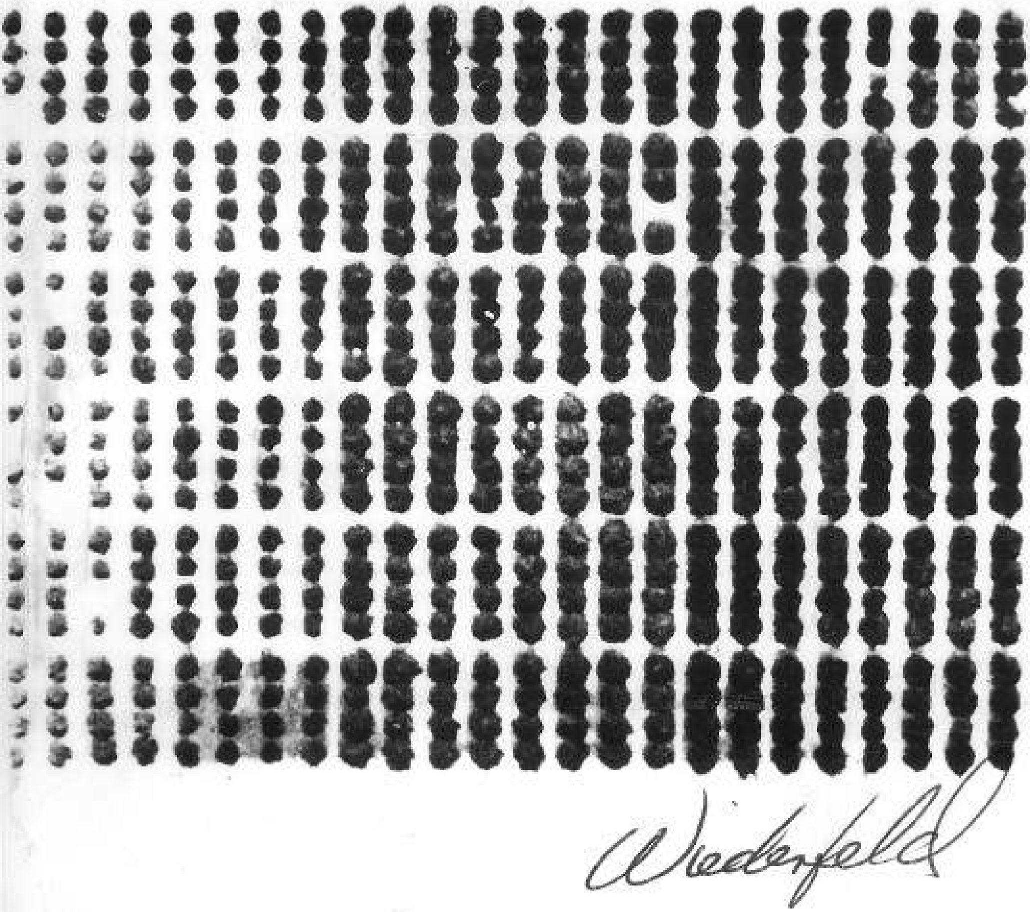

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OF THE

RIO GRANDE VALLEY HORTICULTURAL SOCIETY

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Information for Subscribers

Originally this Journal was published in the month of September. Several years ago the date of publication was moved forward to January. Continuity of both volume number and year was maintained with the result that the journal appearing in January would bear the date of the previous year. For the current volume the date has been moved forward one year to coincide with the date of publication. Accordingly there will be no publication dated 1981. The current volume, Volume 35, 1982 was published in January 1982.

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 of Texas. The Society's aim is to stimulate interest in research and its practical application to the Valley's problems with fruit, vegetables, and ornamentals.

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

The Society sponsors an annual Institute featuring oustanding speakers from all parts of the country who present new developments in the field of horticulture. Panel discussions, social get-togethers, and a barbecue complete the all-day program.

Talks given at the Institute and reports of Valley research are published in the *Journal of the Rio Grande Valley Horticultural Society*, providing a continuing record of horticultural progress in the Valley.

Anyone interested in horticulture can become a member of the Society. The annual dues of $7.50 include a subscription to the *Journal*. Subscriptions by institutions and libraries are $10.00 a year. Applications for membership or subscriptions should be sent to the Secretary, Rio Grande Valley Horticultural Society, Box 107, Weslaco, Texas 78596.

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Recipient of the Arthur T. Potts Award

A former Seguin boy got into the seed business pretty much by chance. He had been working for Weslaco Lumber Co. nine years when he reluctantly went with Francis C. Stokes Co., a major seed house, to straighten out an unprofitable company store in New Jersey. It was 1931 and the depression was rapidly worsening. Walter H. Baxter accomplished the task he was hired for in about six months, and with the store showing a modest profit, promptly resigned and returned to South Texas to stay.

Recognizing the vast agricultural potential of the Valley, Baxter went into the seed business for himself and for six years was president of Baxter, Emmons and Deihl, Inc. In 1938 the company became Ellis-Baxter, Inc. then in 1944 the company assumed the name it bears today. In early 1947 the business was moved to its present location at 416 S. Missouri.

Baxter had a strong hand in the development of hybrid seeds aimed at increasing plant vigor and yield. In the early thirties he developed a green-topped beet which is still marketed nationally. Baxter's Beauty, a hybrid tomato, was developed by crossing five tomato varieties. He's proud of his introduction of dark green Italian parsley. Baxter seeds have been planted in Europe, Japan, South America, Israel, Africa, Canada and Mexico.

Last year Walter Baxter Seed Co. sold 25,000 pounds of two varieties of cantaloupe seed. He sells 7-8 tons of carrot seed routinely and has sold as much as 35,000 pounds of this popular item on occasion. Sales of broccoli seed are measured in tons even though it goes for more than $100 a pound.

He never forgot and seldom allowed his associates to forget that all agricultural enterprise starts with seed. His company's motto reflects that belief: "The hope of the harvest begins with the seed."

Baxter served on the board of Rio Farms, Inc. for 20 years and was president much of that time. He was active in Weslaco Kiwanis Club and had a perfect attendance record for 42 years. He has been a board member of Knapp Memorial Hospital, First Methodist Church and the Methodist Children's Home in Waco. He was recognized by the Weslaco Chamber of Commerce in 1965 as "Weslaco's Outstanding Citizen" and by Kiwanis International as "Man of the Half Century."

He's been married to the former Olga Arnold of Arlington since 1924, just three years after his arrival in Weslaco by boxcar with two mules, a dog, cow, some chickens and the family's household goods.

The couple has two sons and six grandchildren.

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Program of the Thirty-Fourth Annual Institute
Rio Grande Valley Horticultural Society
January 22, 1980

MORNING SESSION: Dr. Rafael Cintron — Presiding

9:00 A.M.	Welcome, J. Victor French, President, Rio Grande Valley Horticultural Society.
9:10 A.M.	"Threshold Levels and Damage by Citrus Rust Mites" — Dr. Jon Allen, Entomologist, IFAS Agricultural Research and Education Center, Lake Alfred, Florida.
10:10 A.M.	Juice and Donut Break
	A symposium - Integrated Pest Management
10:30 A.M.	"Biocontrol of Citrus Mealybug" — Dale Meyerdirk, Entomologist, Citrus Insects Lab., U.S.D.A./A.R., Weslaco, Texas
10:45 A.M.	"Inter-Relation of Chemical and Biological Control" — H. A. Dean, Entomologist, T.A.E.S., Weslaco, Texas
11:00 A.M.	"Development of Extension Demonstration Work and Scouting Techniques for Citrus Rust Mites" — Leon Smith, Citrus IPM Co-ordinator, County Agent - Citrus
11:15 A.M.	IMP Panel Questions and Answers
11:30 A.M.	PRESENTATION OF ARTHUR T. POTTS AWARD Victor French, President of the Society
11:45 A.M.	ELECTION OF OFFICERS AND OTHER SOCIETY BUSINESS - Victor French

Journal Rio Grande Valley Horticultural Society, Vol. 35, 1982.

Energy Producing Plants, with Special Reference to Jojoba and Guayule — Background and Brief Review[1]

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ABSTRACT

Fixed oil-, and hydrocarbon-bearing plants, especially jojoba *(Simmondsia chinensis* (Link) Schneider) and guayule *(Parthenium argentatum*, Gray) are briefly reviewed. These plants are respectively native to the Sonoran and Chihuahuan Deserts of North America. Jojoba produces a liquid wax, unique to plants, which can replace sperm whale oil in cosmetics, lubricants, and other industrial applications. Guayule produces a latex similar to the natural rubber of the rubber tree, *(Hevea braziliensis* Muell. Arg) and which can with minor refining, be used interchangeably with, or in place of, the Hevea natural rubber. Biological considerations regarding the sperm whale (endangered species) and geopolitical considerations regarding sources of either natural rubber or synthetic rubber feedstocks make current cultivation and development of jojoba and guayule in semiarid areas economically feasible in the United States and Mexico.

Essentially all higher plants are energy producing plants. The lignin, cellulose, and lignocellulose remaining after death are sources of stored-up energy.

For purposes of this presentation, energy producing plants will be defined as plants producing significant quantities of fixed oils or of hydrocarbons. Even so, this scope is still too broad. Corn, cotton, soy beans, safflower, sunflower, rape, seasme, and flax are among those plants whose seeds produce significant quantities of fixed oils, generally referred to as triglycerides. The southern pine tree, source of turpentine, also produces a glyceride oil known as tall oil as a by-product of kraft paper manufacture.

In order to keep within reasonable limits, I will concentrate on a review of two plants of regional and timely interest: jojoba and guayule. Jojoba produces a fixed oil (a liquid wax) in the seeds, and guayule produces hydrocarbon polymers in the plant tissue. Both of these plants are native to the Southwestern United States and Northern Mexico (Sonora and Chihuahuan Deserts) and, in the current state of international affairs are of economic interest regionally, nationally and strategically.

Jojoba *(Simmondsia chinensis)*, native to northern Sonora, Southern Arizona, California south of Santa Barbara or Fresno, and Baja California, is a perennial of the Box or Buxaceae family. First reports on the plant and its unique seeds

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[1] Presented before the 35th Annual Horticultural Institute of the Rio Grande Valley Horticultural Society, Jan. 20, 1981, under the title "Energy Producing Plants".

date back to 1701 in epistles of Padre Kino to King Phillip III of Spain (11). A Jesuit priest, Clavijero, assigned to Mexico as a historian, wrote the first published report on jojoba from Venice in 1789 (2). Other reports indicate the use of the oil as a hair tonic or restorer, as a cure for cancer (2), stomach and kidney disorders (9), and other medicinal applications (17).

Jojoba oil is unique and differs from usual vegetable seed oils. As indicated in Table 1 (14) the molecular structure is a monoester of a long-chain fatty acid with a long-chain fatty alcohol. Triester or glyceride structures are found in all other vegetable oils. Most other plant waxes are leaf coatings and are solid; e.g., carnauba from the Brazilian carnauba palm and candelilla wax from a Northern Mexican shrub, candelilia. Distribution of the major constituents in jojoba is not entirely random (14); the principal monoester is the C_{22} alcohol-C_{20} acid ester (Table 1).

Table 1. Major Jojoba Acids and Alcohols (after Miwa, 14)

No. of Carbons and Double Bonds	Acids, %	Alcohols %
18:1	6	6
20:1	35	22
22:1	7	21

Major component is an ester consisting of a C_{22} alcohol and a C_{20} acid.

The jojoba industry has investigated possible products or extractives. Jojoba can replace sperm whale oil as liquid lubricant. It can be reacted with sulfur ($\gtrsim$10%) to make an extreme pressure lubricant and hydrogenated to a solid wax (mp 158° - 168° F) to replace spermaceti, beeswax, and some carnauba and other waxes in cosmetics, candles, and polishes. Jojoba oil is edible and non-fattening; however, it may have the laxative effect of mineral oil.

Jojoba is a perennial that grows as long as 100-200 years according to some investigators (15) and utilization of the plant stem, leaf, and root fiber poses no problem. After extraction of the oil seeds, a seed meal contaning about 30% crude protein can be produced. This meal depressed appetites in test animals in feeding studies due to its content of cyanogen glycoside, simmondsin (Fig. 1) and the presence of the nitrile (-C ≡N) moiety (7, 8). Verbiscar et al (20) have detoxified this group by treating the meal with ammoniacal hydrogen peroxide and have also used an extended hydrolysis with ammonia. Jojoba seeds have hulls similar to soy bean pods and have to some extent been included in the meal. The protein content of the mixture is about 5% less than jojoba meal without the hulls. The hulls have been used as a soil mulch; another possibility is the use of the finely ground hulls as a filler in dynamite and other nitroglycerine based explosives.

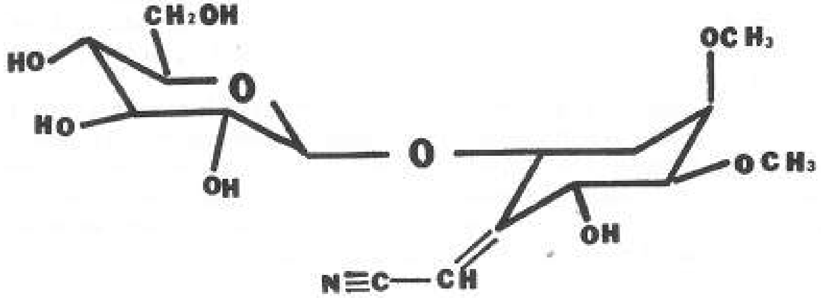

Fig. 1. Simmondsin.

Jojoba plantations have been established on the Papago Indian reservation west of Tucson, Arizona, and on the reservation of the San Carlos Apache Indians, northeast of Globe, Arizona. Additional plantings have been made in the Wellton-Mohawk irrigation area in Arizona near Hyder, and in California. Cultivation is also being tried in Costa Rica. Although jojoba is indigenous to an area having a normal rainfall of 12 inches a year or less, Cluff (3) has indicated that better growth and yield could be obtained using about double this amount of water. A catchment basin arrangement was made in the Papago Indian planting to retard the water run-off, especially water from the summer cloudbursts. Harvesting still presents a problem, as the jojoba seed do not all ripen at the same time. The Papago and San Carlos Apache Indians use tribal labor to pick the seed by hand; such labor would not be available to a commercial jojoba plantation. Cranberry, blueberry and rasberry harvesting rakes have been used with varying degrees of success.

A recent issue of Jojoba Happenings (6) lists 56 individuals and organizations other than the Office of Arid Lands Studies, including the Jojoba Commodities Group of North Hollywood, Calif., offering jojoba plants, products, or services. With the proper strains of plants, jojoba could well be an economic crop for the Lower Rio Grande Valley area.

In North America, interest in hydrocarbon plants has primarily been centered on guayule *(Parthenium argentatum)*, a xerophytic, lactiferous plant native to the Chihuahuan desert (northern Mexico and the Big Bend area of southwest Texas). The Spaniards in the 16th century reported the native Indians playing with a "ball from the juice of a certain herb" (5). The Indians also discovered the rubber could be extracted from the plants by chewing (16). The plant was "rediscovered" in 1852 by Biglow (Droze, 5), and commercial exploitation started in 1888. Mills to utilize the wild plant were built at Jimilco, Mexico in

1902, and in Marathon, Texas in 1909. Meanwhile, the Hevea rubber tree *(Hevea braziliensis)* was being exploited. An Englishman smuggled some 70,000 seeds out of Brazil in 1872 (export of the seeds was illegal in Brazil at that time) in a stuffed alligator, and started the rubber plantations in Southeast Asia. Subsequently, France and the Netherlands joined in producing Hevea rubber in Indo-China (Vietnam) and the then Dutch East Indies (Indonesia). Firestone launched a Hevea plantation in Liberia somewhat later. As a result guayule mills in the U.S. shut down. No commercial plantations of the native Hevea exist in Brazil because it is attacked by an indigenous fungus or rot (10), which is not found in Southeast Asia.

World War II shut off rubber imports from the Malaysia-Indonesia area and shipments from Liberia and Brazil to the U.S. mainland were rendered hazardous by the German U-boats. The Office of Rubber Reserve was established in the 1940's to obtain, by whatever means, enough rubber to sustain the war effort. The synthetic styrene-butadiene rubber (SBR) did not meet Federal specifications during the war for vulcanization characteristics, and it was necessary to use

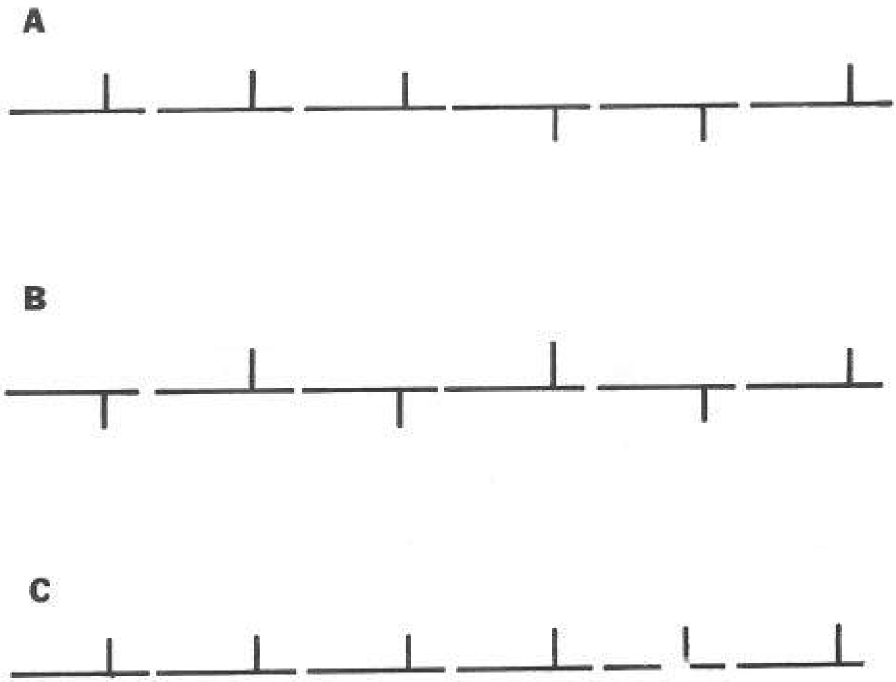

Fig. 2. Isoprene polymers (skeletal structure) A) Isotactic (natural rubber, cis-orientation of the side methyl group) (B) Syndiotactic (gutta percha rubber, trans-orientation of the side methyl group) (C) Atactic (random orientation of the side methyl group).

natural rubber as a co-polymer or adhesive between plies to keep from losing the treads. With improved technology, the synthetic rubber program produced from petroleum, ample quantities of polymers having the desired cis-polyisoprene structure (Fig. 2). In the 1970's the rapid rise in petroleum prices, plus the world-wide geopolitical upheaval rendered the rubber supply again a long-range crisis for the United States for natural and synthetic as well. As a result, attention has been once again directed to the guayule plant.

Guayule will grow on approximately 12 inches of rainfall a year. In guayule, the polyisoprene latex is formed as a result of a drouth-resisting mechanism (12), so that irrigation would have to be withheld for a period preceding harvest, or harvest schedules would depend on antecedent rainfall. The purity of the cis-isoprene polymer in guayule latex is about 80%, compared to 93% purity in Hevea latex, and this is a disadvantage. This problem has been largely solved by an acetone extraction of the component resins (18). The Mexican government has continued research on guayule at a plantation and pilot plant in the area of Saltillo, Coahuila. Harvest is in 2 stages: cutting aerial portions of the plants (pollardization) after 3 years; and total uprooting of the plant after 5 years followed by replantings. An economic survey of guayule made by the Texas Agricultural Experiment Station in 1980 indicates production cost of cis-polyisoprene latex varies between $0.24 and $1.17/lb (19). This appears to be within reasonable economic limits for a profitable cultivation program, depending on a number of circumstances, including the market price of alternative crops, particularly cotton, for use of the same land.

The hydrocarbon bearing plants cover a wide scope. The southern pine tree is not only tapped for turpentine (gum spirits wood turpentine) but the wood is steam-distilled to obtain more hydrocarbon (steam-distilled wood turpentine). Also, a fixed oil, tall oil, triglyceride containing substantial oleic and linoleic acids as well as rosin derivatives are obtained as byproducts of kraft paper manufacture. The major emphasis in this presentation, however, is on lactiferous (latex-bearing) plants. Even this is a wide scope as indicated by the work of Buchanan and Otey (1). In addition to the rubber tree *(Hevea braziliensis)* and the euphorbia species, including "milkweed" and poinsettia, goldenrod, Kok-sagyz (a Russian vine), and cryptostegia, a vine native to Madagascar (4) have been investigated as rubber sources.

The term "gasoline plants", given to the hydrocarbon bearing plants is at best a mild misnomer. Most, if not all hydrocarbons, or their essential oil derivatives found in plants are terpenes, which are based on the monomer isoprene (2-methyl -1, 3-butadiene, Fig. 3). In contrast, 100 octane non-leaded gasoline is 2, 2, 4-trimethyl pentane and all lots of gasoline produced are rated for their "Octane number" with this compound as a standard. Also, olefins or diolefins (as isoprene is) are considered undesirable in gasoline due to gum-forming tendencies. It is possible that isoprene or its lower polymers could be subjected to proper conditions of catalyst, temperature, pressure, and time to yield hydrocarbons suitable for use in gasoline mixtures. Modern refinery technology could doubtless be modified for this purpose if the economics warranted.

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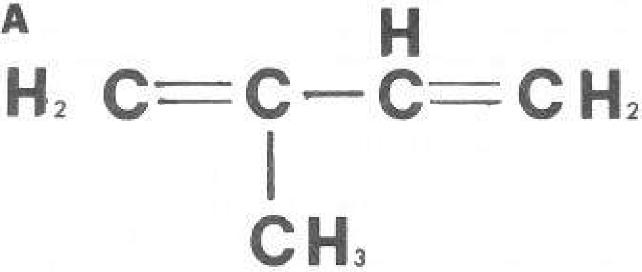

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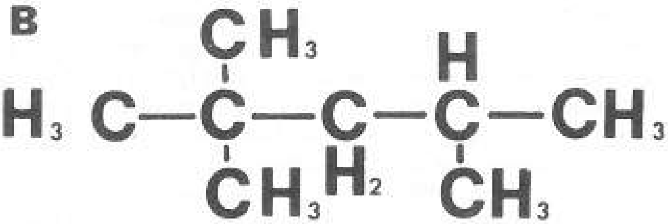

Fig. 3. Structural comparison of : A) Isoprene (2 methyl -1, 3-butadiene) and B) Isooctane (2, 2, 4-trimethyl pentane).

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Reflectance of Litter Accumulation Levels at Five Wavelengths Within the 0.5- to 2.5-μm Waveband

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ABSTRACT

Reflectance was measured for 1-m^2 range grass plots with two canopy treatments (standing and clipped) and four levels of litter accumulation and for grain sorghum with two canopy treatments. Reflectance was significantly higher at the 0.65- to 1.65-, and 2.20-μm wavelengths for both grass and grain sorghum canopies when the canopies were clipped and the resulting litter was removed. The natural accumulation of litter under the grass canopy did not significantly affect reflectance. The 1.65- and 2.20-μm wavelength reflectances of the live grass and the intact litter were 21.8% and 16.2%, respectively, and those of grain sorghum were 21.8% and 16.5%, respectively.

The quantity of biomass on the soil surface is important to a range or farm manager in determining the capacity or duration of a grazing period and protecting the soil from water and wind erosion. The deduction of biomass levels from reflectance measurements would allow the range manager to base grazing decisions on data that are more current, more representative of the area being grazed, and that are available in a more timely manner than is possible with conventional methods. Data with these attributes would reduce the odds that the range would sustain damages due to overgrazing.

Pearson and Miller (5) found that over the 0.35- to 0.80-μm waveband, percent reflectance increased as biomass decreased, bare soil had a higher reflectance than dead vegetation, and green vegetation had a lower reflectance than either the bare soil or the dead vegetation.

Leamer et al. (3) reported that bare soil had a higher reflectance than green vegetation at all wavelengths (WL) between 0.50 and 2.50 μm except those between 0.75 and 1.30 μm, at which green vegetation had higher reflectances. The important WL for determining percent cover for two wheat cultivars from reflectance data were 0.65 to 0.75, 0.90, 1.10, 1.65, and 2.2 μm. However, the linear correlation coefficients for the relation between percent cover and reflectance at the 1.65- and 2.20-μm WL were higher than those at other WL throughout more of the growing season.

Gausman et al. (2) reported that for five out of six crops reflectance differences between dead leaves and bare soils were greatest for WL from 0.75 to 1.35 μm.

Standing sugarcane residue (sugarcane killed by frost) and soil were less reflective than bare soil or soil covered with littered residue (1). The standing sugarcane residue was less reflective than the littered residue because of shadows in the field of view.

Our main objective was to determine the effect of plant litter accumulations beneath perennial grass canopies on reflectances at the 0.55-, 0.65-, 0.85-, 1.65-, and 2.20-μm WL.

MATERIALS AND METHODS

A coastal range site located on a Galveston sand (Typic Udipsamments) with a native vegetation canopy consisting mainly of the bunch grass seascoast blue stem *(Andropogon scoparies* var. *lilloralis)* was selected for one study site. The site had not been grazed for about 20 years and a large quantity of litter had built up between the soil surface and the grass canopy.

A randomized complete block design, replicated four times, with four treatments applied to each of four 1-m^2 plot areas was used. Treatments and order of application were: (1) live vegetation and litter intact (LLI); (2) live vegetation intact, with one-half of litter removed (LIHLR); (3) live vegetation intact, with all litter removed (LIALR); and (4) live vegetation clipped, with litter and live vegetation removed (LLR) (Fig. 1).

Reflectance spectra for all studies were taken with an Exotech Model 20 field spectroradiometer (3). (Mention of company or trademark is for the reader's benefit and does not constitute endorsement of a particular product by the U. S. Department of Agriculture over others that may be commercially available.) One spectrum each for incoming and outgoing radiation was taken for each treatment on each plot; 60 seconds were required to complete both spectra. Reflectance readings were taken from a circular area about 30 cm in diameter within each 1-m^2 plot by positioning the instrument directly over the center of the plots at a height of 1 m above ground. Reflectance measurements were made during the same time period (1030-0230) each day. Outgoing radiation was ratioed to incoming radiation to calculate percent reflectance.

An F ratio was calculated for each of five WL (0.55, 0.65, 0.85, 1.65, and 2.20 μm) to test for significance among treatment means, and means for each wavelength were compared with Duncan's multiple range test ($p = 0.05$).

The 3 canopy components, inflorescences and stems, standing green, and standing brown biomass were determined by clipping the canopy at ground level in 20 quadrats (each 50 cm by 50 cm) and separating the clippings into the 3 components. The 20 quadrats were located next to the 1-m^2 areas used for making canopy reflectance measurements.

The other study site was four 1-m^2 plot areas planted to grain sorghum [*Sorghum bicolor* (L.) Moench] on Hidalgo sandy clay loam (Typic Calciustolls). The plants emerged about September 21, 1978, with populations of 228, 261, 270, and 300 plants/plot.

Reflectance was measured on October 18, 1978, when the plants were about 30 cm tall. After reflectance of plants was measured, the plants were clipped and removed from the plot area. The reflectance of the remaining stubble and the now-exposed dry, crusted soil surface was then measured.

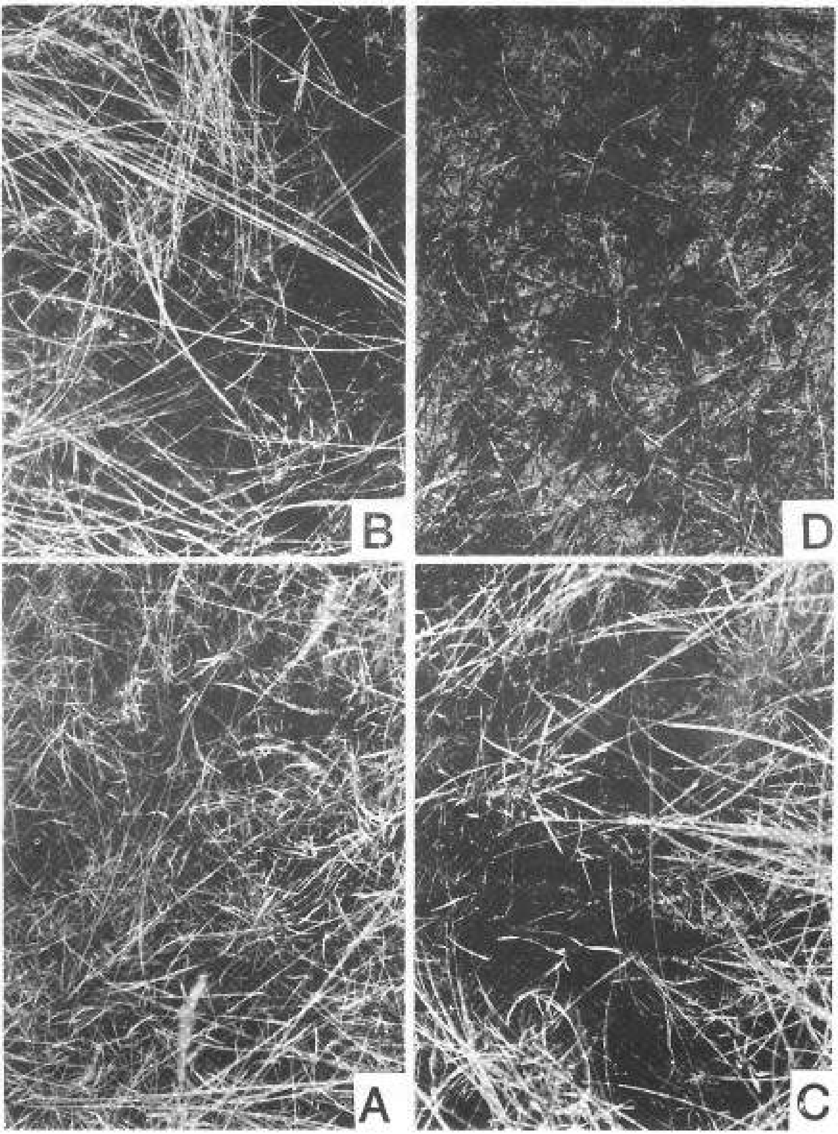

Fig. 1. Grass plot, showing the four treatments: A - live vegetation and litter intact (LLI); B - live vegetation intact, one-half of litter removed (LIHLR); C - live vegetation intact, all litter removed (LIALR); D - live vegetation clipped, with clipping and litter removed (LLR).

Student's t test (p = 0.01) was used to compare reflectance means for plants with those for stubble and exposed soil at the 1.65- and 2.20-μm wavelengths (6).

RESULTS AND DISCUSSION

The appearance of the 1 m^2 grass plots on the coastal sand range site is shown in Fig. 1.

Reflectance spectra associated with the four treatments (LLI, LIHLR, LIALR, LLR) applied to the 1-m^2 plots on the coastal sand range site for the 0.50- to 0.70-μm, 0.75- to 1.30-μm, 1.50- to 1.75-μm, and 2.00- to 2.50-μm wavebands are shown in Fig. 2. The LLR treatment had the highest reflectance for all except the 0.75- to 0.90-μm portion of the 0.75- to 1.30-μm waveband, in which it

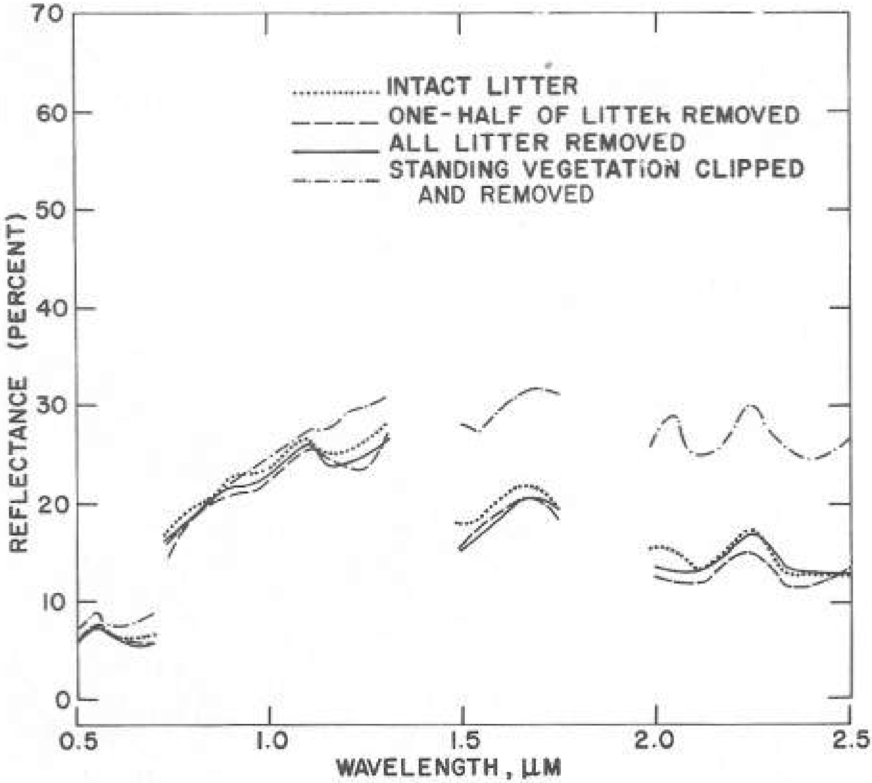

Fig. 2. Spectrophotometrically measured reflectances for the four grass plot treatments: LLI - live vegetation and litter intact; LIHLR - live vegetation intact, one-half of litter removed; LIALR - live vegetation intact, all litter removed; LLR - live vegetation clipped, with clipping and litter removed.

was lower than or equal to the other treatment reflectances. Resulting spectra were as expected, except for the 0.75- to 1.30-μm waveband, for which the reflectance spectra in the 0.75- to 1.10-μm waveband were expected to be much higher, similar to those of live wheat plants (3). However, the vegetation spectra resembled the spectrum for bare soil. The standing vegetation biomass that was clipped, removed from the plots, and oven dried was 29.1% inflorescences and stems, 26.4% standing brown biomass, and 44.5% standing green biomass. It is speculated that the 55.5% nongreen biomass (29.1% inflorescences and stems, and 26.4% standing brown biomass) and shadows (Fig. 1) caused the reflectance for this waveband to be low. This conclusion is supported by the work of Gausman et al. (2), in which dead leaves did not have the characteristically high reflectance of live vegetation in this waveband.

The reflectance levels for vegetation in the 1.10- to 1.30-μm waveband were expected to be similar to those for LLR treatment (Fig. 2) and those for crop residues (1). However, they resembled the spectra for live wheat plants (3).

The 44.5% green biomass probably absorbed sufficient radiation to cause this decrease in reflectance. This is supported by Myers et al. (4), who showed that as leaves are stacked deeper over the spectrophotometer's port, the rate of absorptance for the 1.20-μm WL is higher than that for the 1.10- and 1.30-μm WL's.

The F ratios for 0.65-, 1.65-, and 2.20-μm WL's were significant ($p = 0.05$), while those for the 0.55- and 0.85-μm WL's were not.

Duncan's multiple range test indicated that the reflectance mean for the LLR treatment was higher than and different from all other means, which were alike (Table 1). This was true for all WL with significant F ratios. Since reflectance means for the LLI, LIHLR, and LIALR treatment were statistically alike, it is highly probable that the litter accumulation had no effect on reflectances, and when the quantity (50% or more) of shadow present within the plot area (Fig. 1) is considered, it seems likely that shadows caused reflectances for the three treatments to be alike. For the 0.65-μm WL, Pearson and Miller (5) and Leamer et al. (3) attributed this result to the very efficient absorption of incident radiation by the vegetation, causing a lower reflectance.

The decrease in reflectance for the 1.65- and 2.20-μm WL was also observed by Leamer et al. (3), who attributed this decrease chiefly to a lower-reflecting vegetative canopy that obscured a higher-reflecting soil background. Shadows and plant water contents were also contributing factors.

The calculated t values for the 1.65- and 2.20-μm WL's indicated that reflectances for clipped grain sorghum plots were significantly ($p = 0.01$) higher than those for unclipped plots (Table 2). These results are also attributed chiefly to a low-reflecting vegetation canopy that obscured a high-reflecting soil surface, along with the influence of shadows.

The percent reflectances at the 1.65- and 2.20-μm WL's of grass plots with the LLI treatment were 21.8% and 16.2%, respectively, while those of plots with a grain sorghum canopy were 21.8% and 16.5%, respectively. Therefore, it appears that the species and condition (green or semigreen) of the vegetative canopy did not influence the reflectances for these two WL's.

The shape of the reflectance curve for the 2.00- to 2.50-μm waveband differed widely for the LLR grass plots and for the clipped sorghum plots. The curve for the LLR grass plots was bimodal (Fig. 2), whereas the curve for the clipped grain sorghum plots was bell shaped, with low reflectances for the 2.00- and

Table 1. Percent mean reflectances measured at 3 wavelengths for a grass canopy with 3 levels of litter established under the canopy and for grass canopy clipped with clipping and litter removed.

Treatment	Wavelengths		
	0.65 μm	1.65 μm	2.20 μm
		(Percent)	
LLR[z]	7.68 a[y]	30.98 A	27.55 A
LLI	6.27 b	21.85 B	16.02 B
LIHLR	5.72 b	20.52 B	15.30 B
LIALR	5.65 b	20.38 B	14.73 B

y Significant at the 0.05 or 0.01 levels, respectively. All percent mean reflectances followed by a common letter are not significantly different.

z LLR--live vegetation clipped, with clipping and litter removed;
LLI--live vegetation and litter intact;
LIHLR--live vegetation intact, one-half of litter removed;
LIALR--live vegetation intact, all litter removed.

Table 2. Percent mean reflectances measured at 3 wavelengths for a sorghum canopy and for sorghum stubble.

Treatment	Wavelengths		
	0.65 μm	1.65 μm	2.20 μm
		(Percent)	
Canopy	18.5	29.4	30.48
Stubble[z]	17.7	21.9	16.45
Found t[y]	0.82NS	7.33*	21.93*

z Canopy clipped with clippings removed.

y Required $t_{.05(6)} = 2.45$

* = Significant at the 0.05 level. NS = Not significant.

2.50-μm WL and a high reflectance for the 2.30-μm WL. The differences between these spectra were probably due to a moderate wetness of the soil surface and a dark, decaying organic residue remaining on the stubble after the removal of the grass canopy and litter.

Reflectances at 1.65- and 2.20-μm WL were higher from plots where the canopy was clipped and the litter was removed than from plots with vegetation and litter. Species (grain sorghum or grass) or condition (green or semigreen) of the canopy had no significant effect on the level of reflectance for these two WL.

The level of litter that accumulated between the plant canopy and the soil surface had no effect on level of reflectance at the 0.65-, 1.65-, and 2.20-μm WL. More research is needed to satisfactorily account for the unusual reflectance spectra for grass canopy and litter in the 1.10- to 1.30-μm waveband and for that associated with the LLR treatment in the 2.00- to 2.50-μm waveband.

ACKNOWLEDGEMENT

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Response of Cantaloupe and Cotton Plants to the Antitranspirant Farnesol

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ABSTRACT

Farnesol, an antitranspirant, was sprayed on watered and unwatered cotton *(Gossypium hirsutum* L.) and cantaloupe *(Cucumis melo* L. var. *Cantalupensis* Naud.) plants at concentrations of 22.7, 45.4, and 90.8 g a.i./ha; control plants were sprayed with distilled water. For the unwatered plants, the 45.4 g a.i./ha treatment maintained leaf water content longer and retarded chlorophyll degradation as compared with control plants and the other Farnesol treatments. Leaf water content changes could be detected spectrophotometrically before effects could be seen visually: as leaf water content decreased, reflectance increased at the 1650 and 2200 nm wavelengths. Farnesol had no effect on leaf reflectance of watered plants but reduced their dry weights. Farnesol should be field tested as an antitranspirant on agronomic and horticultural crops using various concentrations at growth stages ranging from emergence to maturity.

In recent years, efforts have been made to find practical uses of plant antitranspirants--substances applied to plants to reduce their transpiration (2, 5, 6). Farnesol, a sesquiterpenoid, is a promising antitranspirant. All-*trans* Farnesol is formed within water-stressed sorghum *(Sorghum sudanese* Hitchc.) plants (4, 7). When all-*trans* Farnesol was applied to intact leaves of grain sorghum *(Sorghum bicolor* (L.) Moench), stomata opening was inhibited for 2 days, then they regained their ability to open (2). Success of the stomatal-closing type of antitranspirant depends on a great reduction in transpiration relative to net photosynthesis (6).

Our main objective was to observe responses of cotton and cantaloupe plants to Farnesol using leaf reflectance to indicate variations in leaf water content. Cotton and cantaloupes are important crops in the Lower Rio Grande Valley of Texas. A reduction in transpiration could reduce the amount of irrigation water needed to produce these crops, providing that photosynthesis and plant growth were not inhibited by the chemical.

MATERIALS AND METHODS

Cantaloupe and cotton seed were germinated in peat pellets (Jiffy pots) in a greenhouse in November and December 1978, respectively. (Mention of a company or trademark is included for the readers' benefit and does not constitute endorsement of a particular product listed by the U. S. Department of Agriculture over others that may be commercially available.) Eight days after emergence, six cantaloupe plants/pot and two cotton plants/pot were transplanted in a mix of one part of Perlite to 200 parts of Hidalgo sandy clay loam (Typic Calciustolls) contained in 2.5 liter capacity plastic pots. A 10-20-5 fertilizer was added to the mix to give the equivalent of 67.2 kg of N/ha. All pots were surface irrigated with equal amounts of rain water.

Cantaloupe plants were sprayed at the fourth leaf stage--cotton plants at the seventh leaf stage. A randomized complete block design was used for each crop. Four replications of four treatments were used: control (plants sprayed with distilled water) and Farnesol at 22.7, 45.4, and 90.8 g a.i./ha. The plants were sprayed with a hand sprayer with a volume equivalent to 252 liters/ha. After treatment, one-half of the pots were watered equally; the other half was unwatered.

A Beckman Model DK-2A spectrophotometer, equipped with a reflectance attachment, was used to measure total diffuse reflectance on the upper (adaxial) surfaces of plant-attached single leaves over the 500 to 2500 nm waveband. Data were corrected for decay of the barium sulfate standard to give absolute radiometric data (1). Reflectance data for each plant were obtained from the third true leaf of the cantaloupe plants and the fourth true leaf of the cotton plants over the entire measurement period. Measurements on cantaloupe and cotton leaves were taken daily beginning just before the plants were sprayed and up to 13 and 14 days after spray application, respectively.

Five wavelengths, selected from the 41 wavelengths measured over the 500 to 2500 nm waveband, were 550 nm (green reflectance peak), 650 nm (chlorophyll absorption band), 850 nm (a wavelength on the near-infrared plateau), 1650 nm (reflectance peak following the water absorption band at 1450 nm) and 2200 nm (reflectance peak following the water absorption band at 1950). The first two wavelengths were used to evaluate the effect of chlorophyll (9), the third to speculate on the effect of leaf structure (3), and the fourth and fifth to show the effect of leaf water content (10) on reflectance. Reflectance data for each wavelength were analyzed for variance: the LSD at $p = 0.10$ was used to test differences between the control and each of the three Farnesol treatments for the cantaloupe plants, and Duncan's multiple range test (8) was used to test the significant differences among treatment means for the cotton plants. The effect of the water content of the test cotton leaves was determined on a dry-weight basis by oven drying at 68°C for 72 h then cooling in a desiccator before weighing after the last spectrophotometric measurement. The effect of the treatments on the linear correlation and regression ($p = 0.01$) between water content and reflectance of the cotton leaves was studied at the 1650 and 2200 nm wavelengths for unwatered plants.

The effect of Farnesol treatment on biomass production was determined from plant dry weights (cotton or cantaloupe) obtained as above. The analysis

variance and Duncan's multiple range test (p = 0.05) ...
ight data.

RESULTS AND DISCUSSION

Unwatered plants: Differences between control and Farnesol-treated canta-upe and cotton leaves were spectrophotometrically apparent at 10 and 6 days fter treatment, respectively, although there were no visual changes in their ppearance.

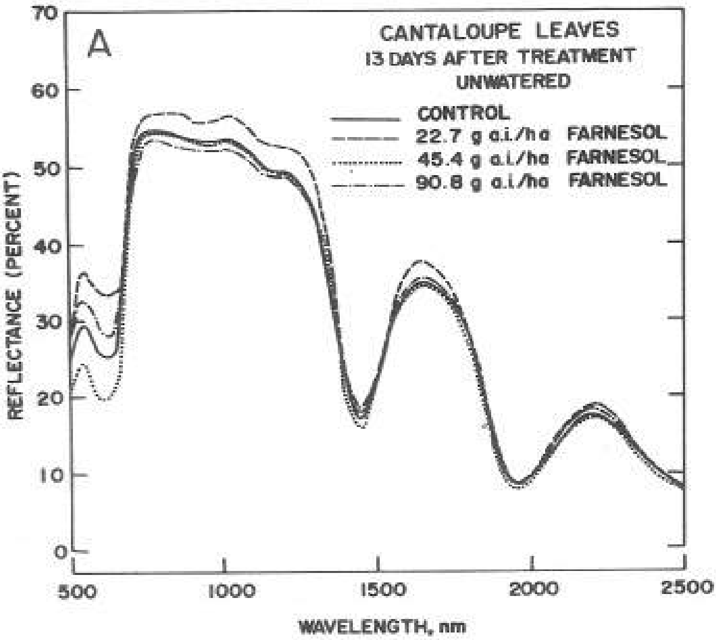
Thirteen days after Farnesol applications to cantaloupe plants, 22.7 and 90.8 g a.i./ha significantly increased leaf reflectance at the 550- and 650-nm visible light wavelengths; whereas, 45.4 g a.i./ha significantly decreased reflec tances as compared with that of control plants (Fig. 1A). Fourteen days afte treatments were applied to cotton plants, reflectances of Farnesol-treated leave at the 550 nm wavelength were 21, 21, and 13% lower than the controls for th 22.7, 45.4, and 90.8 g a.i./ha treatments, respeetively (Fig. 2A). The fact th both cotton and cantaloupe plants treated with 45.4 g a.i./ha had the lowest le reflectance at the 550 nm wavelength suggests that leaves from this treatme had a higher cholophyll concentration than the control and other Farnes treated leaves. Therefore, 45.4 g a.i./ha Farnesol spray apparently retarded le chlorophyll degradation under drought conditions.

Leaf reflectances at the 750 to 1350 nm waveband were influenced more leaf water losses than by changes in internal leaf structure (3). A comparison Fig. 1A and 2A with Fig. 1B and 2B indicates that watered plants had the sa leaf reflectances regardless of treatment; whereas unwatered plants had dif ent leaf reflectances in the 750 and 1350 nm waveband. When a leaf dehydra air spaces are created and reflectance increases.

The higher water content of cantaloupe and cotton leaves treated with 45.4 g a.i./ha concentration was detected at the 1650 and 2200 nm wavelen (Fig. 1A and Fig. 2A, respectively). A decrease in leaf water content was ciated with an increase in reflectance. A relationship expressed by highly si cant linear regressions, $r = -0.87$ ($r^2 = 0.76$) and $r = -0.89$ ($r^2 = 0.79$) fo 1650 and 2200 nm wavelengths, respectively (Fig. 3). The control leaves ha highest reflectance and the lowest water content (68%); whereas, the 4 a.i./ha Farnesol treatment had the lowest reflectance, but it had the h water content (72%). These data are not included in the paper. All Far treated leaves had a significantly lower reflectance than the control leaves 1650 and 2200 nm wavelengths.

The average dry weights for cotton, 1.05, 1.06, 1.12, 1.06 g/plant f control, 22.7, 45.4, and 90.8 g a.i./ha Farnesol, respectively, were not cantly differently but showed a slightly increasing tendency for the Fa treated plants, especially for the 45.4 g a.i./ha concentration. The aver weights for cantaloupe, 0.95, 1.03, 0.96, and 0.97 for the control an 45.4 and 90.8 g a.i./ha treatments, respectively, were also not signi different. Therefore, Farnesol applied at an optimum concentration m crease biomass under drought stress.

Watered plants: Farnesol significantly decreased the average dry we watered cantaloupe plants, 1.84 g for the control compared with 1.75, 1 1.64 g for the 22.7, 45.4, and 90.8 g a.i./ha treatments, respectively.



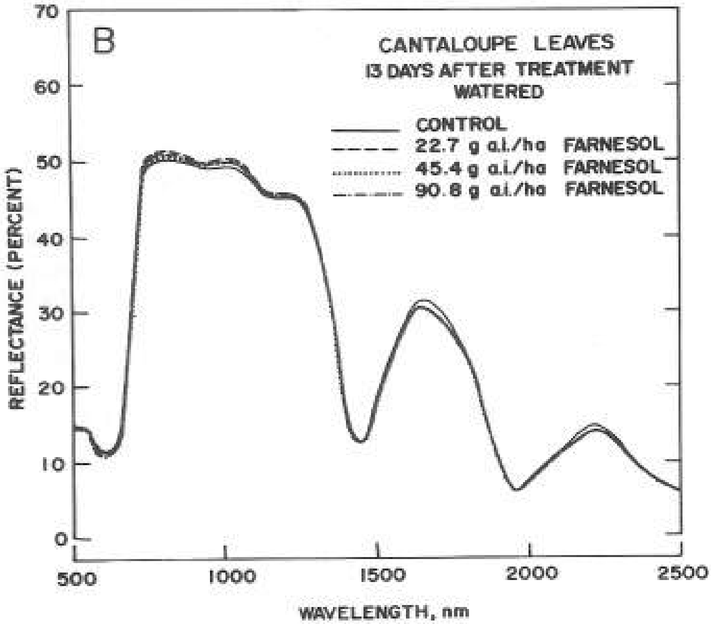


Fig. 1. Effect of Farnesol on reflectance over the 500 to 2500 nm waveband for leaves of unwatered (A) and watered (B) cantaloupe plants.

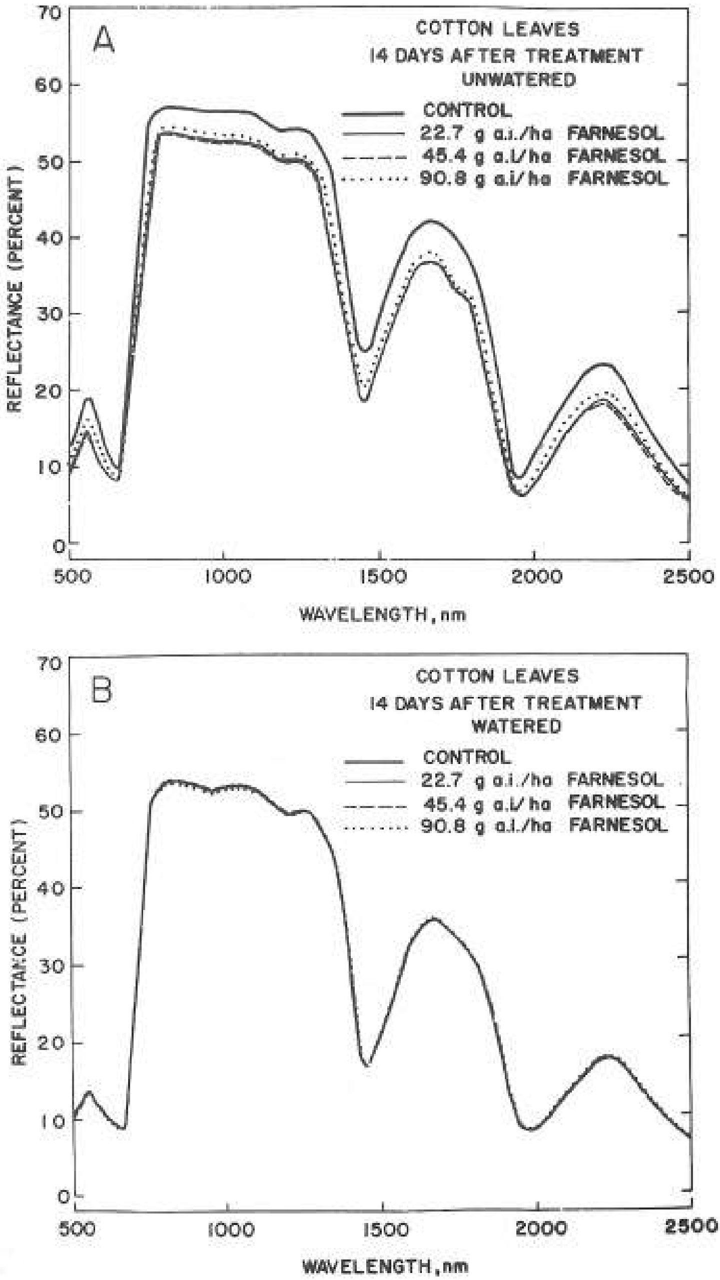


Fig. 2. Effect of Farnesol on reflectance over the 500 to 2500 nm waveband for leaves of unwatered (A) and watered (B) cotton plants.

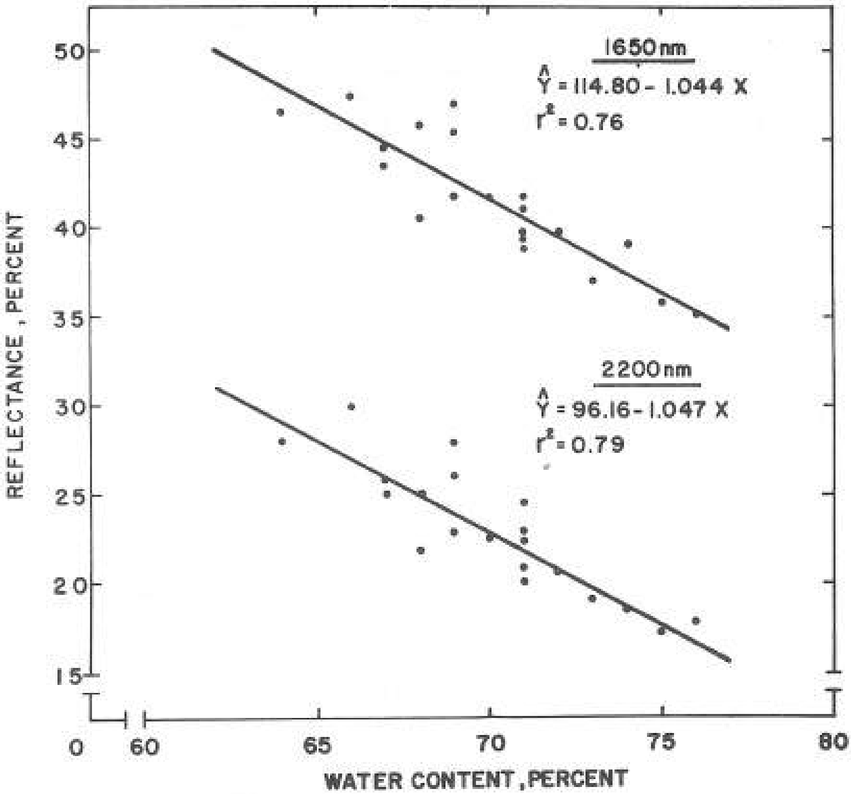


Fig. 3. Linear regression of percent reflectance on percent water content of cotton leaves at the 1650 (upper) and 2200 (lower) nm wavelengths.

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decreased transpiration sufficiently to reduce nutrient uptake and photosynthesis. The lower transpiration gave a higher leaf water content which was detected by the significantly lower reflectance of treated as compared with that of control leaves at the 1650 and 2200 nm wavelengths (Fig. 1B).

Farnesol treatments affected neither the reflectance of cotton plant leaves (Fig. 2B) nor their water content. However, Farnesol showed some impact on the average dry weights of cotton plants: 1.22, 1.38, 1.30, and 1.15 g/plant for the control, 22.7, 45.4, and 90.8 g a.i./ha Farnesol, respectively. Thus, the 22.7 and 45.4 g a.i./ha concentrations increased; whereas, the 90.8 g a.i./ha concentration decreased the dry weights.

Farnesol should be field tested as an antitranspirant on agronomic and horticultural crops using various concentrations at growth stages ranging from emergence to maturity.

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Ultrastructural Observations on Increase of Cold Tolerance in Cotton Plants *(Gossypium hirsutum* L.) by Mepiquat Chloride

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ABSTRACT

Cotton plants, 19 days after emergence, were treated with mepiquat chloride (MC) at the rate of 70 g a.i./ha. Seven days later, plants were subjected to a cold hardening process with 15.5°C day (12h) and 1.7°C night (12h) for 10 days then held at -2.2°C for 24 hours. After the cold exposure, leaf samples were collected from the MC-treated and nontreated plants for electron microscopic (EM) and electrolyte leakage studies.

The MC-treated leaf's plasma membrane was altered by protein aggregation, yet most of the plastidal envelope and the thylakoidal system were intact. The three membrane systems of the nontreated leaf showed extensive degeneration. The difference between treated and nontreated plants was shown by electrolyte leakage and plant mortality data. Nontreated leaf discs leaked two times more electrolyte than treated leaf discs, and 60 and 20% of the nontreated and treated plants died, respectively.

Experimental results indicate that exogenously applied abscisic acid (ABA) increased potato frost hardiness (7) and prevented chilling injury in cotton (13), and mepiquat chloride (MC) increased cotton cold tolerance (4).

Both ABA and MC have antigibberellin activity (15, 16) and increased cold hardiness is usually accompanied by a great reduction in gibberellin activity (15). However, in *Acer negundo* (maple) the development of cold hardiness was not related to gibberellin activity reduction (5).

The basic mechanism for increased cold tolerance is unknown. It is believed that the physiological basis for cold tolerance must be sought largely at the molecular level, perhaps mainly in membrane structure and enzyme activity.

Our objective was to study, with an electron microscopic technique, differences in membrane structure of MC-treated and nontreated cotton plant leaves before and after cold treatment.

MATERIALS AND METHODS

Cotton plant seeds (cultivar, 'McNair 220') were germinated in peat pellets, and seedlings were transplanted into plastic pots containing a 1:200 mixture of perlite and Hidalgo sandy clay loam (Typic Calcustolls). A 10-20-5 fertilizer was added to the mixture at the equivalent rate of 67.2 kg of N/ha. All pots were surface irrigated equally every 2 days with rain water until they were used for cold treatment.

Twenty uniform plants were selected for experiment 19 days after germination. Ten plants were sprayed with distilled water and ten plants with MC (1, 1-dimethylpiperidinium chloride) at 70 g a.i./ha concentration. Seven days later the plants were given a cold hardening process with 15.5°C day (12h) and 1.7°C night (12h) for 10 days, then held at -2.2°C for 24 hours in the dark. Two hours after the cold treatment, the number of damaged plants was counted, and leaves of the same chronological age were randomly selected for electrolyte leakage measurements and for electron microscopic observations.

Five discs, each 15 mm in diameter, were punched out from each of three leaves with a cork borer, weighed and floated on 20 ml of distilled water. The amount of electrolyte that leaked out after 6 hours at room temperature was measured with a model 31 YSI Conductive Bridge (Mention of company name or trademark is for the readers' benefit and does not constitute endorsement of a particular product by the USDA over others that may be commercially available).

Stained sections for examination in a Hitachi HU-11E electron microscope were prepared as follows: leaf tissues were fixed in 4% glutaraldehyde in sym-collidine buffer (pH 7.4) overnight at room temperature with the buffer vacuum-infiltrated into the tissues for 30 minutes at the beginning of the fixation; then fixed-in 2% osmium tetroxide in sym-collidine buffer (pH 7.4) for 1 hour at room temperature. After dehydration of the tissues in two changes each of 25, 75, and 95% acetone, the tissues were rapidly washed in 10 changes of 100% acetone and then embedded in Maraglass-655. Ultrathin sections were cut on a Sorvall-Porter Blum MT-1 ultramicrotome. The sections were mounted on 200 mesh copper grids, stained for 5 minutes in a 50% alcoholic solution of uranyl acetate and followed by lead citrate staining for one minute.

Table 1. Electrolyte leakage of leaf discs from MC-treated and nontreated cotton plants before or after cold treatment at 15.5°C day (12h) and 1.7°C night (12h) for 10 days and then to -2.2°C for 24 hours in the dark.

	70 MC treated	Nontreated
	(conductance, umhos/mg of leaf disc ± sd)	
Before cold treatment	0.176±.042	0.179±.035
After cold treatment	0.878±.130	1.822±.274

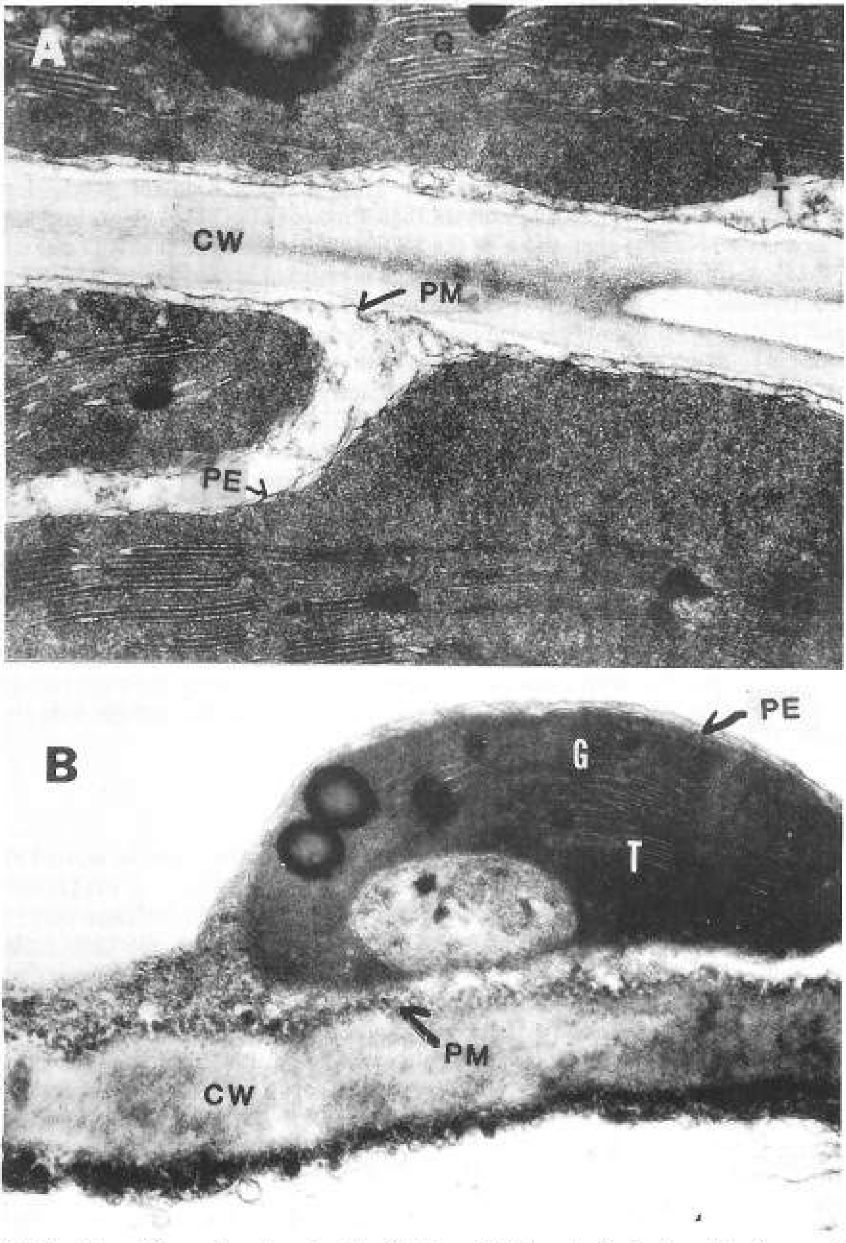

Fig. 1. A portion of cotton leaf cells from MC-treated plant. a) before cold treatment: all structures were normal, magnification X30,200. b) after cold treatment: the plasma membrane was altered, but most of the plastidal envelope and the thylakoidal system were intact, manification X19,200. CW-cell wall, PM-plasma membrane, G-granum, T-thylakoid, PE-plastidal envelope.

RESULTS

After chilling at 1.7°C for ten nights, little damage other than slight wilting was observable on all plants. When the same plants were exposed to -2.2°C for 24 hours 60% of the control plants were killed but only 20% of the MC-treated plants appeared to be dead. Dead plants showed typical freezing injury, a darkened, limp and water-soaked appearance after thawing. Control plants' leaf discs leaked 10 times more electrolytes than those of nonchilled plants and two times more electrolyte than those of the MC-treated and chilled plants (Table 1).

No important ultrastructural difference in membrane structure was noticed in the leaf tissues between the MC-treated and nontreated plants before cold treatment (Fig. 1a). All membrane structures and organelles in the cells appeared to be normal. After cold treatment, however, the plasma membrane of the MC-treated leaf was altered (Fig. 1b). The characteristic organization of the unit membrane was disrupted and densely stained particles appeared in the vicinity of the damaged plasma membrane. Judged by the staining property and the size, those densely stained particles could be protein aggregates. The normal space between the cell wall and the plasma membrane disappeared, but most of the plastidal envelope and the thylakoidal system were inact. This membrane alteration apparently was reversible or could be repaired because some leaves used to collect the discs and showed membrane alteration were alive three weeks after the cold treatment. The three membrane systems of the control tissues showed an extensive degeneration due to freezing damage (Fig. 2). Most organelles were disorganized and the most prominent cellular debris was large and darkly stained irregular bodies. MC-treated plants sustained much less freezing damage than the nontreated plants at the ultrastructural level.

DISCUSSION

We showed that cotton leaf cell membranes and structures may be injured by freezing. The plasma membrane was more sensitive to freezing than the platidal membrane and chloroplast thylakoids. Other researchers made the same conclusion using freeze-injured potato leaf cells (11) and spinach leaf cells (14). However, some damage and alteration in the plasma membrane may not be lethal. Theoretically, according to Levitt and Dear (6), low temperature: denatures proteins reversibly; unmasks reactive SH groups because freeze-dehydration removed cell water; and affects intermolecular bonding caused by SH oxidation by aggregating proteins irreversibly to kill cells. Since plasma membrane proteins have not been investigated there is no direct support for the theory. Though it is known that chemical combination can occur between S atoms of adjacent protein molecules, the origin of the densely stained particles could not be ascertained.

Ultrastructural evidence suggests that the inheritance site of extranuclear temperature-sensitive lethality in the mutants of *Nicotiana tabacum* L. (tabacco) is in the chloroplasts (9, 8). Also, cold hardening is associated with changes in chloroplasts (7): 2-chloroethyl-trimethyl-ammonium chloride (CCC) treatments of *Pisum sativum* (pea) leaves changed the structure of their chloroplasts (10) and abscisic acid (ABA) reduced number and length of stroma thylakoids and total thylakoid length of developing chloroplasts (2). Therefore, it is

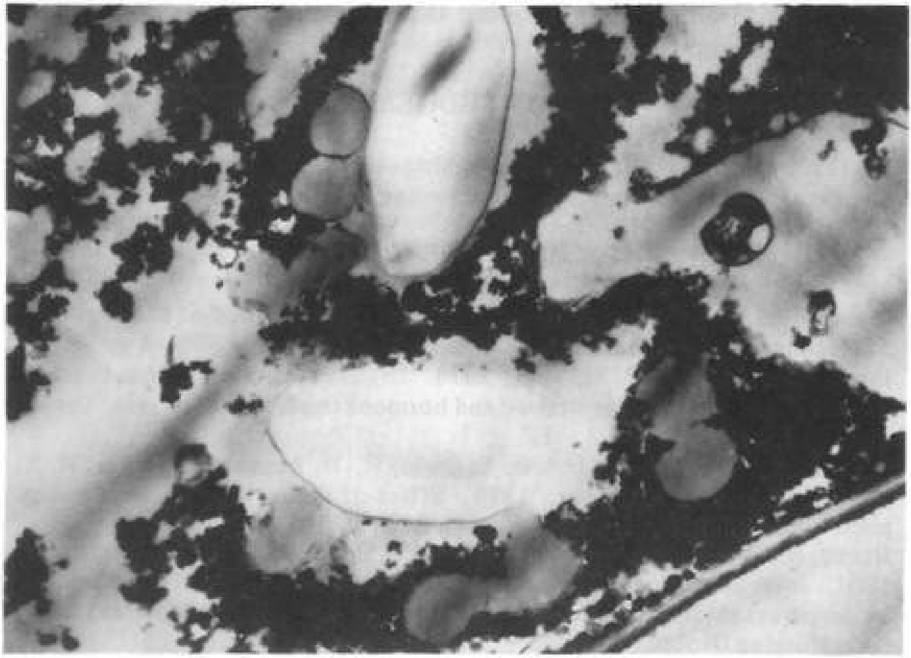

Fig. 2. A portion of cotton leaf cells from nontreated plant showing an extensive disorganization of cellular structures due to freezing damage, magnification X5,200.

reasonable to assume that chloroplast constituents function in cold tolerance induction. Our study indicated that chloroplasts of the MC-treated cotton leaves were more resistant to freezing injury than those of the nontreated leaves.

The increased resistance to cold stress by ABA and antitranspirants is attributed to reduced water loss (13, 1). Gausman, et al. (3) found that MC-treated leaves retained more water than nontreated leaves (79.7% versus 77.8%). Pincock and Kiovsky (12) showed that protein aggregation was less likely to occur when effects of low temperature (slowing down any reaction) and the protection of the reactive groups by the water molecules were combined. but this aggregation would result from the increased concentration of the reactive groups on freeze-dehydration. The increased cold tolerance induced by MC in this study might be explained partially by a higher leaf water content.

Membrane damage must be due to either lipid or protein changes. Our observations showed that cotton leaf membranes were damaged by freezing of the cell's water to form ice crystals especially in the nontreated leaves. Lipid molecules are less likely to be altered by ice crystals than protein molecules because lipids are essentially hydrophobic with little or no freezable water, and they are unlikely to aggregate by chemical bonding. Our results showed that MC increased cold tolerance in cotton plants, but more extensive biochemical and ultrastructural investigations are needed to fully explain the cause of the increased cold tolerance.

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Effects of Various Soil Mixtures on Growth of *Chrysanthemum morifolium*

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ABSTRACT

Peat moss, filter-press mud (a by-product of sugarcane processing), bark and sand were compared singly and in combination as growing media for *Chrysanthemum morifolium*. A medium of 1:1 (V:V) sand and peat moss was considered standard for comparative purposes. While all media used were acceptable, growth of plants was significantly greater in mixtures containing filter press mud.

Peat moss, the main ingredient in most container plant media, is becoming increasingly scarce, expensive and variable in both chemical and physical properties. Thus, the ornamental plant industry is searching for organic substitutes in potting mixtures (3).

Sugarcane and lumber mills produce large quantities of surplus by-products, including bagasse, filter-press mud (FPM), sawdust, wood shavings and bark. Some of these products could find a use in the greenhouse and nursery growing industries (2, 5). The objective of this study was to determine the feasibility of using FPM, pine bark, and peat moss separately and in combination as a media for pot-grown *Chrysanthemum morifolium*.

MATERIALS AND METHODS

Filter-press mud (FPM) was obtained from the Rio Grande Valley Sugar Growers, Inc. of Santa Rosa, Texas. Air dried FPM was crumbled by hand and sieved through 4 and 8 mesh screens. Only particles ranging from 3.2 mm to 6.4 mm were used.

Filter-press mud contains varying amounts of precipitated impurities in sugarcane juice. It is mixed with small particles of bagasse and the juices are filtered out. Solids remaining are called "mud". They are mixed with water and pumped out as a slurry to an outside pit (1, 4).

Shredded, coarse composted pine bark and composted peat moss were passed through a 6.4 mm screen. The washed river bottom sand had 49% porosity, was angular in shape, and was a mixture of quartz, microline, calcite, and mica. Sand and FPM were steam sterilized for two hours at 100C.

Seven media were combined: all FPM; all bark; all peat moss; 1:1 FPM-bark; 1:1 FPM-peat moss; 1:1 bark-peat moss; and 1:1 sand-peat moss.

Rooted *C. morifolium* from Peters Bros. Supply in San Antonio, Texas with 6 cm top growth were chosen at random and planted singly in 15 cm standard plastic containers. Treatments were replicated 5 times. Plants were spaced 18 cm apart on elevated benches.

Supplemental light was provided from 10 PM to 2 AM daily during the first three weeks. Sixty-watt incandescent lamps were spaced 120 cm apart and 60 cm above the plants. Temperatures were regulated for 23 C during the day and 16 C at night. As individual media became dry, 0.25 liter of water was added to each container by hand. Fertilization began with the second watering and continued weekly thereafter. Dosages were 300 PPM of soluble fertilizer, 20-20-20, manufactured by the "Pronto" Plant Food Company.

Five weeks after transplanting, heights of plants were measured from soil level to the tip of apical leaves. Numbers of leaves per plant were also recorded. Treatments were compared with the standard medium of peat moss and sand by Tukey's multiple comparison test at the 5% level of significance.

RESULTS AND DISCUSSION

Chrysanthemums grown in FPM were significantly ($P < .05$) taller than those grown in the standard medium. No other significances were found (Table 1). There were no significant differences in the number of leaves on chrysanthemums among the various treatments. Stem diameters of plants grown in FPM were greater than those grown in the standard medium ($P = 0.05$). Therefore, it is possible that FPM can be substituted for peat moss for production of *C. morifolium* in areas where it can be secured economically.

Table 1. Effect of seven different media on the vegetative growth of *C. morifolium* after five weeks.

Treatment	Height (cm)	No. of leaves	Stem diameter (cm)
FPM	34.5 a[z]	70.4	.51 a
Bark	22.6 b	58.2	.42 b
Peat moss	16.5 b	68.6	.42 b
1:1 FPM-bark	23.5 b	58.6	.46 b
1:1 FPM-peat moss	18.1 b	62.2	.42 b
1:1 Bark-peat moss	21.6 b	60.8	.47 b
1:1 Peat moss-sand[y]	20.1 b	50.8	.39 b
		N.S.	

[z] Means separated by Tukey's multiple comparison test ($P = 0.05$).

[y] Standard medium.

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Development of Purple Blotch of Onion Under Two Different Fungicide Regimes

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ABSTRACT

Both 'New Mexico Yellow Grano' and 'Texas Grano 502' varieties of onion exhibited significant increases in the level of tissue damage by *Alternaria porri* (Ell.) Cif. 4-6 weeks prior to bulb maturity. Bravo 500 and Manzate 200 treatments delayed the increase of tissue damaged by *A. porri* 7-10 days and 3-5 days, respectively, over the untreated controls. Once the level of purple blotch had increased above 10-20%, the percentage of damaged tissue for all treatments increased at similar rates. A visual disease rating taken one week prior to maturity indicated that Bravo 500 treatments applied on 'New Mexico Yellow Grano' onions at 3-, 7-, and 14-day intervals had a significantly lower incidence of purple blotch than did Manzate 200 treatments. Bravo 500 treatments applied at 3- and 7-day intervals had significantly less damaged tissue than all of the Manzate 200 treatments one week prior to bulb maturity on both onion varieties and the 14-day Bravo 500 treatment had significantly less damage than the 7- and 14-day Manzate 200 treatments on 'Texas Grano 502' onions.

Purple blotch, caused by *Alternaria porri* (Ell.) Cif., is a chronic disease of onion foliage in South Texas that causes severe damage during years when weather conditions favor disease development (1, 2). Primary infections of purple blotch generally occur just prior to bulb formation (3). Fungicide applications are usually applied first at bulb initiation and continued until the bulb is mature. Onions are a long season crop, requiring 5-6 months from planting to harvest; therefore, fungicides must be applied 10-15 times to insure adequate disease protection.

In this study, two commonly used fungicides, Bravo 500 (tetrachloroisophthalonitrile) and Manzate 200 (zinc-manganese salt of ethylenebisdithiocarbamate), are compared at three different application intervals to determine the effects of different time intervals on disease control. Data were also collected on the effect of fungicides on the increase of foliage damage caused by *A. porri* over time.

MATERIALS AND METHODS

Fungicides were applied and evaluated on plantings of 'New Mexico Yellow Grano' (NMYG) and 'Texas Grano' (TG 502) onions. Plots were arranged in a randomized complete-block design with three replications per treatment. Each plot consisted of two beds, 40 feet long and 40 inches wide, with four rows of onions per bed. Adjacent plots were separated by two untreated beds which served as a buffer zone to minimize drift of fungicides between plots and as an area for inoculum buildup. To insure adequate free moisture for disease development, plots were sprinkler irrigated several nights each week for five and seven weeks on NMYG and TG 502 onions, respectively. The sprinkler system was operated for 3-4 fifteen-minute periods each night. Bravo 500 and Manzate 200 were applied at the rates of 4.0 pints and 3.0 pounds per acre, respectively. Each fungicide was applied on 3-, 7-, and 14-day intervals. The fungicides were dispersed in water and applied at the rate of 60 gallons per acre through five hollow cone nozzles (25 core and D-2 tips) per bed under 75 pounds pressure per square inch at the pump. Initial fungicide applications were made when the bulbs were ¾ - 1 inch in diameter.

Two different disease ratings were taken: the first at weekly intervals, starting at the first fungicide application and continuing until bulb maturity. Bulbs were considered mature when 50-75% of the onion tops had fallen over. Five plants were randomly selected weekly from each plot and the percentage of tissue damaged by *A. porri* infection was determined for each plant by measuring the total length of damaged tissue on each leaf and dividing by the total length of the leaf.

The other disease rating was a visual rating taken one week prior to bulb maturity. Disease ratings were made for each plot based on an index of 1-10, where 1 indicated no disease symptoms and 10 indicated complete dieback of the leaves. This disease rating is the one most commonly used for evaluating the efficacy of fungicide treatments on onions.

RESULTS AND DISCUSSION

Visual disease ratings taken one week prior to bulb maturity indicate that Bravo 500 treatments resulted in significantly less foliage damage than the Manzate 200 treatments at all application intervals except for Bravo 500 applied every 14 days on TG 502 (Table 1). The percentage of foliage damage was significantly reduced by all Bravo 500 and Manzate 200 treatments over the untreated controls in both NMYG and TG 502.

There was no significant difference in the incidence of purple blotch between application intervals with Bravo 500 on TG 502 or with Manzate 200 on NMYG. The 3-day application interval was significantly better than the 14-day interval with Bravo 500 on NMYG and Manzate 200 on TG 502. On NMYG, all application intervals with Bravo 500 were significantly better than all Manzate 200 treatments. On TG 502, however, Bravo 500 applied at 14-day intervals was not significantly different from Manzate 200 applied at 3-day intervals. All other Bravo 500 treatments exhibited significantly better purple blotch control than did the Manzate 200 treatments.

A better perspective of the effects of fungicides on purple blotch control can be obtained from the disease ratings taken at weekly intervals. The percentage of tissue damaged by *A. porri* increased significantly 4-6 weeks prior to bulb maturity on both NMYG and TG 502 (Fig. 1). Prior to this time the level of purple blotch remained fairly constant at 15% or less. When bulbs began to form, the percentage of damaged tissue increased very rapidly from approximately 15% to about 50% within 2.5 weeks.

Table 1. The effects of various time intervals on the efficacy of two fungicides to control purple blotch.

Treatment	Interval (days)	Disease Index [z] New Mexico Yellow Grano	Texas Grano 502
Bravo 500	3	4.2 a [y]	3.7 a
	7	5.0 ab	3.3 a
	14	5.5 b	4.0 ab
Manzate 200	3	6.5 c	4.8 bc
	7	6.7 c	5.7 cd
	14	7.0 c	6.2 d
Control		7.8 d	7.7 e

[y] Disease Index = Scale of 1-10, where 1 = no lesions and 10= complete foliage dieback. Index made one week prior to bulb maturity.

[z] Numbers followed by the same letter are not significantly different at the 0.05 level.

Bravo 500 and Manzate 200 treatments delayed new infections of purple blotch at low levels of infection. Bravo 500 treatments delayed increases of purple blotch over the untreated controls by approximately 7-10 days. Manzate 200 treatments delayed new infection by 3-5 days.

Once new infection sites of purple blotch were established on treated onions, the percentage of tissue damaged increased at a similar rate regardless of fungicide treatment. This does not agree with van der Plank's (4) concept of the effects of fungicide applications on disease progress curves. Fungicide applications should reduce the rate at which a disease increases over time. According to this concept, the rate of disease increase between a fungicide treatment and the untreated control should not be similar or equal as these data indicate. An explanation for this disparity is that a few lesions on an onion leaf can kill a disproportionate amount of tissue when compared, for example, to a cantaloupe leaf where many lesions are needed to kill the leaf. Fungicides do reduce the rate of increase of new infections in onions; however, this effect is masked and is only obvious at low levels of infection.

The effect of fungicide treatments is to delay new infections. The measure of effectiveness between fungicide treatments on onions is the magnitude of the delay obtained at low levels of infection. Once all leaves are infected, the rate at which tissue is damaged is similar for untreated controls and fungicide treatments.

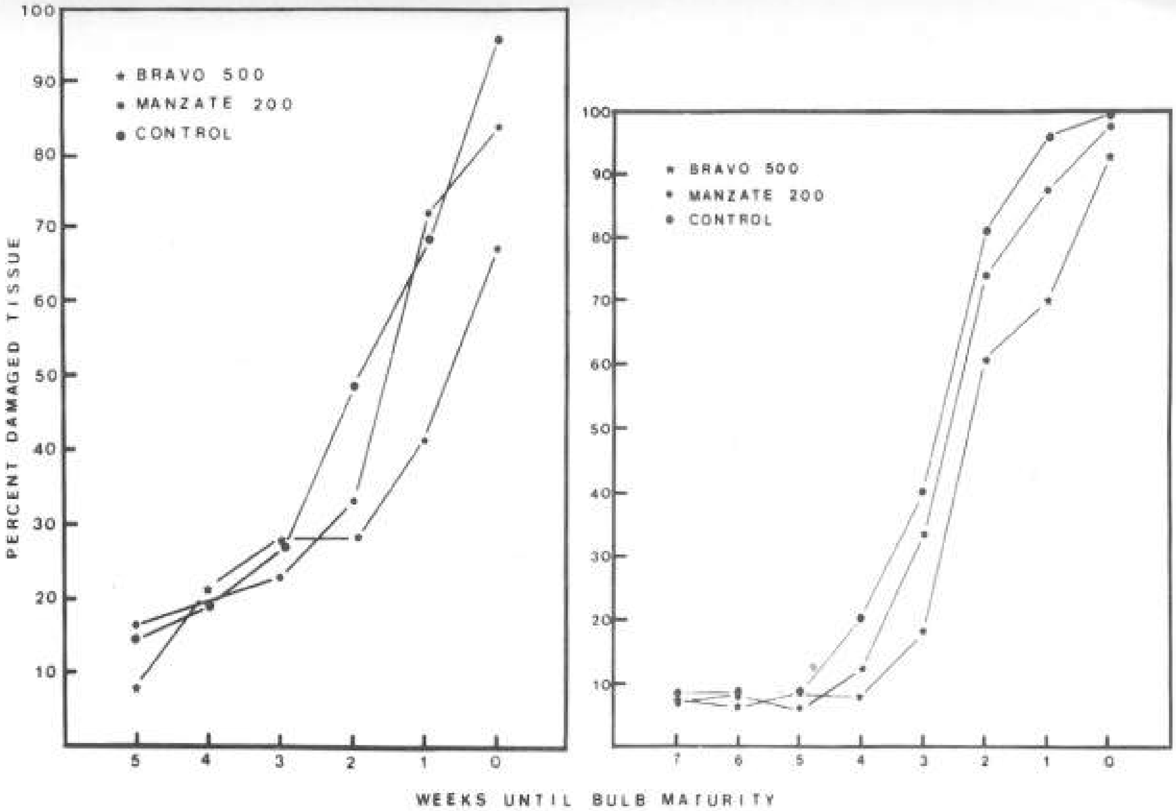

Fig. 1. Effect of fungicides applied every seven days on leaf damage caused by *Alternaria porri* on 'Texas Grano 502' (left) and 'New Mexico Yellow Grano' (right) onions.

The difficulty of controlling foliage damage caused by *A. porri* is illustrated in Fig. 1. Even though the fungicide slowed the rate of increase of new infections over nontreated controls at low levels of infections, once several purple blotch lesions are established on a leaf, these lesions are capable of killing the entire leaf. This points out the importance of preventing purple blotch lesions from forming on noninfected leaves as long as possible and thus delaying the death of the leaf.

To control damage caused by *A. porri* the fungicide must prevent infections at all sites on a given leaf. This type of protection becomes difficult during weather conditions that are ideal for growth and sporulation of *A. porri.*

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Effect of Aluminum Tents on the Success of Shoot Tip Grafting on Avocados in the Late Spring

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ABSTRACT

Avocado plants tip grafted after early May and placed under aluminum foil tents in a shadehouse resulted in significantly more successful graft unions than those not placed under aluminum. Temperatures inside plastic bags with aluminum tents placed over the avocado grafts were 10 to 12 degrees cooler than temperatures in plastic bags without aluminum covers.

Avocados *(Persea americana)* are asexually propagated by budding or grafting to maintain a uniform horticultural variety. The propagation of container grown avocado nursery trees in Texas is an exacting operation.

Rootstock seed is available from September through February. Most nurserymen schedule seed bed plantings so grafting can be started in November and continued into the late spring (April and May). Successful unions will result 85 percent of the time when the grafting technique described in Texas Agricultural Progress (2) is used from November through January.

In the early spring (March) it is not uncommon to have ambient temperatures above 90°F (32°C) and sometimes above 100°F (38°C) for short periods in several consecutive days (3). The number of hours each day above 90°F (32°C) increases as spring progresses.

Avocado nurserymen have a problem in obtaining a high percentage of successful graft unions when temperatures exceed 90°F (32°C) for long periods of time. Brierly (1) found that callus formation stops when ambient temperatures exceed 90°F (32°C). When temperatures exceed 90°F (32°C) grafts in clear plastic bags will be damaged by heat.

This experiment was designed to find an economical technique of modifying the microclimate in a shadehouse so that a high percentage of successful graft unions could be made when ambient temperatures exceeded 90°F (32°C). This would allow avocado nurserymen to lengthen their propagating season and increase the percentage of successful graft unions in late spring.

MATERIALS AND METHODS

Avocado (cv. 'Lula') seeds were planted in January 1977 under shadehouse conditions in raised seedbeds containing peat moss and perlite (1:1v). In preparation for planting, the apical end of the seeds were cut off (about ½") to

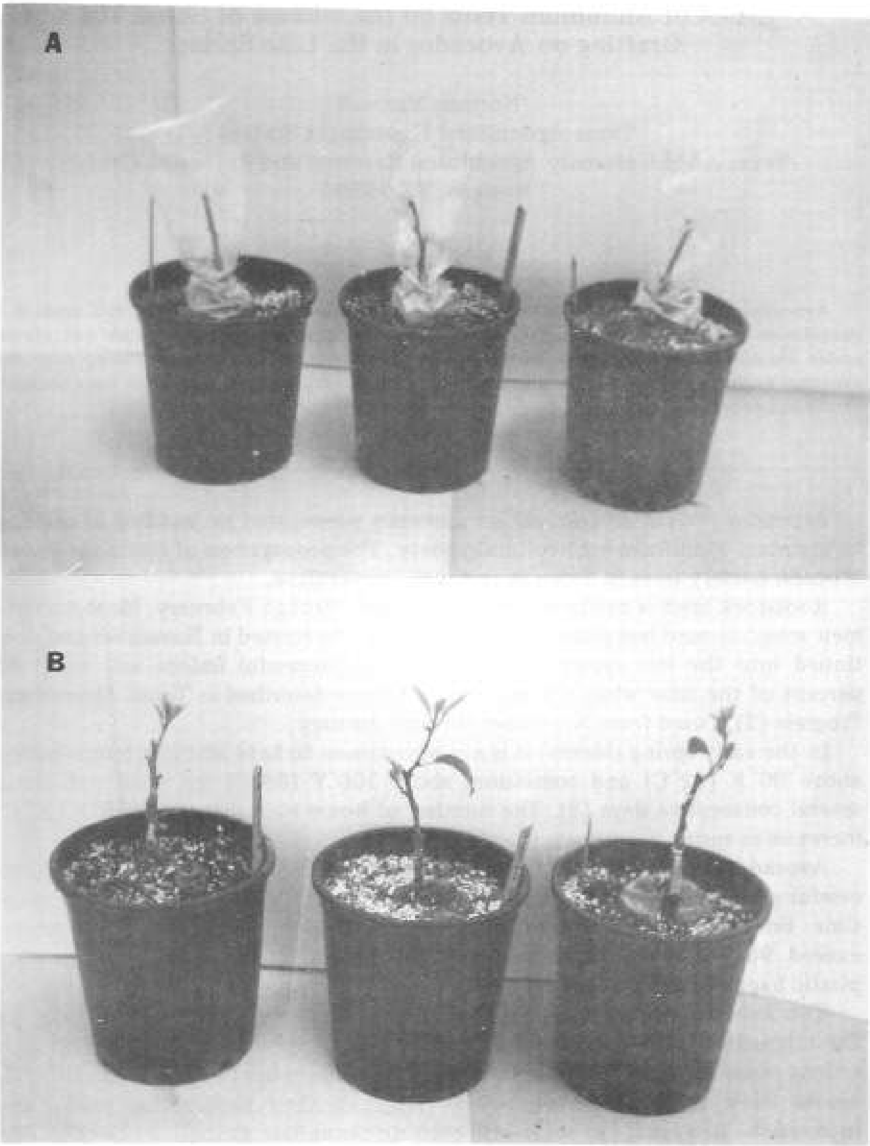

Fig. 1. A) Avocado grafts enclosed by clear polyethylene bags. B) Avocado trees after plastic bags have been removed.

ensure uniform and fast germination. The seedlings were transplanted when pencil diameter into gallon plastic pots containing the same medium as seedbeds. The seedlings were grown in the shadehouse until ready for grafting.

On April 20, May 10 and June 19, 60, 100, and 40 seedlings were tip grafted (2) with the Lula variety of avocado.

The experiment was repeated in 1978 and 1979, with seeds planted in January as previously described.

Graft wood was mature tips of current season wood. Graft wood should have leathery terminal leaves and mature axillary buds.

All grafts were enclosed with a clear polyethylene bag (Fig. 1A) to maintain high humidity. After grafting half of the plants from each group were maintained under shadehouse conditions and half were maintained under shadehouse plus aluminum foil tents (Fig. 2) to aid in heat reflection. Three strips of

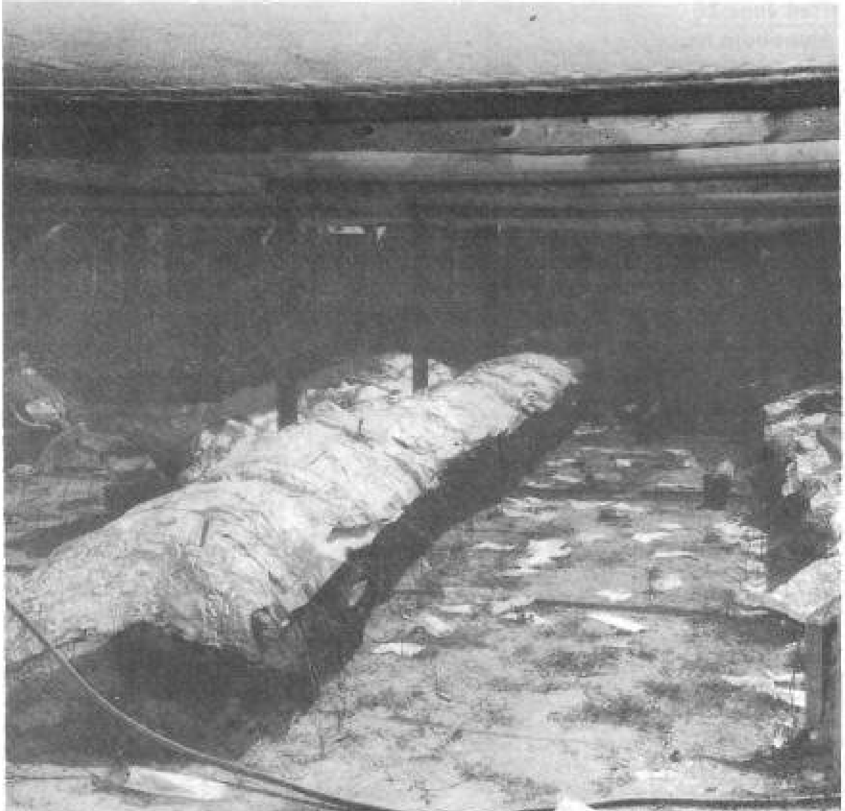

Fig. 2. Grafted avocado trees under aluminum foil tent.

Table 1. Effect of aluminum tents on the success of shoot tip grafting avocado seedlings.

	Total Grafts	No. Successful Unions	% Successful Unions
1977			
Grafted April 20			
Aluminum tent	30	25 N.S.	83
Non-tented	30	18 N.S.	60
Grafted May 10			
Aluminum tent	50	41a[z]	82
Non-tented	50	15b	30
Grafted June 15			
Aluminum tent	20	9a	45
Non-tented	20	1b	5
1978			
Grafted May 17			
Aluminum tent	50	29a	78
Non-tented	50	12b	24
Grafted June 6			
Aluminum tent	30	15a	50
Non-tented	30	1b	3
Grafted June 21			
Aluminum tent	30	15a	50
Non-tented	30	1b	3
1979			
Grafted May 3			
Aluminum tent	25	20 N.S.	80
Non-tented	25	16 N.S.	64
Grafted May 21			
Aluminum tent	25	20a	80
Non-tented	25	7b	28
Grafted June 5			
Aluminum tent	25	15a	60
Non-tented	25	4b	16
Grafted June 22			
Aluminum tent	25	13a	52
Non-tented	25	2b	8
Grafted July 11			
Aluminum tent	25	18a	72
Non-tented	25	2b	8

[z] Means significantly different at 5% level, Chi-square test.

18 in. wide heavy duty household aluminum foil were taped together with air conditioning duct tape and placed over a tent frame of wire hoops. The aluminum foil was placed so the plants received light from the sides. The plants were left under the aluminum foil tents until new growth was about 1 to 3 inches long (Fig. 1B). The time required for a graft to unite is usually 30 to 40 days.

Temperature effects were determined using a tele-thermometer with thermistors to monitor temperatures in the halfshade, within the plastic bag of a graft under halfshade, and inside the plastic bag of a graft under the aluminum foil tent in the halfshade. Temperatures were recorded every hour 9:00 A.M. to 5:00 P.M. on August 8-10, 1979.

A 2 x 2 continuency table based on Chi-square was used to determine significance between treatments. Analysis was run separately on treatments by individual dates.

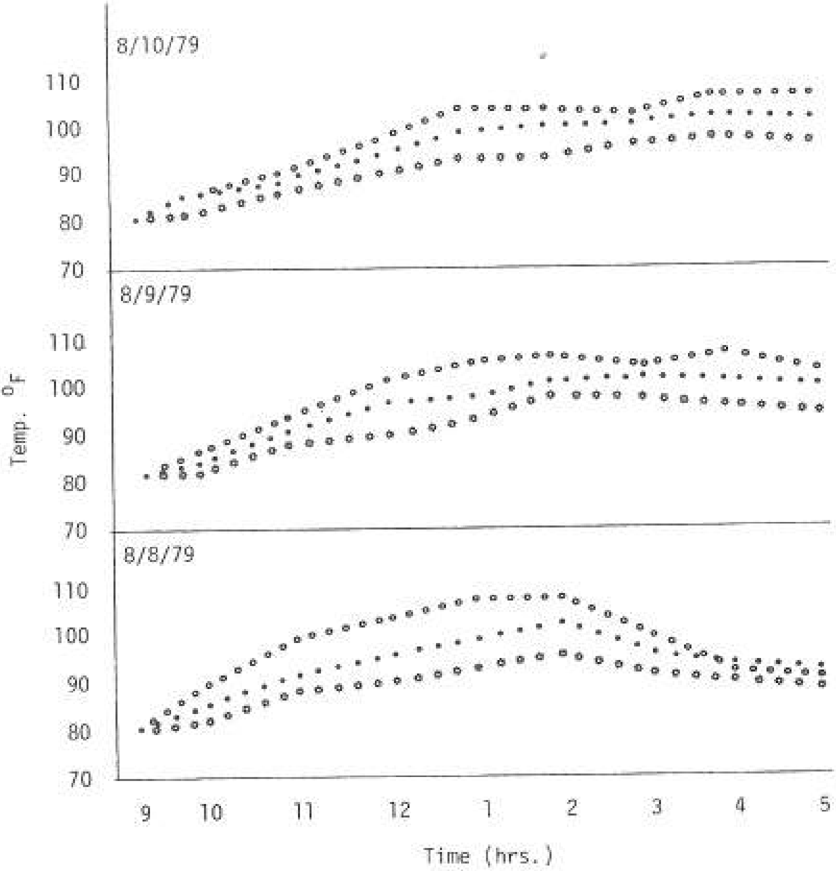

Fig. 3. Shadehouse micro-climate modification
- • Ambient temperature in shadehouse
- o Temperature inside sack not under aluminum
- ¤ Temperature inside sack under aluminum

RESULTS AND DISCUSSION

Placing grafts under an aluminum tent after May 10 significantly increased ($P = 0.05$) the number of successful unions in each of the 3 years of the test (Table 1).

The micro-climate was changed under the aluminum tents (Fig. 3). Temperatures inside the plastic bag under the tent at the hottest part of the day were 4 - 6 degrees cooler than the ambient temperature in the shadehouse and 10 - 12 degrees cooler than the temperature in the plastic bags not covered by aluminum foil.

Placing grafts under aluminum foil tents will allow avocado nurseries to graft in May and June and obtain a high percentage of successful unions.

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Chemical Control of the Citrus Nematode on Grapefruit

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ABSTRACT

Seventeen-year-old grapefruit-sour orange trees infected with the citrus nematode, *Tylenchulus semipenetrans*, were treated with DBCP, Mocap, Nemacur, Temik, or Vydate. Nematode populations and fruit sizes and yields were monitored for three successive years. Although DBCP was the only nematicide that reduced nematode populations, a 34% increase in fruit yield was obtained in the second year following treatment with Temik and Vydate. Apparently, these nematicides lessened the detrimental effects of the nematodes but reductions in populations were not detected. Mites and insects were controlled throughout the test with foliar sprays and presumably had no effect on yield. No yield records could be collected in the third year due to fruit loss to Hurricane Allen.

Increases in citrus yields and fruit size and suppression of populations of the citrus nematode, *Tylenchulus semipenetrans* Cobb, have been demonstrated with soil treatments of DBCP (2, 4, 5). With the cancellation of registration of DBCP and the almost ubiquitous occurrence of the citrus nematode in the lower Rio Grande Valley (2), research on the efficacy of other nematicides is needed. Recently registered and experimental nonfumigant nematicides, which have varying degrees of systemic properties, often lack the ability to effect a quick knockdown of nematode populations (1, 6). However, the possibility of other modes of action for effective nematode control needs to be determined. This study compares the efficacy of unregistered or newly registered nematicides to suppress populations of citrus nematodes and to increase fruit yield and size on grapefruit for three successive seasons.

MATERIALS AND METHODS

Formulations, sources, and rates of nematicides tested were: DBCP (Nemagon 12.1 EC) Shell Chemical Co., 53.7 kg a.i./ha; aldicarb (Temik 15G), Union Carbide Corp. 5.6 kg a.i./ha; ethoprop (Mocap 6 EC) Mobile Chemical Co., 9.0 kg a.i./ha; fenamiphos (Nemacur 3 SC), Mobay Chemical Corp., 5.6 kg a.i./ha; and oxamyl (Vydate 2L), E.I. du Pont de Nemors and Co., 1.1 kg a.i./ha.

Nematicides were applied to 17-year-old nucellar red grapefruit *(Citrus paradisi* Macf.) trees on sour orange *(C. aurantium* L.) rootstock on a 4.8 x 7.6-m spacing. Soil types consisted of Hidalgo fine sandy loam and Hidalgo sandy clay loam. All nematicides were first applied March 29-30, 1978. DBCP and Mocap were metered into 15 cm of water in a flood irrigation system with a gravity flow applicator. Temik was chiseled under the soil with a Gandy applicator; Nemacur was sprayed on the soil surface with a herbicide applicator; and Vydate was applied as a foliar spray with a Hardie Speed Sprayer. DBCP was not applied again. All other nematicides, except Mocap in 1979, were reapplied March 27-28, 1979 and April 28-29, 1980. Trees treated with Vydate received a second application each year in early June. All trees were watered immediately after nematicide application. Irrigated untreated trees served as controls.

Insects and mites were controlled throughout the growing season with foliar pesticide sprays to minimize their effects on fruit quality and yield. Kelthane was applied three times per year either alone or in combination with oil or Supracide.

Treatments were arranged in a randomized complete block design and replicated four times with two rows of 10-12 trees per plot. Nematode population, yield, and fruit-size data were collected from the center six trees.

Soil samples for nematode counts were taken at three sites within each plot and composited. Nematodes were extracted from 100 cc of soil by the standard Baermann funnel technique. Yield was determined by weighing the fruit from six individual trees in each replication in December of each year. Fruit size was determined by sorting fruit with a commercial sizer.

RESULTS AND DISCUSSION

DBCP significantly ($P = 0.05$) reduced nematode populations on two sample dates in 1978 (Table 1). Although no significant reductions in nematode populations occurred with any nematicide in 1979, the post treatment average indicates that DBCP consistently suppressed nematodes throughout the year. In early 1980 populations of nematodes from soil treated with DBCP were still lower than those from the nontreated plots, but by summer and for the remainder of the year populations in the DBCP plots were no longer reduced. No other nematicide had any effect on nematode populations.

No significant increases in yield or fruit size were obtained with any nematicide in 1978 (Table 2). In 1979 Temik and Vydate caused an average 34% increase in fruit yield compared to yields from nontreated trees. Only DBCP caused a significant ($P = 0.05$) increase in fruit size. No phytotoxicity was noted with any materials.

Winds of Hurricane Allen on August 10-12 caused an estimated 20-40% fruit loss in 1980. This, coupled with an off-year for fruit production probably due in part to an irregular bearing tendency of nucellar trees, made yield data unreliable for 1980. Yields averaged only 74 kg per tree.

DBCP reduced nematode populations in a relatively short time, which is consistent with previous reports (2, 4, 5). No other nematicide significantly reduced nematode populations in this study. However, systemic, nonfumigant pesticides have been implicated in causing narcosis or reduced reproduction rather than a quick kill (1, 3). The effects of Temik and Vydate were apparent in the second year following nematicide application. Significant increases in fruit yield were obtained with these compounds despite the failure to decrease

Table 1. Effect of nematicides on populations of *Tylenchulus semipenetrans.*[z]

1978

Treatment	No. of nematodes (in 1000's)/100 cm^3 soil + 3 gms of roots				
	Pre-treatment Mar 20	May 15	Sept 18	Dec 26	Post-treatment Ave.
DBCP	9.9	0.4a	0.0	0.5a	0.3a
Mocap	4.3	1.8b	0.6	23.7c	8.7b
Nemacur	7.9	4.3b	0.1	10.1b	4.8b
Temik	6.4	3.0b	0.2	17.2bc	6.8b
Vydate	6.3	3.3b	0.1	13.6bc	5.6b
None	6.3	2.7b	0.5	13.1bc	5.4b
	NS		NS		

1979

Treatment	Pre-treatment Apr 2	Jun 22	Sept 26	Dec 26	Post-treatment Ave.
DBCP	0.3	0.4	0.3	1.9	0.9a
Mocap	4.0	3.9	0.8	7.2	3.9b
Nemacur	7.5	2.7	0.7	5.5	3.0b
Temik	6.7	1.6	0.8	6.7	3.0b
Vydate	10.5	2.5	0.5	7.6	3.4b
None	8.1	2.9	1.5	5.2	3.2b
	NS	NS	NS	NS	

1980

Treatment	Pre-treatment Mar 6	Jun 13	Sept 9	Dec 8	Post-treatment Ave.
DBCP	2.4a	2.3	3.2	5.6	3.7
Mocap	7.7b	2.5	0.3	2.7	1.8
Nemacur	15.0c	6.6	0.9	5.0	4.2
Temik	12.3bc	3.0	2.8	3.6	3.2
Vidate	8.0b	6.5	1.2	4.3	4.0
None	10.4bc	3.6	2.2	4.6	3.5
		NS	NS	NS	NS

[z] Mean separation by Duncan's multiple range test, 5% level.

Table 2. Effect of nematicide on grapefruit yield and fruit size.[z]

Treatment	Yield (kg/tree)	Fruit Size[y] (% > 9.2 cm)
	1978	
DBCP	133	56
Mocap	128	48
Nemacur	125	53
Temik	134	50
Vydate	152	48
None	126	45
	NS	NS
	1979	
DBCP	167ab	54a
Mocap	160ab	28bc
Nemacur	180ab	26c
Temik	197b	29bc
Vydate	198b	28bc
None	148a	40b

[z] Mean separation by Duncan's multiple range test, 5% level.
[y] % of total fruit weight composed of fruit 9.2 cm in diam or larger.

nematode numbers. These yield increases might be attributed to a suppression of the effects of nematodes since mites and insects were controlled with foliar sprays during the year. We presume that the miticidal and insecticidal properties of Temik and Vydate played no part in the yield benefit since fruit from non-treated trees were not injured by any insect or mite pests. The dual effects on citrus with these two pesticides makes them especially attractive in pest management programs on citrus.

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Effects of Soil Texture on Citrus Root Development and Tree Vigor

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ABSTRACT

Decline symptoms of leaf wilt, defoliation and stem dieback were found in certain areas of 10- to 12- year-old, closely spaced 'Redblush' grapefruit *(Citrus paradisi* Macf.) trees. Analysis of soil cores showed higher clay content under declining than under healthy trees. Root densities were greater under healthy trees at all depths. As soil clay content increased, citrus root density decreased regardless of tree condition. A significant linear relationship showed tree height was inversely correlated to clay content at the 45-60 cm depth.

A citrus "decline" resulting in leaf wilt, defoliation and stem dieback has been observed in grapefruit trees *(Citrus paradisi* Macf.) on sour orange *(C. aurantium* L.) in the Lower Rio Grande Valley of Texas (6). These symptoms were found on 10 to 12 year old close spaced (usually 3.0 x 7.6 m) 'Redblush' grapefruit trees in isolated areas of groves which had been machine leveled for efficient flood irrigation. Trees with decline symptoms were not killed but rather exhibited stem dieback in late summer. This was followed by strong regrowth mainly as suckers along the trunk and main framework in the fall following heavy rainfall and cooler temperatures. A decline causing similar foliage symptoms and death of small feeder roots was observed in Texas over 30 years ago (7).

Preliminary investigations of the present decline have ruled out excess salt, high water table, virus, *Phytophthora* spp., and nutritional deficiencies or inbalances as possible causes (6). Observations of soil profile revealed what appeared to be abrupt textural changes. Root development is affected by physical properties of the soil including strength, bulk density and structure (4, 8, 9) which are influenced by soil texture (3). It was hypothesized that a restricted root zone as a result of soil texture and the closeness of the trees in the high density planting were responsible for the appearance of the decline as tree canopies closed to form hedge rows. This was further supported by observations that the decline was most severe in a dry year when intervals between irrigations were extended. Moisture stress increased to a point where

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decline symptoms appeared in certain areas within the grove. Trees along the perimeter of a grove generally had wider root zones and did not suffer decline. In one adjacent grove which had shown decline symptoms and where every other tree had been removed to increase tree rooting zone (6.0 x 7.6 m spacing), interior trees showed no decline symptoms.

Citrus root development and tree size have been shown to be affected by restrictions on the root zone (2, 5). Higher root densities due to probable overlapping of root systems of adjacent trees were found in close spaced 9 year old navel oranges (5). Height of orange varieties on rough lemon in an area underlain by a lateritic sandy clay (oxic horizon) decreased with reduced depth to the clay layer (2).

This study examined the relationship of soil texture, an easily measurable soil parameter, to feeder root distribution, tree height, and tree vigor of close spaced 10- to 12- year-old grapefruit on sour orange rootstock.

MATERIALS AND METHODS

Two groves with closely spaced (3.0 x 7.6 or 3.7 x 6.7 m), 10- to 12- year-old 'Redblush' grapefruit trees on sour orange rootstock showing the described decline symptoms were selected in two locations of the Lower Rio Grande Valley of Texas: One in the Texan Garden area of western Hidalgo County; the second north of Monte Alto, 42 km (26 miles) to the east. Four or six declining and healthy trees were selected for sampling in each grove. Soil cores 10.2 cm in diameter were taken at the dripline on opposite sides of each tree with a rotary type coring machine to a depth of about one meter. Soil cores were divided into 10.2 or 15.2 cm sections for analysis of soil texture and root quantity. Tree condition (healthy or declining) and height were also recorded.

Sand, silt and clay content was determined by a modified hydrometer method (1, 10). Root quantity was determined by first washing the soil sample through a 40 mesh (425 micron) sieve. Roots and larger particles remaining in the sieve were separated by shaking in a concentrated $CaCl_2$ solution. Roots could be separated since they remained suspended longer than the mineral material. Roots larger than 2 mm in diameter were discarded. The feeder roots were then dried and weighed. Root density was calculated as the quantity of roots per unit volume of soil.

Linear regression was used to evaluate statistical relationships between root density, clay content and depth; and also between tree height and clay content. Regression lines between healthy and declining trees at each location were compared by covariate analysis.

RESULTS

Clay distributions differed with depth between healthy and declining trees at both locations. At Texan Gardens clay contents near the surface were similar for healthy and declining trees (Fig. 1). Covariate analysis of the relationship between clay content and depth revealed statistically different slopes, indicating that the increase in clay content with depth was greater for declining than for healthy trees. At the Monte Alto location, clay content was consistently less at all depths under healthy than under declining trees (Fig. 2). This was verified

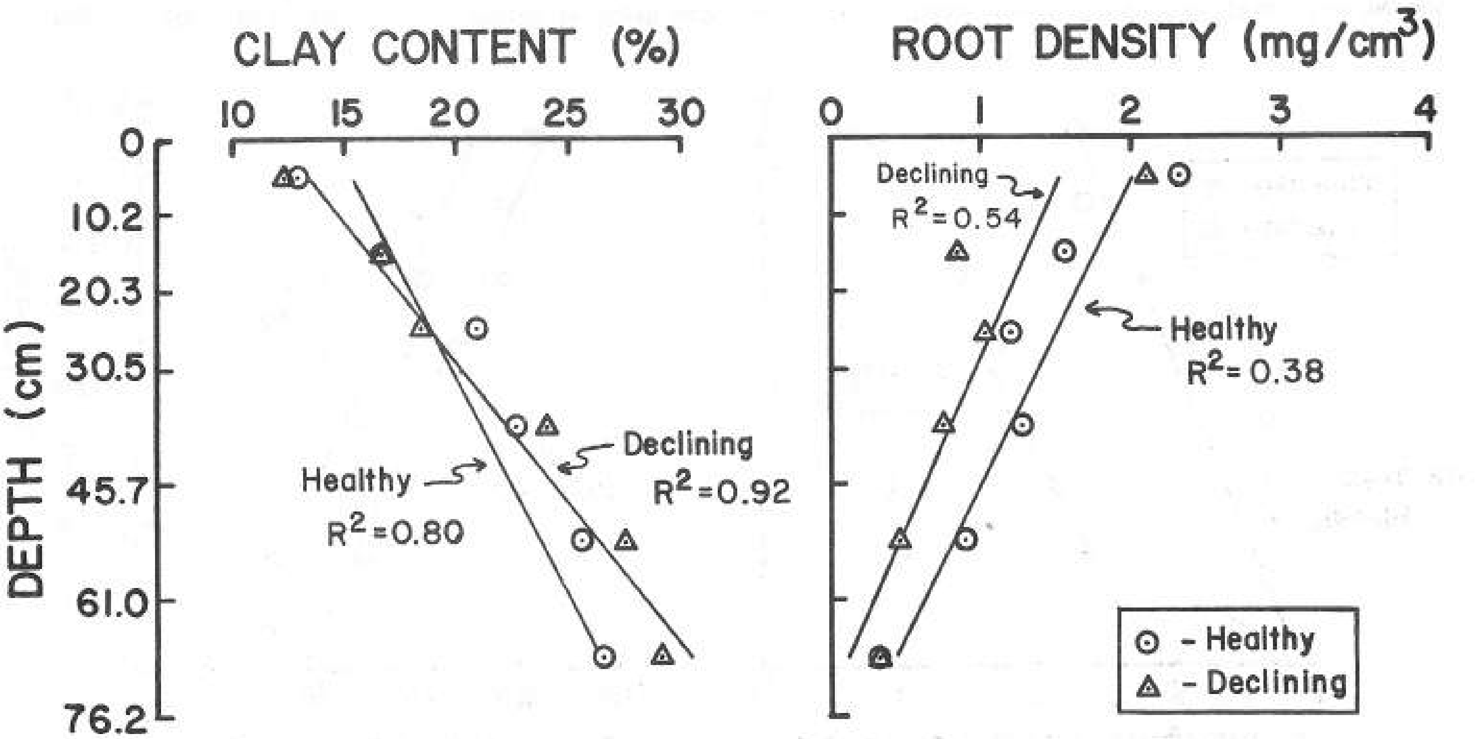

Fig. 1. Soil clay content and root density vs depth under healthy and declining grapefruit trees at the Texan Garden location. Each point is a mean of samples taken on opposite sides of each of two trees.

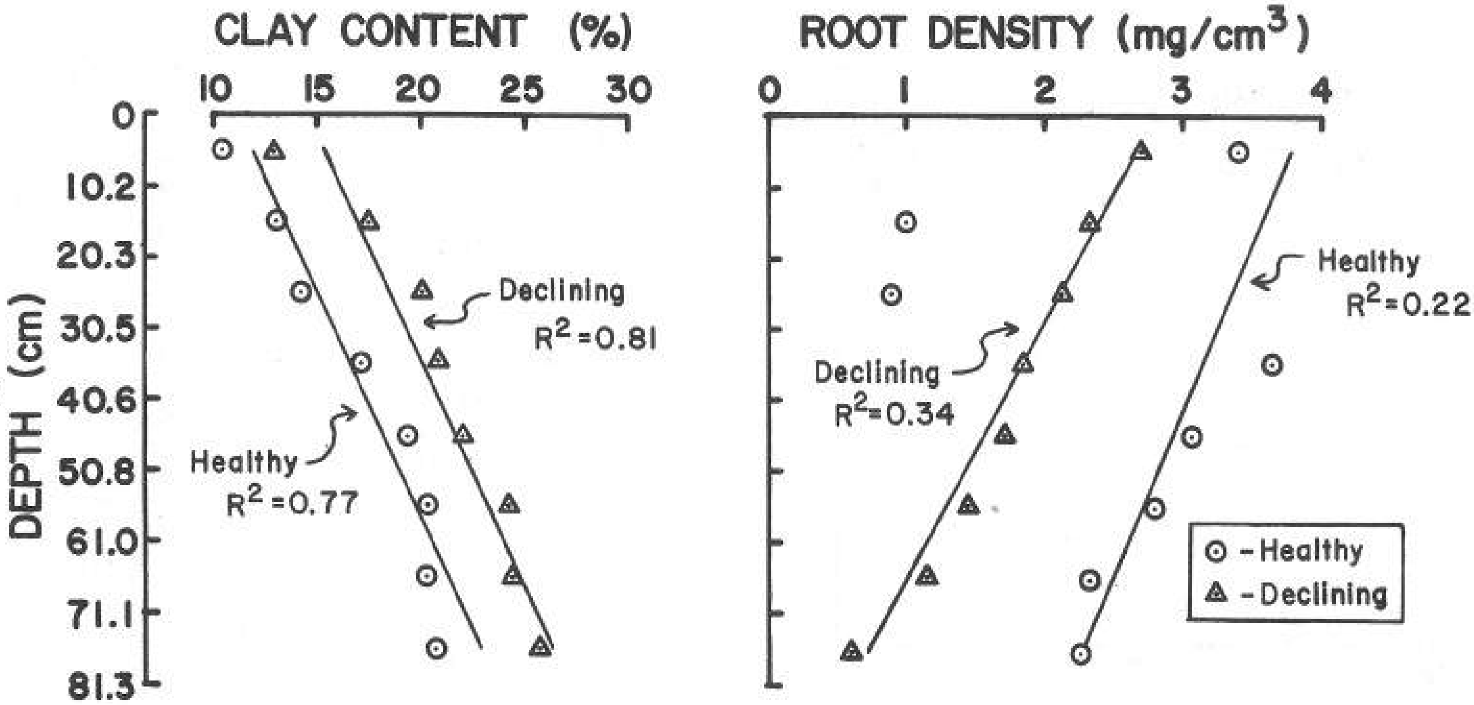

Fig. 2. Soil clay content and root density vs depth under healthy and declining grapefruit trees at the Monte Alto location. Each point is a mean of samples taken on opposite sides of each of three trees.

by covariate analysis which indicated similar slopes, but different intercepts.

Root densities were generally higher under healthy than under declining trees at both locations. At the Texas Garden location, covariate analysis indicated similar slopes but different intercepts between healthy and declining trees (Fig. 1) indicating significantly greater densities of roots under healthy trees. At Monte Alto, root densities at 10.2-30.5 cm under healthy trees were exceptionally low (Fig. 2). No apparent explanation was found, but it may be related to the observed marbled appearance near the surface which was likely created during land leveling operations. The regression line of root density vs depth for healthy trees was therefore obtained excluding these points. When root density vs depth was compared between healthy and declining trees at Monte Alto, significantly different slopes were found, thus indicating root decrease with depth was greater for declining trees.

Root density vs clay content relationships were compared between healthy and declining trees at each location (Fig. 3). At Texan Garden, no differences were found. Thus, the relationship between roots and clay at this location is not associated with tree condition. Data from healthy and declining trees were combined into one linear equation. At Monte Alto, the erratic root densities at 10.2-30.5 cm under healthy trees were again deleted as described earlier. A comparison of the root density vs clay content relationships at this location between healthy and declining trees revealed a common slope but different intercepts.

The pooled equation from Texan Garden and the individual equations for healthy and declining trees at Monte Alto were simultaneously compared to give no differences in slopes, though different intercepts. The common slope indicates that increasing soil clay content consistently influences citrus root distribution by decreasing root density (change in root density per unit change in clay content). Different intercepts indicate that the total amount of roots is influenced by additional factors which may include moisture, location, climate and management.

A highly significant linear relationship was found between tree height and clay content at the 45-60 cm depth (Fig. 4). Condition of the tree correlated with height of closely spaced grapefruit trees. Declining trees average 3.86 m while healthy trees average 4.51 m in height. No declining trees were found where clay content at 45.7-61.0 cm depth was less than 23.5%, while no healthy trees were found where clay content at this depth exceeded 26%.

DISCUSSION

Citrus root distribution and tree size were associated with soil texture. Soil clay content is one of many factors influencing roots; interactions with other variables affecting root distribution are complex. While soil strength as a function of clay content could act as a direct physical impediment to root penetration, texture may also work indirectly by limiting moisture availability.

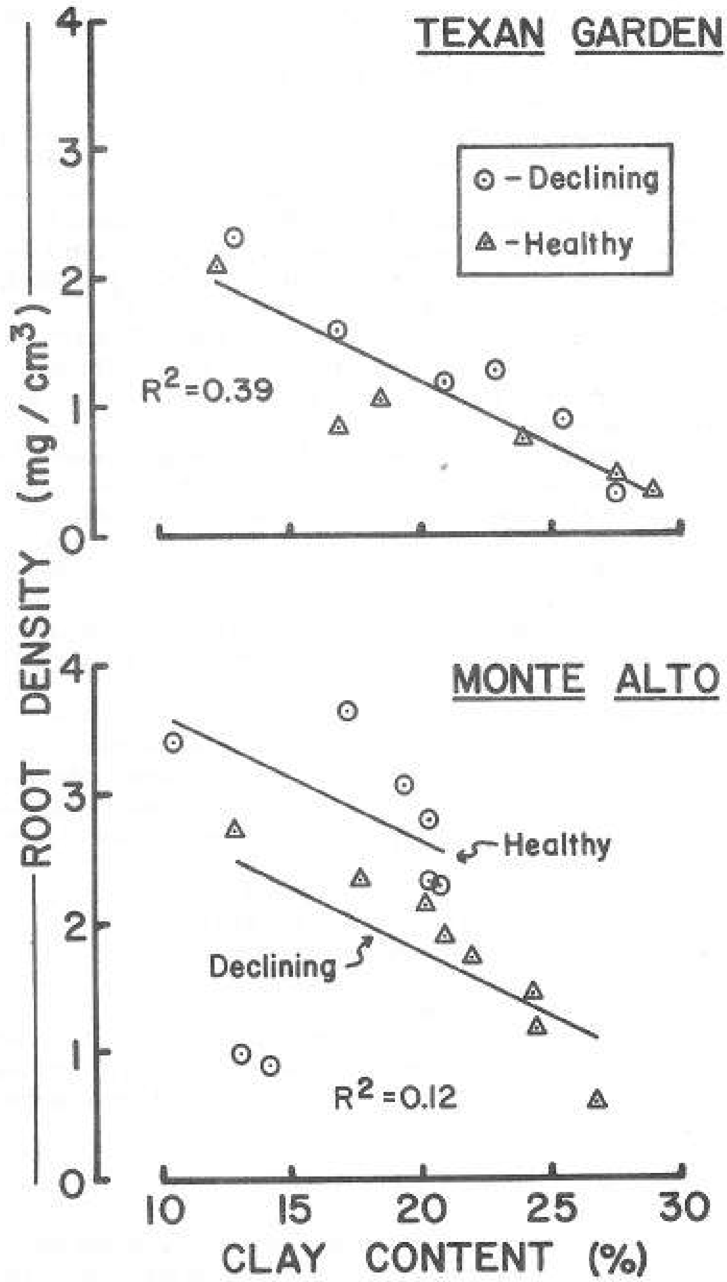

Fig. 3. Root density vs clay content at the two locations under healthy and declining grapefruit trees. Each point is a mean of samples taken on opposite sides of each of two trees at Texan Garden, or three trees at Monte Alto.

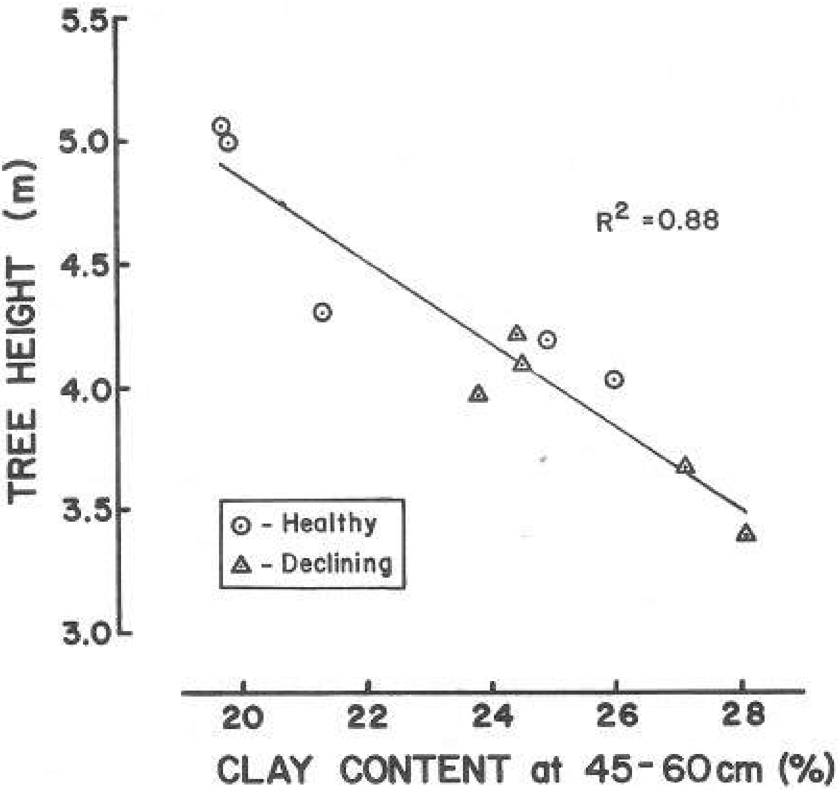

Fig. 4. Height of close spaced 10-12 yr old grapefruit trees vs clay content at 45-60 cm depth.

The decline symptoms are probably a function of insufficient moisture. Useable moisture is a dynamic quantity difficult to define and measure. Textural analysis of soil clay content is a relatively simple, accurate procedure whose values do not change. An indication of useable moisture is discernible from soil clay content. Any measurement of available moisture does not truly determine that which is useable by the plant. The soil textural profile has been shown to correlate with tree vigor.

Solutions for the problem of reduced tree size and vigor due to soil textural influences primarily involve grove management. Grapefruit trees spaced 3 m apart in the row and restricted to infrequent flood irrigation appear to require a minimum rooting volume clay content less than 23.5% to a depth of 60 cm. If soil sampling prior to establishment reveals potential problem areas, wider tree spacing should be considered. If evaluation reveals similar soil problems in an established grove, removing every second or third tree prior to severe decline might be of benefit. In either case, more lateral area is provided from which the tree could utilize available moisture. Better water management, such as more frequent irrigation using less water may also prevent or alleviate decline symptoms. Hedging and topping to control tree size could also be considered as a way to maintain a balance between roots and canopy growth.

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Citrus Responses to Irrigation: I. Irrigation Requirements; Daily, Monthly, and Annual Evapotranspiration Amounts; and Water Management Recommendations

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ABSTRACT

Four irrigation treatments — 80, 60, and 40% depletion of plant-available water in the surface 3 ft of soil year-around, and one that permitted 80% depletion in summer and winter but 60% in spring and fall referred to as A, B, C and D, respectively — were maintained for 7 years in Marrs and Valencia orange and Ruby Red grapefruit. Average annual irrigation requirement, above the 28.8 average annual rainfall, ranged from 3.4 to 26.6 inches and number of irrigations per year ranged from 1 to 9. Water use (evapotranspiration) of 40 inches per year for treatment D was 6 to 8 inches less per year than for the wetter treatments B and C, and 5 to 7 inches more than for treatment A.

The data document that a rainless summertime irrigation interval of 4 weeks for mature grapefruit and 5 weeks for oranges can be tolerated by the trees without affecting current or future years' production. A water use rate of 0.15 inch per day from June through September and 0.05 inch per day from December through February is indicated from which the duration that irrigations up to 5 inches will last can be calculated. For grapefruit, increased tree growth and yield were achieved during the early bearing years by irrigating every 15 to 19 days in summertime rainless periods, a practice that is recommended until the tree canopies touch in the row or cover about 50% of the ground area. Findings of earlier workers that 40 inches of effective rainfall plus irrigation water per year, exemplified by treatment D in this study, is adequate for mature trees are verified; managed in this way, 5 or more inches of rainfall and/or irrigation water per year percolate below the root zone and prevent salt accumulation.

In the Lower Rio Grande Valley of Texas, irrigation is used to supplement rainfall in crop production. Annual rainfall ranges from 26.8 inches at Brownsville to 17.3 inches at Rio Grande City about 90 miles inland, a decrease of approximately 1 inch each 7 miles (17). Most falls in thundershowers so that it is unevenly distributed geographically and seasonally (17). Consequently experiments of several years' duration are required to establish irrigation water requirements and crop responses (14).

Citrus uses less water per unit land area annually than other annual (15), or perennial crops (8) such as pastures (17) or sugarcane (19). The low water use is attributable to its high leaf resistance to water loss (8). Consequently, it is an economically important crop in naturally arid areas such as Israel (3, 20) and Cyprus (21) where citrus is otherwise climatically adapted and irrigation water supplies are limited.

Friend and Hancock (6), estimated that a minimum of 36 inches of water per year including effective precipitation is required to sustain large citrus trees in good production in the Lower Rio Grande Valley. Coit (5) estimated the water requirement ranged from about 40 inches at San Benito, Tx, to 45 or more inches at Mission on the western edge of the citrus production area. McDaniels (16) estimated annual evapotranspiration from citrus orchards in the vicinity of Weslaco at 39.4 inches. Orton et al. (17) used long-term rainfall and evapotranspiration data from McDaniels (16) to calculate the annual irrigation water requirement to be 18.1 inches for Hidalgo County, 8.4 inches for Willacy and Cameron Counties, and 28.1 inches for Starr County.

The typical orchard in the Lower Rio Grande Valley is border-irrigated. The borders are either temporary and constructed for each irrigation or semi-permanent where weeds are controlled chemically. Soils used for citrus range in surface texture from clay loams to loamy sands, with a concomitant range in water retention characteristics (4). A typical irrigation application for this cultural system is 6 acre-inches (13).

The Valley's irrigation water allotment averages about 1.5 acre feet per acre per year and farmers in irrigation districts without metered water are often charged an acre foot of allotment per irrigation. Consequently, water from land not in citrus must often be diverted to citrus to meet the minimum water requirement.

The literature indicates that once Valencia orange fruit is set, the interval between irrigations can be lengthened with little effect on yield and nondetrimental effects on juice quality (7, 10, 11, 21). Irrigation intervals as long as 50 days have been tolerated, the main effect being smaller fruit (21).

Data from Israel document that grapefruit require more water than oranges (20); yields of oranges generally decreased if greater than 30 inches of water per year were applied, but there was no yield reduction for grapefruit when 39 inches of water was applied. Bielorai and Levy (3) found that grapefruit yields did not differ among trees irrigated on 18, 24, or 30 day intervals but that a 40-day irrigation interval decreased yields significantly. Heller et al. (9) reported that grapefruit on heavy soils in Israel are usually alternate row-irrigated on 25 to 30 day intervals in summer while on light- and medium-textured soils each row is irrigated each 16 to 21 days.

The purposes of this paper are to (a) report number of irrigations; measured water application amounts; and annual and monthly evapotranspiration of Marrs and Valencia oranges and Ruby Red grapefruit subjected to four irrigation regimes over a seven year period, 1969-1975, and (b) discuss irrigation management recommendations as related to timing during the year, summer intervals permissible without affecting yields or quality, irrigation as it augments rainfall, and differences between oranges and grapefruit.

MATERIALS AND METHODS

The orchard was planted in 1964 on the Valley Soil and Water Conservation Districts' Research Farm 4 miles north of Weslaco. The trees were certified, grafted 2-year old scions on sour orange rootstock. The soil is a Hidalgo sandy clay loam (Typic Calciustolls). For the first three years trees were irrigated uniformly. The orchard incorporated a randomized block design of 4 irrigation treatments with 3 replications, using Marrs and Valencia oranges *(Citrus senensis* (L.) Osbeck) and Ruby Red grapefruit *(Citrus paradisi* Macf.). Tree spacing was 15 x 22 ft (4.6 x 6.7 m) or 132 trees per acre. Replications were blocks of 16 trees of which the 4 interior trees were harvested and the rest served as buffer trees. Fertilization was 1.5 lb N per tree applied in either January or February each year. Diuron, bromacil + diuron, simazine, and MSMA + sodium cacodylate plus hoeing were used for weed control. Azinphosmethyl, carbaryl, carbophenothion, chlorobenzilate, dicofol, ethion, formetanate hydrochloride, phosalone, spray oil and zineb were used at various times for insect control. Copper hydroxide was used for melanose control.

The irrigation treatments were: (A) irrigate all cultivars any time of the year 80% of the available water was depleted from the surface 3 ft soil layer; (B) irrigate all cultivars any time of the year 60% of the available water was depleted from the surface 3 ft soil layer; (C) irrigate all cultivars any time of the year 40% of the available water was depleted from the surface 3 ft of soil; and, (D) — for Marrs and Ruby Red — irrigate from Nov. 15 to Feb. 14 and from May 15 to Aug. 14 when 80% of the available water was depleted from the upper 3 ft of soil and from Feb. 15 through May 14 and from Aug. 15 through Nov. 14 at 60% depletion of available water in the upper 3 ft soil layer. For Valencia oranges May 15 through Aug. 14 was the only period of 80% depletion; the remainder of the year irrigations were applied when 60% of the available water in the upper 3 ft of soil was depleted. Treatments are summarized in Table 1.

Table 1. Explanation of irrigation treatments applied to three citrus cultivars.

Cultivars	Treatment	PAWD[z] Surface 3 ft Soil	Time of year	Treatment code	Water applied per irrigation
		%			(inches)
All	A	80	Throughout	WD80	4.8
	B	60	Throughout	WD60	3.6
	C	40	Throughout	WD40	2.4
Ruby Red & Marrs	D	80	Nov.15-Feb.14(W)[y]	WD80W	4.8
			May 15-Aug.14(S)	WD80S	4.8
		60	Aug.15-Nov.14(F)	WD60F	3.6
			Feb.15-May 14(Sp)	WD60Sp	3.6
Valencia		80	May 15-Aug.14	WD80S	4.8
		60	Nov.15-Feb.14	WD60W	3.6
			Feb.15-May 14	WD60Sp	3.6
			Aug.15-Nov.14	WD60F	3.6

z Plant-available water depletion based on water retention at 15 and 1/3 bar.

y Quarterly periods are referred to as winter, summer, fall, and spring, respectively.

A subsurface irrigation line through each variety with an alfalfa valve outlet in each moisture treatment replicate and a Sparling meter in each line permitted flood application of 4.8, 3.6, and 2.4 inches of water per application for the 80, 60, and 40% depletion treatments, respectively, in 10 to 20 minutes. Permanently maintained earthen borders enclosed each 16-tree treatment replicate and the area within each such plot was carefully leveled early in 1968 when the moisture treatments were imposed. Data are presented beginning with 1969 when the trees began bearing well. Drain lines at the 7 ft depth provided a well-drained and aerated root zone.

Records of rainfall were obtained at a Class A weather station about 200 yards from the orchard.

Soil water content for determining depletion was measured weekly by neutron scattering to a depth of 4 feet by 1 foot intervals and graphed for the surface 3 ft versus time to display each drying cycle per treatment. When rain fell, the amount in excess of that required to fill the 3 ft root zone to field capacity was assigned to drainage. Evapotranspiration (ET) was determined for monthly periods from;

(irrigation-leaching requirement) + (rainfall-drainage) + (difference in amount of water in the 3 ft deep root zone at the beginning and end of each month)

where all amounts are in inches. Because periodic heavy rainfall takes care of the leaching requirement locally, we did not overirrigate for leaching and this term was zero. The last term in the equation is positive if water depletion occurred for the month and negative if accretion occurred.

Soil samples were taken annually to a depth of 5 ft. for the estimation of salinity by means of electrical conductivity of the saturation extract.

Tensiometers installed at the 30- and 42-inch depths and read and serviced weekly indicated soil water suction at those depths. The hydraulic gradient across that depth interval also indicated whether water flow was upward or downward across the lower boundary of the root zone chosen.

We also calculated daily potential evapotranspiration (PET), the amount that crops that completely cover the ground would evapotranspire if freely supplied with water, from the equation (19):

$$PET = 0.0112(Tm - 20)\ Rs$$

where Tm is mean daily temperature $^{\circ}F$, and Rs is daily solar radiation expressed as equivalent depth of water evaporated. The daily calculations were summed over the number of days in the month to get monthly values.

All cultivars bloomed in March. Marrs oranges were harvested the second week in November of the year of bloom; grapefruit were harvested the first or second week of January, and Valencia oranges the second or third week in March of the year following bloom.

Significance of treatment effects on tree response was determined by analysis of variance and determination of differences among treatments was established by Duncan's multiple range tests of ranked means.

RESULTS AND DISCUSSION

The number of irrigations applied varied from 0 in a number of years in treatment A to 14 in 1974 to the Valencia oranges of treatment C (Table 2).

Table 2. Number of irrigations (I), inches of water applied (II), and water use (III) per year by Marrs and Valencia oranges and Ruby Red grapefruit for four water management treatments, 1969-75.

I. Number of irrigations per calendar year.

	Ruby Red A	Ruby Red B	Ruby Red C	Ruby Red D	Marrs A	Marrs B	Marrs C	Marrs D	Valencia A	Valencia B	Valencia C	Valencia D
1969	3	7	12	6	1	3	8	3	2	5	9	3
1970	0	7	9	3	0	2	7	3	1	5	9	4
1971	1	7	10	3	0	5	8	3	1	7	10	4
1972	1	8	10	4	0	4	10	3	2	8	12	7
1973	0	3	6	2	0	0	5	1	0	5	6	2
1974	2	8	12	5	1	5	11	4	3	9	14	5
1975	3	4	6	3	3	4	6	3	3	4	6	3
Avg	1.4	6.3	9.3	3.7	0.7	3.3	7.9	2.9	1.7	6.1	9.4	4.0

II. Inches irrigation water applied per year.

Rain		Ruby Red A	Ruby Red B	Ruby Red C	Ruby Red D	Marrs A	Marrs B	Marrs C	Marrs D	Valencia A	Valencia B	Valencia C	Valencia D
18.6	1969	15.7	29.1	33.9	26.8	4.7	10.6	19.7	12.0	10.4	19.7	25.0	12.8
27.9	1970	0	29.4	25.4	13.8	0	6.9	17.6	10.9	5.1	20.0	25.2	16.6
28.6	1971	5.2	28.9	30.8	13.3	0	18.4	22.6	11.3	5.2	27.6	30.7	16.1
33.1	1972	4.7	29.4	27.7	14.8	0	13.3	22.8	9.5	9.4	29.0	30.8	25.2
43.0	1973	0	12.0	17.4	7.8	0	0	12.6	3.4	0	18.8	16.9	7.9
22.6	1974	10.0	32.9	34.6	22.5	4.5	17.5	28.4	13.6	14.5	35.8	40.5	20.8
27.8	1975	14.8	15.6	16.7	12.8	14.8	15.4	16.8	12.6	14.8	15.7	17.0	11.6
28.8	Avg	7.2	25.3	26.6	16.0	3.4	11.7	20.1	10.5	8.5	23.8	26.6	15.9

III. Inches water use (irrigation + rainfall - drainage + soil depletion) per year.

	Ruby Red A	Ruby Red B	Ruby Red C	Ruby Red D	Marrs A	Marrs B	Marrs C	Marrs D	Valencia A	Valencia B	Valencia C	Valencia D
1969	32.8	48.0	51.9	43.5	23.5	31.2	37.3	29.9	29.2	39.4	43.0	34.8
1970	28.6	49.5	46.4	41.3	24.7	34.7	42.5	36.7	32.0	44.4	46.5	41.8
1971	32.5	50.3	51.6	37.4	25.7	37.0	47.2	33.5	32.3	51.1	55.3	42.0
1972	31.6	51.6	48.2	41.5	27.9	39.0	45.1	38.4	36.7	51.7	56.8	48.8
1973	39.9	46.5	44.9	44.3	35.1	34.4	39.3	34.0	39.8	50.5	48.2	42.6
1974	28.4	49.1	49.1	36.8	20.4	33.5	41.5	27.6	31.3	52.3	54.8	37.9
1975	31.8	33.1	34.7	32.4	31.8	33.7	35.0	32.8	31.7	33.1	34.7	32.4
Avg	32.2	46.9	46.7	39.6	27.0	34.8	41.1	33.3	33.3	46.1	48.5	40.1

For Ruby Red grapefruit and Valencia oranges treatment A, allowed to deplete 4.8 inches of water year-around, was irrigated only 1 or 2 times a year; treatment B, allowed to deplete 3.6 inches year-around, 6 to 7 times; treatment C, allowed to deplete 2.4 inches 9 to 11 times; and, treatment D, allowed to deplete 4.8 inches prior to irrigation in summer and winter and 3.6 inches in spring and fall was irrigated 4 times a year. The wettest treatment was irrigated more frequently and the driest treatment considerably less frequently than the 5 to 7 irrigations applied in an average year (1). Leyden (13, 14) reported that for a 20 year period of observation, the number of irrigations has ranged from 2 to 8 per year depending on rainfall and its distribution.

During the study average annual rainfall was about 5 inches above the long-term average of 23.3 inches for Weslaco. In 1969 and 1974 recorded rainfall was less than long-term average. The quantity of irrigation water applied depended on both amount and distribution of the rainfall. Average irrigation requirement ranged from: 3.4 to 20.1 inches for Marrs, 7.2 to 26.6 inches for Ruby Red and

Table 3. Average monthly evapotranspiration (inches) for a seven year period for each of four irrigation treatments and three citrus cultivars. The average potential evapotranspiration per month for the seven year period is given for comparison.

Cultivar/ Treatment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						. . . . Inches						
Marrs												
A,WD80	1.10	1.24	1.56	1.71	2.18	3.12	3.34	3.34	4.03	3.01	1.62	.77
B,WD60	1.77	1.67	2.00	2.23	3.22	4.30	4.08	3.98	4.31	3.75	2.48	1.01
C,WD40	2.10	1.99	2.55	3.27	3.78	4.39	4.81	4.93	4.79	4.08	2.64	1.81
D,WD80W/ 60Sp/80S/ 60F	1.27	1.51	2.22	2.42	3.08	3.42	3.62	4.27	4.59	3.78	2.12	.96
Ruby Red												
A,WD80	1.31	1.30	2.09	1.99	2.46	4.16	3.52	4.18	4.27	3.37	2.32	1.27
B,WD60	2.02	2.01	2.83	3.37	4.87	5.12	5.99	6.11	5.41	4.42	3.19	1.55
C,WD40	1.88	2.12	2.79	3.85	4.53	5.18	6.02	5.75	4.95	4.53	3.11	1.96
D,WD80W/ 60Sp/80S/ 60F	1.24	2.06	2.99	3.42	3.74	4.44	3.66	5.05	4.77	4.32	2.68	1.24
Valencia												
A,WD80	1.21	1.43	1.90	2.06	2.23	3.98	3.83	4.87	4.96	3.71	2.19	.91
B,WD60	1.86	2.14	2.64	3.74	4.44	5.17	5.84	5.68	5.53	4.57	2.94	1.53
C,WD40	2.19	2.17	3.07	4.02	4.98	5.60	5.66	5.91	5.10	4.49	3.34	1.94
D,WD60W/ 60Sp/80S/ 60F	1.92	1.77	2.76	3.17	3.33	4.07	3.88	5.10	4.99	4.53	3.22	1.32
Potential evapotranspiration monthly average (inches) for the seven year period:	2.2	2.8	4.5	5.5	6.6	7.1	8.0	7.2	5.6	4.6	3.1	2.4

8.5 to 26.6 inches for Valencia oranges (Table 2). Valencia oranges overtook Ruby Red grapefruit in trunk circumference in 1970 but over the duration of the experiment the two cultivars had about the same ground cover (23). Marrs trees grew more slowly (23), intercepted less solar radiation, and consequently required fewer irrigations to maintain the treatment conditions. Aerial photographs taken periodically during the experiment indicated that border trees differed little in growth from the treatments of adjacent plots and that border effects on the interior test trees were imperceptible.

The amount of irrigation water applied to Treatment B̄ (WD60) is about the same as for treatment C (WD40) for the grapefruit and Valencia oranges. Trees were not water stressed by either treatment; the larger amount of water applied per irrigation of treatment B was offset by the more frequent but smaller water applications of treatment C (Tables 1 and 2). The higher irrigation requirement of treatment C in Marrs, 20.1 inches, versus 11.7 inches for treatment B is caused by its higher number of irrigations; apparently, evaporation directly from the soil readily depleted the surface 3 feet of soil by 40% of its available water capacity.

The water use of treatment A in Marrs averaged about two inches less than rainfall over the 7 year period whereas for Valencia and Ruby Red water use was 3 to 5 inches greater than rainfall. Treatment D had an average water use for the seven year period of 33.3, 39.6, and 40.1 inches for Marrs, Ruby Red, and Valencia cultivars, respectively (Table 2, part III). Water use for treatment D was 6 to 8 inches less a year on the average than for the wetter treatments B and C and 5 to 7 inches a year more than for treatment A.

Monthly water use was high for June, July and August, reaching a peak of almost 6 inches for the two wetter treatments in Ruby Red grapefruit and Valencia oranges in July. The two drier treatments used less than 4 inches of water in July. Calculated potential evapotranspiration also peaked in July at 8.0 inches (Table 3).

The average irrigation interval was 15 days for the Ruby Red grapefruit and Valencia oranges allowed to deplete 2.4 inches of water prior to irrigation (treatment C), 18 or 19 days for those allowed to deplete 3.6 inches before irrigation (treatment B), and 32 to 33 days for the treatments (A & D) that were allowed to deplete 4.8 inches of water from the 3 ft zone prior to irrigation (Table 4). Since for both Marrs and Valencia oranges treatment D yielded as well as the wetter treatments (Table 5), it appears that water can be conserved in summertime by extending the irrigation interval up to 5 weeks.

Table 4. Irrigation interval (days) in summer (June through August) for each cultivar and irrigation treatment.

Cultivar	Irrigation treatment A&D	B	C
	................Days................		
		Mean (Range)	Mean (Range)
Marrs	Insuff. observ.	27 (21-34)	17 (13-19)
Ruby Red	32	19 (17-23)	15 (12-18)
Valencia	32	18 (13-27)	15 (9-19)

Mature grapefruit can tolerate moderately dry conditions in summer and winter without yield reductions. The average summertime irrigation interval of 32 days shown in Table 3 for treatments A and D is the limiting interval we recommend. The higher average yields of the wetter treatments in grapefruit (Table 5) is largely due to the larger yields in the early bearing years 1970 and 1971 (22).

For Ruby Red grapefruit and Valencia oranges, the maximum daily evapotranspiration rate for the two wetter treatments is 0.19 inch per day (Fig. 1). The two drier treatments have more variable water use rates because they are affected by amount of rainfall received; on the average the use rate was about 0.15 inch per day from June through September for Ruby Red grapefruit and Valencia oranges. All cultivars used about 0.05 inch per day from December through February. At a water use rate of 0.15 inches per day, a 5-inch water

Table 5. Average yield of Ruby Red grapefruit, Marrs and Valencia oranges under four irrigation treatments, 1969 - 75.

Irrigation treatment	Marrs	Ruby Red	Valencia
		(Tons per acre)	
A	13.2 bc[z]	21.3 b	12.2 b
B	13.1 c	24.6 a	12.5 b
C	14.4 a	24.3 a	13.2 ab
D	14.2 ab	20.2 b	13.6 a
Significance level	.05	.01	0.10

[z] Means separated by Duncan's multiple range test.

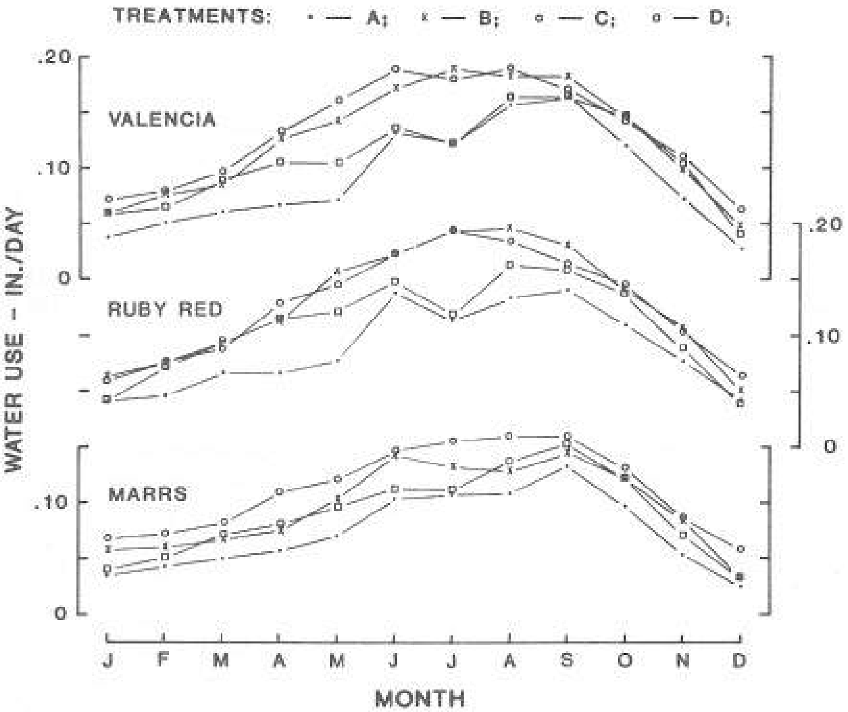

Fig. 1. Average daily water use rate versus time of year from seven years of data for all cultivars and treatments.

application would last 33 days in summer and a 4-inch application 27 days. In the winter period of Dec. - Feb., only the wetter two treatments were ever irrigated and the average irrigation interval was about 45 days. At a 0.05-inch daily water use rate, 2.2 inches of water would last 44 days.

In most orchards where the whole ground area is wetted and the irrigation runs are at least 300 ft long, we estimate that 4 inches of water is about as little as can be applied per irrigation, that the plant extractable water from the surface 3 ft of citrus soils is about 6 inches, and that the irrigation district policy of charging an acre-ft of water allotment per acre irrigated encourages heavy applications that average about 6 inches.

The largest savings in amount of water applied are achieved by extending the irrigation interval in summer. For the Ruby Red grapefruit treatment D had an average irrigation water requirement of 16 inches a year while treatment B required 25 inches, a difference equivalent to two light irrigations. The water use was 40 inches in treatment D and 47 inches in treatment B, a substantial saving for the treatment allowed to extract most of the available water in summer before irrigation (Table 2).

Rainfall is a complication in interpreting irrigation responses and making recommendations. Significant rainfall can occur at any time of the year and amount and distribution is unique for each year (Fig. 2). In four of the seven years little rain fell the last half of June and throughout July; in all years there was enough rainfall in late August or in September to partially eliminate irrigation treatment differences.

Because the trunk circumferences versus cumulative irrigation plus rainfall graphs (Fig. 3) form such a tight pattern among the treatments it is evident that rainfall and irrigation water are about equally effective in tree growth. At the end of the experiment, for a given sum of irrigation and rainfall, Marrs oranges and Ruby Red grapefruit on the dry treatment (D) have as large a trunk circumference as the other treatments. This indicates that a greater proportion of the rainfall was lost to drainage from the wetter treatment as compared with the driest and that water stress for the driest treatment was not often severe enough to restrict trunk growth.

Trees grew faster, as measured by trunk circumference and ground cover, the more frequently they were irrigated. In grapefruit the wetter treatments bore more heavily, especially until the trees began to crowd each other in the rows (22). Thus we agree with Bester et al. (2) that a major benefit of drip irrigation systems is on the growth rate of young trees; with Leyden (12) who found that water savings associated with drip systems result from wetting a smaller soil area; and with Rathwell and Leyden (18) that by the time trees are 6 years old and have canopy diameters of about 15 ft the water requirement becomes about the same regardless of method of application.

Our data on water requirements of grapefruit are in good agreement with those of Leyden (14). In 1975 he drip-applied 0, 11.3, 16.9 and 22.6 acre-inches of water to grapefruit trees and found that only the 0 treatment differed in yields from the others; our irrigations ranged from 12.9 to 16.7 acre-inches and there were no yield differences. In 1976 he drip-applied 0, 4.8, 7.9, 11.3 and 15.8 acre-inches and again found that only the 0 treatment differed in yield from the others (17.2 versus an average of 21.4 tons per acre); our irrigation application rate in 1976 was 4.9, 9.5, and 0.7 acre-inches. The treatment that

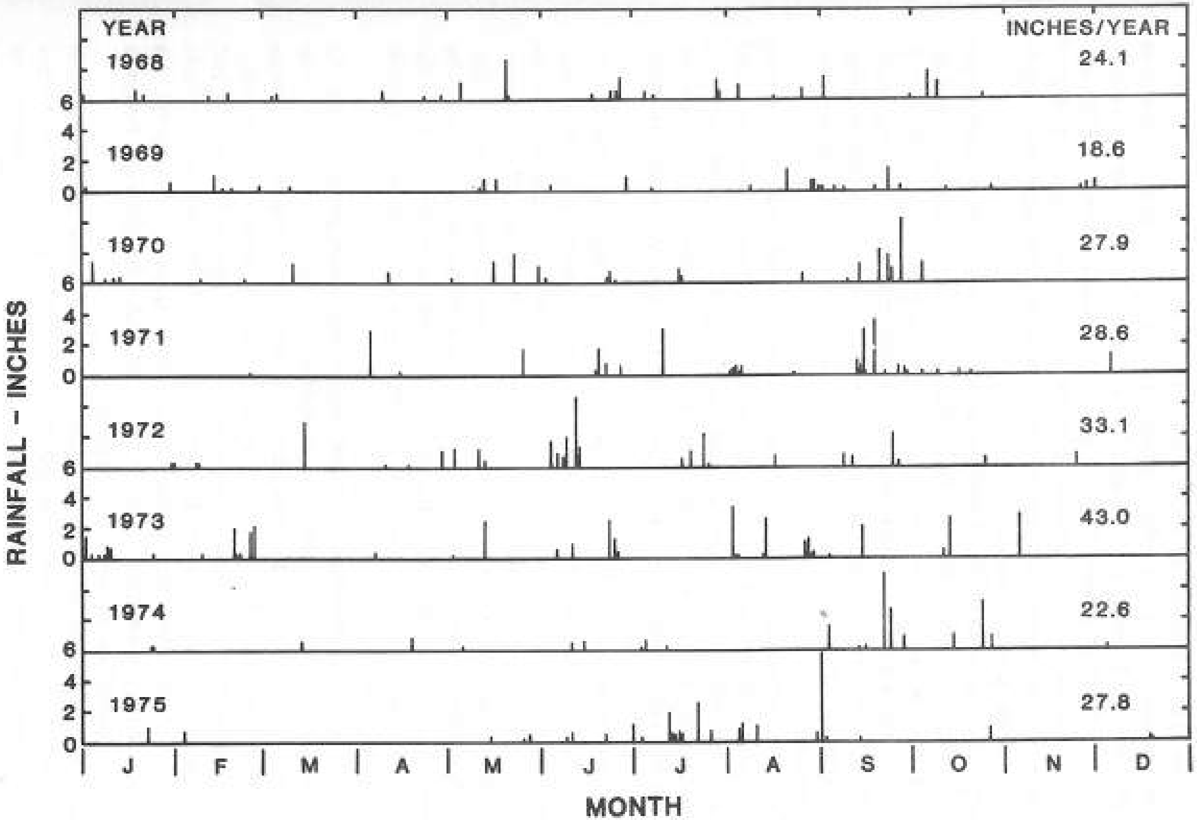

Fig. 2. Rainfall amount and distribution for the years 1968 through 1975. Amounts less than 0.2 inch/day not graphed.

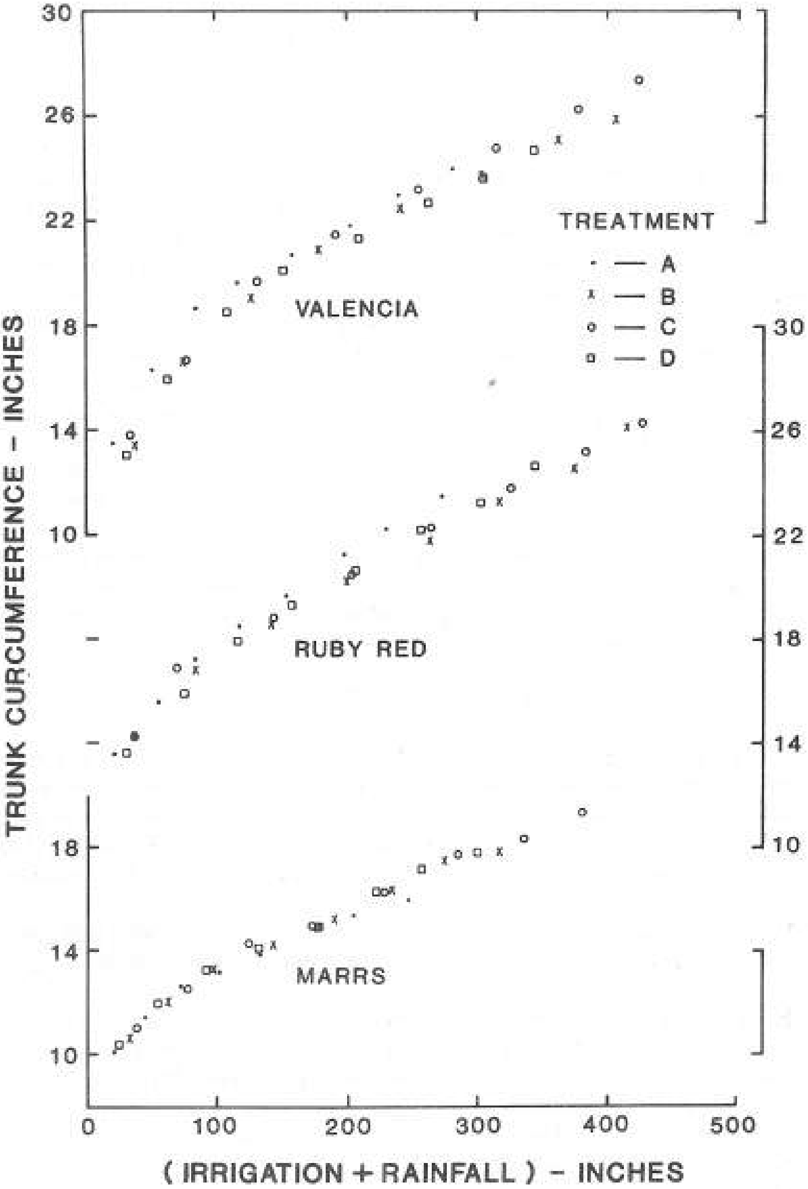

Fig. 3. Trunk circumference for the years 1968 through 1975 versus cumulative (irrigation + rainfall).

received 4.9 inches of water yielded 22.4 tons per acre whereas the other two averaged 32.3 tons per acre. Rainfall in Leyden's experiment was 24.0 and 34.4 inches in 1975 and 1976, respectively; at our test site 27.9 and 32.2 inches.

The data just cited illustrate the importance of rainfall in the irrigation water requirement in the Rio Grande Valley and the low water requirement (rainfall + the lowest irrigation amount that gives no yield increase). Defined this way the water requirement in 1975 for Leyden's experiment was 24.0 inches of rainfall plus 11.3 inches of irrigation water or 35.3 inches and in 1976 it was 34.4 inches rainfall plus 4.8 inches irrigation or 39.2 inches. For our studies the water requirement in 1975 would be undetermined because there were no yield differences associated with irrigation amounts used; in 1976 it would be 37.1 inches. Water requirements arrived at in this way are only approximate because water that drains below the root zone is not accounted for. This error is offset somewhat by upward flow of water from below the 3 ft root zone into it from below if depletion of as much as 80% of the water in the 3 ft-deep surface layer occurs. We estimated for treatment D that up to 15% of the water requirement per year could have been met by upward flow. This amount of upward flow would cause salt accumulation in the root zone if it continued; however, salt accumulation is not a problem on drained irrigated land in the Rio Grande Valley because periodic heavy rainfall leaches accumulated salts below the root zone.

Our data indicate that water use can be estimated at 0.15 inch in summer and 0.05 inch per day in winter and that midsummer irrigation intervals of 4 weeks for grapefruit and 5 weeks for oranges can be tolerated without affecting current or future year's production or fruit quality.

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Citrus Responses to Irrigation: II. Fruit Yield, Size, and Number

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ABSTRACT

Yield of fruit, fruit per tree, and average weight of fruit per tree data for Marrs and Valencia oranges and Ruby Red grapefruit were analyzed by variance and Duncan's multiple range procedures for annual and seven year responses to four irrigation regimes. Seven year average responses showed that irrigation treatment affected yield per acre of all three cultivars, did not affect number of fruit per tree for any cultivar, and affected weight per fruit of Valencia oranges and Ruby Red grapefruit. For oranges, a treatment (D) that permitted 80% depletion of plant-available water in the surface 3 ft of soil in summer and winter and 60% depletion in spring and fall yielded as high as the wettest treatment (C, 40% depletion year-around) but for grapefruit the two wetter treatments (C) and (B, 60% depletion year-around at irrigation) yielded 4 tons more per acre. Yield per acre and its two components, number of fruit per tree and weight per fruit, responded to irrigation treatments for all three cultivars only in 1974, a year in which little rain fell until late in the year. Yield component analysis showed that yields were mainly associated with the number of fruit per tree.

In part I of this series (8) we gave the irrigation treatments imposed on Marrs and Valencia oranges and Ruby Red grapefruit for a seven year period and presented the number of irrigations, irrigation water requirements and water use or evapotranspiration amounts observed and made irrigation management recommendations. In this paper, we summarize the yield of fruit (tons/acre), average number of fruit per tree, and fruit weight (lbs.) data. The yield data reported herein and tree growth responses (9) support the irrigation recommendations.

Leyden (4) found no statistically significant yield differences among Ruby Red grapefruit supplied in 1975 by drip irrigation with 11.3, 16.9, and 22.6 inches of water in addition to the 24 inches of rain that fell, and in 1976 there were no yield differences among trees that received 4.8, 7.9, 11.3, and 15.8 inches of water in addition to the 34.4 inches of rain that fell. In both years, the treatment that received no irrigations differed in yields from all those that received irrigations. Shmueli et al. (5) found in Israel that Shamouti orange yields tended to decline when >30 inches of water was applied but that no yield decrease was observed when 39.4 inches of water was applied to Marsh white grapefruit. In Arizona, twenty years of data showed that yields of Valencia oranges allowed to water stress from August to February, did not differ from the yields of trees that were not water stressed any time of the year (3). Stylianou (7) concluded that four irrigations of 5 inches each during the July to October dry season supplementing the 12 inches of rain from December to March, were adequate for Valencia orange production on Cyprus. Bielorai and Levy (1) reported that yields did not differ among grapefruit plantings irrigated on 18 to 30 day intervals, but that a 40 day irrigation interval decreased yields significantly.

MATERIALS AND METHODS

Cultural practices and the irrigation treatments maintained are described in the "Methods" of Part I of this series of papers. Briefly, the treatments were:

A, water depletion (WD) of 80% year-around at irrigation--WD80

B, water depletion (WD) of 60% year-around at irrigation--WD60

C, water depletion (WD) of 40% year-around at irrigation--WD40, and

D, for Marrs and Ruby Red grapefruit, water depletion of 80%, in winter (W, Nov. 15 - Feb. 14) and summer (S, May 15 - Aug. 14), and 60% in spring, (Sp, Feb. 15 - May 14) and fall (F, Aug. 15 - Nov. 14) -- WD 80W/60Sp/80S/60F. For Valencias, 80% depletion was permitted only in summer with 60% depletion of plant-available water in the surface 3 ft of soil the other quarters--WD 60W/60Sp/80S/60F.

The 80, 60, and 40% depletions required irrigations of 4.8, 3.6, and 2.4 inches, respectively, to return the surface 3 ft of sandy clay loam soil to field capacity.

The four yield trees of each of the three replications in each treatment were individually harvested and the fruit from each tree was weighed, sized, and counted. Marrs oranges were harvested in November in the year of bloom; Ruby Red grapefruit and Valencia oranges in January and March, respectively, of the year following bloom. However, growing seasons or experiment years are uniformly presented for all cultivars according to the year of bloom. Yields per acre are based on 132 trees per acre as provided by the tree spacing of 15 ft x 22 ft.

Analyses of variance (AOV) (6) were run on irrigation treatment effects for individual years and the average of all years. Duncan's (2) multiple range (DMR) tests of treatment mean differences were calculated when AOV results were significant at the 0.10 or greater probability level. The DMR differences were imposed at the same significance level as the AOV.

Temperatures were observed at an environmental station within 200 yards of the orchard throughout the study. A mild freeze occurred in mid-January 1973 during which air temperature was below 28°F for 2 hours; on December 21-22, 1973, air temperature was below 26°F for 6 hours; and in mid-January 1975, air temperature was below 26° for 4 hours the first night of a freeze and for 2 hours the second night.

RESULTS AND DISCUSSION

The fruit yields (tons/acre) versus time for the three cultivars studied for the years 1968 through 1975 are summarized in Fig. 1. The irrigation treatments were established early in 1968, but the trees were only four years old, so production was low for all cultivars. It took the grapefruit until 1969, the Valencia oranges until 1970, and the Marrs oranges until 1971 to achieve yields representative of mature trees. The grapefruit and Valencia oranges both produced their highest average yields, 27.9 and 15.9 tons per acre, respectively, in 1970. The freeze of December 1973 occurred following a warm period and was more

Table 1. Yield of fruit (tons per acre) for three cultivars and four moisture treatments for seven years.

Variety	Treatment	Year 1969	1970	1971	1972	1973	1974	1975	Seven year average
Marrs orange	A, WD80	9.0	12.0	16.1a[y]	15.5	12.4	10.1 b	17.4	13.21 bc
	B, WD60	8.9	10.3	11.2 b	17.4	14.0	12.8 b	17.2	13.12 c
	C, WD40	9.3	9.6	18.3a	16.2	13.9	18.0a	15.4	14.37a
	D, WD80W/60Sp/80S/60F	8.9	11.3	15.9a	18.5	13.4	12.2 b	19.5	14.24ab
	Variety average	9.0	10.8	15.4	16.9	13.4	13.3	17.4	13.73
	Signif. level[z]	NS	NS	.01	NS	NS	.05	NS	.05
Ruby Red grapefruit	A, WD80	23.7a	24.8 b	23.8	21.9	19.0	15.8 b	19.1	21.13 b
	B, WD60	22.0a	32.0a	27.0	24.7	22.9	24.5a	18.9	24.57a
	C, WD40	19.1 b	30.8a	29.3	24.6	20.7	21.2a	24.7	24.32a
	D, WD80W/60Sp/80S/60F	21.8ab	23.9 b	23.1	23.5	9.9	21.9a	17.4	20.22 b
	Variety average	21.6	27.9	25.8	23.7	18.1	20.8	20.0	22.56
	Signif. level	.10	.10	NS	NS	NS	.10	NS	.01
Valencia orange	A, WD80	5.5	16.1	14.5	14.5ab	12.3	10.6ab	11.6 b	12.17 b
	B, WD60	4.4	17.0	13.8	15.3ab	14.0	7.4 b	15.5a	12.47 b
	C, WD40	4.4	14.2	17.1	11.4 b	14.9	12.6ab	18.2a	13.25ab
	D, WD60W/60Sp/80S/60F	4.6	16.4	13.9	18.7a	11.8	15.2a	14.7ab	13.63a
	Variety average	4.7	15.9	14.8	15.0	13.3	11.5	15.0	12.88
	Signif. level	NS	NS	NS	.10	NS	.05	.05	.10

[z] For analysis of variance (AOV) of treatment (main) effects.

[y] Means not followed by the same arabic letter are different in Duncan multiple range test at the same significance level as in the AOV.

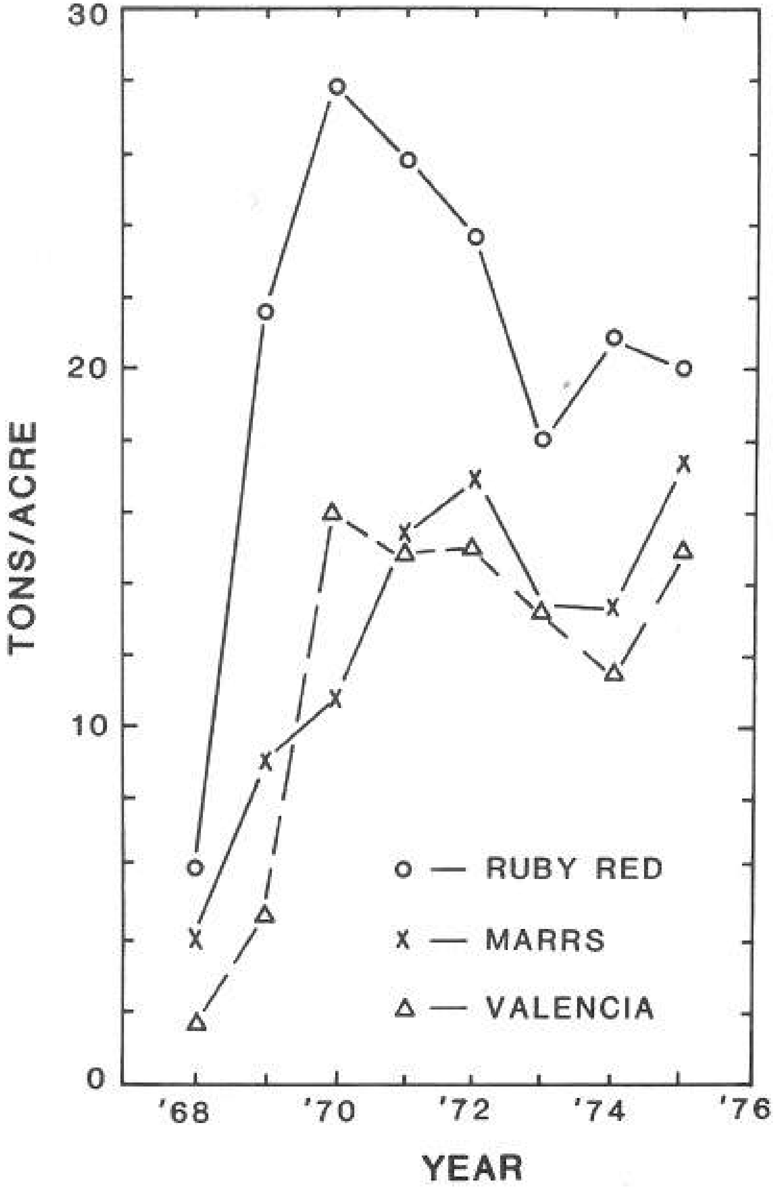

Fig. 1. Average yields of Marrs and Valencia oranges and Ruby Red grapefruit for the years 1968 through 1975.

damaging than that of January 1975 and probably contributed to the low yields in 1974. Field notes on bloom and tree condition fail to corroborate the low yields in 1973.

The average yield per treatment by years for each of the cultivars as well as the seven year treatment average is shown in Table 1. Significant yield responses to irrigation treatments were observed for Marrs oranges in 1971, 1974, and for the seven year average. Ruby Red grapefruit responded to irrigation treatment, but only at the 0.10 probability level in the individual years 1969, 1970, and 1974; the seven year average was significant at the 0.01 level. For the seven year average, treatments B and C yielded alike and significantly higher by almost 4 tons per acre than treatments A and D which yielded alike. The Valencia oranges differed at the 0.05 level in yield among treatments in 1974 and 1975; among years, treatment D had the highest yields and significantly higher than either treatment A or B, but not different from the 40% depletion treatment, C.

In 1973, highest and lowest yields among replicates of treatments A, C, and D differed by 10 to 12 tons per acre so that the low average yield of treatment D was significant at only the 0.13 probability level.

All cultivars responded to irrigation treatments in 1974. That was the only year in which less than 2.6 inches of rain fell in each of the first three quarters of the year. By contrast, in 1973 at least 6 inches of rain fell in each quarter of the year and there was no yield response to irrigation.

Over the seven year period, number of fruit per tree averaged 442 for Marrs, 341 for Ruby Red, and 409 for Valencia (Table 2). Again, 1974 was the only year in which number of fruit harvested was significantly affected by irrigation treatment in all cultivars. For Marrs, number of fruit per tree was affected in the same years, 1971 and 1974, that yield had been and the DMR tests show the same pattern of differences among treatments as yields did. Irrigation treatments had little effect on number of fruit per tree in grapefruit, but number of fruit was affected in 5 of 7 years in Valencia oranges. An alternate bearing pattern appears to have developed in treatment C of the Valencia oranges. In 1971, 1973, and 1975 fruiting was heavy (>500 per tree); in 1972 and 1974 fruiting was light (<380 per tree). Treatment D exhibited heavy fruiting in 1970, 1972, and 1974 (>500 per tree) but light fruiting (<380 per tree) in 1971 and 1973. Low yields of treatment D grapefruit in 1973 and treatment B Valencia oranges in 1974 resulted from the poor fruit set.

The seven year average number of fruit per tree was not significantly affected by irrigation treatment (main effect) in any cultivar. However, the treatment x year interaction was highly significant for all three cultivars indicating that fruit set was differentially affected in specific years.

Average fruit weight was significantly affected by moisture treatment in 1972 and 1975 for Marrs oranges, but the seven year average was not affected by treatment (Table 3). For Ruby Red grapefruit, irrigation treatment affected weight per fruit in four of the seven individual years and the seven year average. Seven year treatment average fruit weight was in the order C B A D with treatment C fruit at 1.06 lb per fruit differing in weight from treatment A (.99 lb per fruit) and D (.97 lb per fruit). The Valencia orange fruit weights were affected by treatments in four of the seven individual years and the seven year average weight was affected at the 0.01 probability level. Fruit of treatment B was heaviest at .50 lb per fruit and differed in weight from treatments A (.46 lb per

Table 2. Number of fruit per tree for three citrus cultivars and four moisture treatments for seven years.

Variety	Treatment	Year 1969	1970	1971	1972	1973	1973	1975	Seven year average
Marrs orange	A, WD80	273	366	576a[y]	623	354	309 b	568ab	438
	B, WD60	307	335	319 b	622	459	377 b	594ab	430
	C, WD40	301	282	631a	441	405	613a	468 b	449
	D, WD80W/60Sp/ 80S/60F	253	358	488a	641	389	356 b	674a	451
	Variety average	284	335	503	582	402	414	576	442
	Signif. level[z]	NS	NS	.05	NS	NS	.01	.05	NS
Ruby Red grapefruit	A, WD80	400a	348	340	397	304	192 b	334	331
	B, WD60	338ab	446	367	364	389	352a	285	363
	C, WD40	302 b	425	395	338	329	274ab	370	348
	D, WD80W/60Sp/ 80S/60F	363ab	334	346	425	152	347a	287	322
	Variety average	351	388	362	381	293	291	319	341
	Signif. level	.10	NS	NS	NS	NS	.05	NS	NS
Valencia orange	A, WD80	181	526	414 b	500a	468ab	344ab	368 b	400
	B, WD60	139	561	379 b	472ab	467ab	192 b	485ab	384
	C, WD40	140	447	539a	339 b	556a	378a	598a	428
	D, WD80W/60Sp/ 80S/60F	141	537	370 b	580a	379 b	514a	458 b	426
	Variety average	150	518	425	473	465	357	477	409
	Signif. level	NS	NS	.05	.10	.10	.05	.05	NS

z For analysis of variance (AOV) of treatment effects.

y Means not followed by the same arabic letter are different in Duncan multiple range test at the same significance level as in the AOV.

Table 3. Average weight per fruit for three citrus cultivars and four moisture treatments for seven years.

Variety	Treatment	Year 1969	1970	1971	1972	1973	1974	1975	Seven year average
		....			.lbs.			....	
Marrs orange	A, WD80	.50	.49	.43	.39 b[y]	.54	.50	.46ab	.47
	B, WD60	.46	.48	.53	.43 b	.47	.52	.44 b	.47
	C, WD40	.47	.52	.44	.56a	.52	.44	.50a	.49
	D, WD80W/60 Sp/ 80S/60F	.53	.48	.50	.44 b	.53	.52	.44 b	.49
	Average	.49	.49	.48	.45	.52	.49	.46	.48
	Signif. level[z]	NS	NS	NS	.05	NS	NS	.05	NS
Ruby Red grapefruit	A, WD80	.89 b	1.08	1.06	.84 b	.96	1.24a	.86 b	.99 b
	B, WD60	.99a	1.09	1.12	1.03a	.90	1.05 bc	1.01a	1.03ab
	C, WD40	.96ab	1.10	1.12	1.11a	.97	1.18ab	1.02a	1.06a
	D, WD80W/60Sp/ 80S/60F	.91 b	1.12	1.02	.84 b	1.03	.97 c	.93ab	.97 b
	Average	.94	1.10	1.08	.96	.96	1.11	.95	1.01
	Signif. level	.10	NS	NS	.05	NS	.10	.05	.01
Valencia orange	A, WD80	.46	.47	.53ab	.44 b	.40 b	.46 b	.48	.46 c
	B, WD60	.48	.46	.55a	.49a	.47a	.58a	.48	.50a
	C, WD40	.47	.48	.48 b	.51a	.41ab	.51 b	.46	.48 bc
	D, WD60W/60Sp/ 80S/60F	.50	.46	.57a	.49a	.47a	.45 b	.49	.49ab
	Average	.48	.47	.53	.48	.44	.50	.48	.48
	Signif. level	NS	NS	.01	.10	.05	.01	NS	.01

[z] For analysis of variance (AOV) of treatment effects.

[y] Means not followed by the same arabic letter are different in Duncan multiple range test at the same significance letter as in the AOV.

fruit) and C (.48 lb per fruit). However, for Valencias the average fruit weights appear to be confounded by the alternate bearing noted for treatments C and D.

The overall average weight of the Marrs and Valencia oranges for the duration of the study was the same, .48 lb per fruit. Evidently, these two cultivars produce about the same size fruit under the same conditions.

Irrigation affected yield per acre of all cultivars, did not affect number of fruit per tree for any cultivar, and affected average fruit weight of Ruby Red and Valencia oranges. However, because fruit weight did not vary greatly among treatments, within year yield disparity was closely associated with a change in number of fruit harvested. The fact that the seven year fruit weight of Valencia and Ruby Red responded to moisture treatments indicates that fruit size was more consistently affected by irrigation treatment than was number of fruit per tree.

To examine the relation between production per tree (lb) and the yield components, number of fruit per tree and weight per fruit (lb), we determined the linear correlation between the following variable pairs for the year 1974: lb fruit per tree (yield) vs. number of fruit per tree; yield vs average fruit size; and fruit per tree vs. fruit size. The individual tree data were used, so there were 48 observation pairs per cultivar. The year 1974 was chosen because it was a year of low rainfall in which moisture treatment effects were expressed.

The analyses are summarized in linear regression equations and coefficients of determination, r^2, presented in Table 4. It is evident that yield per tree is strongly dependent on number of fruit per tree; the r^2 ranged from 0.82** for Ruby Red grapefruit to 0.96** for Valencia orange. In contrast, weight per fruit contributed much less to yield per tree--r^2 ranged from 0.02 to 0.36**.

Table 4. Relationships between yield per tree and fruit per tree, yield per tree and weight per fruit, and between fruit weight and number of fruit per tree for three cultivars in 1974.

Cultivar	Depend. variable	Intercept		Coef.	Indep. variable	r^2
Marrs	Lbs fruit per tree	= 55.02	+	0.353	(fruit/tree)	0.862**
Ruby Red		= 72.02	+	0.835	(fruit/tree)	0.818**
Valencia		= 26.84	+	0.411	(fruit/tree)	0.958**
Marrs	Lbs fruit per tree	= 364.5	-	323.3	(lb/fruit)	0.092*
Ruby Red		= 411.4	-	86.2	(lb/fruit)	0.021
Valencia		= 519.5	-	680.2	(lb/fruit)	0.364**
Marrs	Lb/fruit	= 0.590	-	0.0002	(fruit/tree)	0.337**
Ruby Red		= 1.356	-	0.0008	(fruit/tree)	0.289**
Valencia		= 0.604	-	0.0003	(fruit/tree)	0.519**

For all three cultivars, fruit weight decreased significantly as number of fruit per tree increased (r^2 = 0.29** or 0.52**). However, the coefficients are very small so that fruit size could not offset a poor fruit set.

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Citrus Responses to Irrigation: III. Tree Trunk and Canopy Growth

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ABSTRACT

Trunk girth or circumference and ground cover by the tree canopies were measured annually from 1968 through 1975 in Marrs and Valencia orange and Ruby Red grapefruit plantings subjected to four irrigation treatments. Tree circumference and canopy cover at the end of the study were in the order Valencia orange ≫ Ruby Red grapefruit ≫ Marrs orange and were closely related to irrigation plus rainfall. Irrigation water application amount for the eight year period ranged from 24 inches for the driest treatment of Marrs orange to 205 inches for the wettest treatment of grapefruit. All trees received 226 inches of rainfall. The relation between ground cover and tree canopy diameter is given for the 15 x 22 ft tree spacing of the study and the maximum yields of all cultivars are shown to have occurred when trees touched in the row (55% ground cover). The data suggest that frequent irrigation of newly planted trees is desirable to achieve rapid tree sizing for high early production and that once light is effectively intercepted, less frequent irrigation would help control tree growth without affecting yields.

Citrus trees that are most frequently irrigated usually have the greatest increases in trunk girth or circumference (4, 5, 3, 9, 7, 1). Hilgeman and Sharp (3) noted that trunk growth closely reflected the total water applied and that cessation of trunk enlargement would be a good criterion of irrigation need.

Moderate water stress also reduces the size of the tree canopy compared with amply irrigated trees (3). The number of fruit per tree is usually not much affected by moderate water stress but fruit size is reduced (2, 3, 6, 7).

Both Hilgeman and Sharp (3) and Stylianou (9) noted that restricting water in the summer resulted in smaller, more compact trees with dense foliage.

The purpose of this paper is to present the trunk and canopy tree growth data obtained during a long term experiment in which Marrs and Valencia oranges and Ruby Red grapefruit were subjected to four different irrigation management treatments and to briefly discuss their irrigation management implications.

MATERIALS AND METHODS

The irrigation treatments were:
A, water depletion (WD) of 80% year-around at irrigation–WD80
B, water depletion of 60% year-around at irrigation–WD60
C, water depletion of 40% year-around at irrigation–WD40, and

D, for Marrs and Ruby Red grapefruit, water depletion of 80% in winter (W, Nov. 15 - Feb. 14) and summer (S, May 15 - Aug. 14), and 60% in spring (Sp, Feb. 15 - May 14) and fall (F, Aug. 15 - Nov. 14)--WD 80W/60Sp/80S/60F. For Valencias, 80% depletion was permitted only in summer with 60% depletion of plant-available water in the surface 3 ft of soil the other quarters--WD 60W/60Sp/80S/60F.

The 80, 60, and 40% depletions required irrigations of 4.8, 3.6, and 2.4 inches, respectively, to return the surface 3 ft of sandy clay loam soil to field capacity.

Trunk circumference was measured repetitively at a position 9 inches above the ground and well above the bud union, where a white line had been painted around the trunks. A tape graduated in cm and mm was used to make the measurements, and the measured girth was used as the circumference, even though some trees deviated from a circular growth habit. Circumference measurements were made in May, September and December each year. For this paper we used only the December measurements. The annual measurement in December is referred to as the "year end" circumference; the difference between successive December measurements gives the "yearly increase" in circumference. For example, the circumference difference between December 1969 and December 1968 is the yearly increase in trunk circumference in 1969.

Ground cover changes were recorded photographically. From 1967 through 1970 the photographs were taken in July or August from an aerial lift positioned over the four yield trees using a 35 mm camera with wide angle lens and Kodak Plus-X photographic film. For these photographs, the bottom of the aerial lift bucket was 48 ft above the ground surface and the ground area viewed was only slightly larger than the 30 ft x 44 ft occupied by the four yield trees.

After 1970 we relied on aerial photography of the research groves taken periodically during the summer. We chose the best available from the June through July period. Altitude of the photography ranged from 2000 to 3000 ft. The photography was obtained with a Zeiss 9-inch format camera in 1971 and 1975 and a 70 mm Hasselblad in 1972, 1973 and 1974 using various film types. In making print enlargements for determining ground area occupied by the trees, care was taken to maximize the contrast between the plant canopies and the shadows they cast.

The ground area (Ag) occupied by the 4 harvest trees (30 x 44 ft) within each treatment replication was cut from the prints and weighed on a balance with 1 mg sensitivity. Then the area occupied by only the trees (At) was cut from the print segments and weighed. The weight ratio (At/Ag) was multiplied by 100 to obtain percent ground area occupied by the trees.

Since the ground area occupied by each tree on a 15 x 22 ft spacing is 330 ft^2, then the ground area per tree, A_t, as a mean for the four trees was (330 ft^2) (% ground cover/100). Assuming a circular growth habit of the tree canopy we translated ground cover to diameter of the tree canopy, D, from the equation

$$D = 2\sqrt{A_t / \pi}$$

$$= 1.128 \sqrt{A_t}$$

Table 1. Trunk circumference (inches) for three cultivars and four irrigation treatments for eight years. Measurements were made in December of the calendar years shown and are referred to as year-end circumferences in the text.

Variety/ Treatment	1968	1969	1970	1971	1972	1973	1974	1975
	....	....	....	........Inches	....	....	....	....
Marrs								
A	10.2	11.5	12.6b[z]	13.2b	14.0b	15.0b	15.4b	16.0b
B	10.6	12.0	13.3b	14.2ab	15.1ab	16.3ab	17.4a	17.9a
C	11.0	12.5	14.3a	15.0a	16.3a	17.7a	18.3a	19.3a
D	10.4	12.0	13.3b	14.1ab	15.0ab	16.3ab	17.1ab	17.8a
Avg.	10.6	12.0	13.4	14.1	15.1	16.4	17.1	17.7
Sig. level	NS	NS	.05	.05	.05	.10	.10	.10
Ruby Red								
A	13.6	15.6b	17.2b	18.5b	19.6b	21.1b	22.2b	23.5b
B	14.2	16.8a	18.6a	20.2a	21.8a	23.3a	24.5a	26.1a
C	14.1	16.9a	18.9a	20.5a	22.3a	23.8a	25.2a	26.4a
D	13.6	16.0b	18.0ab	19.3ab	20.6ab	22.2ab	23.3ab	24.6ab
Avg.	13.9	16.3	18.2	19.6	21.1	22.6	23.8	25.2
Sig. level	NS	.10	.10	.10	.05	.05	.05	.05
Valencia								
A	13.5	16.3	18.6	19.6c	20.7c	21.9c	32.0b	24.0b
B	13.5	16.5	19.0	20.9ab	22.4ab	23.5ab	26.0ab	25.8ab
C	13.8	16.9	19.7	21.5a	23.2a	24.8a	26.3a	27.4a
D	13.1	16.0	18.5	20.1bc	21.4bc	22.7bc	23.6b	24.7b
Avg.	13.5	16.4	19.0	20.5	21.9	23.3	24.5	25.5
Sig. level	NS	NS	NS	.10	.05	.05	.01	.05

z Means in columns separated by Duncan's MRT at the AOV significance levels noted at the bottom of each varieties' column.

The relationship between ground cover and tree canopy diameter is shown in Fig. 3.

Analyses of variance, AOV, and Duncan's multiple range tests, MRT (8) were determined on irrigation treatment main effects for individual years and for their effect over the duration of the study.

RESULTS AND DISCUSSION

Trunk circumference did not differ at the 0.05 level among irrigation treatments for any cultivar until 1970, the third year after the irrigation differentials were established and maintained (Table 1). Significance levels generally increase with duration of the study for Ruby Red and Valencia oranges indicating a cumulative effect of irrigation treatment on tree circumference. Grapefruit trees had larger trunk circumference than the Valencia oranges until 1969. Since then the Valencia orange trees have outgrown the grapefruit trees. Marrs orange trees have grown much more slowly than the other two cultivars.

Table 2. Seven-year average year-end trunk circumference and yearly increase in circumference by irrigation treatments[z] and cultivars.

Marrs	Ruby Red	Valencia
Year-end Trunk Circumferences, inches, 7-year average		
C 16.2 a[y]	C 22.0 a	C 22.8 a
B 15.2 b	B 21.6 a	B 21.9 b
D 15.1 b	D 20.6 b	D 21.0 c
A 14.0 c	A 19.7 c	A 20.6 c
Avg. Yearly Increase in Circumference, inches, 7-year average		
C 1,19 a	C 1.76 a	C 1.94 a
D 1.05 a	B 1.70 ab	B 1.75 b
B 1.03 ab	D 1.57 b	D 1.66 b
A .84 b	A 1.41 c	A 1.50 c

[z] Capital letters designate irrigation treatments.
[y] Means followed by the same letter in vertical columns are not different from each other at $p = 0.01$.

Whereas the trunk circumferences in Table 1 did not differ statistically, for any cultivar until 1970, there is significance for annual trunk increase for Valencia orange and Ruby Red grapefruit in 1969, and for Valencia and Marrs oranges in 1970 (Fig. 1). By 1971, the annual rate of trunk circumference increase had stabilized at approximately 1.5 inches per year for the Valencia oranges and Ruby Red grapefruit and at about 1 inch per year for the Marrs oranges. Irrigation treatments B and C did not stress the trees but treatments A and D did slow growth of the trees unless rain fell. In 1973, a very wet year with rains well distributed throughout the year, the annual increase in trunk circumference of treatment A and D trees was not different from that of treatments B and C. In contrast, 1974, a year of light rainfall the first 2/3 of the year there were statistical differences among treatments in growth of the Valencia

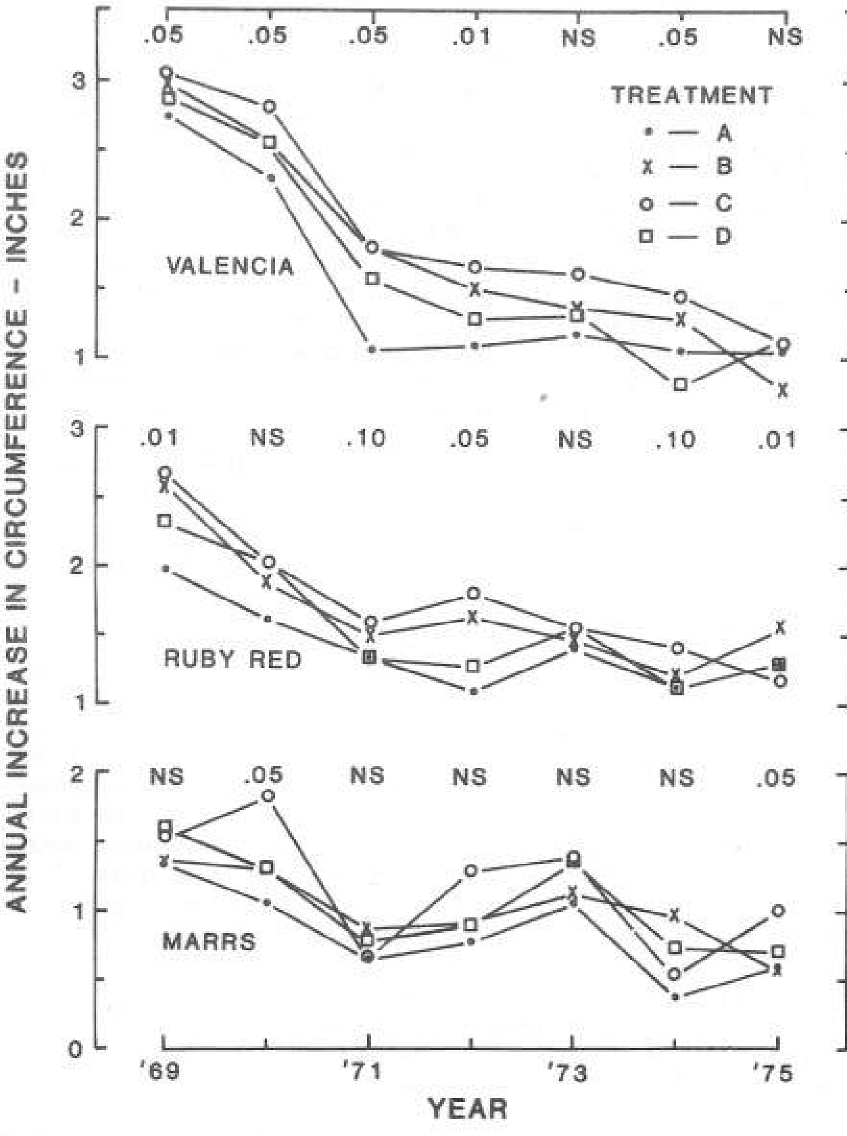

Fig. 1. Annual increase in trunk circumference (inches) for three cultivars and four irrigation treatments for the years 1969 through 1975.

oranges. There are some inconsistencies in the data because of the sensitivity of the annual increases to small errors in measurement of trunk circumference or to tree growth spurts. For treatment C of the Marrs oranges, a trunk enlargement of 1.85 inches in 1970 is followed by a growth of only 0.7 inches, whereas a growth of 0.55 inches in 1974 is followed by a growth of 1.0 inch in 1975–indicating the measured trunk circumference was a little high in 1970 and low in 1974 (Fig. 1); the cumulative growth curves plotted from the data of Table 1 are much smoother than the graphs of yearly increases.

The 7-year average year-end trunk circumferences and yearly increase in trunk circumference data in Table 2 show that irrigation treatment C (40% depletion of the plant-available water in the surface 3 ft of soil year-around at irrigation) had the largest trunks and annual increases in trunk circumferences for all cultivars and that treatment A (80% depletion of soil water in the surface 3 ft year-around at irrigation) had the lowest. The intermediate irrigation treatments, treatment B (60% depletion of plant-available water at irrigation year-around) and treatment D (80% depletion summer and winter and 60% depletion spring and fall) produced tree growth intermediate between treatments C and A.

Except for the yearly increase in circumference of Marrs orange trees, the Duncan multiple range tests in Table 2 generally show that: the growth of treatment C trees was significantly greater than that of treatment A and D trees, but frequently overlapped with treatment B; treatment A trees responded differently from all other treatments, or overlapped with treatment D; and, sometimes the growth response of treatments B and D were similar and differed from the responses of either treatment A or C.

In Fig. 2, the relation between trunk circumference and cumulative inches of irrigation water applied during the eight year period, 1968 through 1975, is presented for each cultivar and irrigation treatment. The data show a much wider spread in irrigation water applied--from a low of 24 inches for treatment A Marrs oranges to 205 inches for treatment C Ruby Red grapefruit--than in trunk circumference, which ranged in 1975 from 16 inches for the treatment A Marrs oranges to 27.4 inches for treatment C Valencia oranges. One reason is that the trees also received a total of 226 inches of rainfall over the 8-year period. Most of the growth of treatment A trees of all cultivars was due to rainfall received since the most irrigation water any cultivar of this treatment received was 60 inches. Cumulative trunk circumference was shown to be a nearly linear function of cumulative irrigation plus rainfall (10).

The amount of irrigation water applied to treatments B and C and the trunk enlargement of the Valencia oranges and the Ruby Red grapefruit closely paralleled each other. The longer interval between irrigations of treatment B than of treatment C was offset by larger water application on irrigation of treatment B (10) so that amount of irrigation water applied differed little between the two treatments. Trunk measurements also differed little (Table 1).

The Valencia orange trees overtook the grapefruit trees in trunk circumference in 1969 but the Valencia tree canopies took until 1972 to overtake the grapefruit in ground cover (Table 3). This was due to the slightly more spreading growth habit of the grapefruit trees compared with the Valencia orange trees.

The poorest quality ground cover data were for the years 1971, 1972, and 1974 because of low contrast between the canopy and shadows when the small

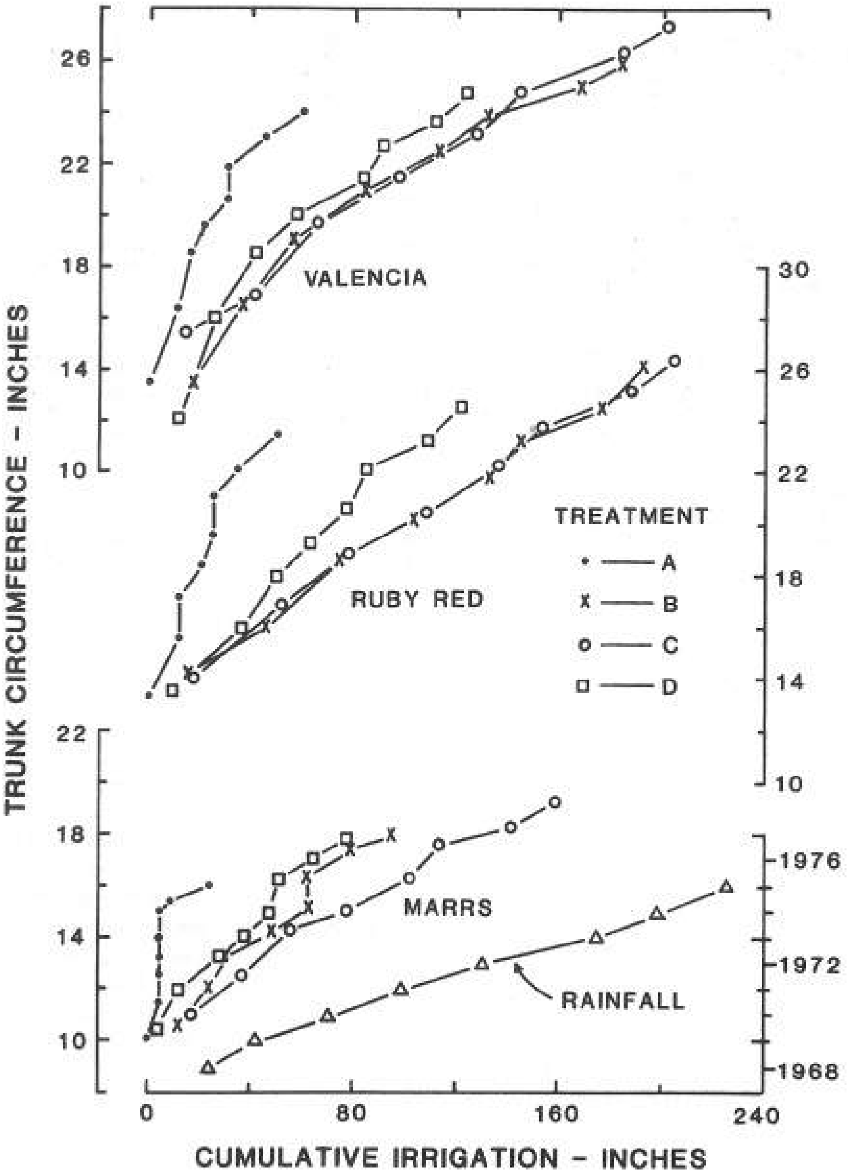

Fig. 2. Trunk circumference for the years 1968 through 1975 versus cumulative irrigation water applied.

Table 3. Percent ground cover for three cultivars and four moisture treatments for the years 1967 through 1975.

Variety/ Treatment	1967 Jul	1968 Aug	1969 Aug	1970 Aug	1971 Jun	1972 Jun	1973 Jul	1974 Jun	1975 Jul
	percent								
Marrs									
A	9.1	15.9	19.8	25.0	25.5	29.9	33.0b[z]	29.6b	41.9
B	9.9	14.8	21.5	27.5	30.4	30.7	38.9ab	41.2a	48.2
C	10.9	17.2	24.2	31.1	30.6	32.3	44.8a	41.1a	53.4
D	10.2	15.4	23.5	28.7	31.0	30.4	40.5a	35.2ab	49.8
Avg.	10.0	15.8	22.3	28.1	29.4	30.8	39.3	37.0	48.3
Sig. level	NS	NS	NS	NS	NS	NS	.05	.10	NS
Ruby Red									
A	14.1	28.7	35.3b	43.8b	47.6b	48.8c	60.6b	66.2b	72.3b
B	14.3	30.3	42.3a	55.5a	60.0a	58.3ab	68.4ab	73.2ab	78.0ab
C	14.0	28.3	39.8a	55.1a	64.5a	61.6a	76.4a	77.8a	86.6a
D	13.6	29.2	38.1ab	48.8ab	54.8ab	52.8bc	60.2b	67.1b	71.4b
Avg.	14.0	29.1	38.9	50.8	56.7	55.4	66.4	71.1	77.1
Sig. level	NS	NS	.10	.01	.01	.05	.05	.10	.01
Valencia									
A	9.7	22.4	34.4	43.2	50.8	54.4	62.6b	64.8b	77.0b
B	10.3	20.7	35.8	47.7	55.8	60.9	70.2a	75.0a	86.8a
C	10.6	20.7	34.7	46.1	56.3	55.5	73.2a	76.4a	86.4a
D	10.4	20.8	35.4	44.9	51.8	54.0	66.5ab	70.8ab	79.9b
Avg.	10.3	21.1	35.1	45.5	53.7	56.2	68.1	71.8	83.3
Sig. level	NS	NS	NS	NS	NS	NS	.10	.05	.05

[z] Means in columns separated by Duncan's MRT at the AOV significance levels noted at the bottom of each column.

scale aerial photography was enlarged. However, the shadows were minimized by the high sun angle in June and the acquisition of the photography during midday.

The analyses of variance in Table 3 give results reminiscent of the trunk circumference data of Table 1 in that the frequency and level of significance increase with time--because ground cover by the tree canopies is cumulative and growth is responding to irrigation treatments. The driest treatment, A, differed statistically from the wettest treatment, C, by 1969 for grapefruit, and by 1973 for both Marrs and Valencia oranges. The Duncan MRT also indicate that treatments B and C as a pair and treatments A and D as a pair never differed significantly for any of the cultivars. For all cultivars, the driest treatment, A (80% depletion of plant-available water in the surface 3 ft of soil before irrigation year-around) had the slowest rate of ground cover.

In Fig. 3 tree canopy diameter (ft) is related to canopy ground cover (percent) for trees spaced 15 x 22 ft. At 55% ground cover, the foliage of adjacent trees planted 15 ft apart in the east-west rows would start touching. This occurred in 1970 for treatments B and C of the Ruby Red grapefruit, in 1971 for treatments B and C of the Valencia oranges, and had not yet occurred in 1975 for

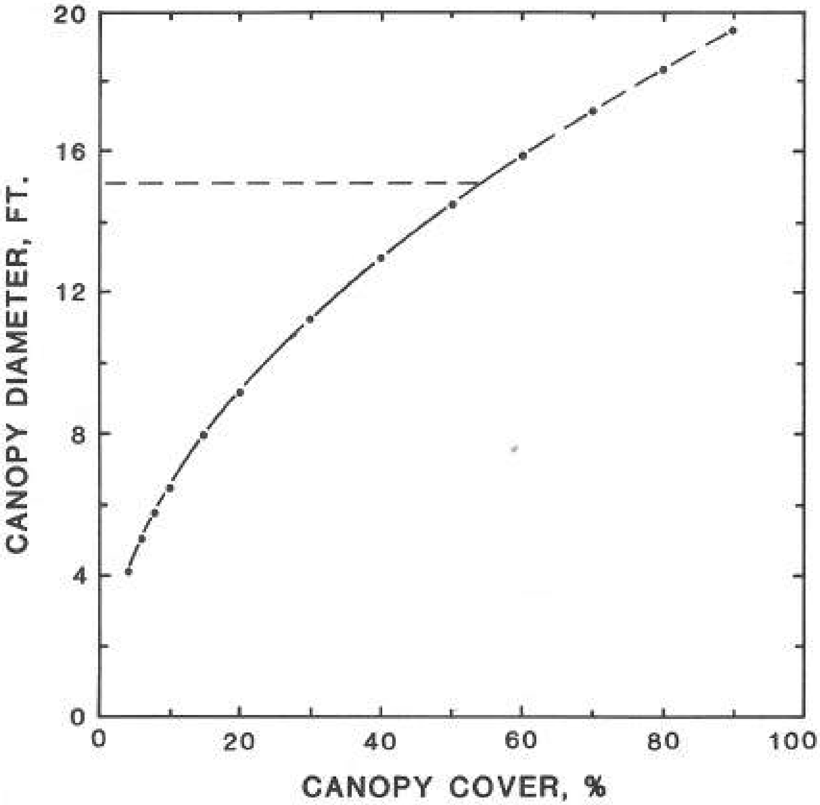

Fig. 3. Relation between ground cover by trees and diameter of individual tree canopies for 15 x 22 ft tree spacing. The solution graphed is exact only until 55% ground cover when trees begin touching in the row.

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the Marrs oranges. The ground cover percentages in Fig. 3 hold strictly only until the trees begin touching. A ground cover of 70% corresponds to a calculated tree diameter of 17 ft indicating that branches of adjacent trees would be protruding into each other about 2 ft. By then, the individual tree rows have formed hedge rows.

The intertree competition for light that occurs when foliage begins overlapping helps explain qualitatively why yields of grapefruit and Valencia oranges from these groves has leveled off since 1970 when highest yields occurred, although conditions that year were also obviously conducive to a large fruit set. Since then there has been increasing overlap of tree canopies on their east and west sides. The highest yields of Marrs oranges occurred in 1975 when average ground cover across irrigation treatments was 48%, corresponding to an average canopy diameter of 14 ft (11).

Trunk circumference and ground cover data show that the more irrigation water applied, the faster the trees grew. This indicates the desirability of frequent irrigations to achieve rapid ground cover and heavy bearing trees of a young age. The trees of this study were transplanted to the grove in 1964 and the Ruby Red grapefruit and Valencia oranges produced their highest yields in 1970. The wetter two treatments in the grapefruit continued to be the heavier producers through 1973; the picture is not as clear for the Valencias because an alternate bearing pattern that clearly developed by 1971 in some treatments (11) may actually have begun in 1970. It took the Marrs oranges until 1975 to achieve the tree size the Valencia oranges and Ruby Red grapefruit had five years earlier, but the 17.4 tons per acre yield of the Marrs in 1975 is greater than those of the Valencias in 1970 (15.9 tons per acre) or 1975 (15.0 tons per acre). The small tree size of the Marrs oranges suggests that a spacing of 11 or 12 ft between rows and trees in the row (360 and 302 trees/acre, respectively) is feasible for this cultivar--as opposed to the 132 trees per acre in this study--provided there is no root depth restricting zone in the soil profile and wider row spacing every several rows is provided for long term access for cultural operations. The closer tree spacing should give a concomitant increase in tonnage of oranges produced per acre for at least the first 5 years of bearing.

The tree growth data also suggest that once an adequate tree size for efficient light interception is achieved for the planting configuration used, then the frequency of irrigation might be reduced in order to help control tree growth that is not associated with an increase in yield.

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Marrs, Valencia and Ruby Red Juice Quality as Affected by Irrigation Plus Rainfall

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ABSTRACT

Soluble solids, citric acid, suspended solids, pH, and naringin (grapefruit) of Marrs and Valencia oranges and Ruby Red grapefruit were related to water use or evapotranspiration (ET) and to the ratio of evapotranspiration to potential evapotranspiration (ET/PET) by quarterly periods for the crop years 1969 through 1975. Evapotranspiration was defined as irrigation water applied + rainfall-drainage + root zone water depletion between the beginning and ending dates for each quarter. Potential evapotranspiration was calculated from weather data.

Wetter soil conditions provided by rainfall or irrigation plus rainfall (larger ET and ET/PET) lowered the measured juice quality characteristics, except pH, in every quarter of the year. For Marrs oranges, ET or ET/PET during the winter quarter preceding bloom was most closely associated with reduced citric acid and percent suspended solids whereas ET and ET/PET during the summer and fall quarters reduced soluble solids more than at other times of the year. For Valencias, water conditions during the winter quarter preceding bloom most influenced °brix; during the fall quarter they most influenced citric acid, suspended solids, and pH; and, during the winter quarter of harvest they mainly affected juice yield. For grapefruit, water conditions during the summer quarter had the greatest effect on soluble solids, whereas wet soil conditions during the fall quarter reduced citric acid, suspended solids, pH, and naringin more than during other quarters of the year.

Citric acid concentration was the only juice characteristic for which half or more of the variation was accounted for by water conditions. Generally, water conditions during the fall quarter preceding harvest had the strongest effect on the juice characteristics of Valencia orange and Ruby Red grapefruit. ET/PET, a measure of relative water stress, was more closely related to juice quality than was ET. The juice quality of Ruby Red grapefruit was more responsive to soil water conditions than that of either orange cultivar.

The minimum water requirement (rainfall plus irrigation) for citrus production in the Lower Rio Grande Valley is approximately 100 cm (2, 8). About half the requirement is met by rainfall; average rainfall for the 30-year period, 1931-1960, is 59 cm for Weslaco and 49 cm for Mission (16). However, rainfall is unique in annual distribution and amount each year. In analyzing irrigation management studies by analysis of variance (AOV), rainfall is uncontrolled variation superimposed on the irrigation treatments.

Cruse et al. (5) reported and interpreted the within and among years analyses of variance of juice characteristics (juice yield, soluble solids, citric acid, suspended solids, ascorbic acid or vitamin C, pH, and naringin content (grapefruit only) for each of three cultivars (Marrs and Valencia oranges, Ruby Red grapefruit) subjected to four irrigation management regimes for a seven year period.

Juice yield and vitamin C did not respond to irrigation treatments, but the among years AOV showed significant reductions in percentages of soluble solids (°brix), citric acid, and suspended solids with increasing irrigation frequency for all cultivars.

The purpose of this paper is to reanalyze those juice quality data, except juice yield and vitamin C, taking rainfall's contribution to the citrus water requirement directly into account.

Previous workers found that increasing irrigation frequency or amount decreased soluble solids, citric and ascorbic acid or vitamin C, and titratable acidity (13) in juice from Valencia orange, Shamouti orange, and Marsh grapefruit (9, 10, 13). Results can also be affected by soil type (1), fertilization (12), application of insecticidal oils (7), and maturity of the fruit at harvest (3, 4).

MATERIALS AND METHODS

The grove was planted in 1964 on the Valley Soil and Water Conservation Districts' Research Farm 4 miles north of Weslaco. The soil is a Hidalgo sandy clay loam (Typic Calciustolls). The grove incorporated a randomized block design of 4 treatments with 3 replications for each of the cultivars, Marrs (15) and Valencia oranges (Citrus sinensis (L.) Osbeck) and Ruby Red grapefruit (Citrus paradisi Macf.). Tree spacing was 4.6 x 6.7 m (15 x 22 ft). Replications were blocks of 16 trees of which the 4 interior trees were harvested and the rest served as buffer trees. Fertilization was at the rate of 0.68 kg (1.5 lb) N per tree applied in either January or February each year. Diuron, bromacil + diuron, simazine, and MSMA + sodium cacodylate plus hoeing were used for weed control. Azinphosmethyl, carbaryl, carbophenothion, chlorobenzilate, dicofol, ethion, formetanate hydrochloride, phosalone, spray oil and zineb were used at various times for insect and mite control, while copper hydroxide was used for melanose control.

The treatments are summarized in Table 1. Metered irrigation water applications were 12, 9, and 6 cm depth of water per irrigation for the 80, 60, and 40% depletion treatments, respectively. Records of rainfall were obtained at a Class A weather station within 200 m of the grove. Table 2 presents the rainfall recorded by winter, spring, summer, and fall quarters, and as an annual total. Subsurface drain lines at the 2 m depth provided a well-drained and aerated root zone.

Soil water content for determining depletion was measured weekly by neutron scattering (19) and amount of water in the surface 90 cm of soil was graphed versus time to display each drying cycle per treatment. When rain fell, the amount in excess of that required to fill the 90 cm root zone to field capacity was assigned to drainage. The water use or actual evapotranspiration (ET) was determined by quarterly periods from:

(irrigation - leaching requirement) + (rainfall - drainage) +
(difference in amount of water in the 90 cm deep root zone at
the beginning and end of the quarter)

where all amounts are in cm. Because periodic heavy rainfall takes care of the leaching requirement locally, we did not overirrigate for leaching and this term was zero.

Table 1. Explanation of irrigation treatments applied to three citrus cultivars.

Cultivars	Treatment	PAWD[z] surface 90 cm of soil	Time of Year	Water applied per irrigation
		(%) (%)		(cm)
All	A	80	Throughout	12
All	B	60	Throughout	9
All	C	40	Throughout	6
Marrs and Ruby Red	D	80	Nov. 15 - Feb. 14 (W)[y]	12
			May 15 - Aug. 14 (Su)	12
		60	Aug. 15 - Nov. 14 (F)	9
			Feb. 15 - May 14 (Sp)	9
Valencia		80	May 15 - Aug. 14	12
		60	Nov. 15 - Feb. 14	9
			Feb. 15 - May 14	9
			Aug. 15 - Nov. 14	9

[z] Plant-available water depletion based on water retention at 15 and 1/3 bar on a pressure plate.

[y] Quarterly periods are called Winter, Summer, Fall, and Spring, respectively.

Daily potential evapotranspiration (PET), the amount that crops that completely cover the ground would evapotranspire if freely supplied with water, was also calculated from the equation (11, 18):

$$PET = 0.0112\ (Tm - 20)\ Rs$$

wherein Tm is the mean daily temperature (°F), and Rs is daily solar radiation expressed as equivalent depth of water evaporated (Langleys day^{-1}/580 Langleys cm^{-1}). The daily PET values were summed for the number of days in the quarter to obtain quarterly amounts. The ratio of actual to potential evapotranspiration (ET/PET) is a relative water stress index. The index value ranged from 1.0 when there is no stress to 0.4 or lower under extreme drought. Over a quarterly period including one or more drying cycles, its value would be expected to be intermediate between 0.4 and 1.0.

Because the prebloom and fall irrigations of treatment D began Feb. 15 and Aug. 15 (Table 1), respectively, this treatment determined the beginning and ending dates of the quarters into which the year was divided. The quarters are described and defined in Table 3. All cultivars typically bloomed in March. Marrs oranges were harvested the second week in November of the year in which they bloomed, grapefruit the first or second week of January, and Valencia oranges the second or third week in March of the calendar year following bloom. Therefore, the grapefruit and Valencia orange juice quality data for a given crop season were related to ET and (ET/PET) for five quarters--from the winter quarter

Table 2. Quarterly and annual rainfall, in cm, for seven years. The years begin November 15 and end November 14.

Crop year[z]	Nov.15-Feb.14 (Winter)	Feb.15-May14 (Spring)	May15-Aug.14 (Summer)	Aug.15-Nov.14 (Fall)	Annual total
	.... cm.				
1969	6.0	8.6	7.3	21.3	43.8
1970	11.7	8.5	20.6	33.9	74.7
1971	0.8	10.1	26.9	31.0	68.8
1972	7.6	21.1	41.5	14.9	85.1
1973	16.0	26.8	36.6	32.5	111.9
1974	3.0	5.6	6.5	41.2	56.3
1975	6.8	1.1	39.2	23.4	70.5

[z] Based on the calendar year in which bloom occurred.

of or preceding bloom through the winter quarter of or preceding harvest (Table 3). The water use data for the winter quarter of harvest, Q5, for one crop year was also the prebloom winter quarter, Q1, water use data for the next crop year's juice characteristics.

The juice characteristic data were analyzed by multiple step-wise linear regression procedures according to the model:

juice quality parameters = a_o + b(Q1) + c(Q2) + d(Q3) + e(Q4) + f(Q5)

where the juice quality parameter was, in turn, °brix, citric acid, suspended solids, pH and naringin (grapefruit only) and Q1. . . Q5 represent either (ET) or (ET/PET) for the quarterly periods defined in Table 3. Since there were 7 years of data and 4 treatments there were 28 observations per analysis within each cultivar.

The first fruit harvest utilized was in 1969. All fruit in the blocks being harvested were picked "clean the tree" and passed through a mechanical sizer and fruit counter. Size of oranges analyzed for juice quality was 200-125 (7.8 to 9.0 cm diamter) and for grapefruit it was 70-54 (11.0 to 12.1 cm diameter). Sixty fruit in each treatment replication were randomly chosen for analysis. Some 15 to 20 fruit of each variety were taken for priming the extractor.

Fruit were washed on a set of motor-driven brush rolls and drain-dried. Samples were weighed and juice extracted in an FMC Model 091 B in-line state test extractor. Sucrose equivalent sugar in degrees brix, referred to as soluble solids was determined with a Bausch & Lomb Abbe 3-L refractometer and corrected to 20°C. Citric acid was determined by titration with standardized sodium hydroxide solution to pH 8.2-8.3 as indicated by a Corning Model 7 pH meter and reported as precent anhydrous citric acid. pH of the juice was determined with the same meter.

Pulp (suspended solids) was determined by centrifuging 50 ml of well-agitated, deaerated juice in an International Centrifuge size 1, type 5B at

Table 3. Definition of quarterly periods by which rainfall and water use data were summarized.

Water use periods (Quarters)	Definition	Quarters used by cultivar Marrs	Valencia	Ruby Red
Nov. 15 - Feb. 14	Winter of bloom, Q1	Q1	Q1	Q1
Feb. 15 - May 14	Spring, Q2	Q2	Q2	Q2
May 15 - Aug. 14	Summer, Q3	Q3	Q3	Q3
Aug. 15 - Nov. 14	Fall, Q4	Q4	Q4	Q4
Nov. 15 - Feb. 14	Winter of harvest, Q5		Q5	Q5

1300 rpm for 10 minutes. The solids reading obtained was doubled and reported as a percent by volume. Juice yields were obtained by weighing the whole fruit sample prior to extraction, allowing the extractor manifold to drain for 70 seconds, weighing the juice in a tared container, dividing the net juice weight by the net sample weight and reporting the result as a percent. Naringin was run by the Davis test (6) and reported as parts per million (ppm).

RESULTS AND DISCUSSION

Rainfall received by quarterly and annual peiods for each of the seven crop years of the study is summarized in Table 2. The wettest year was 1973; rainfall totaled 112 cm and was well distributed in all four quarters. The next wettest year was 1972 but most of the rain fell in the spring and summer quarters. In 1974 the first three quarters were dry but excessive rain fell in the fall.

The average evapotranspiration (Table 4) for the four irrigation treatments for the seven year period was 86 cm for the Marrs oranges, 107 cm for the Valencia oranges, and 105 cm for the Ruby Red grapefruit. Valencia and Ruby Red trees were about equal in ground cover and considerably larger than Marrs orange trees. Water use (Table 4) was higher than average during quarters of heavy rainfall because water was readily available for evaporation directly from the soil surface as well as for transpiration in all treaments. The coefficients of variation (c.v.) of quarterly and yearly means of four irrigation treatments (Table 4) show that the biggest disparity in water use among years, relative to the mean value, occurs in the winter quarter (c.v.=35%) and that water use is most similar in the fall (c.v.=17%) when rainfall usually contributes much of the citrus water requirement.

The ET values are similar among cultivars in 1975 because that year we switched from scheduling irrigations on the basis of neutron scattering determinations to scheduling based on the Jensen-Haise method (11, 18) which utilizes a time-of-year dependent crop coefficient and weather data. The same crop coefficient was used for all three cultivars. Because the Marrs orange trees covered less of the ground than the other two cultivars (20), a different crop coefficient would have been appropriate for this cultivar. Also, Nixon and Smith

(14) reported that the Jensen-Haise procedure used underestimates PET by about 20% from October through April for south Texas; this error contributes to the low annual total in 1975.

The linear correlation coefficients, r, between water use (ET) by quarterly periods and soluble solids, citric acid, suspended solids, pH and naringin of the juice at harvest of Marrs and Valencia oranges and Ruby Red grapefruit are given in Table 5. Similar analyses but for actual to potential evapotranspiration ratio (ET/PET) versus these same parameters of juice quality are presented in Table 6.

Winter of bloom water conditions correlated negatively with the citric acid and suspended solids content of Marrs orange juice, whereas wetter summer water conditions reduced soluble solids (Tables 5 and 6). For Valencia oranges, ET each quarter correlated negatively with citric acid content but ET/PET related to citric acid only for the summer and fall quarters. ET/PET in fall was also negatively correlated with suspended solids and pH. Winter of bloom ET/PET correlated negatively with soluble solids.

For Ruby Red grapefruit both ET and ET/PET each quarter affected citric acid but the relation was strongest for the fall quarter (r=-.793 for ET and -.854 for ET/PET); citric acid decreased in every case as wetter conditions were provided by rainfall, or by irrigation plus rainfall. Soluble solids also decreased as wetter soil conditions were provided--as indicated by larger ET or ET/PET--during summer fall, or winter of harvest. Suspended solids were significantly decreased by wetter fall conditions. Naringin content of grapefruit juice was negatively correlated with spring and fall ET and with summer ET/PET.

In the above findings, the correlations are negative between soil water availability, as expressed by ET or ET/PET, and all the juice quality characteristics measured except pH. Oranges are generally recognized as more drought tolerant than grapefruit. The lower frequency of occurrence of significant correlations for oranges than grapefruit in Tables 5 and 6 support this observation. The linear correlation coefficients, although statistically significant, are generally low except for citric acid. This indicates that citric acid content is closely associated with availability of water to the trees. Most of the variation in the other juice characteristics is due to unconsidered factors; the quarterly time period of data summarization is inappropriate; or the influential factors are not closely associated with soil water conditions. Within years analyses would help remove the year to year variation, but there was an insufficient number of observations within years for meaningful analysis. The low coefficients of variation (Table 5) show that soluble solids, citric acid, suspended solids, and pH were stable across the seven year period; consequently there is little variation to explain. Naringin content of grapefruit does have a large coefficient of variation (34%).

The multiple regression equations, relating juice quality to evapotranspiration (ET) and to the ratio of actual to potential evapotranspiration (ET/PET) by quarterly periods, for which the coefficients of determination (R^2) were statistically significant are given in Table 7. The equations are limited to those that included only two quarters and the quarters whose coefficients are significant by a t-test are underscored. For Marrs oranges, ET/PET explains more of the variation in percent solids than does ET. For Valencia oranges, the variation attributable to ET/PET was significant for percent solids, juice yield and pH whereas it was not for ET; the amount of variation explained by ET and by ET/PET was about the same for brix and citric acid. For the grapefruit, the

Table 4. Quarterly and yearly evapotranspiration (ET), as the average for four irrigation treatments, of three citrus cultivars over the 7 year study period.

Cultivar	Crop year	Nov. 14-Feb. 15 (Winter)	Feb. 15-May 14 (Spring)	May 15-Aug. 14 (Summer)	Aug. 15-Nov. 14 (Fall)	Yearly amount
		....	....	cm.	....	....
Marrs	1969	10.0	15.1	23.7	27.3	76.1
	1970	11.0	17.6	28.6	31.9	89.1
	1971	8.1	16.2	30.4	31.8	86.5
	1972	12.9	23.2	35.9	28.3	100.3
	1973	15.6	16.0	27.4	28.6	87.6
	1974	11.3	15.4	24.8	28.0	79.5
	1975	10.9	17.8	31.3	24.3	84.3
	Avg.	11.4	17.3	28.9	28.6	86.2
	c.v.(%)	37	28	23	17	
Valencia	1969	11.3	18.0	32.4	30.8	92.5
	1970	11.6	19.7	34.0	37.6	102.9
	1971	15.9	24.7	35.8	38.3	114.7
	1972	14.0	28.4	41.9	38.5	122.8
	1973	20.8	22.5	36.1	35.3	114.7
	1974	14.6	22.7	39.5	37.6	114.4
	1975	11.4	18.0	30.7	24.2	84.3
	Avg.	14.2	22.0	35.8	34.6	106.6
	c.v.(%)	32	27	21	18	
Ruby Red	1969	11.3	22.7	39.1	35.2	108.3
	1970	16.5	20.1	35.0	36.6	108.2
	1971	12.6	26.2	34.3	33.8	106.9
	1972	14.2	27.6	37.4	32.8	112.0
	1973	17.6	19.9	37.8	34.9	110.2
	1974	13.7	20.6	36.2	34.7	105.2
	1975	11.5	17.8	31.0	24.2	84.5
	Avg.	13.9	22.1	35.8	33.2	105.0
	c.v.(%)	34	30	23	16	

Table 5. Statistically significant linear correlation coefficients (r) between evapotranspiration by quarterly periods and soluble solids, citric acid, suspended solids, pH, and naringin of the juice at harvest for Marrs and Valencia oranges and Ruby Red grapefruit for 7 seasons, 1969 through 1975. Means, standard deviation (S.D.) and coefficients of variation x 100 (c.v.) are also provided for juice characteristics.

Cultivar	Size	Quarterly period	Soluble solids °Brix	Citric acid %	Suspended solids %	pH	Naringin ppm
			r				
Marrs	200	Winter of bloom,Q1	-	-.426*[z]	-.421*	-	NA[y]
		Spring, Q2	-	-	-	-	
		Summer, Q3	-.423*	-	-	-	
		Fall, Q4	-	-	-	-	
		Mean	10.26	.55	17.43	4.20	
		S.D.	.59	.03	1.53	.27	
		c.v.(%)	5.7	5.4	8.8	6.4	
Valencia	200	Winter of bloom,Q1	-.454*	-.441*	-	-	NA
		Spring, Q2	-	-.493**	-	-	
		Summer, Q3	-	-.442*	-	-	
		Fall, Q4	-	-.655**	-	-	
		Winter of harvest, Q5	-	-.421*	-	-	
		Mean	11.22	0.82	16.10	3.91	
		S.D.	0.50	0.08	2.06	0.3	
		c.v.(%)	4.5	9.8	12.8	7.7	
Ruby Red	70	Winter of Bloom,Q1	-	-.402*	-	-	-
		Spring, Q2	-	-.518**	-	-	-.377*
		Summer, Q3	-0.621**	-.578**	-	-	-
		Fall, Q4	-0.508**	-.793**	-0.472**	-	-.608**
		Winter of harvest, Q5	-0.413*	-.443*	-	-	-
		Mean	7.36	1.19	12.33	3.34	153.3
		S.D.	0.50	.08	1.56	0.29	51.5
		c.v.(%)	5.3	6.7	12.6	8.7	33.6

z r(0.05)* = 0.367; r(0.01)** = -.470; n = 28
y Naringin determined only for the grapefruit.

variation explained by ET/PET was signifiicant at the 0.01 probability level for all five juice characteristics whereas R^2 was significant at the 0.01 level for three juice characteristics using ET in the regression analyses. Consequently, ET/PET, the ratio of actual to potential evapotranspiration related more closely to juice characteristics than did evapotranspiration, ET.

The order in which the quarters were entered in the regression equations and their underscoring indicate that, for Marrs oranges, the winter quarter preceding bloom (Q1), was most influential for citric acid and percent solids, whereas water availability during the summer and fall quarter most decreased soluble solids. For Valencias, water availability during the winter of bloom (Q1) most affected soluble solids; the fall quarter (Q4) most influenced citric acid,

Table 6. Statistically significant linear correlation coefficients (r) between actual to potential evapotranspiration (ET/PET) by quarterly periods for a 7-year study period and soluble solids, citric acid, suspended solids, pH, and naringin of juice at harvest of three citrus cultivars. Overall means and standard deviations among treatments for ET/PET are also provided.

Cultivar	Size	Quarterly period	ET/PET Mean	ET/PET Standard deviation	Soluble solids °Brix	Citric acid %	Suspended solids %	pH	Naringin ppm
			. . . cm/cm		. . . . .r				
Marrs	200	Winter of bloom, Q1	.62	.25	-	-.399*	-.549**	-	NA
		Spring, Q2	.49	.12	-	-		-	
		Summer, Q3	.51	.12	-.431*	-	-	-	
		Fall, Q4	.71	.13	-	-	-.374*	-	
Valencia	200	Winter of bloom, Q1	.77	.28	-.452*	-	-	-	NA
		Spring, Q2	.62	.16	-	-	-	-	
		Summer, Q3	.62	.13	-	-.417*	-	-	
		Fall, Q4	.66	.15	-	-.679**	-.469*	+.544**	
		Winter of harvest, Q5	.76	.27	-	-	-	-	
Ruby Red	70	Winter of bloom, Q1	.76	.28	-	-.370*	-	-	-
		Spring, Q2	.62	.16	-.543**	-.671**	-	-	-
		Summer, Q3	.62	.13	-.553**	-.568**	-	-	-.477**
		Fall, Q4	.83	.17	-.528**	-.854**	-.625**	+.452*	-
		Winter of harvest, Q5	.75	.27	-.421*	-.457*	-	-	-

Table 7. Regression equations and coefficients of determination (R^2) relating juice characteristics to evapotranspiration (ET) and to ratio of actual to potential evapotranspiration (ET/PET) by quarterly periods for three citrus cultivars. Equations are limited to the two most influential quarters, and quarters whose coefficients are significant by a t-test are underscored.

Cultivar	Fruit size	Regression variable	Regression Equations	R^{2z}
Marrs	200	ET	Brix = 11.933-0.030(Q3)-0.028(Q4)	0.222*
			Citric acid = 0.567-0.006(Q1)+0.002(Q3)	0.246*
			Percent solids = 20.513-0.127(Q1)-0.057(Q4)	0.203*
		ET/PET	Brix = 11.813-1.722(Q3)-0.936(Q4)	0.228*
			Citric acid = 0.555-0.092($\underline{Q1}$)+0.123(Q3)	0.284*
			Percent solids = 20.958-2.880(Q1)-2.386(Q4)	0.342**
Valencia	200	ET	Brix = 11.567-0.077($\underline{Q1}$)+0.035(Q2)	0.322**
			Citric acid = 1.149-0.008($\underline{Q4}$)-0.002(Q2)	0.446**
		ET/PET	Brix = 11.473-0.100(Q1)+0.868(Q3)	0.250*
			Citirc acid = 1.189-0.334($\underline{Q4}$)-0.120(Q3)	0.491**
			Percent solids = 21.546-7.881($\underline{Q4}$)+1.814(Q5)	0.268*
			Juice yield = 57.575-6.721($\underline{Q5}$)+7.519(Q3)	0.280*
			pH = 2.983+1.427($\underline{Q4}$)-0.400(Q5)	0.402**
Ruby Red	70	ET	Brix = 10.806-0.056($\underline{Q3}$)+0.039(Q1)	0.460**
			Citric acid = 1.557-0.010($\underline{Q4}$)-0.002(Q5)	0.642**
			Percent solids = 18.286-0.169($\underline{Q4}$)+0.075(Q2)	0.276*
			pH = 2.916+0.036($\underline{Q4}$)-0.022(Q3)	0.234*
			Naringin = 315.7-8.256($\underline{Q4}$)+3.110(Q3)	0.468**
		ET/PET	Brix = 10.667-2.835($\underline{Q3}$)+0.623(Q1)	0.382**
			Citric acid = 1.546-0.369($\underline{Q4}$)-0.062(Q5)	0.769**
			Percent solids = 16.543-6.759($\underline{Q4}$)+2.373(Q3)	0.416**
			pH = 2.784+1.260($\underline{Q4}$)-0.786(Q2)	0.315**
			Naringin = 245.4-216.6($\underline{Q4}$)+141.5(Q3)	0.306**

z $R^2(0.05)^*$ = 0.199; $R^2(0.01)^{**}$ = 0.298

suspended solids and pH; and, the winter quarter mainly affected juice yield. For grapefruit, the summer quarter (Q3) most affected soluble solids, whereas the fall quarter affected citric acid, suspended solids, pH, and naringin the most.

The R^2 values in Table 7 are the proportion of the sum of squares attributable to regression. ET explaiins 44.6% and ET/PET 49.1% of the variation in citric acid content of the Valencia oranges, and they explain 64.2 and 76.9%, respectively, of the variation in citric acid content of grapefruit juice. Citric acid content, the only characteristic for which half or more of the variation is explained by soil water conditions, is the juice quality most closely related to soil water availability.

Our findings indicate that water conditions during the fall quarter (Q4) most influence the juice characteristics of Valencia orange and Ruby Red grapefruit. Though harvested in later quarters, the fruit is sizing rapidly in fall. The negative linear correlation coefficients between ET and ET/PET and all the juice characteristics, except pH, indicate that the fruit enlarge disproportionately more than the content of soluble solids (brix), citric acid, suspended solids, and hydrogen ion concentration (pH) increases at this time of year.

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Evaluation of Vendex 4L® and Vydate L® for Suppression of Citrus Rust Mite

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ABSTRACT

Vendex 4L® (fenbutatin-oxide) and Vydate L® (oxamyl) were evaluated for efficacy against citrus rust mite, *Phyllocoptruta oleivora* Ashmead, in full season trials on grapefruit. Vendex 4L at 2.0 lb ai/acre applied at ca. 10-week intervals, provided full season rust mite suppression in 1979. Vendex 4L at 1.0 lb ai/acre was less effective, with efficacy against rust mite declining at 6-8 weeks post spray. Three applications of Vydate L at 1.0 lb ai/acre, provided effective rust mite suppression in both 1979 and 1980. The residual effectiveness of Vydate L was not enhanced by the addition of 1.0 lb ai/acre of chlorobenzilate 4E. The percent of rust mite damaged fruit at harvest was lower from all Vendex 4L and Vydate L spray treatments than from untreated controls in both seasons (P=0.05).

Vendex 4L® (fenbutatin-oxide) and Vydate L® (oxamyl) were registered for use on Texas citrus in early 1981. Vendex 4L, a contact acaricide, was labelled for the control of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), and Texas citrus mite, *Eutetranychus banksi* (McG). Vydate L, a foliar-applied systemic pesticide, was labelled for control of citrus rust mite and citrus nematode, *Tylenchus semipenetrans* Cobb. Both chemicals have been included in screening trials at the Texas A&I University Citrus Center and this communique reports on their efficacy against the citrus rust mite. Preliminary results of trials with Vydate L and a wettable powder formulation of Vendex (50 WP) on mites were published previously (3, 4). Data on Vydate's efficacy against citrus nematode are reported elsewhere (7, 8, 9).

MATERIALS AND METHODS

Vendex 4L formulated as 4 lb ai/gal liquid and Vydate L formulated as 2 lb ai/gal liquid were evaluated in full season rust mite suppression programs. Initial spray treatments were applied at postbloom and reapplications made as needed during the season with either a John Bean F-357 CP Speed Sprayer® or a Lockwood Hardie Super 40 Sprayer®. Nozzle adjustment, pressure and sprayer speed through the orchard were regulated to apply 250 gal/acre. Efficacy of each acaricide against rust mite was determined by pre-and-post treatment mite counts made at ca. 3-week intervals. Rust mite counts were made on leaves in early season and on fruit in mid-and-late season. A 10X handlens with a 1 cm^2 grid was used to count mites in 3 fields on the bottom of each leaf and one field on the top, median and bottom of each fruit. One hundred leaves and/or fruit were examined per treatment replicate. Counts were subjected to analysis of variance and separated by Duncan's Multiple Range Test.

Rust mite feeding damage (russeting) was assessed on harvested fruit from test trees in December. One hundred fruit randomly selected from each treatment were rated for damage severity. Russeted fruit would be marked as U. S. #2 grade fresh, or used for processing.

Vendex Spray Trial — In 1979, a spray trial comparing Vendex 4L and Vendex 50WP formulations for suppression of rust mite was conducted in a block of 20-year-old Ruby Red grapefruit trees (25 X 30 ft spacing). Treatments and rates (ai per/acre) were: no treatment; Vendex 4L (1.0 & 2.0 lb); Vendex 50 WP (2.0 lb); and Vendex 50 WP (2.0 lb) plus Nu-film® Extender (3.0 pts). The latter material was added to determine if it would increase residual effectiveness of Vendex 50 WP. Treatments were arranged in a randomized complete-block design with 3 replications. Individual plots were 3 rows of 5 trees each. All plots were separated by untreated guard rows to minimize spray contamination. Initial sprays were applied on May 3, 1980. Treatments were reapplied on July 7 and September 24. Counts of citrus rust mite were not made after the last spray date.

Vydate L Spray Trial — Spray trials with Vydate L were conducted in 1979 and 1980. Vydate L applied alone and as a tank mix with chlorobenzilate 4E (standard acaricide), were tested for rust mite efficacy in a block of 25-year-old Ruby Red grapefruit trees on 40 X 24 ft spacing. Treatments and rates (ai/acre) were: no treatment; Vydate L (1.0 lb); Vydate L (1.0 lb) plus chlorobenzilate (1.0 lb); and chlorobenzilate (2.0 lb). Treatments were arranged in a randomized block design with two replications on plots of 18 trees each. All plots were separated by untreated guard rows to minimize spray drift. In 1979 treatment sprays were applied May 7, July 9, September 24, and in 1980, on May 1, June 9, and October 7. Mite counts were not continued after the last spray.

RESULTS

Vendex Trial — Both formulations of Vendex (4L and 50 WP) at 2.0 lb ai/acre, applied at ca. 10-week intervals, provided full season suppression of citrus rust mite (Table 1). Vendex 4L at 1.0 lb ai/acre gave shorter residual mite suppression, with efficacy declining at 6-8 weeks post spray. Performance of Vendex 50 WP was not enhanced with the addition of Nu-film® spreader sticker.

The percent of rust mite damaged fruit at harvest was lower (P=0.05) in all Vendex treatments than in the untreated controls (Table 1). No phytotoxicity was observed after any spray treatments.

Vydate L Trials — Suppression of citrus rust mite with Vydate L at 1.0 lb ai/acre was superior to that obtained with chlorobenzilate 4E at 2.0 lb ai/acre in both the 1979 and 1980 seasons (Table 2). Efficacy of Vydate against rust mite extended through 6 weeks post spray. The residual effectiveness of Vydate L against rust mite was not enhanced by the addition of 1.0 lb ai/acre of chlorobenzilate 4E.

The percent of rust mite damaged fruit at harvest in both 1979 and 1980 was lower (P=0.05) from the Vydate L and Vydate L plus chlorobenzilate 4E

Table 1. Counts of citrus rust mite on mature Ruby Red grapefruit trees sprayed with Vendex 4L and Vendex 50 WP and from untreated trees April-Sept, 1979.

		No. of rust mite/cm^2									
Treatment	Rate lb ai/ acre	(-1)[z]	5/3 Spray	(+4)[y]	(+8)	7/7 Spray	(+3)	(+6)	(+10)	9/24 Spray	Percent[x] Russet
Vendex 4L	1.0	0.0a[w]		0.0a	9.5b		1.1b	6.8a	9.4b		21b
Vendex 4L	2.0	0.1a		0.0a	0.2c		0.0b	0.2b	5.3bc		16b
Vendex 50WP	2.0	0.2a		0.0a	0.2c		0.1b	0.6b	0.5c		8b
Vendex 50WP + Nu-Film	2.0 + 3.0 pt	0.0a		0.0a	0.3c		0.1b	0.1b	3.5c		13b
Untreated		0.1a		0.3a	25.1a		25.0a	6.7a	29.3a		66a

[z] Prespray count on leaves.
[y] Weeks post spray, counts made on fruit.
[x] Percentage of fruit down graded to US #2 fresh or process fruit due to rust mite injury; 100 fruit evaluated per treatment.
[w] Treatment means per column separated by Duncan's Multiple Range Test at P=0.05.

Table 2. Counts of citrus rust mite on mature Ruby Red grapefruit trees sprayed with Vydate L and chlorobenzilate 4E and from untreated trees, April-Sept., 1979 & 1980.

1979		No. of rust mite/cm^2								
	Rate	5/7 Spray					7/9 Spray		9/24 Spray	
Treatment	lb ai/ acre	(-1)^z	(+2)^y	(+4)	(+6)	(+8)	(+3)	(+8)		Percent^x Russet
Vydate L	1.0	0.0	0.0a^w	0.1a	1.1b	7.8b	0.3b	3.1c		17c
Vydate L +	1.0 +	0.0	0.0a	0.0a	0.2b	10.9b	0.0b	0.4c		5c
chlorobenzilate 4E	1.0									
Chlorobenzilate 4E	2.0	0.0	0.0a	0.1a	1.3b	17.5a	3.0b	33.2a		63a
Untreated	-	0.0	0.1a	0.4a	6.4a	16.8a	32.4a	22.7b		43b

1980		5/1 Spray			6/9 Spray				10/7 Spray	
		(-1)^z	(+2)^y	(+4)	(+3)	(+6)	(+10)	(+14)		Percent^x Russet
Vydate L	1.0	0.2b^w	0.0b	0.4c	0.0b	0.0b	0.0b	2.8c		12c
Vydate L +	1.0 +	2.7a	0.0b	1.5c	0.3b	1.2b	0.9b	7.6b		23b
chlorobenzilate 4E	1.0									
Chlorobenzilate 4E	2.0	2.4a	0.2b	17.3b	3.4b	5.1a	0.3b	1.3c		18bc
Untreated	-	2.4a	1.9a	89.9a	17.2a	1.0b	4.8a	18.6a		33a

^{z} Prespray count on leaves.
^{y} Weeks post spray, counts made on fruit.
^{x} Percentage of fruit down graded to US #2 fresh or process fruit due to rust mite injury; 100 fruit evaluated per treatment.
^{w} Treatment means per column separated by Duncan's Multiple Range Test at P=0.05.

treatments than from untreated controls (Table 2). In 1979 the percent of damaged fruit from the chlorobenzilate 4E treatment exceeded that from the untreated controls. Phytotoxicity was not observed following any spray treatment.

DISCUSSION

Both Vydate L and Vendex 4L performed well against citrus rust mite and have some advantages over other acaricidal formulations currently used on Valley citrus. While Vydate L kills rust mite on contact, it is also absorbed by the foliage and translocated systemically downward in the tree to affect root feeding citrus nematodes. However, the most consistent suppression of citrus nematode has been at rates generally higher than used for rust mite control, with fruit yield and size increases in some seasons following Vydate's use (7, 8). Vydate L provides initial knockdown but little residual suppression of Texas citrus mite (1). It has shown efficacy against the citrus mealybug, *Planococcus citri* Risso (5).

Advantages of liquid formulations over wettable powders include: 1) liquids can be accurately measured in the field volumetrically; 2) liquids are not as easily wind borne as are wettable powders and a formulator working with the liquid is therefore less likely to contact toxicants. In recent years, Vendex 50WP has been marketed in 1.0 lb water soluble bags to circumvent the aforementioned problems. This has forced growers to use 1 lb of Vendex, or multiples of 1 lb, since opening bags and weighing of partial amounts not only defeats the purpose of the soluble bag, but is specifically prohibited by labelling. Moreover, there have been occasions when the bags did not completely dissolve resulting in the clogging of the sprayer's filtering system.

Vendex 50WP has demonstrated efficacy against Texas citrus mite (2), and is of low toxicity against certain beneficial insect species, such as the brown lacewing, *Sympherobius barberi* (Banks) (6).

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Mycorrhizal Fungi Associated with Citrus in South Texas

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ABSTRACT

Mycorrhizal fungi were associated with citrus in all of the 20 orchards sampled in the lower Rio Grande Valley of Texas. Eight species forming versicular-arbuscular mycorrhizae were identified. *Glomus microcarpus, G. etunicatus, and G. fasciculatus* were the most commonly found species.

Citrus, like the majority of flowering plants, is normally infected by fungi forming vesicular-arbuscular mycorrhizae (4, 6, 8, 9). These beneficial fungi stimulate growth of citrus in nutrient-poor soils by increasing the efficiency of nutrient uptake(4). Mycorrhizal fungi are largely nonspecific and have extremely wide host ranges (2). In addition, a single plant species may be infected with several species of mycorrhizal fungi (5). Several species of mycorrhizal fungi associated with citrus roots or soil in both California and Florida have been identified (6). The purpose of this study was to discover the occurrence of mycorrhizal fungi associated with citrus in South Texas.

MATERIALS AND METHODS

Four to six 500g soil samples were collected from each of 20 citrus orchards across the citrus belt of the lower Rio Grande Valley of Texas. The area within the survey was approximately 25 by 90 kilometers. All trees, whether varieties of oranges or grapefruit, were grown on sour orange *(Citrus aurantium* L.) rootstock. Soil texture ranged from sandy loam to sandy clay. The soil pH was 7-8. Samples in each location were pooled and screened through a series of sieves by the procedure of Gerdemann and Nicolson (1). Citrus roots, the adhering soil, and spores, when present, were placed next to the roots of one-week-old sudangrass *(Sorghum vulgare* Pers.) seedlings. The inoculum and roots of the seedlings were wrapped in filter paper and planted in sand in 12 cm-diameter plastic pots. The inoculum from each pooled sample was divided into two pot cultures. Sudangrass seedlings were grown in a greenhouse at temperatures ranging from 22 to 36°C and watered when necessary with a dilute Hoagland's solution (3) minus phosphorus.

Soil samples from each pot culture were collected 10-12 months after inoculation. Each sample was screened for spores which were examined under a microscope for identification.

RESULTS AND DISCUSSION

More than one species of mycorrhizal fungi was identified in 13 of the 20 orchards. Eight total species were identified (Table 1). In comparison, seven species were identified each from California and Florida citrus. Each citrus area contains species not commonly found in the other two.

Table 1. Occurrence of mycorrhizal fungi in citrus orchards of Texas, California, and Florida [z].

	Orchards containing species (%)		
Mycorrhizal fungi	Texas (20 orchards)	California (79 orchards)	Florida (66 orchards)
Glomus constrictus	0	37	1
G. etunicatus	45	5	21
G. fasciculatus	25	84	14
G. macrocarpus	5	10	15
G. microcarpus	55	28	0
G. monosporus	0	10	0
G. mosseae	15	0	9
Gigaspora heterogama	10	0	0
G. margarita	5	0	50
Sclerocystis coremioides	15	0	0
S. sinuosa	0	5	15

[z] California and Florida results from reference no. 6.

Glomus microcarpus Tul. and Tul., a species commonly associated with citrus in California but rarely found in Florida (7), was the most common species found in Texas citrus (Table 1). Sporocarps were frequently produced in pot cultures. Other species that were commonly recovered included *G. etunicatus* Becker and Gerd. and *G. fasciculatus* (Thaxter sensu Gerd.) Gerd. and Trappe. Spores of *G. etunicatus* were produced abundantly in pot cultures. No sporocarps were observed. Spores of *G. fasciculatus* were either produced singly in the soil or in dense sporocarps.

Less commonly recovered species (from two or three orchards) included *Glomus mosseae* (Nicol. and Gerd.) Gerd. and Trappe, *Gigaspora heterogama* (Nicol. and Gerd.) Gerd. and Trappe, and *Sclerocystis coremioides* Berk and Broome. Spores of *Glomus mosseae* were larger than those reported from Florida citrus. The average size for spores of *G. mosseae* in Texas was 268 μm; spores from Florida citrus averaged 102 μm (6). Fair numbers of sporocarps were produced by *S. coremioides* in pot culture.

Very few spores of *Glomus macrocarpus* Tul. and Tul. and *Gigaspora margarita* Becker were recovered. *Gigaspora margarita* was identified by a single spore.

There was no discernible pattern of distribution of individual species over the citrus-growing area of South Texas.

Each area, Texas, California, or Florida, has a unique list of mycorrhizal fungi on citrus. Texas citrus contained three species not found associated with Florida citrus. However, two of these species, *Gigaspora heterogama* and *S. coremioides*, have frequently been found in other locations in Florida (7). Four species in Texas, *Glomus mosseae*, *Gigaspora heterogama*, *G. margarita*, and *S. coremioides*, have not been found in California citrus soils. One of the major mycorrhizal fungi of California citrus, *Glomus constrictus* Trappe, was not found in Texas. The major citrus-infecting fungus in Florida, *Gigaspora margarita*, appears to be rare in Texas citrus.

Pure pot cultures (a single fungus involved in the mycorrhizal association) of *Glomus microcarpus*, *G. etunicatus*, *G. fasciculatus*, *G. mosseae*, *Gigaspora heterogama*, and *S. coremioides* are being maintained on sudangrass at the Citrus Center.

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Influence of Rootstock and Weed Control Method on Production of Ruby Red Grapefruit Over Twenty-one Years

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ABSTRACT

A 27 year study of Ruby Red grapefruit on sour orange or cleopatra mandarin rootstock grown under chemical weed control with no tillage, clean cultivation or sod culture was made. Mean yields over 21 seasons and 3 weed control systems from trees on sour orange were greater than those from trees on cleo. Trees under chemical weed control outyielded other systems, ($P=0.01$). During the past 12 years, a period free of freezes or hurricanes, trees on cleo rootstock and under chemical weed control averaged 21.5 tons an acre, those on sour 18.5, ($P=0.05$). On medium textured soils and under proper management cleopatra mandarin can be an alternative to sour orange rootstock.

Historically Texas citrus has been on sour orange (SO) *(C. aurantium L.)* rootstock almost exclusively. In the early 1940's the citrus industries of Argentina and Brazil, which were also predominantly on SO, were being devastated by the virus disease tristeza (1, 6). The potential threat to Texas citrus led to establishing in 1947 the USDA Rootstock Investigation in Weslaco (11). The project's primary purpose was to test the adaptability of tristeza-resistant rootstocks to Texas conditions (2). In the early years of these studies Cleopatra mandarin (CLEO) *(C. reticulata Blanco)* looked promising and following the 1951 freeze was widely used by nurserymen in the Valley. Many orchards established at that time incorporated SO and CLEO rootstocks into their design.

Wherever citrus is grown studies have been conducted comparing various weed control systems, often referred to as cultural practices. Norris and Smith (10) in Florida reported that a system of minimum cultivation gave the highest yields on Lakeland fine sand. Permanent sod was best on rolling land in Gayndah, Australia (4). Similarly in Japan (12) a 12 year study found yields greatest with clover sod. Cary's (3), 20 years study in New South Wales, Australia comparing tillage and non-tillage on sandy clay loam soil, found that bare soil with no tillage provided the highest yields. The work reported here evaluated grapefruit production on SO and CLEO rootstocks planted in medium textured soil and maintained under 3 weed control systems.

MATERIALS AND METHODS

Ruby Red grapefruit *(C. paradisi Macf)* on SO or CLEO rootstock were planted on Hidalgo sandy clay soil (Typic Calciustolls) in November 1953. Spacing was

20 X 22 ft with 28 trees a row and rootstocks alternating in the row. At time of planting 3 cultural practices were established on four-row-plots: 1) Chemical weed control with no tillage (CWC) was maintained with weed oil, a contact herbicide, until 1958 when it was replaced with residual herbicides; 2) Clean cultivation (CULT) was disced down the row and across rows thru the first 4 years after which tree size precluded travel across rows. Plots were disced 6 to 10 times a year. In sod culture (SOD) weeds were allowed to grow then mowed or shredded as needed. Weeds were cut 6 to 10 times a year. Nitrogen fertilizer was added in December or January each year. The rate averaged 1.2 lb N a tree and ranged from zero in 1962 following the January freeze to 1.9 in 1963.

Annual rainfall over the 27 years ranged from less than 8 to more than 39 inches. The number of irrigations ranged from 1 to 8 and the total water (ppt + irrigation) from 39 to 55 inches. Thru age six, trees on SOD usually required one more irrigation a year than did trees on bare soil plots (7). By 9 years-of-age, trees had grown together in the row and tree canopies covered more than 50% of the soil surface. Differences in soil moisture depletion between the weed control systems were no longer present.

Yield records have been taken on an individual tree basis in the two center rows of each plot since 1959. Fruit has been sized into 3 classes: less than 96, 96 to 80 (3-3/16 to 4-3/16 inch diam.), and greater than 80. Citrus fruit must meet state maturity standards until 15 December each year to be marketable. The standards include percent juice, percent soluble soilds, and ratio of solids to acid. In the early years of this study fruit was sampled every 2 weeks beginning about mid-October and continuing until maturity standards were met or 15 December was reached.

Where appropriate, data were subjected to analysis of variance and means separated by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Extreme weather events affected production on several occasions during the 27 year history of this orchard. During a local freeze on 1 December 1957 temperature minimums were 20°F on SOD, 25° on CULT, and 26° on CWC. Trees on sod were damaged severely and commercial production delayed a year or two. The major freeze of January 1962 with minimums recorded at the 5 ft level of 10.5°F on SOD, 12.5° on CULT, and 15° on CWC injured SOD the most, CWC the least, and CULT intermediately. The same temperature relationships between cultural practices has occurred on all nights of radiation cooling. Hurricane Beulah, September 1967, resulted in 40 to 60% fruit loss in the orchard. All these weather induced reductions in yields are included in the long-term record.

Initially there were 28 trees of each rootstock culture combination except CLEO/CWC which had 25 and CLEO/CULT which had 23. Loss of original test trees has been minor over the 27 year span of the orchard as the percentage of original trees surviving in 1979 reveals (Table 1). All of the losses are considered to have been freeze related.

The highest yield could be found with virtually any of the culture/rootstock combinations in a given year (Table 2). In 17 of the 21 seasons highest yields

Table 1. Survival of Ruby Red grapefruit trees on sour orange or cleopatra rootstock and grown under three soil management systems, 1953-1979.

Rootstock	Cultural System[z] CWC	CULT	SOD	Rootstock Avg
	%Surviving at age 27			
Sour	96	93	93	94
Cleo	96	100	82	92
Cultural System Avg	96	96	87	

[z] CWC = chemical weed control with no tillage
CULT = clean cultivation
SOD = sod culture

were on SO; in 4 seasons on cleo. Averaged over both rootstocks highest yields occurred 11 times under CWC, 7 times on SOD, and 3 on CULT.

The effect of the January 1962 freeze is readily apparent in Table 2. Yields for 2 or 3 years following the freeze were directly related to the amount of freeze injury sustained by the particular combination of culture/rootstock. Wood damage was heavy on SOD, less on CULT, and least on CWC. Trees on CLEO/SOD were damaged most severely; trees on SO/CWC the least. By the third crop after the freeze trees on SO/CWC produced 17 tons an acre, 80% of their pre-freeze average (9).

Rootstock effect averaged over 21 seasons showed yield of trees on SO much superior to CLEO (Table 3). This highly significant difference can be attributed to a strong negative interaction between CLEO and SOD, the result of the freeze damage mentioned above. Only in the last 5 years has the combination CLEO x SOD produced satisfactory yields (Table 2).

Cultural systems, averaged over the 21 seasons and 2 rootstocks separate into 2 statistical classes with CWC outyielding CULT and SOD. On SO there were no significant differences between cultural systems; on CLEO there were 3 statistical separations with CWC > CULT > SOD.

In an effort to remove or reduce the influence of the January 1962 freeze on the data, yields for the last 12 seasons, 1968 thru 79, have been analyzed separately (Table 4). During this period trees were 16 to 27 years old, and void of major natural hazards such as freezes or hurricanes. The magnitude of the yields in Table 4 indicate that production was maintained at a high level under most rootstock/culture combinations. Over these 12 seasons SO again gave better yields than CLEO (P=-0.05). Cultural practices averaged over the 2 rootstocks separate into the same 2 statistical classes as in Table 3, CWC > CULT = SOD. Within cultural systems there were significant interactions for each rootstock.

Table 2. Yield of Ruby Red grapefruit on sour orange or cleopatra mandarin rootstock and under chemical weed control with no tillage, clean cultivation, or sod culture, 1959 - 1979, Weslaco, Texas.

		Sour Orange			Cleopatra Mandarin		
Year[z]	Age	CWC	CULT	SOD	CWC	CULT	SOD
				(Tons an Acre)			
1959	7	21.7	18.6	14.1	10.8	8.0	5.7
60	8	22.3	18.5	18.3	16.8	13.3	12.7
61	9	19.9	20.4	21.5	17.6	17.9	17.0
62	10	0.5	0.1	0.1	0	0	0
63	11	2.4	1.1	0.4	2.9	1.3	1.4
64	12	17.0	11.0	9.2	11.9	3.2	1.4
65	13	21.7	24.4	19.4	21.1	15.2	12.1
66	14	18.8	18.5	10.7	17.4	14.7	9.4
67	15	7.5	11.4	13.1	8.1	7.2	5.7
68	16	21.6	23.3	22.7	21.9	17.9	12.2
69	17	19.3	19.9	18.2	19.8	12.4	2.6
70	18	24.4	21.4	20.7	26.2	15.5	4.8
71	19	16.8	12.8	13.5	15.1	4.5	2.4
72	20	22.8	20.5	22.7	25.7	15.4	10.9
73	21	18.1	18.4	17.8	13.7	12.1	12.3
74	22	21.5	20.8	27.7	23.6	15.5	8.8
75	23	16.3	16.0	24.5	20.3	21.7	18.0
76	24	22.0	18.2	28.7	30.4	22.0	21.3
77	25	13.2	16.1	25.9	19.7	20.1	18.7
78	26	10.5	12.6	25.9	19.6	20.0	17.6
79	27	15.8	18.6	27.7	22.3	23.3	18.3
21 yr ave		16.9	16.4	18.2	17.4	13.4	10.2

[z] Year refers to year of bloom

Table 3. Average annual yield of Ruby Red grapefruit growing on two rootstocks and three cultural systems, 1959-1979, Weslaco, Texas.

	Cultural system[z]			
Rootstock	CWC	CULT	SOD	Rootstock Avg
		(Tons an acre)		
Sour	16.9 A[y]	16.4 AB	18.2 A	17.2 A
Cleo	17.4 A	13.4 BC	10.2 D	13.6 B
Cultural System Avg	17.3 A	14.9 B	14.2 B	

[z] CWC = chemical weed control with no tillage,
CULT = clean cultivation,
SOD = sod culture.

[y] means separated by DMRT (P=0.01)

Table 4. Average annual yield of Ruby Red grapefruit growing on two rootstocks and three cultural systems, 1968 thru 1979, Weslaco, Texas.

	Cultural system[z]			
Rootstock	CWC	CULT	SOD	Rootstock Avg
		(Tons an acre)		
Sour	18.5 b[y]	18.2 b	23.0 a	19.9 a
Cleo	21.5 a	16.7 c	12.3 d	16.8 b
Cultural System Avg	20.0 a	17.5 b	17.7 b	

[z] CWC = chemical weed control with no tillage,
CULT = clean cultivation,
SOD = sod culture.

[y] means separated by DMRT (P=0.05)

With CULT and SOD trees on SO outyielded trees on CLEO, but under CWC trees on CLEO, from age 16 to 27, averaged more tonnage than trees on SO, 21.5 and 18.5 tons an acre, respectively.

Mean fruit size for the 12 seasons 1968 thru 1979, was affected by rootstock and culture with differences significant at the 5% level (Table 5). Over all cultural systems trees on SO produced a higher percentage of the crop in size 96 to 80 than did trees on cleo. Considering cultural systems over both rootstocks the highest percent of fruit size 96 to 80 occurred with CWC. Calculating from Table 4, the tonnage produced in size 96 to 80 followed the same pattern as percentage with respect to main effects: SO 15.2 tons an acre, cleo 12.4; CWC 16.0, CULT and SOD each 12.8. Trees on SO produced the most fruit of sizes 96 to 80 in 7 seasons, those on CLEO in 1 season, and in 4 seasons there were no differences. Wtih respect to cultural system effect over both rootstocks, trees on SOD actually produced the highest percent 96 to 80 in more seasons than did CWC, five as opposed to four, although the 12 year average favored CWC. Weather factors, which were not considered here, apparently interact differently with the different cultural systems (5).

There were no consistent differences in maturity related to rootstock or cultural system. In most years fruit from this orchard did not pass state maturity standards before 15 December.

There is no universal weed control system for citrus orchards (3, 4, 9, 10, 12). Factors such as soil type, topography, rainfall pattern and intensity of rainfall would influence the choice at a particular location. With SO, over the long term,

Table 5. Percent of crop in size classes 96 to 80 (3-6/16 to 4-2/16 inches) averaged over 12 seasons, 1968-79.

	Cultural system[z]			
	CWC	CULT	SOD	Rootstock Avg
		(Percent of crop)		
Sour	82 a[y]	77 a	77 a	79 a
Cleo	78 a	69 b	65 c	71 b
Cultural System Avg	80 a	73 b	71 b	

[z] CWC = chemical weed control with no tillage,
CULT = clean cultivation,
SOD - sod culture.

[y] means separated by DMRT (P=0.05)

one weed control system was as good as another in this study. However, under freeze conditions SOD is colder than the other systems so that short term differences may arise. Since the occurrence of the next damaging freeze cannot be predicted the choice of SOD represents a considerable gamble.

There is no reliable record of the number of acres planted to CLEO in the 1950's. However, commercial experience with CLEO at that time was disastrous for growers. Tonnage was light, fruit was small, trees showed foliar symptoms of iron chlorosis all or part of the year. In some cases the chlorosis was followed by dieback which eventually resulted in stunted trees. By 1960 most orchards on CLEO were considered problem orchards and after the freeze of January 1962 most of the commercial CLEO was pushed out. The orchard reported on here provides the only known continuing record of production of grapefruit on CLEO in Texas. By age 9 CLEO was producing more than 17 tons an acre regardless of cultural system (Table 2). By the fourth season after the freeze the combination CLEO/CWC was producing over 20 tons an acre and for the last 12 years this combination was in the top statistical class (Table 4).

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Hedging Mature Valencia Orange Trees in South Texas

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ABSTRACT

Twelve-year-old 'Valencia' orange trees spaced at 15 X 20 ft in east-west rows were hedged on the north side, south side, both sides or left unhedged in February, 1978. Hedging one side removed about 12% of the canopy volume. Yields for all treatments the next season were greater than prehedging yields, but there were no yield differences among treatments when averaged over 4 successive seasons. Hedging increased the proportion of fruit on the bottom-inside of the canopy, especially on trees hedged on the north side. Fruit size was increased the season after hedging in trees hedged on the south side and both sides. In north-side hedged trees fruit size decreased the season after hedging, then increased almost 50% the next year. These results suggest a direct response of shoot growth and fruiting to changes in light intensity and direction. The factors which underlie the reported variations in of 'Valencias' to hedging and topping are discussed.

Nearly all the world's major citrus areas grow 'Valencia' orange, *Citrus sinensis*, (L) Osbeck, and in many, tree size has been controlled by hedging and topping. The following general conclusions can be drawn from the reports on hedging and topping (4, 6, 12, 13, 16, 19, 20, 21, 22, 24, 25):

1. Yields in the year following severe hedging and topping are reduced roughly in proportion to the amount of foliage removed.
2. Tree size is best controlled by starting a hedging and topping program early and maintaining size with regular, light hedging thereafter.
3. Hedging at a 10-15° angle from vertical is superior to a vertical or more steeply angled cut.
4. Better light penetration after hedging and topping usually improves fruit quality by changing the distribution of fruit within the tree canopy.

Outside these general conclusions, differences in hedging and topping results outweigh similarities. Hedging young or old 'Valencia' trees in California generally reduced long-term yields while the effect on fruit quality was inconsistent (8, 9, 10). In Florida, on the other hand, 'Valencia' yields averaged over the 3 to 4 post-hedging years, were higher than unhedged trees (1, 22). The effect on fruit quality was again varied though one report stated hedging improved quality but not yields (2). In a conference on hedging and topping, Florida growers reported a wide range of techniques and results (3). Researchers in Australia showed hedging and topping consistently improved 'Valencia' yields, fruit quality and broke a strong biennial bearing pattern (4, 6, 26).

Since reports of hedging in Texas have been limited to pruning nursery trees or those damaged by insects, wind or freezes, the results of hedging 'Valencia' oranges are described and compared to those reported from other citrus areas.

MATERIALS AND METHODS

Twelve-year-old 'Valencia' orange trees (ca. 15 ft high x 20 ft wide) on sour orange *(Citrus aurantium)* rootstock were hedged in February 1978, about 2 weeks after harvesting a rather light crop. The canopies of the trees, spaced at 15 ft x 20 ft, had closed together in the east-west oriented rows. Four treatments: hedging the north side only, south side only, both sides and an unhedged control were replicated twice on randomly selected rows. Rows not in the experiment were hedged on both sides. Yields and other data were taken from 2 randomly selected trees in each row.

The orchard, at 26° N. latitude and 74 ft altitude, was under chemical weed control and flood irrigation. The predominant soil type was sandy clay loam (Hidalgo series).

The cutting boom of the hedger, constructed at the Citrus Center, was inclined 10° from the vertical (Fig. 1). Since the cut at the bottom was 4 ft deep, hedging one side removed about 12% of the canopy volume. Fruit were harvested from the north and south half of each tree by sections: bottom-outside, bottom-inside, top-outside and top-inside. Bottom fruit was that harvestable from the ground (ca. the lower half of the canopy); outside fruit, that within arm's reach of the canopy edge. Yields by number and weight of fruit were recorded just before hedging and in late February the next 3 years. Where appropriate, standard analysis of variance, regression and mean separation statistical methods were used.

RESULTS

Averaged over 4 seasons yields were not affected by hedging (Table 1). While most of the yield variation was due to differences between seasons, there were several significant comparisons in the hedging treatment x season interaction. Contrary to common experience, none of the hedging treatments reduced yields in the season after hedging, 1978. The unhedged trees' yields were most irregular primarily due to the low pre-hedging harvest. Hedging the north side of the trees resulted in the least yield variation over the seasons.

The percent of fruit on the bottom half of all trees gradually increased after hedging (Table 2). By 1980, the proportion of fruit on the bottom-inside had doubled, due primarily to a gradual reduction in the percent of top-outside fruit. All hedging treatments exhibited a similar change in fruit distribution which was substantiated by a significant interaction between hedging treatments and seasons.

The analysis of variance (not presented) showed hedging changed the north-south distribution of fruit within the canopy. Before hedging, 40% of the fruit was on the north and 60% on the south half of the tree. Averaged over the 3 post-hedging years, the north-half had 47% of the fruit compared to 53% for the south half. Of the main factors and interactions contributing to the variability in fruit distribution, 28% is associated with canopy position and another 20% to the position x hedging treatments x seasons interaction.

Canopy and season were the dominant factors influencing average fruit weight. Hedging did significantly modify the seasonal responses, however, with north-side and both-side hedged trees showing the most variation between

Fig. 1. Hedging machine constructed at Texas A&I Citrus Center. The 14 ft boom holds seven 28-inch diameter circular blades powered by a 46 HP engine.

seasons (Table 3). The effect of hedging on fruit weights averaged over 4 years was not particularly striking. The bottom-inside produced the largest fruit, followed by top-inside with outside significantly smaller (Table 4). The average weight of fruit on the south side was slightly larger than north-side fruit. The difference was consistent for all canopy locations and was not altered by either season or hedging treatments. The improved light penetration resulting from hedging adjacent rows increased the yields of unhedged trees six-fold (Table 1).

Table 1. The number of fruit[z] harvested/tree by season and hedging treatment.

Season	Hedging Treatment				
	North Side	South Side	Both Sides	Unhedged	Season Mean
1977 before hedging	376BC	280AB	312B	96A	280A
1978	488CDE	848H	584CDEF	640EFGH	640C
1979	624DEFG	736FGH	736FGH	824GH	728C
1980	424BCD	368BC	456BCDE	400BC	416B
Treatment mean	488A	560A	552A	444A	

[z] Means of 4 trees per treatment except for following treatments, 1977-78: both sides and unhedged m = 2 trees; north side m = 3 trees. Season and treatment means separated by Duncan's Multiple Range Test, 1% level.

Table 2. Distribution of fruit within the canopy of Valencia orange trees over four seasons.

Season	% Fruit by Location in Canopy[z]			
	Bottom Outside	Bottom Inside	Top Outside	Top Inside
1977 before hedging	20BCD	12A	41H	27CDEF
1978	22CDE	19ABC	38H	21BCD
1979	30EF	14AB	37GH	19ABC
1980	23CDEF	27DEF	30FG	20BCD
Location Mean	24B	18A	36C	22AB

[z] =Means combine all hedging treatments and are separated by Duncan's Multiple Range Test, 1% Level.

Table 3. The effect of hedging on Valencia fruit size (lb/fruit) over tour seasons[z].

Season	Hedging Treatment: North Side	South Side	Both Sides	Unhedged	Season Mean
1977	.42CDE	.37ABC	.36AB	.41BCD	.39A
1978	.35A	.43CDEF	.48EFG	.43CDE	.42B
1979	.51G	.43CDEF	.46DEFG	.42BCDE	.45C
1980	.47DEFG	.47DEFG	.49FG	.47DEFG	.47C
Treatment mean	.44AB	.42A	.46B	.44AB	

z -Means separated by Duncan's Multiple Range Test, 1% Level.

Table 4. 'Valencia' fruit size (lb/fruit) by location in tree canopy[z].

	Bottom		Top		
	Outside	Inside	Outside	Inside	North-South Mean
North Side	.40	.48	.39	.45	.43
South Side	.41	.52	.40	.47	.45
Location Mean	.40A	.50C	.39A	.46B	

z =Means, averaged over 4 seasons and all hedging treatments, are separated by Duncan's Multiple Range Test, Locations = 1%, North-South = 5% level.

DISCUSSION

Data from a previous experiment showed the yields of these 'Valencia' trees had declined progressively the 3 years before hedging and reached a minimum in 1977. Over the same period the percent of fruit in the top of the tree canopy rose from 50 to 65% while bottom fruit decreased proportionately. Hedging appeared to reverse this pattern. The data also suggest hedging the north side of trees of this size, spacing and row orientation, had a more sustained though less dramatic effect than hedging the south side, to wit the nonsignificant yield differences between 1977 vs. 1978 and 1979 vs. 1980 for north-side hedged trees compared to the others.

An explanation may be the way growth patterns react to changing light conditions. As in Australia and California, the most vigorous shoot growth occurs on Texas citrus trees in early spring (7, 11). In 1977 this was about 3 weeks after hedging. At our latitude in early spring the south side of trees in east-west rows are exposed to full sun all day while the north side is shaded (17). From early May through late August when the second, less vigorous "June" flush occurs, the north side of the trees receives more direct sunlight. These differences in light intensity and direction in the spring would tend to produce earlier and more vigorous, compact growth on the south side while on the north side, shoots would start growth later and have longer internodes. The resultant regrowth would make a denser more uniform canopy on the south compared to a more open, protracted canopy on the north. This response was supported by data from an experiment involving 12-year-old grapefruit trees hedged in December (14). In late March the new shoots on the south side of trees in east-west rows were twice the length of north-side shoots. By July, however, the shoots on the north side were half again as long as those on the south side. For the June flush this growth response could be reversed with shoots on the north being shorter and more compact than those on the south side. Since the June flush is usually less vigorous, the resultant canopy surface and shading effects would be quite different from the spring flush. Thus after hedging, the south side of the tree would recover leaf area and fruiting capacity more rapidly than the north side. However, selfshading on the south side would soon tend to reduce fruiting while in the more open north canopy light penetration might be sufficient for sustained, uniform fruiting.

Another indication of the subtle relationship of light, shoot growth and fruiting was the significant interaction of hedging treatments x canopy location x season on fruit distribution (data not shown). The season after hedging, the percent of fruit on the bottom inside of north-side hedged trees increased from 6 to 16 compared to an average increase of 3% in this location for the other treatments. The percent of fruit on the bottom inside and to a lesser extent, bottom outside of both north and south-side hedged trees fluctuated much more than trees hedged on both sides or unhedged. Bacon (5) felt a reduced photosynthate supply was responsible for the poor regrowth and flowering following fall hedging. Being directly affected by light, photosynthate production and use could underlie the fruit set and distribution responses cited above.

The increases in the proportion of fruit on the bottom and inside of the tree canopy following hedging can account for most of the significant changes in average fruit weight. The rate of recovery of leaf area with respect to fruit load would also be important. In 1978, for example, fruit size on south-side hedged trees was maintained in spite of the large increase in fruit numbers while fruit size on north-side hedged trees decreased. By 1980 the full recovery of leaf area coupled with a reduced fruit load resulted in uniformly good sized fruit on all trees regardless of hedging treatment.

Ideally, a careful, step-by-step reconciliation of world-wide results of hedging and topping Valencia oranges should produce a formula with which the optimum response to hedging and topping could be attained. The state of the art (or science) has not yet reached that point.

One problem is the lack of agreement on the purpose and place of hedging and topping in the culture of citrus. In practice, citrus trees are hedged or topped when crowding or shading demands, yet research has consistently emphasized the merits of early and systematic hedging and topping to maintain tree size (2, 12, 13, 25). A California study concluded hedging and topping couldn't be economically justified on the basis of yield and fruit quality improvement, yet Florida growers felt hedging and topping were profitable because they improved fruit quality, yields and the effectiveness of other cultural practices (1, 2, 3, 15).

Secondly, a conclusive comparison of hedging 'Valencia' oranges in Texas with other areas is precluded because all relevant data is either not considered or not included in most reports on hedging and topping citrus trees. For example, improved light penetration into the tree canopy is a frequently cited benefit of hedging and topping, but there is no data to document this conclusion. Seldom is sufficient information provided to permit evaluating results on the basis of changes in light conditions.

The factors which might affect the responses of 'Valencia' oranges to hedging or topping are grouped below into four general categories with examples of their pertinent components:

1. Geographical. These include the gross determinants of light and temperature such as latitude, atmosphere, altitude as well as regional climatic characteristics.
2. Locational. The local site and orchard characteristics which influence the meso and micro-environment of the trees, e.g. topography, soil type and surface, tree size, age, and spacing, row orientation, and canopy density.
3. Physiological. Primarily those internal tree processes which interact with the effects of hedging and environmental factors to produce an observed response, e.g. stage or rate of growth, carbohydrate levels, growth regulator gradients, flowering or fruiting status, cropping pattern and rootstock/scion relationships.
4. Cultural. Production practices like irrigation, fertilizing, pesticide or growth regulating sprays, type of hedging or topping equipment, which affect tree or fruit development directly or via some physiological process.

I made a checklist of 12 of these factors in order to compare point by point my results with reports from Australia, California and Florida. At best, information on 8 of the 12 factors was noted; the average was only 6. The degree of latitude could be approximated from an atlas. Altitude and slope were never mentioned, yet these together with atmospheric conditions and time of year determine the intensity, quality and incidence of sunlight (23). Other factors seldom mentioned were tree size and row orientation, canopy or foliage density and cropping pattern. Until these information gaps are filled, the experimental results of hedging and topping citrus will be difficult to reconcile and the practical results unpredictable.

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Cold Hardiness of Young 'Ruby Red' Grapefruit Trees as Influenced by Rootstock, Trickle and Flood Irrigation, and Chloride and Boron in the Irrigation Water

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ABSTRACT

One-year-old 'Ruby Red' grapefruit *(Citrus paradisi* Macf.) trees on 20 rootstocks given trickle and flood irrigation with Rio Grande River water alone and with 500 ppm chloride (Cl^-) or 6 ppm boron (B) were exposed to a radiation freeze that reached a minimum of -5.6°C (22°F) for 3.5 hr at this test site. Freeze injury ranged from twig injury to trees killed to the bud union. Significant rootstock difference in cold tolerance occurred in each of the treatments. Overall, trees on Cleopatra mandarin *(C. reticulata* Blanco), Rangpur lime selections *(C. reticulata* var. austera Swing. hyb.), citrumelo W-2 *(P. trifoliata* X *C. paradisi* Macf.), and Rusk citrange [*Poncirus trifoliata* (L.) Raf. X *C. sinensis* (L) Osbeck], rootstocks had good cold tolerance, while those on Troyer and Carrizo citrange [*Poncirus trifoliata* (L.) Raf. X *C. sinensis* (L.) Osbeck], alemow *(C. macrophylla* Wester), and Ponderosa, Iran, and Golden DiGeorgio Lemon [*C. limon* (L.) Burm. f. hyb.] rootstocks had poor cold tolerance. The influence of rootstock and irrigation method on seasonal leaf Cl^- and B content of the trees was highly significant; but despite obvious content differences between the river water and the Cl^- - or B-treated trees, the influence of Cl^- and B on the cold hardening of this group of rootstocks did not differ significantly. However, the influence of Cl^- and B on cold hardiness of these rootstocks was demonstrated when correlation coefficients for leaf Cl^- or B content vs. freeze injury were determined separately for the rootstocks with low Cl^- and those with high Cl^- content.

Freezing temperatures that severely damage citrus are a major problem in commercial production of citrus in the United States (2, 4, 9, 15). Salinity is also a problem in isolated areas, and chloride salts have been found to affect the ability of citrus trees to cold harden (7, 8). Citrus species vary considerably in cold hardiness (5, 11), and when they are grafted, the rootstock affects their cold hardiness (1, 15, 16) and salt tolerance (3, 6). Consequently, plant breeders have been using cold and salt tolerance as well as other traits in the selection of parental material for their crosses (5). Salt-tolerance tests of various selections from the Florida Citrus Breeding Program were in progress when a natural freeze occurred on December 20-21, 1973 (13). The salt tolerance and mineral uptake of this group of rootstocks have been reported (10, 14). This paper reports on the cold hardiness of these young 'Ruby Red' grapefruit trees as influenced by rootstock, trickle and flood irrigation, and Cl^- and B in the irrigation water.

MATERIALS AND METHODS

One-year-old, 'Ruby Red' grapefruit *(Citrus paradisi* Macf.) trees grafted on the following 20 rootstock selections: Troyer SF/52-2, Troyer SF/52-1, Carrizo SF/52-14, Carrizo SF/52-16, Carrizo SPB 330, and Rusk HF 7-16-15 citranges [*Poncirus trifoliata* (L) Raf. X *C. sinensis* (L.) Osbeck]; H-181 and Texas alemows *(C. macrophylla* Wester); Iran lemon HF 2-9-9, Ponderosa lemon, lemon hybrid Golden Di Georgio, rough lemon variant DBI-407, Heyman's red rough lemon, rough lemon S-514-29-12, rough lemon S-514-29-13, and rough lemon S-SPB-51-2 [C. limon (L.) Burm. f. hyb.]; citrumelo W-2 *(Poncirus trifoliata* X *C. paradisi* Macf.); Rangpur SF/19-22 and Rangpur H-44 limes *(C. reticulata* var. *austera* Swing. hyb.); and Cleopatra mandarin *(C. reticulata* Blanco) were treated with trickle and flood irrigation of Rio Grande river water alone and with Cl^- and B added as previously described (10, 14).

The tests started June 2, 1973 and by November 14 had received 13 irrigation treatments and 53.6 cm (21 in.) of intermittent rains. Trees were evaluated and sampled on August 20 and again on November 14 and the leaf samples were prepared and analyzed for Cl^- and B content by previously described methods (10).

A radiation freeze on December 20-21, 1973 (13) caused a wide range of freeze injury to trees in the salt-tolerance tests in progress. Tree freeze injury was estimated visually after buds appeared on live wood as follows: 0 = no injury; 1 = completely defoliated; 2 = defoliated with 25% terminal twigs killed; 3 = 50% of tree killed; 4 = 75% of tree killed; 5 = tree killed to the bud union. Freeze injury data were analyzed as a split split-plot and uptake data as a split plot. Rootstock means were compared with Duncan's multiple range test at 0.05% probability or better. Correlation coefficients were determined between freeze injury and leaf Cl^- or B content in November of trees of (a) the group of rootstocks that took up little Cl^- (lemons and hybrids, limes, and alemows); (b) the group of rootstocks that took up excessive Cl^- (trifoliate hybrids) and Cleopatra, and (c) all rootstocks combined.

RESULTS

Trees received 20 days of mean night temperatures below 12°C (54°F) and day temperatures below 27°C (80°F); and during the 5 days preceding the freeze received 66 hr of 12.8°C (55°F) or below and 38 hr of 7.2°C (45°F) or below. The freeze of December 20-21, 1973, was a radiation type freeze (13) and temperatures, which are generally colder at ground level, reached a low of -5.6°C (22°F) that lasted 3 - 1/2 hr at a 1.8-m (6 ft) level at the test site. There were highly significant differences in freese injury in all tests among rootstocks but not between irrigation method or treatment. An interaction on freeze injury existed between rootstock and irrigation method. In November, rootstocks differed significantly in Cl^- and B content with irrigation method in the river water and Cl^- tests but not in the B test. There was an interaction on leaf B content between rootstock and irrigation method only in the river-water test.

Freeze injury to the young trees (henceforth referred to by their rootstock) ranged from defoliation with some terminal twig injury to trees killed down to the bud union, and the degree of cold hardening induced by each rootstock varied in the Cl^-, B, and river-water tests (Table 1). The rootstock means of all tests combined show that the Troyer citranges were injured the most and the other citranges (except Rusk), both alemows, Ponderosa lemon, Iran lemon, and lemon hybrid Golden Di Georgio had similar injury. Cleopatra mandarin had the least injury; and both Rangpur Limes, Citrumelo W-2 and Rusk citrange had injury almost equal to that of Cleopatra. The rest of the lemons and hybrids had intermediate injury.

Trees showed seasonal differences in Cl^- and B content, vigor and expression of toxocity symptoms. Leaf Cl^- and B levels were lower in November than in August. However, vigor was lower in November than in August in trickle and flood irrigation of both Cl^- and B tests.

In November, leaves of trees in the Cl^- and B had 2 times more Cl^- and up to 8 times more B respectively, than those in the river water test (Table 2). Rootstock Cl^- content ranged from .08 to 31% and B content from 134 to 218 ppm in the river-water test; Cl^- content from 0.14 to 0.66% in the Cl^- test; and B content from 430 to 1131 ppm in the B test. Within each test, the citranges generally had 2 times as much Cl^- and only slightly less B than the lemons and hybrids.

Correlation coefficients for leaf Cl^- or B content vs. freeze injury ratings in the river water test, when calculated for all rootstocks combined and for 2 rootstock groups separately (Table 3), were highly significant for Cl^- content in all groups except the trifoliate hybrid group with trickle irrigation; but were significant for B content only in the 2 separate groups with flood irrigation. In the Cl^- test, correlations between Cl^- content and freeze injury were significant mainly in the trifoliate hybrid group. In the B test, correlations between B content and freeze injury were significant only in the trifoliate hybrid group with trickle irrigation.

DISCUSSION

In previous salt-tolerance tests, observations and leaf samples were taken at the end of the test in August; however, at this time, the trees were not in the same condition as when they went into the winter months (November). Therefore, this study reports on the condition of trees in November in relation to freeze injury sustained in December. The radiation freeze of December 20-21, 1973, with minimums ranging from -6.7 to -3.9°C (20° to 25°F) across the citrus area of Texas caused various degrees of fruit and tree damage to mature commercial orchards and killed many young trees in new plantings, especially those in low areas with poor air drainage. The rootstocks tested here, all with varying degrees of inherited cold hardiness and a wide range in ion-uptake characteristics, included trifoliate hybrids, which were generally Cl^- pumps; lemons and hybrids which took up excessive B; Rangpur limes and Cleopatra mandarin, which screen out Cl^-; and alemow, which screened out B. Neither the Cl^- nor B treatments augmented freeze injury to the trees over that to trees in the river-water tests, although there was an obvious difference in Cl^- and B in their leaves just before the freeze. The differences induced by Cl^-, B, and irrigation treatments, which were small and not significant, were overshadowed by the highly significant rootstock differences and the interaction between rootstock and irrigation method.

Table 1. Freeze injury to one-year-old 'Ruby Red' grapefruit trees on 20 rootstock selections treated with trickle and flood irrigation of Rio Grande River water and with 500 ppm Cl^- ($NaCl + CaCl_2$) or 6 ppm B (H_3BO_3) added.

Citrus rootstock variety	River water test: Trickle	River water test: Flood	Chloride test: Trickle	Chloride test: Flood	Boron Test: Trickle	Boron Test: Flood	Rootstock mean of all tests
Citranges							
Troyer SF/52-2	4.7 a[z]	4.4 a	3.6 abc	5.0 a	4.3 ab	3.5 abc	4.3 A
Troyer SF/52-1	4.2 ab	4.5 a	4.0 a	4.8 ab	4.3 ab	3.6 ab	4.2 A
Carrizo SF/52-16	4.0 ab	3.0 abcde	3.7 abc	4.7 ab	4.3 ab	3.4 abc	3.8 AB
Carrizo SF/52-14	3.6 abc	4.4 a	3.2 abcd	4.3 ab	4.0 ab	3.4 abc	3.8 AB
Carrizo SPB 330	3.7 abc	2.8 abcde	3.3 abcd	4.6 ab	2.5 bc	3.4 abc	3.4 ABCDE
Rusk HF 7-16-15	2.9 bc	3.4 abcd	1.4 e	2.1 de	- - [y]	2.9 abc	2.4 EF
Alemows							
H-181	2.6 bc	3.1 abcde	4.5 a	4.2 abc	3.9 abc	3.4 abc	3.6 ABC
Texas	3.3 abc	2.9 abcde	4.2 ab	4.4 ab	- -	2.8 abc	3.5 ABCD
Lemons & hybrids							
Iran lemon HF 2-9-9	4.1 ab	4.2 ab	4.5 a	3.4 abcd	- -	3.9 a	4.0 A
Ponderosa	3.2 abc	3.9 abc	3.2 abcd	3.5 abcd	- -	3.3 abc	3.4 ABCDE
Lemon hybrid golden DiGeorgio	3.2 abc	3.0 abcde	3.8 abc	3.4 abcd	3.9 abc	3.4 abc	3.4 ABCDE
Rough lemon variant DBI-407	3.1 abc	2.8 abcde	2.5 bcde	3.9 abc	4.7 a	3.0 abc	3.3 BCDE
Heyman's Red Rough lemon	3.1 abc	2.6 bcde	3.1 abcde	3.9 abc	3.2 abc	3.8 ab	3.3 BCDE
Rough lemon S-514-29-13	3.5 abc	3.1 abcde	2.6 bcde	3.4 abcd	3.9 abc	2.9 abc	3.2 BCDE
Rough lemon S-514-29-12	3.0 abc	3.2 abcde	1.8 de	3.0 bcde	3.5 abc	3.4 abc	3.0 BCDE
Rough lemon S-SPB-51-2	2.9 bc	2.5 bcde	2.6 bcde	3.7 abcd	2.2 c	2.9 abc	2.8 CDE
Citrumelo							
W-2	2.6 bc	2.3 cde	2.2 cde	2.5 cde	4.0 ab	2.0 bc	2.6 EF
Limes							
Rangpur SF/19-22	2.0 c	2.1 de	2.1 cde	3.4 abcd	2.9 bc	3.2 abc	2.6 EF
Rangpur H-44	3.1 abc	2.0 de	2.1 cde	3.2 abcde	2.6 bc	2.0 bc	2.5 EF
Mandarin							
Cleopatra	3.4 abc	1.5 e	1.8 de	1.6 e	- -	1.7 c	2.0 F

[z] Mean of 5 single-tree replications except Texas alemow, which had 2 in the Cl^- and B tests. Scale: 0 = no freeze injury; 1 = defoliated 100%; 3 = 50% killed; 5 = killed to bud union. Rootstock mean separations within columns by Duncan's multiple range test at 5% level (lower case) and 1% (upper case).

[y] -- = Rootstocks not included in trickle-irrigation treatment.

Table 2. Chloride and boron content in November in leaves of one-year-old 'Ruby Red' grapefruit trees on 20 rootstocks tested with trickle and flood irrigation of Rio Grande River water alone and with 500 ppm Cl^- or 6 ppm B added.

	Chloride content (% dry wt)				Boron content (ppm dry wt)			
	River water test		Chloride test		River water test		Boron test	
Citrus Rootstock Variety	Trickle	Flood	Trickle	Flood	Trickle	Flood	Trickle	Flood
Citranges								
Troyer SF/52-2	0.30 a[z]	0.25 b	0.53 a	0.60 a	158 cd	148 fg	640 cd	680 cd
Troyer SF/52-1	0.31 a	0.30 a	0.57 a	0.64 a	159 bcd	163 cdefg	630 d	642 cd
Carrizo SF/52-16	0.24 b	0.23 bc	0.48 a	0.62 a	181 abcd	154 efg	813 abcd	697 cd
Carrizo SF/52-14	0.27 ab	0.24 b	0.52 a	0.63 a	170 abcd	163 cdefg	797 abcd	827 abc
Carrizo SPB-330	0.28 ab	0.23 bc	0.53 a	0.66 a	139 d	167 bcdefg	1,090 a	693 cd
Rusk HF 7-16-15	0.24 b	0.19 cd	0.48 a	0.56 ab	174 abcd	184 abcdef	--[y]	666 cd
Alemows								
H-181	0.12 d	0.12 efg	0.23 bcd	0.28 de	144 cd	159 defg	514 d	430 d
Texas	0.14 cd	0.09 fg	0.26 bcd	0.28 de	182 abc	134 g	--	439 d
Lemons & hybrids								
Iran lemon HF 2-9-9	0.17 c	0.12 efg	0.17 cd	0.29 de	185 abc	207 ab	--	930 abc
Ponderosa	0.12 d	0.14 ef	0.47 a	0.45 bc	209 a	218 a	--	1,131 a
Lemon hybrid DiGeorgio	0.11 d	0.10 fg	0.15 d	0.25 de	149 cd	195 abcd	734 bcd	821 abc
Rough lemon variant DBI-407	0.11 d	0.10 fg	0.26 bcd	0.24 de	166 bcd	197 abcd	1,039 ab	1,066 ab
Heyman's Red Rough lemon	0.12 d	0.09 fg	0.19 bcd	0.28 de	163 bcd	203 abcd	787 abcd	712 cd
Rough lemon S-514-29-13	0.11 d	0.11 efg	0.31 bc	0.25 de	156 cd	189 abcdef	1,013 ab	728 bcd
Rough lemon S-514-29-12	0.11 d	0.10 fg	0.33 b	0.22 de	160 bcd	198 abcd	1,000 ab	875 abc
Rough lemon S-SPB-51-2	0.11 d	0.09 fg	0.20 bcd	0.25 de	169 abcd	178 abcdef	980 abc	883 abc
Citrumelo								
W-2	0.18 c	0.16 de	0.32 b	0.36 cd	172 abcd	191 abcde	824 abcd	702 cd
Limes								
Rangpur SF/19-22	0.10 d	0.08 g	0.24 bcd	0.14 e	159 bcd	153 efg	755 abcd	824 abc
Rangpur H-44	0.10 d	0.08 g	0.15 d	0.15 e	169 abcd	180 abcdef	819 abcd	694 cd
Mandarin								
Cleopatra	0.11 d	0.09 fg	0.19 bcd	0.18 e	200 ab	215 a	--	810 abc

[z] Mean of 5 single tree replications except Texas alemow, which has only 2 in the Cl^- and B tests. Rootstock mean separations within columns by Duncan's multiple range test at 5% level.

y-- = Rootstocks not included in trickle-irrigation treatment.

Table 3. Correlation of freezing injury with chloride and boron content in November in leaves of young 'Ruby Red' grapefruit trees on 20 rootstocks treated with trickle and flood irrigation of Rio Grande River water alone and with 500 ppm Cl^- or 6 ppm B added.

Rootstock groups	Freeze injury vs. leaf Cl^- content		Freeze injury vs. leaf B content	
	Trickle	Flood	Trickle	Flood
	Chloride Test		Boron Test	
All rootstocks	0.12 NS [z]	0.52 *	0.34 NS	0.08 NS
Lemons [y]	0.07 NS	0.09 NS	0.03 NS	0.22 NS
Trifoliate hybrids [x]	0.66 +	0.91 **	0.87 **	0.43 NS
	River Water Test		River Water Test	
All rootstocks	0.64 **	0.65 **	0.26 NS	0.18 NS
Lemons	0.70 **	0.86 **	0.02 NS	0.50 +
Trifoliate hybrids	0.60 NS	0.88 **	0.57 NS	0.80 *

[z] + = 10%; * = 5%; ** = 1% of significance; NS = not significant.
[y] Includes lemons and hybrids, limes and alemows.
[x] Includes trifoliate hybrids and Cleopatra.

The rank in freeze injury of this group of rootstocks, even though some have favorable and some unfavorable inherited cold hardiness, was very similar to the rank in Cl^- levels in their leaves. Correlation coefficients for freeze injury vs. leaf Cl^- or B content were calculated for all rootstocks combined in each test to see how much the Cl^- or B in the tree foliage affected the cold hardiness of this group of rootstocks (Table 3). Coefficients indicated that B did not affect the cold hardiness of these trees; however, Cl^- affected their cold hardiness when Cl^- levels in the irrigation water were low. When Cl^- levels in the irrigation water were high, only flood-irrigation treatments showed a Cl^- effect. The effect of high leaf Cl^- levels on the cold tolerance of trees in flood irrigated plots is in agreement with previous tests (8); and, in these tests, the range in Cl^- content and cold tolerance was as wide in the trickle irrigated plots as in the flood-irrigated plots. When scatter diagrams were plotted of freeze injury vs. leaf Cl^- content of the rootstocks in the individual tests, the points representing each rootstock were segregated into 2 groups, the trifoliate hybrids, with high leaf Cl^- levels, and the lemons and hybrids, with lower leaf Cl^- levels; both groups had similar ranges in freezing injury.

Correlation coefficients calculated for the 2 separate groups of rootstocks disclosed the influence of th Cl^- and B on the cold hardiness of these rootstocks. Although the lemons and hybrids take up little Cl^-, their cold hardiness is affected by smaller amounts of Cl^- than required to affect the cold hardiness of the trifoliate hybrids which take up more Cl^-. Leaf Cl^- levels above 0.17% of trees on lemons and hybrids are already in excess and have already induced their maximum effect on the cold hardiness of these trees. On the other hand, levels up to 0.66% Cl^- in trees on trifoliate hybrids will augment cold injury to different degrees. Leaf B levels affected cold injury but primarily that of trees on trifoliate hybrids. Correlation coefficients also showed how Cl^- and B affected the severity of freezing injury differently when water was applied by flood and trickle methods.

The influence of the individual rootstocks on the freezing injury of the young trees as affected by Cl^-, B and irrigation method is summarized in Table 1. Of particular interest is the cold hardiness of Rusk citrange and Rough lemon S-514-29-12 in the Cl^- treatment, and the lack of cold hardiness of Citrumelo W-2 in the B treatment and Cleopatra mandarin in the river water treatment with trickle irrigation. Apparently the high moisture conditions around the roots created by trickle irrigation affected the rootstock's influence on the ability of these trees to cold harden. Overall, Rusk citrange HF 7-16-15 and Citrumelo W-2 were more cold hardy than the rest of the trifoliate hybrids and, like both Rangpur limes, which are generally thought to be not very cold hardy, were about equal to Cleopatra mandarin, which was the most cold hardy of this group of rootstocks. Redblush grapefruit trees on Rangpur mandarin lime rootstocks have tolearted 5.4°C (22.8°F) for 4 hrs. in field cold hardiness tests with only 55 to 85% leaf injury and a trace of twig injury and those on Troyer citrange and sour orange had less injury (16). However, trees on Rangpur mandarin lime rootstock can not tolerate lower freezing temperatures because during the 1962 freeze, when temperatures reached -11.°C (12.0°F) in some areas in Monte Alto, six-year-old nucellar and virus infected trees had 50% of the 2.4 to 2.6 in. diam. limbs injured compared to 50% of the 1.5 to 2.4 in. diam. limbs of trees on Cleopatra mandarin; and the twelve year old trees on Rangpur mandarin lime had 50% of the 4.3 in. diam. limbs injured and 67% of them died (18). Also, 200 Rangpur mandarin lime seedlings 24 to 28 - months old were killed to the ground while trifoliate hybrids had only a trace of twig injury (17). Other tests are needed to establish lower and upper limits of Cl^- and B in the irrigation solution that will affect the cold hardiness of the more commonly used rootstocks, especially the trifoliate hybrids, which have good cold hardiness in California.

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Fruit Set Survey of Star Ruby Grapefruit

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ABSTRACT

Nineteen Star Ruby orchards in the Lower Rio Grande Valley of Texas were surveyed to determine fruit set percentage and time of fruit drop. No location in the Valley had better producing trees than any other. Initial fruit set taken 4 weeks after full bloom was 9.8%, decreasing to 2.6% by mid-September.

Low fruit production of Star Ruby grapefruit *(Citrus paradisi* Macf.) is an apparent problem in the Lower Rio Grande Valley. The extent of the problem and the underlying causes are unknown. One way of studying the problem is to observe a representative sample of Star Ruby orchards and determine precisely how they perform in terms of fruit production. This survey, based on a representative sample of the 4500 acres planted with Star Ruby, sought to answer several questions:

1. Do Star Ruby trees set more fruit in one Valley location than another?
2. What is the average fruit set of Star Ruby trees in the Valley?
3. When does the greatest fruit drop occur?

MATERIALS AND METHODS

Nineteen Star Ruby orchards comprising ca. 1200 acres were selected to represent the Valley. The survey included orchards as far north as Texan Gardens and as far south as Brownsville (Fig. 1). In each orchard six trees were randomly selected for flower and fruit counts. On each tree four branches with at least 100 flowers each were selected. The branches were tagged and the flowers counted. Four, 12, and 20 weeks later the fruit on each tagged branch was counted. Selected tree branches were counted weekly to determine when fruit drop occurred.

RESULTS AND DISCUSSION

Although there were differences in fruit set among orchards, no general Valley location was better than another. Final fruit set percentages ranged from 0 to 11.4% Valley wide. Differences among individual orchards could be a reflection of care practices, soil conditions, budwood source, or many other factors.

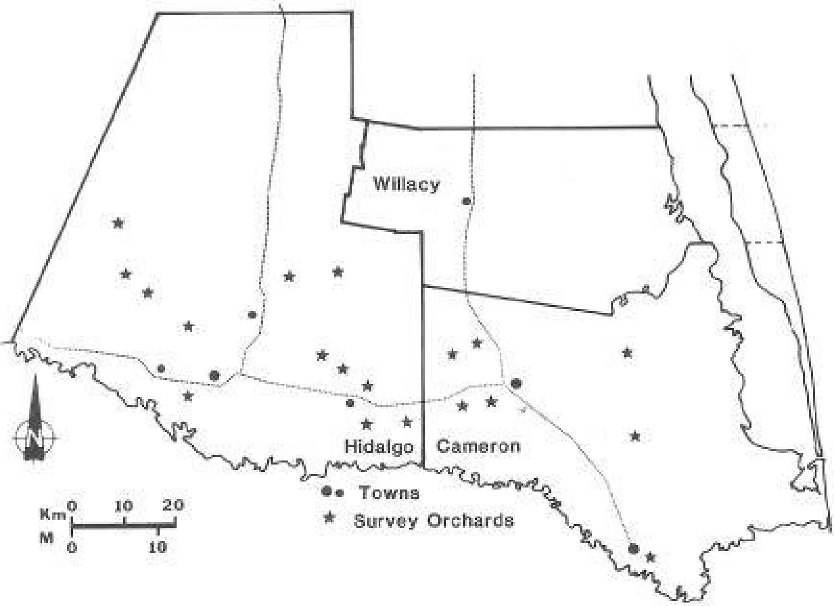

Fig. 1. Location of Star Ruby orchards (shaded stars) included in the survey. Shaded circles are major towns, from east to west: Brownsville, Harlingen, Weslaco, Edinburg, McAllen, and Mission.

Mean fruit set 4 weeks postbloom was 9.8%. The final fruit set determined September 17, 1981, twenty weeks after flowering, decreased to 2.6%. This value is higher than fruit set percentages for some other citrus cultivars. Valencia and Washington navel oranges in California had mature fruit percentages of 1.0% and 0.2%, respectively (3), while Shamouti orange in Israel had a mature fruit percentage of 2.2 - 5.3% (2).

Weekly fruit counts on tagged branches showed that the majority of fruit dropped early in development (Fig. 2). This drop of immature fruit, often called "June drop", occurred from mid-to-late April. After this period, fruit are more likely to withstand adverse environmental conditions, such as high temperatures and water stress, and develop into mature fruit.

These results suggest that Star Ruby does not have a fruit set problem. It must be kept in mind however, that this is a relatively small sample during a single season. Further study is ongoing to better understand factors involved in the fruit set of Star Ruby (1).

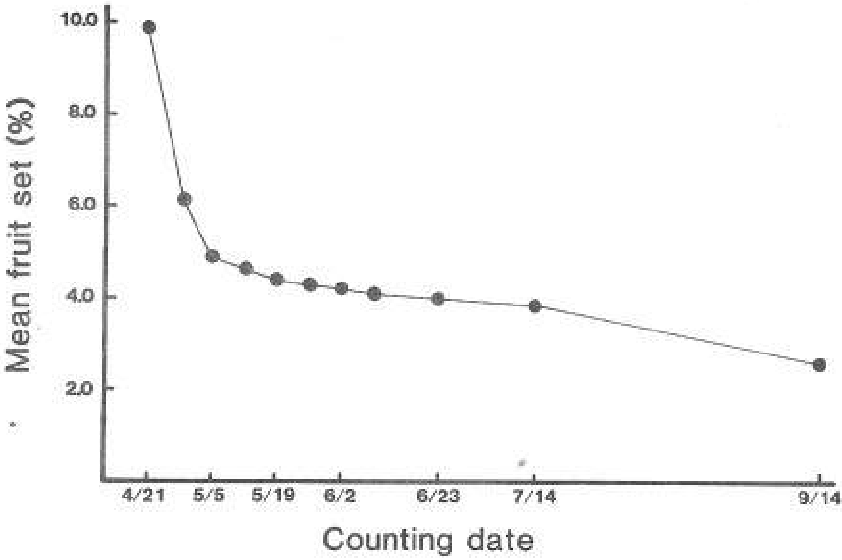

Fig. 2. Fruit set of Star Ruby grapefruit. Each point is the mean of 48 individual counts made on 12 trees.

ACKNOWLEDGEMENT

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Pollination and Fruit Set of Star Ruby Grapefruit

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ABSTRACT

Star Ruby grapefruit flowers cross-pollinated with Hudson or Ruby Red grapefruit pollen resulted in more fruit produced than did flowers that were self-pollinated. Star Ruby lacks the ability to set fruit without pollination. Cross pollination, using Hudson pollen, resulted in fruit that was larger than fruit resulting from self pollination. The number of seeds per fruit was not significantly affected by pollen donor.

Star Ruby grapefruit, a recently introduced cultivar derived from irradiated seeds of Hudson grapefruit, has been commercially available since 1970. During this time, particularly the last 3-5 years, unfruitfulness has been an apparent problem in some orchards.

The cause of unfruitfulness in Star Ruby is unknown. Speculation has encompassed the full range of causes from soil nutrient deficiencies to lack of stress to nucellar vigor. None of these explanations can be ruled out with available evidence. The intent of this study was to 1) estimate the ability of Star Ruby to set fruit without pollination and 2) determine whether pollination, either self or cross, is important in the fruit set of Star Ruby as has been found with Clementine mandarin (6) and Orlando tangelo (5).

MATERIALS AND METHODS

Hand pollinations were performed on flowers of ten-year-old Star Ruby trees at the Texas A&I University Citrus Center in Weslaco, Texas on March 24, 1981, during full bloom. Trees were selected that had similar histories and yield records. Pollen-bearing stamens were hand collected from Ruby Red, Hudson, and Star Ruby flowers. Pollen from these three sources was placed on the stigmas of Star Ruby flowers. This procedure was carried out on 25-50 tagged flowers of two separate trees for each pollen donor. After each hand pollination was complete, the flower was depetaled. To simulate fruit set without pollination, 25-50 tagged flowers of two Star Ruby trees were emasculated and depetaled. No attempt was made to isolate the treated flowers since bees are not attracted to depetaled citrus flowers and citrus pollen is not distributed effectively by wind (2). The percent of fruit set as a result of open pollination was estimated by counts of fruit in September on branches tagged during full bloom when flowers were counted. Fruit diameter measurements were made ca. every two weeks until September 4 when the final fruit set was determined and the fruit were cut open to determine the number of seeds per fruit.

RESULTS AND DISCUSSION

Pollination is important to obtain fruit set in Star Ruby and the pollen source made a distinct difference in fruit set (Table 1). The fruit set percentages shown here are extremely high, most likely due to the favorable conditions provided by hand pollination. Star Ruby flowers pollinated with Hudson pollen set and retained about three times more fruit than self-pollinated flowers. Star Ruby trees in this study did not set fruit when left unpollinated. Star Ruby was derived from Hudson grapefruit seed that had been irradiated with thermal neutrons (3). Because of this close relationship, one might not expect Hudson to be an efficient cross pollinator.

The number of seeds per fruit was not increased by cross pollination. This contrasts the results found in other similar studies (5, 6, 7). It may be that more seeds are present initially in cross-pollinated fruit, but degenerate at an early stage. If a comparison is made between the cross pollination treatments (Hudson, Ruby Red) and the self pollination treatment (Star Ruby), a significantly higher number of seeds are found in the cross pollinated treatments, suggesting that cross pollination does increase seed number to some extent, but not to a level that would make the fruit commercially seedy.

Fruit resulting from flowers cross-pollinated with Hudson pollen were larger than self-pollinated fruit (Fig. 1). Again, the initial presence of developing seeds may be important. Krezdorn (4), Cameron et al. (1), and Soost (6) found significant correlations between seed number and fruit size in the Orlando tangelo, Valencia orange, and Clementine mandarin, respectively, but this was not observed here.

Table 1. Percent fruit set and number of seeds per fruit from hand pollinations of Star Ruby grapefruit trees.

Pollen Source	% Fruit Set (as of 9/4/81)	No. of seeds/fruit
Hudson	59.7 a[z]	1.8
Ruby Red	36.0 b	1.7
Star Ruby	14.0 c	0.8
Open Pollination	2.9 c	1.7
Non-pollinated.	0 d	-
		N.S.

[z] Means separated by Duncan's New Multiple Range Test, 5% level.

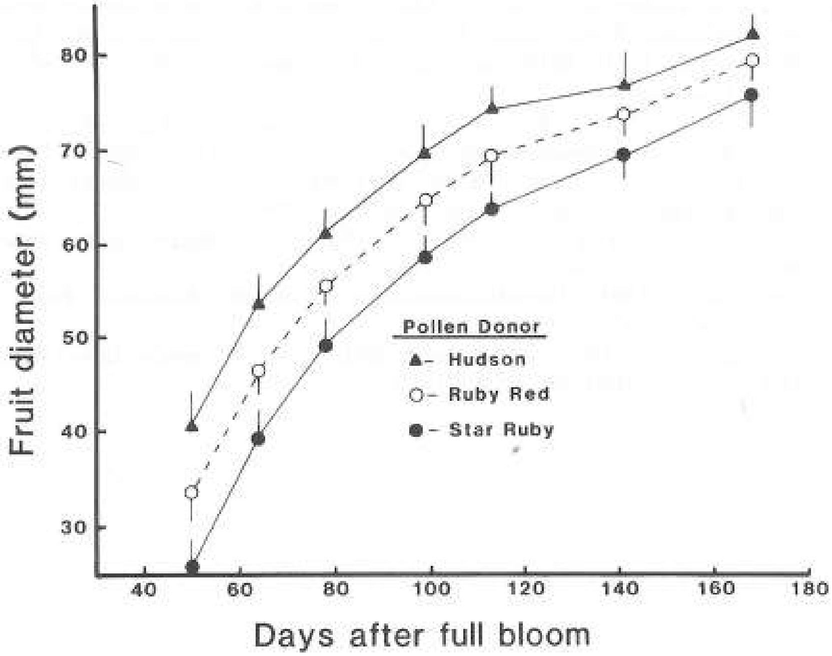

Fig. 1. Diameters of Star Ruby fruit resulting from pollination with three pollen donors. Bars represent ± one standard deviation.

Star Ruby grapefruit lacks the ability to set fruit without pollination. Pollination especially cross-pollination, is important to obtain optimum fruit set. If pol pollination can be controlled, e.g. bees, then cross pollination may increase fruit production. Cross pollination does not increase the number of seeds per fruit to levels that would make the fruit commercially seedy.

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Evaluation of 5 Media and 5 Fertilizer Treatments for Container Citrus

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ABSTRACT

Stem length, stem caliper and total root system dry weight of sour orange *(Citrus aurantium* L.) seedlings increased greatest when grown in medium containing composted bark, perlite and sand than in media of various combinations of peat moss, perlite and sand. Nutrients at 300 PPM N, P and K applied weekly gave increased growth over other scheduling. A medium containing bark with nutrients applied weekly gave maximum seedling growth.

The realization of container citrus nurseries will require a growing medium having the desired physical properties while maintaining the most favorable chemical conditions for plant growth. Maintaining the necessary available plant nutrients for an indefinite period under a variety of conditions can be accomplished by adding them at the time of medium preparation and/or by periodic nutrient applications. Mixes developed and compared for citrus (2, 8, 9, 10), that require a complex of liquid nutrients (6) which are difficult to obtain may preclude the general acceptance of these media. Research using annuals, foliage plants and woody ornamentals has indicated increased growth in media amended with composted bark (1) and suppressive effects on certain pathogens (3, 4, 5, 7). Composted pine bark has been shown to suppress Phytophthora and Pythium root rots (3).

This work was initiated to determine the optimum potting medium and nutrient program for container citrus trees in the Lower Rio Grande Valley of Texas.

MATERIALS AND METHODS

A factorial experiment using 5 potting media and 5 levels of fertilizer was designed with 10 replications per factor. The potting materials were: Canadian peat moss, perlite, composted pine bark and Rio Grande River sand. These materials were measured by volume and combined in a mixer (Table 1).

Uniform seedlings of sour orange *(Citrus aurantium* L.) were selected from a seedbed and planted in 5 qt. plastic containers. The experiment was conducted in a shadehouse covered with 55% shadecloth. Plant height was measured 1 week after planting in June when the first fertilizer treatment was applied. In early November, shoot lengths, stem diameters (caliper) 15 cm above the soil line and total root system dry weights were measured.

Table 1. Composition of potting medium and fertilizer treatments.

Medium treatment by volume	
Medium 1	peat moss, perlite (1:1)
Medium 2	peat moss, perlite, sand (1:1:1)
Medium 3	peat moss, perlite, sand (1:1:2)
Medium 4	composted pine bark, perlite, sand (1:1:1)
Medium 5	sand
Fertilizer treatment	
Nutrient A	Control, no added nutrients
Nutrient B	19-6-12 time release
Nutrient C	1-week interval with 20-20-20 at 300 PPM N
Nutrient D	2-week interval with 20-20-20 at 300 PPM N
Nutrient E	4-week interval with 20-20-20 at 300 PPM N

Each of 5 nutrient treatments (Table 1) was applied to a block of 50 container trees composed of 10 plants of each potting medium. Treatments included a control receiving no added nutrients, Osmocote[1] 19-6-12 slow release at the recommended rate of 8 lbs per cu yd incorporated in the medium, and a water soluble 20-20-20 analysis applied at 300 ppm N at intervals of 1, 2 and 4 weeks. Soluble fertilizer treatments were applied until leaching, and other plants were watered weekly or as needed between fertilizer applications.

RESULTS AND DISCUSSION

Shoot length increase for medium 4 containing bark was significantly superior to all other media (Table 2). Plants in medium 4 also produced the greatest shoot extension, stem caliper and root weight.

Fertilizer treatment C produced plants with the greatest shoot growth and caliper. The weekly application of soluble nutrients resulted in better shoot growth than the other treatments. Root weights were significantly greatest for treatments C and E. The non-fertilized control was the poorest.

Interaction between media and fertilizer treatment was not significant. Combined effects of medium 4 and nutrient treatment C yielded the largest seedlings with respect to shoot extension, caliper and root weight (Table 3).

Significantly greater plant growth and development of container citrus trees occurred in medium 4 containing bark and nutrient treatment C applied weekly at 300 ppm N, P and K. Although shoot extension is important for developing new leaves and is one measure of growth, sufficient stem diameter is

[1] Mention of a product does not constitute a recommendation or endorsement of the product by the Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that may be suitable.

Table 2. Influence of various potting media and fertilizers on growth of sour orange seedlings in containers.

Medium			
Treatment	Shoot length(cm)	Stem diam(cm)	Root dry wt(g)
1	9.1 c[z]	.28 b	2.6 b
2	8.8 c	.26 bc	2.5 b
3	11.8 b	.29 b	2.9 b
4	17.2 a	.39 a	4.5 a
5	8.6 c	.22 c	3.1 b

Fertilizer			
Treatment	Shoot length(cm)	Stem diam(cm)	Root dry wt(g)
A	1.7 d[z]		2.1 c
B	10.4 c	.23 c	3.2 b
C	20.2 a	.37 a	3.7 a
D	13.2 b	.28 b	3.0 b
E	10.0 c	.26 c	3.8 a

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

necessary for propagation by budding or grafting. Only medium 4 and nutrient treatment C produced seedlings with stem diameters ususally exceeding 0.5cm, a caliper size acceptable for budding.

These results indicate that bark could be added to or substituted for peat moss in potting mix 2, and the resulting medium could produce a larger plant in less time.

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Table 3. Influence on growth of sour orange seedlings by combinations of 5 media and 5 fertilizer treatments.

Fertilizer	Medium	Shoot Length(cm)	Caliper(cm)	Root Dry wt(g)
A	1	3.1	-y	3.2
	2	1.8	-	1.6
	3	0.9	-	1.6
	4	1.0	-	1.6
	5	1.8	-	2.6
B	1	8.7	.24	2.2
	2	4.5	.08	1.8
	3	9.1	.26	2.7
	4	15.9	.32	4.1 d
	5	13.5	.25	5.0 c
C	1	12.1	.32	2.5
	2	18.8 cd[z]	,39 b	3.5
	3	28.1 b	.40 b	3.5
	4	31.6 a	.49 a	6.8 a
	5	10.6	.25	2.0
D	1	10.4	.27	2.1
	2	11.8	.29	2.8
	3	13.9	.28	3.3
	4	21.2 c	.39 b	4.7 c
	5	8.7	.18	2.4
E	1	11.1	.27	3.4
	2	7.1	.25	3.1
	3	7.3	.21	3.3
	4	16.1 d	.35 b	5.5 b
	5	8.2	.20	3.5

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

[y] Plant calipers less than .05 cm.

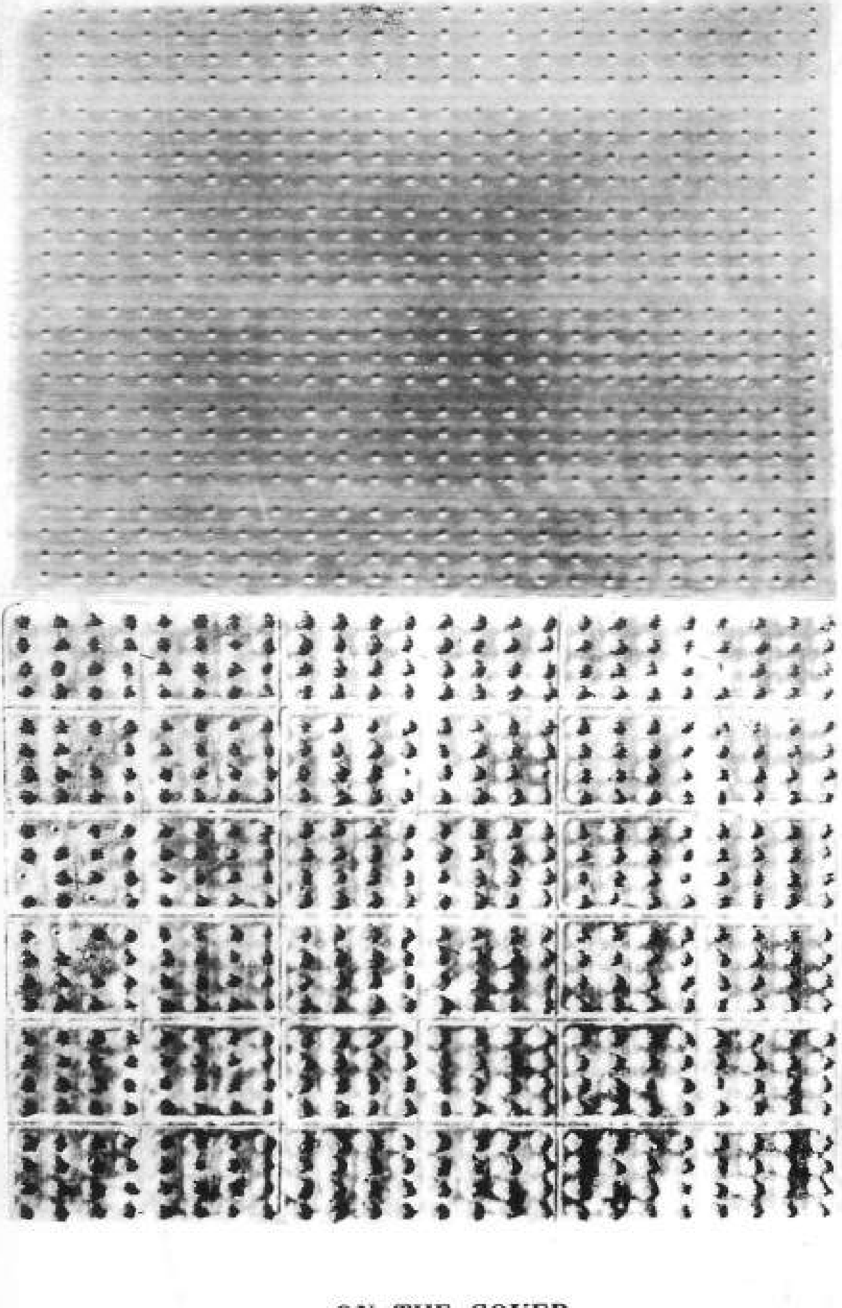
6. Labanauskas, C. K., E. M. Nauer and C. N. Roistacher. 1967. Initial soil-mix and post-planting liquid fertilization effects on nutrient concentrations in Valencia orange seedling leaves. Hilgardia 38:569-577.
7. Malek, R. B. and J. B. Gartner. 1975. Hardwood bark as a soil amendment for suppression of plant parasite nematodes on container grown plants. HortScience 10:33-35.
8. Nauer, E. M., C. N. Roistacher and C. K. Labanauskas. 1967. Effects of mix composition, fertilization, and pH on citrus grown in U.C.-type potting mixtures under greenhouse conditions. Hilgardia 38:557-567.
9. ________ , __________ and ____________. 1968. Growing citrus in modified UC potting mixtures. Citrograph 53:458, 460-461.
10. Richards, S. J., P. W. Moore and J. E. Warneke. 1967. Growing citrus in soil containers. Citrograph 52:339-340.

Errata

Vol. 34, 1980, page 73

Table 2 should read as follows:

	Canopy Volume [z](m^3)
Container grown	18.62 a[y]
Field grown	24.15 b



ON THE COVER

Citrus trees planted in 1964 were photographed in 1965 (top), 1969 (bottom) and 1975 (front cover). There are 8 rows each of Marrs orange (left), Ruby red grapefruit (middle), and Valencia orange (right). Tree growth, yields, juice quality, and water use are reported on beginning on page 73. (Photos by Ron Bowen USDA-ARS, Weslaco.)

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