaged 1 man-hour for 430 units or pairs of blocks. At this rate, with one unit to a tree and 100 trees to an acre, a little more than 1 man-hour was required for 5 acres.

SUMMARY

Petroleum coke blocks for freeze protection of citrus trees, were burned under the tree close to the tree trunk. The fuel blocks were formulated to release the bulk of their heat during a 4 hour period.

Burning 1200 lb of fuel blocks to an acre, average temperature increases within the canopy, over the 4 hours, were 5.6 F at the 5-foot level and 4.4 F at the 10-foot level. Throughout a 7-acre heated area a mass effect averaging 4.7 F over a 5-hour period suggested that convection of heat was caused by the burning blocks.

Burning 600 or 700 lb of fuel blocks to an acre gave an average temperature increase over a 4-hour period of 3.4 F and 3.6 F within the canopy at the 5-foot level.

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Cold Protection of Citrus by Under-the-Tree Heating with Petroleum Wax Heaters[1]

NORMAN MAXWELL and MORRIS BAILEY[2]

Preliminary tests with small under-the-tree heat sources (Young et al., 1964) indicated this type of orchard heating might have promise for the Valley. The first tests were with single citrus trees. During the winter of 1964-65, a major oil company furnished sufficient solid-fuel heaters to test their performance when an acre or more of trees were heated under varying wind conditions.

Performance of these under-the-tree heaters under still and windy conditions are reported herein.

MATERIALS AND METHODS

The solid fuel blocks were composed of petroleum wax encased in a waterproofed cardboard cylinder. The blocks were 10 inches high and 7¾ inches in diameter. The floating wick was made of fiber glass. The blocks were designed to burn 12 to 15 hours at a rate of about 20,000 B. T. U.'s per hour.

The thermometers used to record the temperatures had metal backs and were calibrated in 1°F. increments with an accuracy of plus or minus 0.5°F. These were placed in the unheated tree at the 5-foot level in the center of the tree and in 4 other sites, 3 and 6 feet north and south of the center. In the heated area the trees had thermometers at the 5-foot level in the center of the tree and in all four quadrants at 3 and 6 feet from the center.

The tests were run in 2 mature red grapefruit groves, one in the Adams Garden district and the other near Weslaco at the Experiment Station. In the Adams Garden orchard the test was conducted on a calm, still, clear night. The trees were about 12 feet in diameter and 12 feet high with tight canopies close to the ground.

In the Experiment Station orchard the test was conducted on a cloudy, windy night. The trees were about 15 feet in diameter and 12-15 feet high. The tree canopies were semi-open and foliage began 2-3 feet from the ground. Several weeks previous to the test the trees had been partially defoliated by a combination of strong north winds and a period of very low humidity.

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[2] Associate Horticulturist, Texas Agricultural Experiment Station and Extension Horticultural Specialist, Texas Agricultural Extension Service, Weslaco.

[1] Part of a talk given at the Regional Cold Protection and Cold Hardiness Conference, April 28-30, 1965, Weslaco.

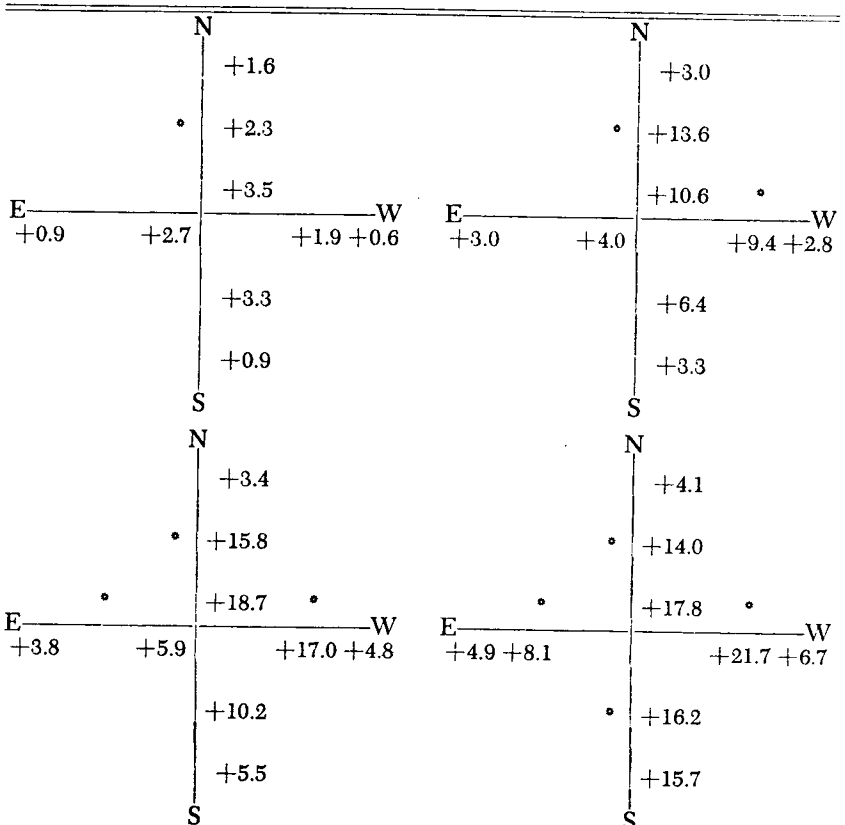
In both tests the heated area was one to one and one half acres in size.

The solid fuel blocks were placed three to four feet from the trunks of the trees on the north, west, south and east sides. Unpublished data of Morris Bailey had indicated that 3 blocks placed in this manner were most effective.

RESULTS AND DISCUSSION

Two heating tests were conducted. Table 1 gives the results obtained in the Adams Garden district during the early morning hours on a calm,

Table 1. Average temperature increases[1] of heated over unheated trees and heat dispersion patterns obtained from burning one, two, three and four solid fuel blocks, per tree.



[1] Solid fuel blocks placed three to four feet from trunk, thermometers placed in center of tree at five-foot level and in all four quadrants at three and six-feet intervals from the center. Calm, clear night with 0-5 wind velocity.
• Locations of burning solid fuel block heaters.

clear, non-freeze night (December 14, 1964), with radiation conditions. One heater per tree caused a chimney effect under the tree and gave poor heat distribution through the center of the tree. When two heaters were used, the heat columns came together and caused fair heat distribution through the twelve-foot area in the center of the tree. When three and four heaters were lit under each tree, the heat distribution pattern within the twelve-foot circle improved. Air temperatures rose 8°-10° when three burning blocks released approximately 60,000 B. T. U.'s per tree per hour.

The wind drift was ranging from northwest to northeast. A mass heating effect was observed with one, two, three or four heaters burning under each tree. The tree on the south side of the orchard showed greater temperature gains (Table 2).

Table 3 gives the data recorded on a non-freeze, cloudy night (March 2, 1965) when winds were as high as twelve miles per hour. The amount of heat retained in air within the tree canopy was reduced as the wind velocity increased. Even so, with three or four heaters burning under each tree, the 12-foot circle inside the trees had an average temperature increase of about 4°. The mass heating effect occurring under still conditions was less apparent and often non-existent when the wind velocity increased (Table 4). The trees were fairly open canopied, and were partially defoliated from a strong north wind previous to the test night. This open-type growth favored heat loss from the trees since there was less foliage to restrict wind movement and heat transfer.

In both of the tests, the only damage to the trees came when a branch or fruit was directly in the fire.

In lighting the solid fuel block, a fuel mixture of half diesel and half gasoline was the most satisfactory. Some difficulty was experienced in lighting the blocks during the first test at Adams Garden. We decided

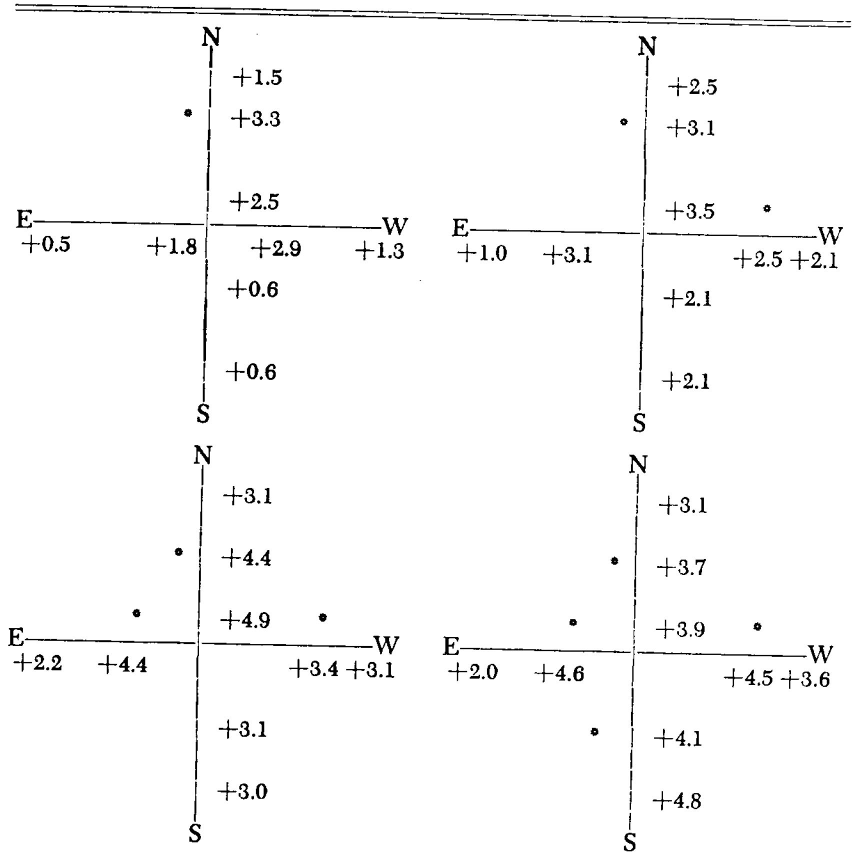
Table 2. Temperature increase (°F) of heated over unheated trees in 12-foot circle inside of tree at the 5-foot level.

Burning Solid Fuel Blocks (No.)	*Air temperature increases at indicated sites*			
	Tree at north side of orchard	*Tree at center of orchard*	*Tree at south side of orchard*	*Average*
1	1.8°	1.8°	2.0°	1.8
2	5.3	5.1	8.3	6.2
3	8.7	8.9	10.7	9.4
4	11.8	11.1	13.4	12.1

Test size – one and one half acres
Clear – Humidity 56-62%
Wind direction and velocity variable (northwest to northeast, 0-5 mph)
Tree size 12' x 12' x 10' – 12' high
Tight canopies on trees

that the poor ignition was due to dry wicking. In the second test we placed a small piece of wax on top of each fuel block and most of the heaters ignited without difficulty. The wick is being corrected by the oil company's engineers and new models of the solid fuel heater should not have an ignition problem.

Table 3. Average temperature increases[1] of heated over unheated trees and heat dispersion patterns obtained from burning one, two, three and four solid fuel blocks per tree..



[1] Heaters placed three to four feet from trunk, thermometers placed in center of tree at the five foot levels and in all four quadrants at three and six feet from the center. Windy, cloudy night with 0-12 wind velocity during test period.
• Locations of burning solid fuel block heaters.

Table 4. Temperature increase (°F) of heated over unheated trees in 12-foot circle inside of tree at the 5-foot level.

Burning Solid Fuel Blocks (No.)	Air temperature increases at indicated sites				
	Tree at west side of orchard	Tree at center of orchard	Tree at east side of orchard	Average	Wind Velocity mph
1	1.0°	2.3°	1.6°	1.6°	0-3
2	2.4	2.4	2.5	2.4	5-8
3	3.5	3.8	3.1	3.4	5-8
4	3.7	4.0	3.7	3.8	6-12

Test size – one acre
Cloudy – humidity 54-48%
Wind direction – northeast
Tree size – 15' x 15' x 10'-15' high with high open canopies
Trees 25% defoliated by strong wind prior to this test

CONCLUSIONS

Three heating tests under still and windy conditions showed that heaters were effective when placed equilaterally under the tree in three locations (north, west and east sides) about three to four feet from the trunk. Air temperatures rose 8-10°F. on a still, calm, clear night when three burning blocks released approximately 60,000 B. T. U.'s per tree per hour. The heaters were most effective on calm nights with a 0-5 mph wind velocity. As the wind velocity increased above 5 mph the efficiency of the heaters decreased. Even so, a temperature rise of 3-5° was obtained with a wind velocity of 6-12 mph. A mass heating effect of 1.5 to 3.0°F was obtained in one and one half acre area on a still calm night.

Burning cylindrical solid fuel blocks of petroleum wax caused a rise in temperature sufficient to protect the major framework limbs against freeze damage in a repetition of Valley radiant freezes since 1949.

Several problems with the wick and exterior cover were found in the present heater design but are being corrected by the oil company's research staff.

LITERATURE CITED

Young, R., Maxwell, N., Bailey, M., and Cowley, W. R. 1964. Temperatures in and around grapefruit trees as affected by under-the-tree heat sources. Jour. Rio Grande Valley Hort. Soc. 18:15-20.

ACKNOWLEDGEMENT

The solid fuel blocks were supplied by Texaco Incorporated.

Citrus Tree Cold Protection Utilizing Solid Petroleum Fuel Blocks as Under-the-Tree Heaters[1]

Morris A. Bailey, Jr. and Norman Maxwell[2]

Conventional orchard heaters placed between the trees have not always provided adequate protection for citrus trees during freezes in the Lower Rio Grande Valley of Texas. Wind machines and conventional heaters in combination did not provide adequate protection in limited tests (Young and Peynado, 1964). Placement of the heat source under the tree, rather than between the trees, seemed to offer promise in this area (Young et al., 1964). One of the several "heaters" tested utilized solid petroleum wax as fuel. Two major oil companies developed research models for further testing during the winter of 1964-1965. This is a report on the performance of one of these research models.

MATERIALS AND METHODS

The under-the-tree heater evaluated in this report consisted of a shallow pan filled with solid petroleum wax (a high molecular weight petrolatum) and a section of non-combustible wicking material. The fixed rock-wool wick was located in the center of the pan. The pan was 17 inches long, 12 inches wide and 2½ inches high. The wick, which was 12 inches long, 4¼ inches wide and 2½ inches high, was easily lit with an ordinary grove torch. The fuel on both sides of the wick melted and fed the wick like wax in a candle. The height of the flame was 10 to 12 inches. A divided cover over the pan exposed the desired burning area. The sliding cover was designed to be used to extinguish the flame, as well as to protect the fuel and wick when the heater was not in use.

The heaters were designed to burn at a rate of approximately 20,000 BTU's per hour with a burning period of at least ten hours. They were extinguished readily by cutting off the oxygen supply for a few seconds. They can be re-lit any number of times as long as fuel is available.

The heaters were tested in a 14-year-old grapefruit grove under trees which averaged 15 feet in height and 15 to 16 feet in diameter. Preliminary tests were conducted in a single tree to determine the best placement of the heaters under the tree and to further study the heat distribution pattern. Sixty-four copper constantan thermocouples calibrated to ± .5°F. were taped to plastic rods inside the tree canopy. These temperature-sensing elements measured air temperatures 2, 4, 6 and 8 feet from the trunk in eight directions (N, NE, E, SE, S, SW, W, and NW) 5 and 9 feet above the ground. Control temperatures were taken in the adjacent tree north of the test tree. Control readings were made at the 5-foot level 2½ feet south and 4 and 8 feet east of the trunk. These 3 readings were averaged and in comparison with readings from the heated tree used to compute the temperature rise resulting from the use of heaters.

One to four heaters located 2 to 5 feet from the trunk were burned during single-tree tests. The heaters were generally positioned on the north, east, west, and south sides of the trunk. In one test, they were located on the north, northwest, and west sides.

Four orchard heating tests were conducted to determine the effectiveness of one to four heaters per tree. Two of these tests are discussed herein.

Heaters were placed on the north, east, and west sides of the trees three feet from the trunk. Approximately 1½ acres (108 trees) were involved in the tests. The tree spacing in the test grove was 25 by 20 feet. Temperatures were recorded in the tree with 64 thermocouples; this tree was located in the center of the orchard. In addition, 9 thermometers were placed in two other trees (one on north side and one on south side of orchard). Metal-back minimum-temperature thermometers with ± .5°F. accuracy were placed approximately 3 and 6 feet from the trunk on the north, east, west, and south sides and in the center of the tree. The thermometers were located about 5 feet above the ground. In the orchard-heating tests, the control tree was located 3 rows north of the heated area. Thermometers in the control tree were placed 3 and 6 feet north of the trunk, 3 and 6 feet south of the trunk, and in the center of the tree 5 feet above the ground. An average of these 5 readings was used to compute the temperature rise in the heated area.

The tests described in this report were conducted on non-freeze nights. The conditions, other than temperatures, were mostly the same as those occurring during past freezes. It can be shown mathematically that approximately the same number of BTU's are required to raise the temperature one degree regardless of the base temperature. These experiments were conducted on this premise.

RESULTS AND DISCUSSION

Single Tree Tests

In single-tree tests, 3 to 4 solid petroleum fuel blocks, each burning at the rate of 20,000 BTU's per hour, produced and maintained a significant temperature rise throughout the canopy of a large citrus tree.

The best average temperature increase occurred when 4 heaters were burning 4 feet from the trunk on 4 sides with only a slight wind drift (Table 1). Under fairly windy conditions, 4 heaters burning at the same position produced the best average increase, although 4 heaters 3 feet from the trunk produced the highest increase at the 5-foot level. Four

[1] Part of a talk given at the Regional Cold Protection and Cold Hardiness Conference, April 28-30, 1965, Weslaco.

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Table 1. Increases in air temperature (°F.) produced by 3–4 solid petroleum fuel blocks burning at various distances from the trunk of a 14-year-old grapefruit tree. (Single Tree Test)

Number of Heaters	Distance from Trunk (feet)	Sky	Wind Direction	Wind Speed (mph)	Increase in air temperature at 5-foot level[4] at indicated distances from trunk (°F.)				Increase in air temperature at 9-foot level[4] at indicated distances from trunk (°F.)			
					2 ft.	4 ft.	6 ft.	8ft.	2 ft.	4 ft.	6 ft.	8ft.
3[1]	3	Cloudy	NW	5-10	5.7	5.5	2.6	.6	2.5	2.1	1.4	1.7
3[2]	3	Clear	WSW	0-3	6.9	7.8	6.5	3.3	2.2	2.8	2.3	1.6
4[3]	2	Partly Cloudy	NW	0-3+6	14.4	11.5	4.1	1.2	10.2	6.1	2.5	.9
4[3]	3	Clear	NW	3-6	8.5	10.3	6.0	1.9	4.2	6.2	6.6	3.4
4[3]	3	Clear	NE-NW	3-10	7.8	8.3	6.5	3.4	3.3	3.0	3.0	3.1
4[3]	4	Clear	NW	5-10	5.3	8.3	6.0	1.7	6.6	6.2	7.3	3.5
4[3]	4	Clear	NNE	0-3	8.1	13.9	7.1	3.3	11.5	12.4	7.1	2.2
4[3]	4	Partly Cloudy	NNE	3-12+15	6.7	7.5	5.6	4.2	2.8	3.0	3.2	2.7
4[3]	5	Partly Cloudy	NNE	3-12+15	4.6	5.0	5.5	3.6	1.8	1.8	2.4	2.3

[1]Heaters positioned on N, NW, and W sides of trunk.

[2]Heaters positioned on N, W, and E sides of trunk.

[3]Heaters positioned on N, W, E, and S sides of trunk.

[4]Measured at 8 points (N, NE, E, SE, S, SW, W, and NW).

heaters 2 feet from the trunk afforded excellent protection within the immediate trunk area.

Grouping 3 heaters on the same side was not as effective as placing them symetrically around the tree. Three heaters 3 feet from the trunk on the north, northwest, and west sides did not provide adequate protection on all sides, since the heat was more or less concentrated on one side. (Table 2). With this heat concentration, a pronounced chimney effect would likely be produced under still conditions.

Four heaters 5 feet from the trunk on 4 sides produced an average temperature rise of 1 to 2°F. less than 4 heaters in the same position 4 feet from the trunk under the same test conditions. Much of the heat was apparently lost outside the tree when heaters were placed 5 feet from the trunk.

Higher wind velocities reduced the effectiveness of the heaters. Five to 10 mph winds caused an average temperature loss of 2.5°F., and winds 3 to 12 mph with gusts to 15 mph caused an average loss of over 5°F. at the 9-foot level.

Heat distribution under the tree was affected by wind velocity and direction (Table 2). The effect was even more pronounced at the 9-foot level. Under calm conditions, distribution was affected only slightly by the direction of the wind drift.

Four heaters produced a larger temperature rise and a more desirable heat distribution pattern than 3 heaters in single-tree tests. Three heaters effected significant increases, however, particularly at the 5-foot level.

Orchard-Heating Tests

During each test, temperature increases were measured in 3 trees (nine points in 2 trees and 64 points in the third). Since it was not feasible to average these readings, they are reported separately. The readings in the tree with 64 thermocouples gave a more detailed account of the heat distribution pattern and the temperature increases.

The same average temperature increase was produced by 2 and 3 heaters under both windy and still conditions in the north and south trees. (Table 3). However, in the center tree (with 64 thermocouples) the temperature increase was quite different when the wind conditions changed. (Table 4). Several factors contributed to these apparently inconsistent results.

In some instances, thermometers and thermocouples positioned directly over a heater had unusually high readings ("hot spots"). The effect was more pronounced in the north and south trees where only 9 readings were taken.

Location of the trees within the grove also had a definite effect. The north tree was bounded on the north by several rows of closely spaced trees which served as a wind-break, minimizing the effect of the wind.

Table 2. Increase in air temperature (°F.) produced by 3–4 solid petroleum fuel blocks burning 2–5 feet from the trunk of a 14-year-old grapefruit tree. (Single-Tree Test)

Number of Heaters	*Distance from Trunk (feet)*	*Wind Direction*	*Wind Speed (mph)*	[4]*Increase in Air Temperature at Indicated Directions from the Trunk* N	NE	E	SE (°F)	S	SW	W	NW
3[1]	3	NW	5-10	.7	3.1	5.2	5.9	5.3	1.2	.9	-.3
3[2]	3	WSW	0-3	3.8	10.4	6.9	2.3	3.2	2.0	2.0	2.8
4[3]	2	NW	0-3+6	2.3	5.4	14.2	8.4	10.2	4.9	4.0	1.3
4[3]	3	NW	3-6	1.6	7.1	8.6	10.6	9.3	6.4	2.8	.7
4[3]	3	NE-NW	3-10	2.2	2.5	2.4	6.5	8.8	6.5	6.3	3.2
4[3]	4	NW	5-10	3.1	8.4	4.7	8.2	7.7	8.8	2.9	1.2
4[3]	4	NNE	0-3	10.7	3.5	7.8	7.5	11.2	8.3	8.5	8.1
4[3]	4	NNE	3-12+15	3.0	1.4	2.1	5.9	8.2	6.2	5.7	3.4
4[3]	5	NNE	3-12+15	2.3	1.4	1.7	4.6	6.4	5.1	3.2	2.3

[1]Heaters positioned on north, northwest, and west sides of trunk.

[2]Heaters positioned on north, west, and east sides of trunk.

[3]Heaters positioned on north, west, east, and south sides of trunk.

[4]Measured at 4 points (2, 4, 6, & 8 feet from the trunk) at 5 and 9 foot levels.

Table 3. Increase in air temperature (°F.) produced by 1–3 solid petroleum fuel blocks burning three feet from the trunk of mature grapefruit trees. (Orchard-Heating Test)

Number of Heaters	*Arrangement of Heaters*	*Sky*	*Wind Direction*	*Wind Speed (mph)*	[1]*Increase in Air Temperature* *Tree at North Side of Orchard (°F)*	*Tree at South Side of Orchard (°F)*	*Average (°F)*
1	N side	Cloudy	NNW	5-10	3.7	3.6	3.6
2	N & W sides	Cloudy	NNW	5-10	6.0	6.2	6.1
3	N, W, & E sides	Cloudy	NNW	5-10	6.0	8.5	7.2
1	N side	Clear	NE	0-3	5.8	4.7	5.2
2	N & E sides	Clear	ESE	0-3	5.0	7.0	6.0
3	N, E, & W sides	Clear	SE	0-3	7.1	7.4	7.2

[1]Measured by metal-backed minimum thermometers three and six feet from the trunk on N, E, S, and W sides and in the center of the tree, five feet above the ground.

Table 4. Increase in air temperature (°F.) produced by 1–3 solid petroleum fuel blocks burning three feet from the trunk of mature grapefruit trees. (Orchard-Heating Test)

Number of Heaters	Position of Heaters	Wind Direction	Wind Speed (mph)	Increase in air temperature at 5-foot level[1] at indicated distances from trunk				Increase in air temperature at 9-foot level[1] at indicated distances from trunk			
				2 ft.	4 ft. (°F.)	6 ft.	8ft.	2 ft.	4 ft. (°F.)	6 ft.	8ft.
1	N side	NNW	5-10	3.0	2.7	1.8	1.4	.8	1.2	1.1	.8
2	N & W sides	NNW	5-10	3.7	3.7	3.8	3.0	2.1	2.0	2.6	3.2
3	N, W, & E sides	NNW	5-10	6.1	6.4	5.5	4.6	2.9	3.1	3.1	3.0
1	N side	NE	0-3	5.4	5.2	4.2	3.4	3.9	3.7	3.7	3.8
2	N & E sides	ESE	0-3	19.2	10.0	7.8	6.2	14.0	8.2	6.0	5.7
3	N, E. & W sides	SE	0-3	20.2	12.0	12.6	9.2	16.0	10.6	8.6	8.6

[1]Measured at 8 points (N, NE, E, SE, S, SW, W, and NW).

The south tree was surrounded on the north and northwest sides by several large trees, which also served as windbreaks. The center tree was bounded on the northwest by trees which had been severely damaged during the 1962 freeze. These trees were fairly small and afforded little windbreak protection.

When the wind drift was slight (0 to 3 mph), the center tree gained the maximum benefit from the massing effect regardless of wind direction. The massing effect gained by the north and south trees was highly dependent on wind direction.

During fairly windy conditions, two heaters under each tree produced a moderate temperature increase under the tree (Table 4). When a third heater on the east side of the tree was ignited, an additional temperature rise of 2°F. occurred under the tree at the 5-foot level. However, only a slight increase was recorded at the 9-foot level.

The increase produced by 1 to 3 heaters under each tree during still conditions was significant. One heater on the north side caused a larger temperature increase than was produced by 2 heaters under windy conditions. As additional heaters were ignited, the temperature increased accordingly. Temperature increases were quite large at the 9-foot level when winds were calm. Under calm conditions, 2 and 3 heaters caused a large temperature rise in the immediate trunk area (at both levels). This indicated that the trunk and main frame limbs could be protected from freeze damage during extremely cold weather.

Heat distribution patterns (Table 5) were affected by wind velocity and direction, particularly when only 1 and 2 heaters were burning. Under calm conditions, the heat was well distributed throughout the tree, regardless of wind direction. However 5 to 10 mph winds caused uneven heat distribution, particularly at the 9-foot level.

The heat massing effect was apparently quite important during calm conditions. A comparison of temperature increases shown in Tables 1 and 4 provides an indication of this effect. In the single-tree test, 3 heaters produced an average increase of 3.3°F. 8 feet from the trunk (at the 5-foot level) under calm conditions. while 3 heaters caused an increase of 9.2°F. 8 feet from the trunk in the orchard-heating test. The effect at the 9-foot level was even more pronounced.

In past freezes, severe freeze damage to citrus trees in the Lower Rio Grande Valley has occurred when winds were calm. We believe that 3 solid petroleum fuel blocks, each burning at the rate of 20,000 BTU's per hour, can provide adequate cold protection for Valley citrus trees when used properly.

Heater Problems

The solid petroleum fuel block discussed in this report was a research model. Several design problems were discovered during testing operations. The sliding covers were not satisfactory; they fit loosely, admitting oxygen, and made it difficult to extinguish the flame. In addi-

Table 5. Increase in air temperature (°F.) produced by 1–3 solid petroleum fuel blocks burning three feet from the trunk of mature grapefruit trees. (Orchard-Heating Test)

Number of Heaters	*Position of Heaters*	*Wind Direction*	*Wind Speed (mph)*	*Increase in Air Temperature at Indicated Directions from the Trunk*[1] (°F.) N	NE	E	SE	S	SW	W	NW
1	N	NNW	5-10	1.2	3.1	3.7	1.7	1.0	.7	.6	.8
2	N & W	NNW	5-10	1.6	2.7	4.7	4.8	4.6	2.2	2.1	1.4
3	N, E, & W	NNW	5-10	3.5	4.6	5.4	7.8	4.8	2.9	3.0	2.8
1	N	NE	0-3	4.2	3.6	3.3	3.8	3.7	3.9	6.3	4.6
2	N & E	ESE	0-3	9.1	10.8	11.5	11.0	8.0	9.1	9.7	8.0
3	N, E, & W	SE	0-3	11.7	11.2	10.3	11.7	10.0	12.4	19.7	10.6

[4]Measuredat 4 points (2, 4, 6 & 8 feet from the trunk) at 5 and 9 foot levels.

tion, the necessary "setting" of the lids to the proper wick opening was time-consuming. Consequently, company research engineers decided to alter the design, replacing the sliding covers with fixed covers.

When the heaters were left upright, they collected water, which changed to steam during burning and splattered hot wax. This problem can probably be avoided if heaters are kept upside-down until needed.

SUMMARY

Pan-type solid petroleum fuel blocks were tested during the winter of 1964-65 to determine their effectiveness as under-the-tree heaters. Single-tree tests indicated that heaters should be placed symetrically around the tree 3 to 4 feet from the trunk. Orchard-heating tests showed that 3 solid petroleum fuel blocks, each burning at the rate of 20,000 BTU's per hour, could produce significant temperature increases under the tree to protect *at least* the trunk and main frame work limbs from freeze damage during calm conditions. Moderately high winds lowered the effectiveness of the heaters, although a 5.6°F. temperature increase was maintained over a 16-foot diameter area under the tree during 5-10 mph winds.

ACKNOWLEDGEMENTS

The solid petroleum fuel blocks utilized in these tests were designed and supplied by the Humble Oil and Refining Company. The Company also supplied the thermocouples and temperature indicators used in the experiments.

Special thanks is due Mr. M. T. Waddell, Esso Research and Engineering Company, for his advice and assistance in planning and conducting these tests.

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Microclimate Temperatures of Large and Small Citrus Trees as Affected by Heat from LP Gas Heaters[1-2]

ROGER YOUNG[3]

Since the severe 1962 freeze in Texas, the effects of various heat sources on the microclimate temperatures of citrus trees have been studied. Those included in the studies were University return stack heaters with wind machines and small "under-the-tree" heat sources (Young and Peynado, 1964; Young et al., 1964). Among those showing some promise for freeze protection when tested under the tree was an LP gas heater.

This report summarizes preliminary trials during the 1964-65 winter on the effect of heat from LP gas heaters on microclimate temperatures of large and small citrus trees.

METHODS AND MATERIALS

Grove and "under-the-tree" tests were conducted in a 4-year-old navel orange grove north of Mission, Texas. Tree spacing in the grove was 13 x 22 feet with rows running north and south. Diameter or breadth of the trees was about 8 feet. In grove tests, heaters with a vertical stack were placed on the northwest side of alternate trees 5 feet from the trunk and about 1 foot outside the tree canopy (Figure 1A). Several reflectors and radiators with a portable heater also were tested both outside and under the canopy of the 4-year-old trees. A vertical stack (Figure 1A), a horizontal stack (Figure 1B) and the heater without a reflector or radiator (Figure 1C) were included in the tests. "Under-the-tree" tests were also conducted under a single 15-year-old Red Blush grapefruit tree with a diameter or breadth about 16 feet.

The heat output of the portable heater was determined by measuring the amount of fuel burned in 1 hour at 1, 2, and 4 lbs. pressure and converting to BTU output at 100% efficiency. Efficiency ratings of the burners are not known but are assumed to be high. Heat output per hour in BTU's was 1 lb. – 45,402; 2 lb. – 51,888; and 4 lb. – 64,860. The BTU per hour output for individual heaters in the grove tests was not measured but at 2 lbs. pressure appeared to be similar to the single portable heater.

In the grove tests, air temperatures at 5 feet were measured with sheltered thermometers which have an accuracy of ±0.25°F. Three

1 The work was part of a cooperative project of the Agricultural Research Service, U. S. Department of Agriculture, and the Texas Agricultural Experiment Station, Weslaco, Texas.

2 Part of a talk given at the Regional Cold Protection and Cold Hardiness Conference, April 28-30, 1965.

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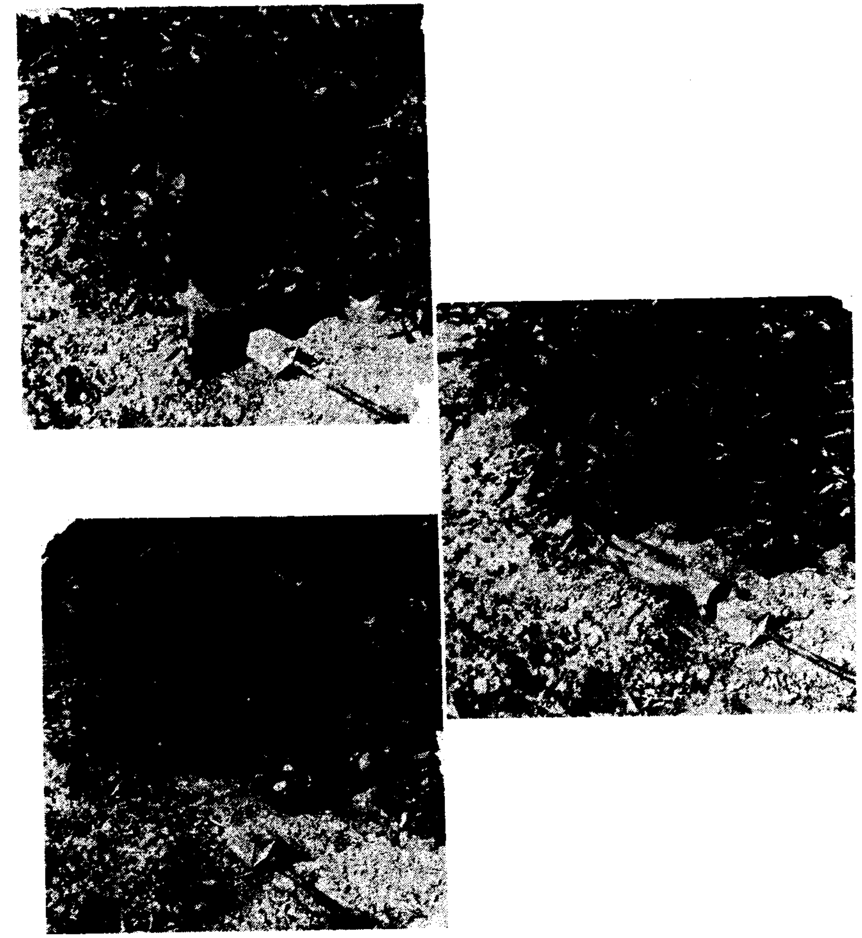

Figure 1. A heater located about 5 feet from the tree trunk with (A) vertical stack, (B) horizontal stack, and (C) no stack or reflector.

thermometers were placed in the 6 unheated rows on the west side of the grove, 6 in the 10 to 16 heated rows (each with 24 to 33 trees) in the middle of the grove, and 3 in the 6 unheated rows on the east side of the grove. In the heated rows, thermometers were placed next to trees without adjacent heaters. Temperatures reported are averages of 3 to 5 hourly readings taken from 6 thermometers in both heated and unheated areas.

Leaf temperatures on heated and unheated trees were measured with thermocouples in both grove and single-tree tests with orange trees. Temperatures of exposed leaves 4 feet high on the northwest, northeast, southeast, and southwest sides, 2 feet high in the center of the tree, and 6 feet high in the top were measured on both heated and unheated trees. Temperature differences reported are the averages of 2 readings taken at one-half-hour intervals.

Air temperatures 5 and 9 feet high 2, 4, 6, and 8 feet from the trunk, at each of the 8 cardinal points (N, NE, E, SE, S, etc.) under a 15-year-old grapefruit tree, were measured with thermocouples. Thermocouples were placed 2 feet from the trunk on the south side and 6 and 8 feet from the trunk on the east side (5-foot level) in an unheated tree for comparisons. Temperature differences reported are the averages of 2 readings taken at one-half-hour intervals.

RESULTS

Grove tests: The results from 6 grove tests are sumarized in Table 1. Heaters were burned at 2 lbs. pressure in 2 to 3 acres on December 19, 1964, and on February 19 and 25, 1965, and in one acre on January 10, 18, and 25, 1965.

Air temperature increases in the grove ranged from 0.0° to 0.9°F. where one acre was heated to 1.5° to 2.9° where 2 to 3 acres were heated. The largest effect occurred on February 25, 1965, where 3 acres were heated and the air temperature minimum in the grove reached 28.8°F. The heaters, placed just outside the tree canopy and on the northwest side, burned like small oil heaters. The bottom one-third of the stack was red-hot and emitted some radiant heat.

Leaf temperatures were measured only in the 1-acre tests which were conducted on January 10, 18, and 25, 1965. Those summarized in

Table 1. Influence of heat from LP gas heaters burned at 2 lb. pressure on air temperatures in the 4-year-old orange grove during variable weather conditions.

Date	Acres Heated	Weather: Wind (mph)	Weather: Cloud cover (%)	Weather: Humidity[a] (%)	Temperatures during trials: Unheated area (°F)	Temperatures during trials: Heated area (°F)
12/19/64	2 to 3	3-9	100	56	36.5	38.0
1/10/65	1	0-5	0	33-49	50.5	50.5
1/18/65	1	0-1	0	57-68	39.3	40.2
1/25/65	1	3-6	0	82-84	59.8	59.2
2/19/65	2 to 3	0-2	0	57-72	50.5	53.1
2/25/65	2 to 3	0-2	0	70-86	31.1	34.0

[a] Humidity data obtained from the Federal Aviation Agency, McAllen, 10 miles south of the test grove.

Table 2 were recorded on January 10 when no effect on air temperature was measured. Average leaf temperatures increased 1.2° to 3.2°, but only those on the northwest and northeast sides and in the center were affected. Generally, only leaves within a 3-foot radius of the heater received heat. Leaves on the northwest side of the tree received slightly more heat when the vertical and horizontal stacks were used.

"Under-the-tree" tests: Average leaf temperatures were raised 5.3° to 7.8°F. on a small orange tree under which a heater was burned (Table 2). Leaf temperatures on 4 sides and the center of the tree were affected but those in the tree top were not. The greatest increase in leaf temperature occurred near the trunk.

Heat distribution in a large grapefruit tree was similar to that in a small orange tree. Under the large tree, the area of influence from a heater covered a 2- to 3-foot radius and shifted with the position of the heater under the tree (Table 3). The heater placed 2 and 4 feet from the trunk distributed heat into the area 2 feet from the trunk at both 5- and 9-foot levels. Little or no heat was found 4, 6, and 8 feet from the trunk. When placed 6 feet from the trunk, the heater distributed some heat into the area 2 feet from the trunk and much more into the area 4 feet from the trunk. Little or no heat was found 6 to 8 feet from the trunk. Heat from the heater moved upward through the tree and was located primarily on the tree sides next to the heater.

Burning rates of a heater placed under the grapefruit tree markedly influenced heat distribution. More heat was distributed to the area 2 feet from the trunk and less to the area 4 feet from the trunk at 2 and

Table 2. Influence of heat from LP gas heater[a] on the increase in temperatures (°F) of leaves on a 4-year-old orange tree when the heater was placed 1 foot outside tree canopy, January 10, and under the tree, January 25, 1965.

Location and height of leaf	Open flame: Outside canopy	Open flame: Under canopy	Vertical stack: Outside canopy	Vertical stack: Under canopy	Horizontal stack: Outside canopy	Horizontal stack: Under canopy
Top (6 feet)	0.0	0.0	0.0	0.0	0.0	0.0
Center (2 feet)	0.7	15.5	1.1	23.6	1.9	16.3
NE side (4 feet)	1.2	1.0	0.5	3.6	1.5	1.8
NW side (4 feet)	5.5	5.3	14.7	7.5	15.5	8.1
SW side (4 feet)	0.0	8.2	0.0	5.2	0.3	4.0
SE side (4 feet)	0.0	2.0	0.0	7.0	0.0	4.9
Ave.	1.2	5.3	2.7	7.8	3.2	5.8

[a] Heater placed 5 feet from trunk on NW side of tree, January 10, and 2 feet from trunk on SE side of tree, January 25. Heater burned at 2 lb. pressure.

4 lbs. pressure than at 1 lb. (Table 4). At the 2 and 4 lb. rates, a stack action under the tree occurred as indicated by small temperature differences between the 5- and 9-foot levels 2 feet from the trunk, and by large temperature differencs between the 5- and 9-foot levels 4 feet from the trunk. Little or no heat was found 6 and 8 feet from the trunk at any of the burning rates.

The use of different reflector or radiator devices with the open-flamed heater affected the heat distribution in both small orange and large grapefruit trees (Tables 2 and 5). Under the small tree average leaf temperatures were raised 2.5°F with the vertical stack above those that occurred with use of the open-flamed heater. Under the large tree,

Table 3. Increases[a] in air temperatures (°F) in a 15-year-old grapefruit tree from heat from an open-flamed LP gas heater at various distances from the trunk, January 27, 1965.

Thermocouple elevation and placement of heater	*Distance from trunk (ft.)* 2		4		6		8	
Feet above ground	5	9	5	9	5	9	5	9
2 feet from trunk – SE side	11.0	8.1	0.5	0.2	0.0	0.0	0.0	0.0
4 feet from trunk – SE side	9.3	11.1	0.9	0.9	0.1	0.0	0.0	0.0
6 feet from trunk – SE side	2.8	4.6	7.1	5.3	0.8	1.8	0.0	0.0

[a] Increase in air temperature measured at 8 cardinal points (N, NE, E, etc.) above those in an unheated tree. Wind from southeast 0-3 mph.

Table 4. Increases[a] in air temperatures (°F) in a 15-year-old grapefruit tree from heat from an open-flamed LP gas heater burned at different rates, January 27, 1965.

Thermocouple elevations and burning rates (lbs. pressure)	*Distance from trunk (ft.)* 2		4		6		8	
Feet above ground	5	9	5	9	5	9	5	9
1	7.5	4.3	8.1	3.3	0.9	0.9	0.0	0.0
2	9.3	11.1	0.9	0.9	0.1	0.0	0.0	0.0
4	13.3	14.6	0.6	1.4	0.5	1.0	0.3	0.0

[a] Increase in air temperature measured at 8 cardinal points (N, NE, E, etc.) above those in an unheated tree. Heater placed 4 feet from trunk on SE side. Wind from southeast at 0-3 mph.

Table 5. Increases[a] in air temperature (°F) at various distances from trunk in a 15-year-old grapefruit tree at 5- and 9-foot levels from burning an LP gas heater at 1lb. pressure and with various modifications, February 12, 1965.

Thermocouple elevations and modifications to burner	*Distance from trunk (ft.)* 2		4		6		8		*Mean tree T°*[b]
Feet above ground	5	9	5	9	5	9	5	9	
Open flame–pointed west	1.0	0.7	4.0	3.1	1.3	1.3	0.9	0.9	1.7
Open flame–pointed at trunk	8.1	7.4	0.3	2.6	0.0	1.0	0.0	0.2	2.5
Vertical stack	5.8	2.3	3.4	2.0	1.0	1.5	0.1	0.5	2.1
Horizontal stack	2.0	0.3	2.0	1.0	2.0	1.5	0.9	1.0	1.3
Tin shield pointed west	5.6	2.0	3.3	2.1	1.0	1.5	0.1	1.6	2.2
Tin shield pointed at trunk	7.4	6.0	1.4	3.1	0.4	1.5	0.4	1.1	2.7

[a] Increases in air temperature measured at 8 cardinal points (N, NE, E, etc.) above those in an unheated tree. Heater placed 2 feet from trunk on north side. Wind drift from the north at 0-5 mph.

[b] Average increase in air temperature for 64 thermocouple locations in tree.

the effects of the various reflectors or radiators were small. The maximum increase in air temperature was 1.0° greater than that with the open-flamed heater. An open flame pointed west and an open flame burned with a horizontal stack caused a slight and poorly distributed temperature rise in the whole tree. The heater flame burned with a vertical stack or under a flat piece of tin distributed heat throughout the tree better and increased temperatures slightly in the whole tree. Although heat distribution was poor, the open flame, pointed at the trunk, gave the highest temperature increase in the area 2 feet from the trunk. The best heat distribution and highest average temperature increase was recorded with the heater pointed at the trunk and with the flame burning under a tin shield. Some radiant heat was emitted by using vertical or horizontal stacks but the effect on leaf and air temperatures was not separated from that of convective heat. The tin shield placed above the open flame was as effective as the vertical or horizontal stacks in distributing the heat. Little or no radiant heat was emitted when the tin shield was used.

DISCUSSION

Six grove tests with 60 LP gas heaters per acre, emitting approximately 3 x 10^6 BTU/acre/hr., raised air temperatures up to 2.9°F. on nights with variable weather conditions. On three test nights no rise in air temperature was recorded. The largest increase in air temperature occurred on a test night when a mild freeze occurred. These effects were small but expected on the basis of reported results of tests where relatively small amounts of heat were released per acre per unit time (Brooks, 1960; Young and Peynado, 1964). Maxwell and Otey (1954) reported an air temperature rise of 5° to 7° with 70 return stack heaters releasing 21 x 10^6 BTU/acre/hr. The LP gas heater system, as described, (i.e. when placed outside the tree canopy) appears to have limited value for freeze protection. Some protection may be obtained during mild freezes or frosts but during hard or severe freezes appears insufficient for complete protection.

When the heaters were placed under the trees, they appeared to have more promise for freeze protection although some disadvantages existed even when used under a large tree. A single heater, placed under a large tree 2 to 4 feet from the trunk and burned at 2 lbs. pressure, resulted in stacking the heat up through the tree and in giving poor heat distribution throughout the tree. The general area of influence was about 2 to 3 feet lateral to and up to 9 feet above the heater. Therefore, heat was available to provide protection to the tree in a columnar area with a 3-foot radius from the trunk. In previous tests, the use of 4 solid petroleum block heaters, each placed symmetrically under the tree and kept burning at approximately one-half the intensity of the LP gas heater, obtained much better heat distribution and higher temperatures throughout a large tree (Young et al., 1964). Thus, several small heat sources under the tree were more effective than one large heat source.

An unmovable or stationary gas heater under the tree was a disadvantage since a wind drift from any direction other than that from the heater to the tree trunk resulted in movement of heat away from the center of the tree. This disadvantage probably can be overcome by using 3 to 5 small heat sources spaced symmetrically under the tree, as was done in the 1964 trials (Young et al., 1964). This, however, may not be economically feasible with the gas heater system.

SUMMARY

Sixty LP gas heaters, releasing approximately 3 x 10^6 BTU per acre per hour with a vertical stack radiator, raised air temperatures in a 4-year-old orange grove up to 2.9°F. during variable weather conditions. A single heater placed under a small tree produced higher leaf temperatures and better heat distribution in the tree than when placed 1 foot outside the tree canopy. Most heat from a heater under both small and large trees remained in a 2- to 3-foot radius from the heater. Higher burning rates with an open-flamed heater created a stack action within the large tree. The LP gas heaters placed outside the tree canopy appeared to have only a limited value for freeze protection, but when placed under the tree canopy gave promise of more protection.

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VEGETABLE SECTION

Comparative Virulence of Texas and California Polyhedrosis Virus of the Cabbage Looper[1]

MICHAEL F. SCHUSTER[2]

The polyhedrosis virus of the cabbage looper, *Trichoplusia ni* (Hbn.), is enzootic in Texas and at times causes epizootics. Similar epizootics have been known to be caused by polyhedrosis viruses in other parts of the United States and it is believed that these virus diseases of *T. ni.* are the same.

Getzin (1962) reported on the effectiveness of the virus in the Lower Rio Grande Valley and found its effectiveness comparable to that found in California by Hall (1957). Hall (1957) found that concentrations of 1 x 10^5 polyhedra per ml. killed 2nd instar larvae in five to nine days at 22°C. This investigation was conducted in 1959 at College Station, Texas to compare the relative virulence of virus obtained from Blyth, California[3] and College Station and to determine if the addition of carborundum would accelerate infection.

PROCEDURES

Insects were reared individually in cotton-stoppered glass tubes at approximately 30°C. from eggs which had been disinfected in a 0.75% chlorox solution for 1 hour. The diet consisted of whole cabbage parts which had been washed in a 10% chlorox solution to eliminate any entrance of virus through this medium. Upon reaching the 3rd instar, larvae were divided into groups of 12 for treatment.

Treatments consisted of Texas virus, California virus, California virus plus 600 mesh carborundum. Two groups of checks were used. The first groups of checks were manipulated at all operations first and the second check group manipulated last to determine possible contamination.

The virus suspensions contained 1 x 10^5 polyhedra per ml (hemacytometer count) adjusted to pH7. Circular sections of cabbage leaves 5 cm in diameter were dipped in the various suspensions and allowed to air dry before being placed in the tubes. Fresh leaves were substituted on the third day after virus introduction.

The larvae were observed daily to determine the number dead.

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2 Assistant Entomologist, Texas Agricultural Research and Extension Center, Weslaco.
3 Acknowledgement is due Dr. I. M. Hall, University of California, Citrus Research Center and Agricultural Experiment Station, Riverside, for supplying looper virus from California.

Table 1. Virulence of polyhedrosis virus from California and Texas to the cabbage looper.[1]

Treatment[2]	Number of larvae	Number dead on days following 1	2	3	4
Check	24	0	0	0	0
Texas virus	12	0	1	7	12
California virus	12	0	1	5	12
California virus plus carborundum[3]	12	0	0	4	12

1 Larvae were in 3rd instar.
2 1 x 10^5 polyhedra per ml.
3 .005 g carborundum per ml.

RESULTS

The data indicated there was no difference in virulence of virus from the different sources (Table 1). The addition of carborundum failed to decrease the number of days between feeding and death under the conditions of this test.

It was noted that larvae feeding on virus-contaminated leaf disks consumed considerable less leaf area after the first day.

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The Influence of Variety, Spacing, and Length of Growing Season on the Yield of Potatoes[1]

Bruce A. Perry[2]

The potato is one of the more important vegetable crops in south Texas. It is grown chiefly as an early spring crop. These early-crop potatoes produce smaller yields than late-crop potatoes grown in other potato-growing areas. However, the higher prices generally received for the early crop tend to make up for the difference in yield. In many years the market price for early potatoes decreases as the harvest season progresses. Therefore, it is important to know how much can be sacrificed on yield in order to take advantage of the better prices in the beginning of the season. This paper reports results of a study to ascertain the influence of variety, spacing, and length of growing period on potato yields.

MATERIALS AND METHODS

Potatoes were grown on a Crystal sandy loam soil in South Texas in 1963 and in 1964. The soil moisture was maintained at an optimum level by furrow irrigation. Fertilizer mixture of 16-20-0 was applied in the row, beneath the seed pieces, at the rate of 500 pounds per acre. Twenty percent ammonium sulfate was applied 6 weeks after planting at the rate of 100 pounds per acre. Granular Di-Syston insecticide was placed below the seed-piece in the area of the fertilizer at planting (Harding 1962). Certified potato seed-pieces were planted in 36-inch rows, spaced 12 inches apart in the row. The soil was then bedded over the row to cover the seed-pieces 4-5 inches deep.

In Experiment 1: Kennebec, Ona, Red LaSoda and Redskin varieties were planted on January 30, 1963 in a randomized block experiment. Each variety plot consisted of a single row 25 feet in length; each variety being replicated 4 times. The harvesting began on April 24, 1963, after a growing period of 84 days, and continued at weekly intervals for 4 successive weeks. One complete replicate was harvested each week.

In Experiment 2: Kennebec, Red Pontiac and Red LaSoda varieties were planted on February 5, 1964 in randomized plots, replicated 4 times; each planting being made in quadruplicate. Harvestings began on April 30, 1964 after a growing period of 85 days and continued at weekly intervals as in 1963.

In Experiment 3: The Red Pontiac variety was planted on January 23, 1964 with in-row spacings of 6, 9, 12 and 15 inches in randomized plots with 4 replications. This test was harvested and graded into U. S.

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No. 1 quality A and B sizes on May 12, 1964; a growing period of 110 days.

RESULTS AND DISCUSSION

Experiment 1: The weekly yields of the 4 varieties of potatoes grown in 1963 are shown in Figure 1. The yield of tubers increased for all varieties through 3 harvest periods. At the final harvest period Kennebec and Red LaSoda showed a significant increase in yield over the previous harvest period. Yields of Ona and Redskin were not significantly different from those of the 3rd harvest period; made 98 days from planting. These results are presented graphically in Figure 1.

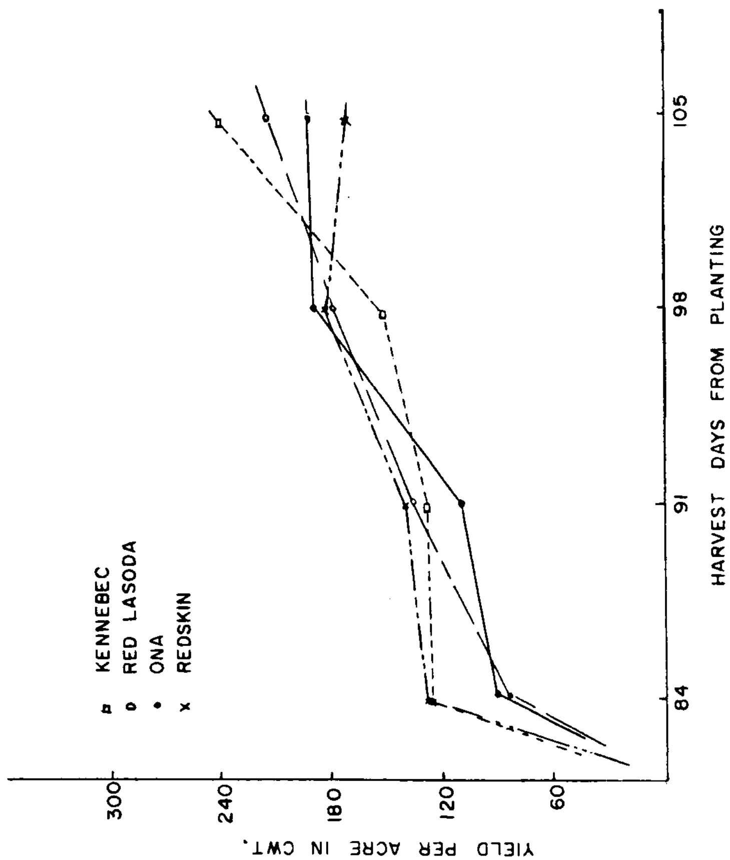

Figure 1. The marketable yield (1963) of four potato varieties at weekly harvests, beginning 84 days from plantings. Differences required for significance 28 cwt.

Table 1 shows the weekly specific gravity of the four varieties. Generally the specific gravity of an individual variety was constant throughout the harvest period. The specific gravity of Red LaSoda was significantly less than that of the other three varieties, and Kennebec was significantly less than that of the other three varieties, and Kennebec was significantly greater than Ona. The specific gravity of Redskin was greater than that of Ona but the difference was less than the requirement for significance.

Experiment 2: Figure 2 indicates that Kennebec made its most rapid tuber development between 98 and 105 days from planting in 1963 but was a week earlier in 1964 (Figure 2). Red LaSoda followed more nearly a uniform rate of growth both years, except for a rather sharp drop in 1964 after 99 days (Figure 2). This sharp drop in marketable yield of the Red LaSoda variety was due to the decrease in "grade-out" as a result of heat sprouting. Thus, it would appear that soil temperature as well as market price should be considered in timing the harvest period for most profitable returns.

Experiment 3: The yield of Red Pontiac tubers increased with a decrease in distance between hills. However, the increase in yield was only 8 cwt per acre more at 6 inch spacing than at 9 inches. When the hill spacing was increased from 9 to 12 inches and from 12 to 15 inches there was a reduction in yield of 42 cwt per acre for each interval. This is shown by the straight line decrease in the graphic presentation in Figure 3. The yield data and the graphic presentations in Figure 3 indicate that most economical yields would be expected with hill spacings in the 9 to 12 inch range.

Table 1. Specific gravity of four potato varieties at weekly harvest intervals. Crystal City, Texas. 1963.

Variety	*1st Week 84 Days*	*2nd Week 91 Days*	*3rd Week 98 Days*	*4th Week 105 Days*	*Weekly Average*	*Analysis°*
Red La Soda	1.050	1.054	1.055	1.060	1.055	
Ona	1.063	1.062	1.062	1.058	1.061	
Redskin	1.063	1.064	1.065	1.068	1.065	
Kennebec	1.069	1.067	1.062	1.066	1.066	

° Means not paralleled by the same line are significantly different.

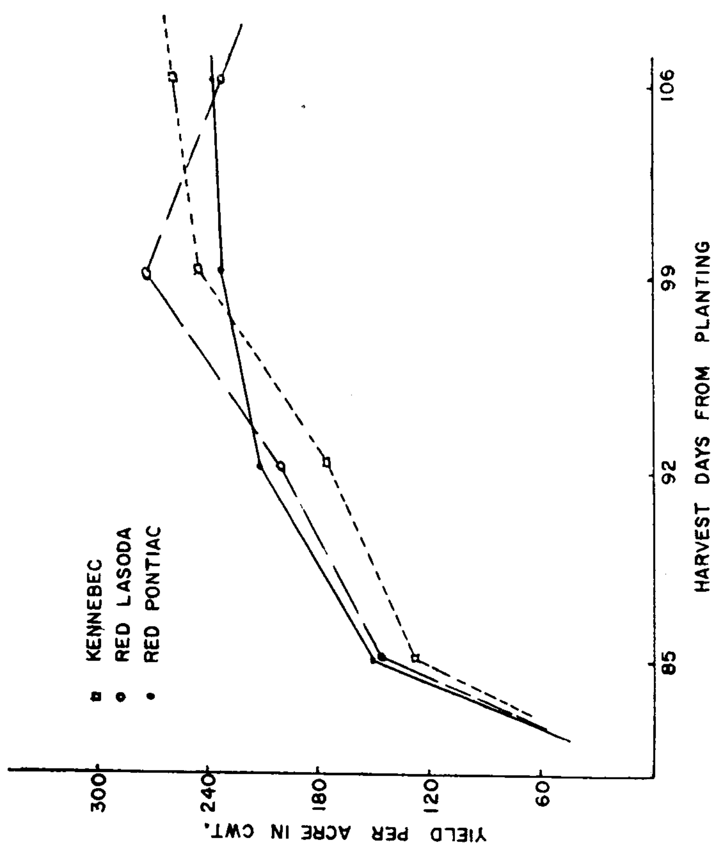

Figure 2. The marketable yield (1964) of three potato varieties harvested at weekly intervals, beginning 85 days from planting. Differences required for significance 36 cwt.

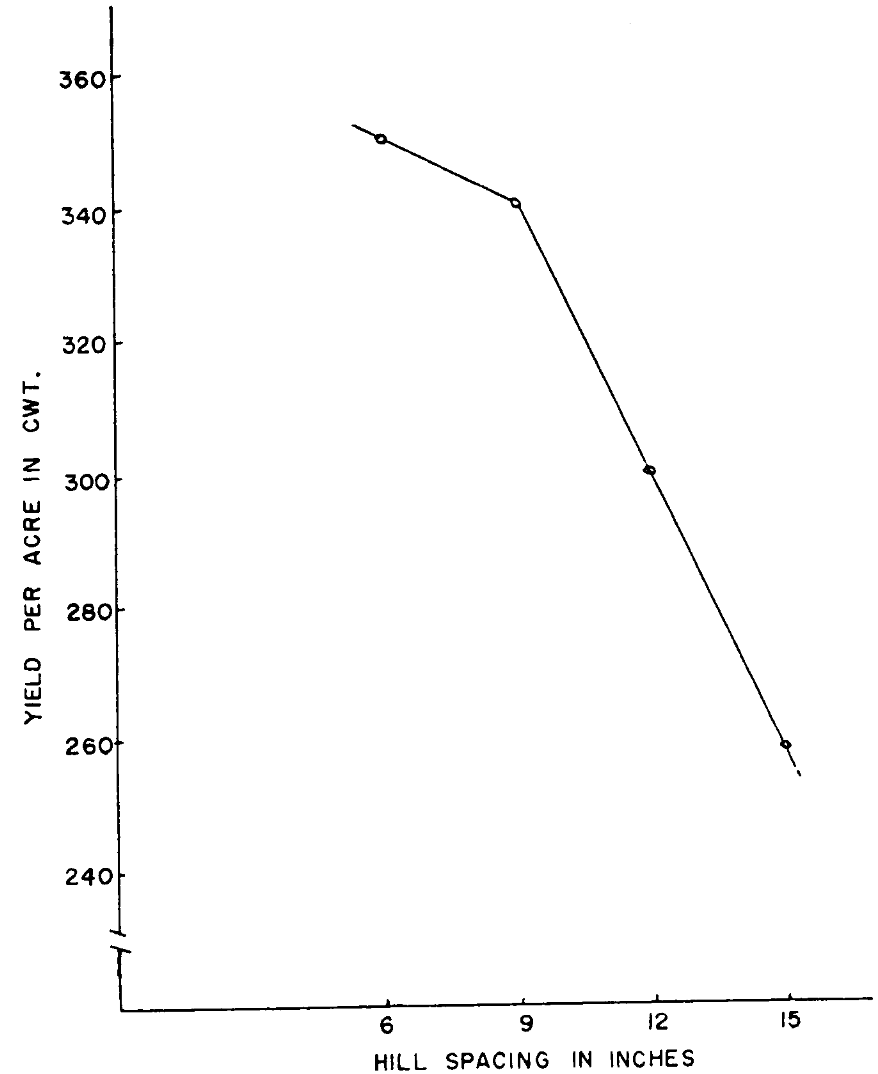

Figure 3. The yield of Red Pontiac potatoes at different hill spacings. Growing period 110 days. Differences required for significance 60 cwt.

SUMMARY AND CONCLUSIONS

A growing period of about 100 days is necessary for good marketable potato yields in South Texas.

Specific gravity, in these tests, was not influenced by the date of harvest.

Red Pontiac should be planted with hill spacings of 9 to 12 inches for most economical returns.

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Dixie Savoy Spinach

BRUCE A. PERRY, R. E. WEBB and D. M. MCLEAN[1]

Seed of Dixie Savoy spinach, developed and introduced cooperatively by the United States Department of Agriculture and Texas Agricultural Experiment Station, was released to commercial seedsmen in February 1965 for increase. A limited supply of seed from commercial seed stores should be available for planting in the fall of 1965.

Fresh market spinach varieties grown in Texas are generally of the savoy-leaf types; planting of semi-savoy strains is limited. However, both growers and shippers show a definite preference for the highly savoyed varieties. The spinach crop in Texas is mainly grown in fall and winter, when outbreaks of downy mildew are often severe. Dixie Savoy, developed to provide a variety immune to downy mildew, decreases this loss.

HISTORY AND DESCRIPTION

Dixie Savoy, evaluated for several years as Strain S-473, is an open-pollinated variety developed through a rigid program of progeny-testing and selection from the cross, Virginia Savoy X a smooth-leaf, mildew immune selection of 12-15 x 42-21, with one backcross to Virginia Savoy. We derived its immunity to mildew from a backcross and selection program, using segregating selections received from Dr. Paul Smith of the University of California. He had found segregates for mildew resistance in spinach PI 140467 (Smith 1950). Cucumber mosaic (blight) resistance was derived from Virginia Savoy (Smith 1920).

Dixie Savoy is a fast-growing, high-yielding, savoy spinach. When drilled in rows to give high plant populations, the variety grows upright and can be machine-harvested. When allowed more space, the growth of the plant is more decumbent, and leaves are thicker and more highly savoyed. Its good, dark green color makes an attractive fresh market pack. Dixie Savoy plants develop rapidly and tend to bolt early. However, when it is planted in the fall, the cool, short days suppress bolting. Spring and summer plantings are not recommended for the North where longstanding character is needed. Developed chiefly as a fresh-market variety for the South, Dixie Savoy will no doubt be used in other areas for freezing and perhaps for canning, if to a limited extent.

DISEASE RESISTANCE

Dixie Savoy is immune to known races of downy mildew, and highly resistant to cucumber mosaic (spinach blight). Resistance to mosaic

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Figure 1. Dixie Savoy Spinach – showing foliage type and general growth habit.

breaks down at high temperatures. Dixie Savoy is not resistant to the curly top virus and yellow dwarf virus, and to the white rust fungus disease.

YIELD COMPARISONS

Experimental tests conducted in Texas over the past 4 years indicated that Dixie Savoy will produce considerably larger yields than the Bloomsdale variety generally grown. The relative superiority of Dixie Savoy could be even more pronounced when outbreaks of downy mildew or mosaic become severe. Experimental yields over the years of testing are reported in Table 1.

Table 1. Yield in tons per acre of Dixie Savoy and Commercial variety.

Location	*Season*	*Year*	*Bloomsdale*	*Dixie Savoy*
College Station	Fall	1964	6.7[1]	8.6
Crystal City	Spring	1964	6.4	12.9
Weslaco	Fall	1963	4.8	6.2
Crystal City	Fall	1963	5.3	6.5
Weslaco	Fall	1962	----	12.6[2]
Crystal City	Fall	1962	5.3	7.5
Weslaco	Fall	1960	4.0	6.9
Four-year Average			5.4	8.1

1 Virginia Savoy used as check variety in this planting.
2 This yield not used in figuring average, since no check variety was included in this test.

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Symptoms of Tobacco Ringspot Virus Infections on Periwinkle, *Vinca Rosea* L.

D. M. McLean[1]

Cucumber, *Cucumis sativus* L., has been used successfully as an index plant for demonstrating soil transmission of tobacco ringspot virus (TRSV) (Fulton, 1962; McLean & Machmer, 1963). However, Lownsberry (1964) considered cucumber either a non-host or a very poor host for the TRSV nematode vector, *Xiphinema americanum* Cobb. In a search for a more sensitive plant in greenhouse soil transmission studies, periwinkle *(Vinca rosea)* seedlings were mechanically inoculated with TRSV on the leaves. Price (1940) listed periwinkle as a host of TRSV, but did not describe symptoms. A yellows virus (undetermined) is reported on periwinkle from Texas (Index of Plant Diseases in the U. S., 1960). In the present study virus was easily transferred by mechanical inoculations from periwinkle to cowpea, cucumber, and spinach. Since symptoms on periwinkle resulting from TRSV inoculations were distinct and differed from the usual ringspotting characteristic on many hosts of TRSV, they are herein described.

Faint, ephemeral, systemic, chlorotic stippling appeared mostly on new growth 10 to 21 days after inoculation, soon followed by dark necrotic lesions which appeared mostly at the base of infected leaves, or on those which developed subsequent to inoculation. Necrotic lesions did not develop a distinct pattern and were indefinite in outline but frequently coalesced into larger spots (Fig. 1, A). Affected leaves appeared as if frosted. Not all leaves developed symptoms. Epinasty developed on necrotic leaves and their margins curled under (Fig. 1, B). Such leaves soon abscised. Older infected plants were generally chlorotic and brittle with successive loss of yellowed leaves which shattered easily. Plants did not recover. Terminal leaves were smaller than normal and sometimes appeared as yellow rosettes. Flowers were small with occasional whitish streaks on the purple petals.

Periwinkle, a perennial in the Rio Grande Valley, is widely used in home landscapes in South Texas and natural TRSV infections are very common on these plants. Periwinkle is another suscept of TRSV which should be added to the growing list of potential reservoirs or as carryover hosts for susceptible important vegetables in the Lower Rio Grande Valley (McLean, 1962; 1963). It is not a good index plant for use in soil transmission studies because of the slow growth of seedlings and long incubation period.

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Figure 1A. Leaves from a TRSV-infected periwinkle plant. Note necrotic lesions pronounced at base of leaves, and the general frosted appearance.
Figure 1B. Shoot from infected periwinkle plant. Note epinasty of affected leaves and inward curling of leaf margins.

An insect vector is not known on periwinkle. Infected periwinkle is a good plant to maintain the virus for experimental purposes.

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Fungi Occurring on Blossom-End Rotted Tomatoes

BAILEY SLEETH[1]

Blossom-end rot is a common-occurring physiological disorder of tomatoes which is usually associated with either low soil moisture or some nutritional deficiency, or both. The development of the disorder has been well described by Geraldson (1957) as follows: "Blossom-end rot becomes apparent as a water-soaked area under the fruit wall on the blossom-end of the fruit. The lesion usually develops rapidly, eventually resulting in a blackened, dry, sunken, leathery spot. Frequently, the dead tissue is attacked by saprophytic organisms. Another form of disorder occurs as internal browning or blackening and may be present without the characteristic rot being visible." The blossom-end rot type of injury has occurred in many Lower Rio Grande Valley tomato fields; but the internal browning type of disorder has been observed less frequently.

Under Valley conditions fungi readily invade the injured blossom-end and are freely sporulating by the time the fruit matures. It is not known at what stage of blossom-end rot development that fungi invade the weakened or necrotic areas. Parasitic fungi may invade the weakened tissue in the early stages of breakdown in the blossom-end, while invasion by saprophytic fungi would be delayed, probably a very short period, until the affected tissue dies. Observations indicate that fungi invade the blossom-end rot areas early and are well established by the time the disease lesions are apparent.

Even though blossom-end rot is a physiological disorder, the damaged tissues provide an excellent point of entry for pathogenic fungi, which cause rotting and a substrate for the growth of saprophytic fungi- Tomatoes with either type of injury are culls. However, in processing tomato juice a small number of tomatoes with blossom-end rot may be processed ,and the black fungus-invaded blossom-end rot tissue break up into small fragments. These black fragments permeated with fungus hyphae are of concern to the tomato-juice processor and especially so if classified as rot fragments by the plant inspector. A lower grade juice results when the number of fungus fragments exceeds the tolerance for a top quality juice.

Ripe Chico tomatoes with blossom-end rot were examined to determine the various fungi that were established on the affected areas and the extent of internal decay development. Fungi were identified by microscopic observation of spores; tomato fruits were cut to observe rot penetration; and cultural isolations were made of internal rot.

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RESULTS

Two fungi, *Alternaria* and *Cladosporium*, were the most prevalent fungi found sporulating on the blossom-end rotted areas of Chico tomatoes. In most instances, these two fungi were present on the same black areas. Of 125 tomatoes with blossom-end dot, *Cladosporium* was found on 98 percent, *Alternaria* on 97 percent, *Fusarium* on 15 percent and other fungi on 2 percent.

The depth of blossom-end rot lesions, even though fungi were present, was usually shallow, seldom exceeding one-sixteenth of an inch. In 11 percent of 100 blossom-end rotted tomatoes decay had penetrated deeper than an eighth of an inch. From these 11 tomatoes, both *Alternaria* and *Fusarium* were isolated from 6 fruits at a depth of one-half to one inch.

SUMMARY

Blossom-end rot lesions of ripe Chico tomatoes were found to be invaded by fungi. In most cases two fungi occurred on the same lesion. *Cladosporium* was found on 98 percent of the lesions, *Alternaria* on 97 percent, *Fusarium* on 15 percent and other fungi on 2 percent. Blossom-end rot lesions provided an entry point for fruit decay in 11 percent of the tomatoes examined. Both *Alternaria* and *Fusarium* were isolated from slightly more than half of the tomato fruits with internal decay.

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An Improved Granular Herbicide Applicator for Field Experiments

R. M. Menges and J. L. Hubbard[1]

The commercial use of granular herbicides has recently increased in the Rio Grande Valley of Texas because of (A) the lower cost of application equipment compared to that of herbicide sprayers, (B) greater convenience in handling chemicals, and (C) ease of calibration of application equipment. In order to select a reliable unit for field research, distribution patterns of clay granules from experimental and commercial applicators were studied. This paper describes the distribution patterns of one commercial applicator which was readily altered for more accurate distribution of granules.

MATERIALS AND METHODS

The commercial applicator unit consists of a hopper with rhombic perforations in the bottom and cam-controlled slide plate with 1 outlet connected by plastic tubing to each of 2 metal scatter pans each 7 inches wide.[2] A ground-driven 5-blade rotor provides hopper agitation. The scatter pans are commercially fabricated with stationary metal diverters to enhance the distribution of granules (Figure 1). Each pan disperses a 7-inch band of granules and a series of pans is used for wider band application.

Tests were conducted in the laboratory and field with several sets of distributor pans to determine the output variation across the 14-inch band. The diverters of one set of pans were manually twisted to change the pattern of granular flow to the scatter pans (Figure 1). Field tests were conducted with 4 mph tractor speed and 13 to 14 rpm distributor rotor speed; laboratory tests simulated rotor speeds and deposit rates of field tests. Clay granules 15/30 RVM AA Attaclay, were collected in a 24-inch long by 12-inch wide by 3-inch deep metal pan fabricated with vertical metal separators spaced ½ inch apart; each separate sample was weighed. Data presented in Figure 3 are the weights (g.) of granules distributed within each ½ inch of the total band width of 14 inches.

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[1] Research Horticulturist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and Associate Agronomist, Texas Agricultural Experiment Station, respectively, Weslaco.

[2] The granular distributor was manufactured by Gandy Co., Inc., Owatonna, Minnesota and is marketed as the Gandy "Ro-bander". Mention of this brand name is for identification only and should not be construed as endorsement over other products.

RESULTS AND DISCUSSION

The cam gauge metered the flow of granules accurately when calibrated and no pulsing occurred. Repeated trials showed that the unmodified pans distributed granules in uneven patterns with the greatest concentrations of granules deposited in the centers of each 7-inch band (Figure 2). Wyoming researchers reported similar distribution patterns with this commercial applicator, and fabricated an experimental unit based on another distribution principle[3]. In the present experiment, modifications in the angles of diverters within the distribution pans provided patterns more acceptable to commercial applications of granular pesticides.

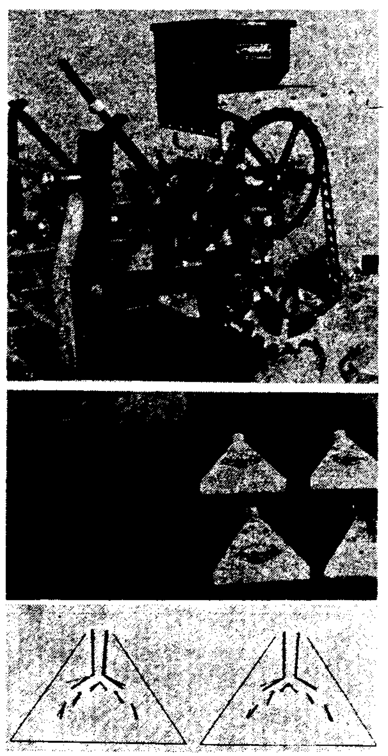

Figure 1. The Gandy "Ro-wheel" incorporator with 2 front-mounted 7-inch "Ro-bander" scatter pans (upper photo); interior and exterior top views of the pans (middle photo); arrangement of diverters in 2 pans before (solid bar) and after (striped bar) modification (lower photo).

[3] Becker, C. F. and G. L. Costel. 1962. Metering and distributing granular carriers for pesticides. Paper presented at the winter meeting of Amer. Soc. Agr. Engn.

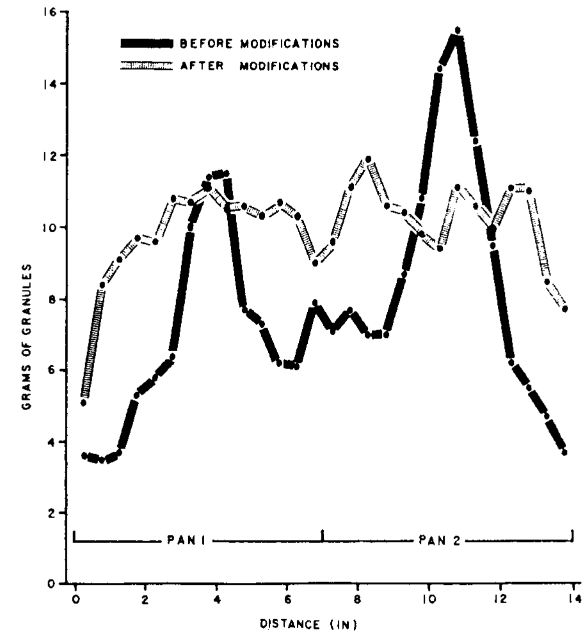

Figure 2. Granule distribution in a 14-inch band before and after modifications in the two 7-inch scatter pans.

Uniform soil application of herbicides is especially important because the chemical applied affects plant growth. Excessively low rates of application may fail to control weeds and high rates may injure the crop.

ABSTRACT AND SUMMARY

A commercial granular distributor commonly used for the application of pesticides in the Rio Grande Valley of Texas was tested for uniformity of application. The unit concentrated the granules in the centers of its 7-inch distribution bands. Modifications in the arrangement of the internal diverters of the distributor pans, however, provided improved patterns of deposit.

MISCELLANEOUS

Potential Water Resources for the Lower Rio Grande Valley[1]

Karl O. Vartia[2]

In any orderly discussion of water resources, it is first necessary to dwell at least briefly on water needs, since without the need for it, water is not a resource. Obviously, wherever people elect to remain for any significant period of time, there is a water need. We cannot live without it. However, it is only when people elect to remain in an area in relatively large numbers that we begin to have water problems. The problems may be easily solved or they may not, depending upon the balance between the supply and the need.

Valley water needs for many years were no problem, beyond those associated with maintaining pumping plants along a river channel constantly liable to change as the swift currents of uncontrolled Rio Grande floods rolled down to the Gulf. Then Falcon Dam came into being and the river was tamed – but meanwhile more people elected to remain in the Rio Grande Valley and the delta areas to the north and south. Being resourceful, as is characteristic of people on this continent, they got all the mileage they could out of the favorable combination of climate and water. In fact, they got into such a high gear that the motive power, the actual firm water supply, can no longer pull all the load. So there is now the painful problem of readjustment.

This readjustment could take either of two forms, either elimination of some of the load – or a bigger water supply. Since from a resource-planning standpoint we hate to eliminate a paying load, I prefer to talk about the possibility of more motive power, or in other words, the chances of a larger water supply. Two of the 3 possibilities, the Valley Gravity Canal and some alternative solutions to the salt problem, have in common one major defect – they cannot increase the water supply – they can only help improve the quality of the supply and thus make it go farther. In terms of crop output, for instance, eliminating the need for extra water to move excess salts through the soil profile to a safe distance below the root zone permits spreading irrigation water over a larger area for greater output; or where water amounts have been insufficient to adequately leach the salts though the profile, the reduction of yield due to excess salt can be gradually eliminated through use of better quality water.

The third possibility, the Texas Basins Project, and more particularly

[1] Address presented to the 19th Annual Institute of Rio Grande Valley Horticultural Institute, Weslaco, Texas, January 26, 1965.
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the Interbasin Canal of that project, would increase the water supply. In fact, it is proposed to bring into this lower Texas area an additional supply nearly equal to the supply which presently supports the impressively large economic machinery of the Valley.

The map (shown during the address) shows in orange color the various reservoir units of the Texas Basins Project, as well as a number of other potential reservoirs and conveyances that are not a part of that specific project. You may wonder how the particular grouping of units composing the Texas Basins Project was arrived at. In part it is arbitrary. Mostly it is based upon the rational philosophy that before the more westerly and less bountifully supplied river basins of Texas can ask for excess water from the eastern basins, they must do their best at developing their own supplies. This the reservoirs shown in orange in the western portions of the map – added to those included in other plans – will do. Tenaha reservoir in the east will provide an increment to the regulated supply from the Sabine basin to meet projected demands several decades in the future.

The project has been defined as "one-third of a State-wide water use and control plan that originated in the minds of Texans and was then honed to . . . perfection by the coordinated effort of several echelons of Government working in remarkable concert". The reference is in part to the work of the U. S. Study Commission for Texas and the agencies which cooperated in that effort. The project does not bring or make available to the western basins one third of all the firm water supply available in Texas. It falls considerably short of that. The one-third refers rather to the project's proportion of the estimated construction expenditures that will be required to complete all the reservoirs and major conveyances required to meet 2010 water demands throught the State.

Another definition or description of the project appears in a recent publication of the Texas Research League as follows; "The Bureau of Reclamation has proposed a $1.3 billion project including 17 major reservoirs and a 400-mile canal to capture some three million acre-feet of water yearly in the State's eastern river basins and move it southwest for use by cities and industry along the Gulf Coast and by agriculture in south Texas. By serving coastal needs from the canal, the project would release waters now dedicated to those purposes for requirements upstream on the rivers in mid-state."

As responsible planners we cannot propose such a project except on the basis that it will more than repay its cost. Only by making profitable use of the capital resources of the nation can we keep our nation solvent and continue to improve its standard of living. We do not propose that the project make a financial profit in the sense that a private corporation must make a profit to stay in business. But we do propose that the water users pay the reimbursable costs that the economists say they can and should pay. This is not an arbitrary decision. By continuing efforts over the years to establish economic yardsticks, the Bureau of Reclamation in concert with other federal agencies has developed rules to determine

what should be repaid. If the user can pay these costs we have a potential going project. Needless to say, the Texas Basins Project looks like such a project. It looked like such a project over ten years ago when we had finished a first quick look. If it had not, we would not have given it the longer look, in more detail, that has gone into the report that was circulated in draft form during the past year. In giving it a longer look we found nothing to materially alter the basic conclusions of the first look.

What are the really basic conclusions? To get to rock bottom, they are but two: first, that the project can be built and, second, that it should be built. These are important conclusions, but they are only our conclusions. Another decision is prerequisite before those conclusions attain fully accredited status: namely, since the State of Texas is sovereign over its water resources, the decision lies with the State of Texas as to whether water should be brought into this area from other parts of Texas. The time has not yet come for the State to make a decision on the report, but we have circulated the draft version to insure that the decision makers will have adequate time for full evaluation of the project's impact upon the State.

Our report describes the circumstances relating to that decision, points out to what extent water appears to be available, or, in other words, will not be used in other parts of Texas according to our best possible estimates, and points ou the potential favorable economic impact of putting such water to work through interregional transfer.

It is entirely legitimate to question our conclusions and our descriptions of the circumstances. As has been aptly stated by one water authority of my acquaintance, estimated future water demands are from anybody's crystal ball. Whether one makes estimates by using projections of present trends, by drawing parallels from presumed analogous circumstances elsewhere, or by some sort of inventory of related resources that would require only the catalyst of an abundant water supply to bring into being a new and provident economic machine, one still does not draw aside the veil that curtains the future. We use in our reports a term that is patently incorrect – "the foreseeable future", just as though we had peeked behind the veil. I hope that all of you and all who read our reports will recognize that term as being but a shorthand way of saying that under the specified set of circumstances there is a strong probability that the particular circumstance being discussed will come into being. In all planning work one necessarily operates on the basis of probabilities.

To insure that no wishful thinking would throw our planning astray, we called upon what we have every reason to believe are unbiased experts to evaluate the probabilities on future water use in the State of Texas. Our own experts told us the probabilities on water supplies. Wishful thinking could not enter here since they are bound by the hydrologic records and by mathematical probabilities.

We have made a detailed study of the technical problems relating to construction of the various project features and feel reasonably sure that our estimates of construction cost are an accurate basis for making decisions.

From this background we propose to recommend to the Congress, should the State so desire, that the Federal Government make the long-range capital investment necessary for construction of the project. We propose to couple our recommendation for construction with recommendations relating to repayment that will recapture directly to the Federal Government from project water users a substantial portion of the construction cost. I am sure it will be noted in Congress and elsewhere that the remainder of the investment and a whole lot more will be recaptured by the Federal Government in the form of income taxes on the increased income resulting from the increased economic activity. It should be noted that the Federal Government can afford to be neutral in regard to the State's decision. Of course, the Federal Government is all of us and we aren't all equally neutral on various proposals. But, while we who have worked in the planning of this project feel rather strongly that it should be built, we must also admit that other profitable opportunities are available for the investment of Federal cash in water-resource projects. While every project is uniquely advantageous in at least some of its features, the economic forces, the manufacture and use of more things to add interest and enjoyment to the lives of more people, will operate to keep us moving as a nation whether or not we foster development in Texas.

A second major decision concerns when it should be built. A substantial part of the project water supply is proposed for use in extending irrigated agriculture. Critics very reasonably point to crop surpluses and ask why we should spend money on works calculated to add to such surpluses. In reply it can reasonably be pointed out that population is increasing and should eventually need all that agriculture can produce, that it takes a long time to get an irrigation project into being, and that it wouldn't hurt to be on the safe side and have a little too much for awhile rather than to run the risk of having too little. However, this is not a compelling argument. We know that in a real emergency the most essential items of construction required to get water moving under the Texas Basins Project could be compressed into a relatively few years' time. The usual long program is favored in the interest of orderly investment and orderly social development.

A more urgent note can be struck for the municipal and industrial water aspects of the project. Specific instances can be pointed out of potential industrial developments in the western Gulf Coast area which did not occur because sufficient water could not be assured for the industry and the required satellite communities. Industry in general does not create its own water supply, it locates where government at some level – local, State or Federal – has already provided it. But we could say at this point, from the National standpoint, what matters it where the industry located; it still contributes to the National economy. In the same vein various State interests can and do suggest that in East Texas where the water is, there is plenty of room for more industry. So the

State's decision makers could argue that if local government is not sufficiently interested to develop a local or basin supply, why should the State go out on a limb for an interregional supply. And it is a fact that there is yet water for local or basin development in much of Texas other than the High Plains, the far west and the whole of the Rio Grande Valley. The flaw in such local developments is that they do not solve problems sufficiently far into the future. Just as a prospective home owner can get into a financial jam by attempting to pay off a mortgage on such a short term basis that he has no resources left for financing the other necessities of modern living, a water supply agency can find itself facing a water deficit for its area of responsibility before it has gotten far enough out of the financial woods to undertake a new and probably more costly addition to its water supply. And more than likely, a vicious circle sets in to the effect that maximum use cannot be made of the water actually available to the agency much of the time, because municipalities and industries cannot or will not accept critical period shortages and do not thrive in the face of such possibility. Consequently the water agency's financial position is made more difficult and the local economy suffers because the catalyst, an assured long-rang water supply, is missing. And while there is undoubtedly more room in east Texas for industry, there are just as surely a number of advantageous circumstances along the western portions of the Gulf Coast that, with a water supply, would bring into being types of industrial development that would not occur in the areas of east Texas where there is yet ample room.

But even yet we could say let us bide our time. Wait until the needs are clearly evident. Then, if necessary, initiate the crash program of construction and hope that the reservoirs will fill in time to meet the needs. It may be possible. On the other hand, it may not be at all possible by reason of a factor that is looming ever more important.

I refer to right-of-way.

We all know that land values go up from year to year. In many areas farm land prices are entirely out of line with their economic value for cropping purposes. These prices reflect the expectation that cities or industries will eventually need these areas, and the present owner is gambling that he can hold on for a real killing. Our cost estimates attempt to take such items into consideration. But we cannot afford to buy the city or industry if it actually gets there first. We can only alter our plans and, in the case of a canal, go around. If it is a reservoir, we abandon it and find a substitue.

The Inter-basin Canal would start near the lower end of the Sabine River. It needs to – so that only water about to be lost into the Gulf will be taken. It traverses the flat coastal plain on its way westward. It needs to. Only in this area can it go on a relatively direct line toward its objective without the need to twist and turn in attempting to maintain the nearly level water surface of a large canal. The proposed canal is about 420 mile in length. The highway distance between Beaumont and Raymondville is about 420 miles. The canal extends east from Beaumont a few miles but you can see from the mileage figures that it doesn't wind around very much.

Let us contrast that with the circumstance away from the Coastal Plain. The highway distance from Denison to San Antonio is about 350 miles. But the distance between these points along the generalized 500 foot contour is about 4,750 miles! The best we could no with a canal line in such an area, even going to extremes with deep cuts and long siphons, would be about 2,000 miles. So you can understand we would not be dealing with the same kind of a canal. The coastal route is far better. It can result in low cost water.

But suppose we wait many years to begin building this coastal canal. What do you suppose will be the chances of finding undeveloped areas in a connected line through the Houston area for instance? Even now we are exploring the closest alternatives in this area to our preferred location and find they will increase costs, if we have to use them, by many tens of millions of dollars. Every foot of additional pumping that must be introduced into the system to go up into the higher ground to avoid urban and industrial development adds many hundreds of thousands of dollars to project operation costs. To date, such increases over our first studies do not add up to more than small fractions of a cent per thousand gallons on anticipated deliveries of water. Your guess is as good as the next man's on what may happen later on, but we are not optimistic about right-of-way. If for no other reason than this we feel that it is urgent to get on with the job.

Desalinization of sea water also is a potential water supply for the Valley. The subject has made the headlines frequently. Within the last fortnight I saw one article quoting a prospective price of 67 cents per thousand gallons for a fairly large distillation-type plant using nuclear fuel. That is about $220 per acre-foot. How much water do you suppose the Valley's economy can advantageously use at that price? Other estimates based upon combining distilling of sea water with production of electric power in nuclear plants suggest far lower costs, but no one knows how long it will take to develop such plants.

The fact seems to be that we can convey water a long distance, after nature has freshened it, at much less cost than we can compete with the atmospheric processes that draw moisture from the sea and bring it to earth as rain. Our Texas Basins Project cost estimates indicate a cost for delivered water on the order of 5 cents a thousand gallons. Even the most optimistic researchers in desalinization work do not suggest prices in that range. However, as I indicated in discussing right-of-way, this presupposes an early start on the project, and an orientation of industrial development in the State to the circumstance of an unlimited water supply. The irrigation phase can be re-examined while construction proceeds. We know from irrigation experience here in the Valley that irrigation is a paying proposition. If industry should need the water more irrigation plans can be tailored to fit.

The important thing is to get on with the job before it is too late.