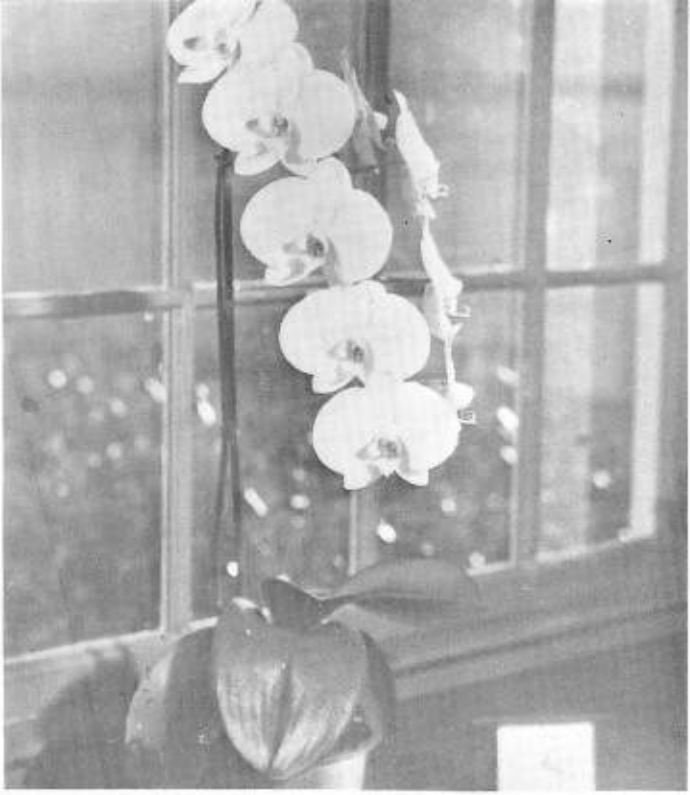
JOURNAL

OF THE

RIO GRANDE VALLEY HORTICULTURAL SOCIETY

Volume 37, 1984

ISSN 0485-2044



TOP: A phalaenopsis.

BELOW: Close-up of a phalaenopsis flower.

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RIO GRANDE VALLEY HORTICULTURAL SOCIETY

Volume 37 1984

Published by

RIO GRANDE VALLEY HORTICULTURAL SOCIETY
P.O. Box 107, Weslaco, Texas 78596

The *Journal,* the official publication of the Rio Grande Valley Horticultural Society, is published in January in one volume and one issue annually.

PRINTED: JaMar Printing Company
506 E. Monroe
Harlingen, Texas 78550
(512) 423-2618

Aims and Objectives of the Society

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

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

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

The *Journal of the Rio Grande Valley Horticultural Society,* provides a continuing record of horticultural progress. Along with research reports, talks given at the Institute are published in the *Journal.*

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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Noel E. Ryall

1984 Recipient of the Arthur T. Potts Award

Noel E. Ryall graduated from Texas A&M University in 1928 with a B.S. degree in Agricultural Administration. He promptly headed for the Lower Rio Grande Valley where, two years later, he married Hazel Mae Downs formerly of Tuscola, Illinois. Noel and Hazel have two daughters, Noelda and Ramona.

With the help of Arthur T. Potts, whose name this award bears, Noel established the Bayview Orchard Service in 1932 and began a long and successful career in the orchard care business. The Bayview Orchard Service is still going strong some fifty-two years later.

Being on the scene in the early days and being an activist Noel was, as you might expect, involved in the very beginnings of some of the organizations that have been important to Valley agriculture. He was a charter member and chairman of the Texas Citrus Federal Marketing Order Committee. He was a charter member and served on the Board of Directors of Texas Citrus Mutual. He helped found the Bayview Citrus Association of which he was President and served as a long-time Board member. He served on the Board of Directors of the Texas Citrus Exchange. He was also a member of the Edinburg Citrus Association.

Cameron County Water Improvement District #11 had the benefit of his leadership over a forty-two year span as a member of their Board of Directors. Noel served on the Advisory Agriculture Committee of Texas A&M University. He has been a cooperator with Texas A&I Citrus Center in citrus research. In 1966 Noel served as President of the Rio Grande Valley Horticultural Society and was for many years on the Board of Directors. Noel Ryall was the Texas Citrus Mutual Man of the Year in 1972.

Noel's activities were not limited to agriculture. He was a Board member and vice-president of Texas Southmost College from 1955-1967; a long-time member of the Los Fresnos Chamber of Commerce and Director of the Valley Chamber of Commerce; in 1966 President of the Board of Realtors of Brownsville. Noel was a founder and member of the Board of Directors of the Merchant Marine Bank, Port Isabel where he also served as chairman of the board. Noel was a member of the board of the Los Fresnos School Board and sometimes President.

Noel has been a long-time member of the Los Fresnos United Methodist Church where he has served as a Board member and sometimes chairman. By his own words Noel credits any success he may have achieved to the support of his dear wife Hazel who has worked side by side with him in all his endeavors.

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All manuscrips are subject to peer review by two associate editors who may seek additional review by appropriate specialists. Where the associate editors disagree as to the merits of a paper the editor will seek the opinion of another specialist before a decision on acceptance is made. Acceptance of a manuscript may depend on some revision following review. Authors should subject their contributions to review within their organization prior to submission.

One author of the paper must be a member of the Rio Grande Valley Horticultural Society. There will be a page charge of $15.00 per printed page in the Journal.

When in doubt as to manuscript preparation or literature citation style, please consider that we attempt to follow the style of the Journal of the American Society for Horticultural Science where this does not conflict with specific guidelines as follows:

Title: Keep title brief, but let it reflect important aspects of the article. Capitalize only the first letter of important words.

Byline: Author's name follows the title, followed by author's affiliation (title and institution) and institutional address with zip code.

Additional index words: This heading with a list of additional key words not used in the title may follow the byline.

Abstract: An author-written abstract follows the index words separated with space. The abstract should be brief, concise, and informative. Do not exceed 5% of the length of the paper. Separate the abstract from the text with a solid line, use two to four spaces above and below the line.

Text: An "Introduction" heading is not used. Introductory statements should give the background and objectives of the research work reported, or purpose of the article. Use no footnotes, supplementary informtion should be included in the text and may be parenthesized.

The body of a research paper should be divided into sections such as **materials and methods, results, discussion, followed by acknowledgements and literature cited,** or other appropriate headings. Subheadings with the first letter capitalized may be placed at the beginning of paragraphs and underlined.

Names of proprietary substances, materials, and special apparatuses should be followed by parenthesized named and addresses of the manufacturers.

Chemicals, fungicides, insecticides, herbicides, etc., should be listed by approved common names. The chemical name should be parenthesized follo the common name when it is first used in the text. Use the chemical name wher common name is not available. Use trade names only if no other name is availa

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Each table should be typed on a separate page without crowding its columns.

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Chew, Victor. 1976. Uses and abuses of Duncan's multiple range test. Proc. Fla. e Hort. Soc. 89:251-253.

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L. Bryan-Jones and D. J. Finney. 1983. On an error in "Instructions to ors." HortScience 18:179-282.

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AMENDMENT TO THE BY-LAWS

At the Annual Institute business meeting, 18 January 83 an amendment was adapted changing Article V. Sections as follows:

ARTICLE V. SECTIONS

1. The Society shall be divided into Sections representing the various interests of horticulture in the Rio Grande Valley as follows:

Citrus and Special Fruits
Vegetables
Ornamentals
Gardening and Landscape.

Under the amendment Citrus and Special Fruits are now combined in one section. A new section, Gardening and Landscape now covers the subject matter previously under ornamentals. The section entitled Ornamentals is now oriented towards the wholesale nursery industry.

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Harvest Date and Yield Relationships of Texas Grapefruit

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Weslaco, TX 78596

ABSTRACT

The effects of harvesting grapefruit (*Citrus paradisi* Macf. cv. Ruby Red) trees late in the season was examined in two separate studies. In the first, the number and weight of fruit/tree were recorded for three harvest dates, November 1969, February 1970 and April 1970. The 1970-71 yields were not affected by date of harvest, but were negatively correlated with the 1969-70 yields. In the second study, yields of grapefruit trees harvested early (before January 15) were compared to trees harvested late (after April 15) for eight pairs of seasons. The trees were located in four different orchards. In the year of differential harvest the early-harvested trees had more fruit/tree than the late-harvested trees whose yields were often reduced by heavy fruit drop in late spring. In the early, but not the late-harvested trees, the first year's yields were positively correlated with the second year's. These results are compared to those from other areas in relation to the mechanism by which delayed harvesting might affect subsequent yields in citrus.

In Texas, concern over the effects of late harvesting typically arises when a citrus grower finds in early fall his trees' yields are below average following their final picking the previous May or June. Recognizing no other causes, the grower assumes the late harvest led to the yield reduction and feels he should be compensated for his loss.

This situation raises several questions. First, if late harvesting occurs randomly over a variety of seasons and orchards, is the subsequent yield consistently and predictably reduced? In one study, yields of Florida grapefruit trees were progressively reduced with successively later harvest dates (18). However, a subsequent test showed no effect of late harvesting under similar conditions (19). The second question, if late harvesting does reduce the next season's yield, at what point and how is its effect exerted? Several reports indicate harvesting Valencia oranges in late versus early spring lowered the next year's yields although there was no consensus on causal mechanisms (1,2,7,8,11,13).

These varied responses plus the occurrence of late harvesting in Texas prompted a study of how Valley grapefruit trees react to late harvesting and what factors might influence their response.

PROCEDURE

The first experiment covered two seasons and was similar to the Florida studies (18,19). The second involved several seasons and orchards, and addressed the typical late harvesting season described above.

Experiment 1. In September 1969, 24 uniform, 8-year-old Ruby Red grapefruit trees were randomly assigned to three groups of eight trees each. The first group harvested November 12, 1969, the second, February 2, 1970, and the third, April 14, 1970. The number and weight of fruit from each tree were recorded. The same data were taken for the 1970-71 crop. The trees were harvested from November to February 15, but the yields were adjusted by the formula $w = (n - d) \times f$ where w = adjusted yield (lbs.); n = number of fruit harvested; d = fruit drop between date of harvest and Feb. 15, and f = avg. fruit weight on Feb. 15. The yield data were normally distributed with variances homogeneous and independent of the means. Statistical evaluations included analysis of variance and regression of the 1970-71 yields, **y**, against the 1969-70 yields, **x** (24).

Experiment 2. Trees picked before January 15 were defined as early-harvested and those picked after April 15, as late-harvested. These dates are consistent with early and late picking in the commercial harvest season which normally runs from late October through May. The interim period, January 16-April 14, usually encompasses spring growth initiation and bloom for Texas grapefruit. Data were taken from yield records of four Citrus Center grapefruit orchards in which two groups of trees, under similar care, were picked either early or late to meet particular harvesting or experimental needs. The records provided eight seasonal pairs in which yields from 6 to 20 pairs of early and late-harvested trees could be compared. The following year all the trees were harvested together, usually from December through March. The resultant assortment of seasons, orchard locations and tree ages provided a representative sample of the early and late harvesting situation typical of Valley grapefruit orchards. Since a preliminary examination of the yields showed the near normal distribution to be right-skewed and a positive correlation between variance and means, the common logarithms of the yield values were used for the appropriate statistical analyses (15). Means were separated using Bayes LSD with k = 100 which favors making a Type II over a Type I error (23).

RESULTS

Experiment 1. Date of harvest the previous season had no effect on the 1970-71 crop although heavy fruit drop significantly reduced the yields of the late-harvested trees in 1969-70 (Table 1). Since there was a decreasing yield trend with delay in harvest dates, an alternate bearing pattern was not induced. This was contrary to the reports of Jones and Cree (11) and Ramirez and Krezdorn (18) which found late harvesting accentuated alternate bearing. However, the alternate bearing characteristic was tested by regressing the number of fruit/ tree in 1970-71, **y**, against the number of fruit/tree in 1969-70, **x**. The resultant regression was highly significant with the fruit load in 1969-70 accounting for 77 percent of the yield variability in 1970-71 (Table 2). The regression coefficient, **r**, for the early-harvested trees, $-.74$, was not significantly different from the late-harvested trees, $-.84$, at the 1% level.

Table 1. Two Season's Yields (lb./tree) of Ruby Red Grapefruit Trees as Affected by Three Harvest Dates.

	Harvest Date[z]			
Season	Nov. 12	Feb. 2	Apr. 14	Mean for Seasons
1969-70	370 B	367 B	235 A	324 B
1970-71[y]	207 A	247 A	268 AB	241 A
Means for Harvest Dates	288 A	307 A	251 A	

z — Trees harvested November 1970 — February 1971 with all yields adjusted to a February 15, 1971 harvest date. (see text).

y — Means within box, for seasons and for harvest dates separated by Duncan's New Multiple Range Test, 1% level.

Table 2. Variability Associated with Grapefruit Yields (lb./tree) for Two Successive Seasons and Tree Harvest Dates.

Source of Variation	d.f.	Sum of Squares	Mean Square	F
Total	17	1993266	—	—
Harvest Dates[z]	2	92984	46492	1.75 n.s.
Regression[y]	1	1528635	1528635	57.6 (p = 0.001)
Deviation from Regression	14	371646	26546	—

z — Eight trees each harvested Nov. 12, Feb. 2, Apr. 14, 1969-70. Following season trees were adjusted to a Feb. 1971 harvest date. (see text).

y — 1969-70 yields = **x**, 1970-71 yields = **y**

Experiment 2. Over the eight pairs of seasons the early-harvested trees averaged 37 pounds more fruit per tree than the late-harvested trees (Table 3). However, this difference resulted from higher yields for the early-harvested trees in Year 1, rather than for Year 2. In Year 2, the early-harvested trees' yields were not significantly different from the yields of late-harvested trees and showed no consistent higher or lower trend. Therefore, harvesting date had no effect on the next year's crop.

The relationship between Year 1 and Year 2 yields was again examined by regression analysis (Fig. 1). In contrast to Experiment 1, the early-harvested trees' yields were positively correlated with Year 2, $r = .32^{**}$. This suggests that despite age or orchard location individual tree yields in any pair of successive years are closely related and can, using the equation in Fig. 1, be estimated with an average error ± 11%.

DISCUSSION

Delaying harvest of grapefruit in Texas until late spring had no consistent effect on the succeeding crop. The penalty for late harvesting was a reduction in yields resulting from the accelerated drop of mature fruit which usually occurs in the late spring months.

In these experiments, yield variability between trees accounted for 50 percent of the total variation in yields (A.O.V. table, not shown). Differences between seasons accounted for another 20 percent of overall variability. Such nonuniformity makes detecting small yield differences virtually impossible.

Another factor which makes year to year yield comparisons difficult is the significant but inconsistent correlation between successive year's yields. The generally positive correlation between one year's yields and the next is unpredictably interspersed with alternate bearing years when the correlation is either negative or not significant. However, even when the variability associated with this correlation was removed from the Year 1 to Year 2 yield relationship, there was no effect due to late harvesting for the Texas trees. This could explain the conflicting results of late harvesting grapefruit in Florida versus Texas. In the first Florida experiment, Year 2 yields were presumably reduced by late harvesting in Year 1, but statistical significance is not shown nor was the possibility of a negative correlation between Year 1 and Year 2 yields examined (18). The second experiment which showed late harvesting had no effect on yields either year was not comparable to the first experiment because the trees were harvested on the same dates both years (19). While the author's assumption that gain in fruit weight in Year 2 offset the anticipated yield reduction from late harvesting may be correct, these conclusions seem premature in view of seasonal yield variability. The results of Experiment 1 would be equally suspect except they are supported by the data of Experiment 2. Two other dissimilarities between Florida and Texas grapefruit are the large differences in average yields, ca. 1200 versus 225 lbs./tree and the apparently inconsequential fruit drop in Florida compared to Texas trees. These two factors alone could account for the different responses to late harvesting between the two areas.

There are three critical periods which determine the potential fruit crop: flower bud formation, bloom and fruit set, and fruit growth and development (5). Since late harvesting's effect, if any, on fruit size occurs primarily through influencing fruit numbers, the mature fruit apparently exerts control during the flower bud formation

Table 3. Yields of Early and Late Harvested Grapefruit Trees Over 8 Pairs of

Season Pair	Age of Trees	Yields (lbs./tree)[z]			
		Early Harvest		Late Harvest	
		Year 1[y]	Year 2	Year 1	Year 2
1966, 1967	12,13	432	383	287	284
1967, 1968	6, 7	58	180	78	141
1969, 1970	15,16	500	417	276	470
1969, 1970	8, 9	180	351	141	447
1971, 1972	3, 4	188	203	113	142
1974, 1975	5, 6	222	169	149	104
1975, 1976	6, 7	165	239	88	237
1976, 1977	7, 8	191	338	155	326
Means for Harvest Dates:[x]		222	185		

z — Bayes LSD for separation of means = 114 lb., S.E. = ± 29 lb.

y — Year 1 is the year of early or late harvest; Year 2 all trees were harvested at the same time.

x — Means significantly different, (p=0.01) 1% level. S.E. = ± 23 lb.

or bloom and fruit set stages. The time of flower bud differentiation may occur from six months to two weeks before bloom (4,17,21). For most citrus varieties this period would be considered an early to mid-season harvest. The question remains then, how does old fruit affect flower buds? And why is the effect so inconsistent? Apparently old fruit do not decrease the potential number of flowers. Late harvesting may reduce the amount of bloom, but early or mid-season harvests do not (18). The most researched hypothesis, supported largely by studies on Valencia oranges, suggests mature fruit suppress flowering or new fruit growth by competing for carbohydrates or their metabolic products (7,13,14,22). However, variety and climate differences limit the applicability of these results to Texas grapefruit. Another hypothesis suggests mature fruit may influence the synthesis and translocation of the growth regulators involved in flower and fruit development (10,17). Most likely both of these theories are involved, operating via some feedback mechanism or as Monselise (16) suggests by hormonal regulation of key metabolic processes.

The effects of harvesting the same trees late for several years in succession was not evaluated. This was not the question to be answered and furthermore is not likely to occur in a typical, commercial, Texas citrus orchard. The resolution of the erratic

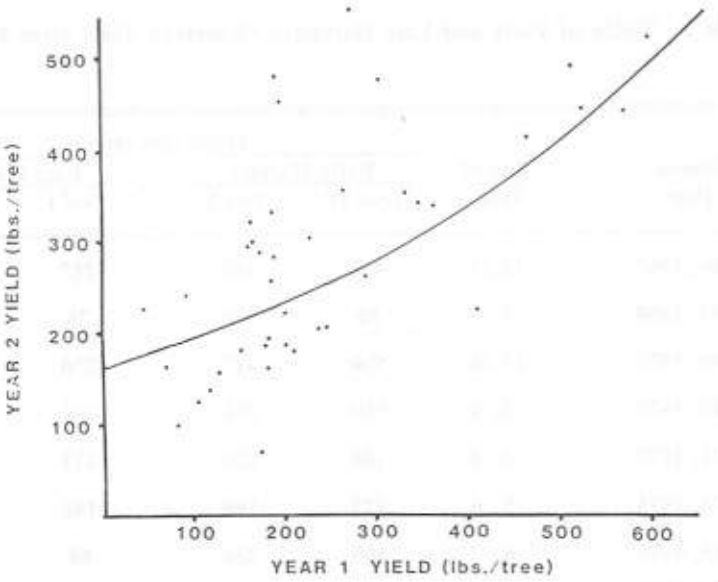

Fig. 1. The relationship between yields of Ruby Red grapefruit trees in any given season Year 1 (x), to the next, Year 2 (y). The correlation, $y = 168.002^{x}$, with $r = .32$, is significant at >1%. The data, from a study of late harvesting effects on the succeeding crop, cover eight seasonal pairs of yields from 1966-77.

results of late harvesting, depends on formulating a hypothesis of how and when a mature fruit affects the process of flowering and fruit set on an individual branch, which tends to be extremely alternate bearing and sensitive to environmental influences (6,9,12,20). At bloom, a branch bearing a grapefruit has few flowers and nearly zero fruit set (3). The effect of fruiting on the whole tree, therefore, depends on the proportion of fruit-bearing branches in the canopy and how they individually respond to their immediate environment. As we gain more information on the characteristics and behavior of the individual branch or fruiting unit, many questions on flowering and fruit set in citrus will be answered.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Factors Affecting A Postharvest Discoloration on Texas Grapefruit

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ABSTRACT

The association between postharvest injury and a red discoloration in the flavedo of Texas grapefruit was examined. The discoloration was the result of subtle, postharvest scratches and abrasions, being most prevalent on 'Duncan White' and least prevalent on 'Star Ruby' grapefruit. Fruit flavedo discolored in 10 days at 24°C and in 21 days at 11°C. Sodium-o-phenylphenate increased, while benomyl and diphenyl decreased the appearance of the red discoloration as compared to the control.

Harvesting and postharvest handling of grapefruit invariably causes physical injury to the fruit peel. Two general types of injury occur: 1) surface scrapes, punctures, and scratches and 2) bruising (2). Surface scratches are undesirable since the injury provides an opening for decay organisms (i.e. *Penicillium spp.*) (6). Surface blemishes result in poor external appearance which downgrades the fruit (1).

In January of 1982 and 1983, a red discoloration on exported grapefruit from Texas was observed. The cause of the discoloration was not readily apparent; however, it seemed to be associated with physical injury since the discoloration only occurred in scratched areas of the fruit. This discoloration was distinct from the rind discolorations described for Florida oranges and California lemons (4,7,8). In this study, an attempt was made to determine if this red discoloration is caused by physical injury and some of the factors that alter its appearance.

MATERIALS AND METHODS

Four grapefruit cultivars (*Citrus paradisi* Macf. 'Duncan White', 'Foster Pink', 'Ruby Red', and 'Star Ruby') were tested to determine their relative responses to scratching injury. The injury was induced by scratching the fruits' surface with a dissecting needle that was mounted onto a Chatillon pressure gauge. A uniform pressure of 0.008-0.02 kg/cm^2 (0.1-0.2 lbs/in^2) was maintained during the scratching procedure. The injured fruit of each cultivar were then divided into 4 groups of 8

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fruit each and given standard postharvest fungicide treatments. Sodium-o-phenylphenate (SOPP at 1.86% a.i.) or benomyl (Benlate, 600 ppm a.i.) were applied by hand-trigger sprayer. Diphenyl was applied by setting injured fruit between two domestic-type diphenyl pads (2.2 g diphenyl per pad). A control group of fruit was sprayed with distilled water. After applying the fungicide treatments, the fruit were again divided into two groups for storage at room temperature (24 ± 1 °C) or refrigerated at 11 ± 1 °C. The fruit were examined after 10 days storage and periodically thereafter for up to 23 days.

Observations and measurements of the fruit included a visual rating of the injured areas and measurements of the scar width. A visual rating system (0 = no discoloration, 5 = dark red discoloration) was used to rate the red discoloration of the injured areas. Measurements of scar width were made at the stem end, equator, and stylar end of each fruit.

RESULTS AND DISCUSSION

Discoloration of the fruit stored at 11 °C did not become evident until 21 days. These fruit were observed and measured after 23 days in storage. Red discoloration of the injured areas was affected by several factors (Table 1). Sodium-o-phenylphenate (SOPP) caused the greatest discoloration. Solutions of SOPP are brownish-red and may contribute to the discoloration produced in the flavedo. SOPP tends to "fix" itself to injured areas as the free phenol and this may also contribute to the discoloration response (9). However, Eaks reported no enhancement of the rind staining of 'Washington' navel oranges due to 0.5-1.0% a.i. SOPP (3). Benomyl inhibited the discoloration response compared to the water-sprayed control.

The discoloration response of the four cultivars to injury differed markedly (Table 1). The original reason for choosing the fruits of these cultivars was their differing degrees of red pigmentation in the endocarp (flesh). If the discoloration of the flavedo was influenced by the pigmentation of the flesh, then 'Duncan White' should have the least red discoloration and 'Star Ruby' the most. In contrast, as the flesh color changed from white to red in these fruit, the red discoloration of injuries was reduced. It is possible that with red flavedo, the red discoloration is difficult to recognize.

The red discoloration appeared much sooner in fruit stored at room temperature than in refrigerated fruit. The biochemistry responsible for the red discoloration is not known, but it is likely that reaction rates would increase with temperature. Reddish-brown phenolic compounds are known to form more quickly at higher temperatures in injured flavedo of 'Valencia' orange (5).

SOPP increased the width of the scar (Table 1). Again, since SOPP "fixes" itself to wounds, its effects are likely to be more apparent. Although significant statistical differences were apparent among the four cultivars regarding the width of scars, the differences are small in practical terms and probably of little consequence.

The storage temperature also affected the width of the scars (Table 1). Fruit stored at room temperature had a higher rate of water loss from the flavedo, thus causing the scars to separate. Although the difference in the scar width between fruit stored at 24 °C and 11 °C is small (0.04 mm), it likely reflects the differences in water loss under the two storage conditions.

Table 1. Factors affecting the appearance of red discoloration of Texas grapefruit.

Factor	Measurement	
Fungicide Treatment[y]	Visual Rating[z]	Scar width (mm)
Control (water)	1.2 b[x]	0.29 a
SOPP	2.0 c	0.50 b
Benomyl	0.8 a	0.30 a
Diphenyl	0.9 ab	0.26 a
Cultivar		
Duncan White	2.1 d	0.34 b
Foster Pink	1.6 c	0.27 bc
Ruby Red	1.2 b	0.26 a
Star Ruby	0.02 a	0.39 c
Temperature[y]		
24 °C	1.4 b	0.36 b
11 °C	1.1 a	0.32 a
Location on fruit[y]		
Stem end	—	0.22 a
Equator	—	0.49 c
Stylar end	—	0.31 b

[z] 1 = no discoloration; 5 = dark red discoloration.

[y] Means are from all four cultivars.

[x] Means in columns within each factor have been separated using Duncan's New Multiple Range Test at the 1% level.

Differences in scar width depended on the area of the fruit. The stem-end, stylar-end, and equatorial areas of the fruit had scar widths of 0.22, 0.31, and 0.49 mm, respectively (Table 1). The larger scar widths at the equator of the fruit can be explained by the greater tension that area of the fruit experiences because of its oblate spheroid shape (10).

The red discoloration that appears on Texas grapefruit during mid-season was closely associated with physical injury. The discoloration did not originate from the flesh of the fruit. Rather, it was synthesized in the flavedo in response to the injury. Preliminary attempts to determine the chemical nature of the red discoloration showed that the compound(s) was not an anthocyanin.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Foliar Fertilization of Cucurbits in South Texas

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ABSTRACT

Multiple foliar applications of a multi-nutrient fertilizer were applied to several cucurbits. Cantaloupe, watermelon, squash and cucumber yields and size were unaffected by three different rates of foliar fertilization. Soil nutrient levels during this study appeared to be adequate for good cucurbit production.

Numerous processes can reduce availability of nutrients in soil applied fertilizers to a crop. For example, nutrient losses and transformations into unavailable forms diminish fertilizer utilization efficiency. Cultural practices such as fertilizer placement, timing of application, and the use of materials which release nutrients slowly have been sought to control availability of nutrients. Rapidly growing crops such as cucurbits may require more nutrients during a portion of their growth cycle than the root system is capable of taking up even though adequate supplies are available in the soil.

Foliar fertilization of vegetable crops offers several possible advantages over conventional soil applied fertilizers (2). Foliar feeding could improve utilization and speed uptake of applied nutrients by bypassing transfer inefficiencies and losses in the soil. The needs of the crop during growth could be met quickly and efficiently.

There are limitations to the use of foliar application as a method of supplying most nutrients. Chemical forms of several nutrients which are most efficiently absorbed and metabolized in the foliage, particularly in combinations, have not been extensively evaluated for various crops. Phytotoxicity limits the rate of application of major nutrients necessitating multiple applications. Proper spray coverage and suitable environmental conditions are important to minimize leaf burn and enhance uptake.

Certain circumstances may justify incurring the added problems and expense of foliar fertilization. Foliar application is used extensively to correct micronutrient deficiencies since smaller quantities of these nutrients are required by the crop. During high rainfall, flooded-field conditions inhibit nutrient uptake by roots by limiting

Table 1. Nutrient Content of Bayfolan Plus™ Fertilizer.

Nutrient	Content
	—%—
N (total)	11
$CO(NH_2)_2$-N	6.70
NH_4^+-N	2.75
NO_3^--N	1.55
P_2O_5	8
K_2O	5
B	.020
Co	.0005
Cu	.050
Fe	.100
Mn	.050
Mo	.0005
Zn	.050

Bayfolan Plus is a registered trademark of Helena Chemical Company.

Table 2. Cumulative cantaloupe yield at each harvest date and average cantaloupe size for all harvests at the various foliar fertilization rates.[z]

		Application Rate (L/ha/wk)			
	Date	0	4.7	7.0	9.4
		t/ha			
Total Weight	6/24	12.2	11.6	11.1	12.2
	6/26	17.7	17.6	17.6	18.2
	6/30	23.0	24.4	23.6	23.8
	7/07	23.4	25.0	24.2	24.6
		kg/melon			
Average Size		1.36	1.38	1.33	1.42

[z]No significant differences between treatments ($p = 0.10$).

available oxygen for this active metabolic process. Foliar feeding may temporarily sustain the crop, though no studies have documented this. Crop demand during fruiting may be augmented by foliar application. Yield responses to such a practice by soybeans have in some cases been promising (1). The rapid growth of cucurbits allows very little time to correct nutrient deficiencies without reducing yields. Foliar fertilization may allow more precise tailoring of the nutrition program to the needs of a high value crop.

This study was conducted to determine whether cucurbits in South Texas could benefit from multiple foliar applications of the multi-nutrient fertilizer Bayfolan Plus, a product of Helena Chemical Company, Memphis, Tennessee.

PROCEDURES

Field studies were conducted during the spring of 1980 at the Texas A & M University Agricultural Research and Extension Center at Weslaco on a Hidalgo sandy clay loam soil (Fine-loamy, mixed, hyperthermic Typic Calciustoll). The crops were cantaloupe (*Cucumis melo* cv. Perlita), watermelon (*Citrullus lanatus* cv. Jubilee), squash (*Cucurbita pepo* var. *melopepo* cv. Early Prolific) and cucumber (*Cucumis sativus* cv. Poinsett).

Cantaloupes and watermelons were planted on 1 April, and squash and cucumbers were planted 14 April. Cantaloupes, watermelons and cucumbers were planted in 2 M rows, and squash was planted in 1 M rows. Standard cultural practices included chemical and mechanical weed control, thinning, irrigation, and chemical pest control as required.

Treatments consisted of weekly applications of Bayfolan Plus™ (Table 1) at rates of 0, 4.7, 7.0 and 9.4 L/ha applied to plots 2.0 x 15.2 M in randomized complete block designs with 6 replications for each crop. Treatments were begun 3 weeks after planting and continued until the first harvest of cucumbers and squash for a total of 5 applications and 3 weeks before first harvest on cantaloupes and watermelons for a total of 6 applications. Fertilizer applications were made by diluting the required amount of material in water so that solutions were applied to all plots at the rate of 305 L/ha with a hand held CO_2 pressurized sprayer with a 2 M spraybar containing 4 nozzles.

Observations of plant condition during the foliar fertilization treatment period were recorded. Multiple harvests were made on all crops to meet market standards. Analysis of variance was applied to the data using the 10% significance level.

RESULTS AND DISCUSSION

Plant growth and development were quite uniform across all treatments for all crops in this study. No visual indications of nutrient deficiency or leaf burn from the foliar applications were observed.

Cantaloupe yields averaged 24.3 t/ha and showed no significant differences due to the foliar fertilization treatments (Table 2). Size of cantaloupes was also unaffected by treatments. Watermelon yields averaged 42 t/ha and also showed no statistically significant differences due to treatment (Table 3). Watermelon size was unaffected by treatment. Squash yields were very consistent among treatments at all harvest dates (Table 4). Final squash yields averaged 5.2 t/ha. There was no significant

Table 3. Cumulative watermelon yield at each harvest date and average watermelon size for all harvests at the various foliar fertilization rates.[z]

		Application Rate (L/ha/wk)			
	Date	0	4.7	7.0	9.4
		t/ha			
Total Weight	7/03	16.7	16.1	19.8	13.1
	7/07	22.0	18.5	24.7	17.7
	7/11	24.1	22.5	28.5	21.9
	7/14	30.3	26.9	29.8	27.1
	7/21	41.3	37.9	40.7	32.5
	7/24	46.1	41.8	45.6	34.5
		kg/melon			
Average Size		5.6	5.4	5.4	4.8

[z]No significant differences between treatments ($p = 0.10$).

Table 4. Cumulative squash yield at each harvest date and average squash size for all harvests at the various foliar fertilization rates.[z]

		Application Rate (L/ha/wk)			
	Date	0	4.7	7.0	9.4
		t/ha			
Total Weight	5/28	2.0	2.1	1.9	2.0
	5/29	2.3	2.3	2.3	2.4
	6/02	3.0	3.1	2.9	3.0
	6/10	4.6	4.8	4.7	4.8
	6/12	4.7	5.0	4.9	5.0
	6/16	4.8	5.1	5.0	5.0
	6/24	5.1	5.3	5.2	5.2
		g/squash			
Average Size		130	132	126	130

[z]No significant differences between treatments ($p = 0.10$).

Table 5. Cumulative cucumber yield at each harvest date and average cucumber size for all harvests at the various foliar fertilization rates.[z]

		Application Rate (L/ha/wk)			
	Date	0	2	3	4
		t/ha			
Total Weight	6/10	3.4	3.8	2.5	2.6
	6/12	4.4	5.0	3.5	3.5
	6/16	6.4	7.2	5.6	5.4
	6/23	12.2	12.8	11.5	11.4
	6/27	13.9	14.3	13.4	13.1
	7/02	15.3	15.8	15.1	14.9
	7/08	16.8	17.7	17.2	16.6
	7/15	18.6	19.0	18.9	17.8
		g/cucumber			
Average Size		269	273	268	274

[z]No significant differences between treatments (p = 0.10).

difference in squash yields and sizes among treatments. Cucumber yields averaged 18.6 t/ha and again no statistically signficant differences due to treatment were found. Cucumber size differences among treatments were also not statistically significant (Table 5).

Multiple foliar applications of a multiple nutrient fertilizer proved to have very little impact on growth and yield of several cucurbits in this study. Soil nutrient levels during this study appeared to be adequate for good vegetable production. Additional nutrients supplied through the foliage may benefit yields, but may also encourage vegetative growth delaying or reducing yields. When soil nutrient levels are deficient as indicated by foliar symptoms, foliar fertilization would be expected to have a greater impact.

ACKNOWLEDGEMENT

This study was partially funded by Helena Chemical Company, Memphis, Tennessee.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Influence of Nitrogen and Phosphorus Fertilizer on Respiration Rate, Premature Seedstalk Formation and Yield of Yellow Granex Onions [1]

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Additional index words: *Allium cepa, bolting.*

ABSTRACT

In a factorial experiment involving rates and sources of N and P, the respiration rate (CO_2 evolution) of whole Granex onion bulbs at harvest decreased as the rate of P was increased from 0 to 50 kg/ha. As N from $(NH_4)_2SO_4$ was increased from 0 to 112 kg/ha at the 0 level of P there was an increase in the rate of respiration. As N from KNO_3 was increased from 0 to 112 kg/ha at 0 level of P there was a decrease in the rate of respiration. The respiration rate declined to half the value at harvest over an 8-day storage period at 20 °C. As the rate of P was increased from 0 to 25 kg/ha, seedstalk formation in Granex onions increased 100 percent. Fifty-six kg N/ha gave a significant reduction in the number of onion bulbs producing seedstems. The use of K_2HPO_4 and K_3PO_4 as a source of P resulted in a significant decrease in the stand of marketable onions. KNO_3 was inferior to NH_4NO_3 and $(NH_4)_2SO_4$ as a source of N in this experiment. As N and P were increased from 0 to 56 and 0 to 25 kg/ha both the yield and size of Granex onion bulbs increased.

In commercial growing areas, temperatures of 10°C and below for 7-10 days during the latter half of the growing season when the onion plant is 1.5-2.0 cm. in diameter can result in 50-90% premature seedstem formation (bolting) particularly in early plantings (13). Entire fields of onions in Texas are often abandoned due to seedstem development. Both early planting of direct seeded onions and/or the use of large transplants would result in higher yields of marketable onions if bolting could be controlled (3). Bulb development and flowering in the onion is a complex phenomenon involving daylength, temperature, plant size, variety and mineral nutrition (3,6,8,9,11,12,13,14). Most higher plants show a reduced rate of growth and foliar damage when fertilized with the ammonium ion (NH_4^+) (4). Tomato plants are particularly prone to NH_4^+ toxicity (4). Other plant species, especially monocots, may show only moderate damage or prefer the NH^+ for optimum growth (4). Early yellow types such as Granex make up approximately 25% of the 47 million dollar onion production in Texas (10). In a preliminary study in 1962, nitrogen (N) reduced and phosphorus (P) increased bolting as well as the uptake of oxygen (O_2) and the respiratory quotient (RQ) of Yellow Granex onion bulbs at the time of premature seedstalk development (9). The present experiments were conducted to evaluate the effects of various sources and rates of nitrogen (N) and phosphorus (P) on respiration rates, seedstem development and yield of Yellow Granex onions.

MATERIALS AND METHODS

Three sources and rates of N were interacted with 3 sources and rates of P in a 3x3x3x3 complete factorial inside a 9x9 quasi-Latin square experimental design with the highest order interaction confounded with the rows and columns of the square (5). The fertilizer treatments included all possible combinations of 0, 56 and 112 kg N/ha from ammonium nitrate (NH_4NO_3), ammonium sulfate ($(NH_4)_2SO_4$) and potassium nitrate (KNO_3); 0, 25 and 50 kg P/ha from monopotassium phosphate (KH_2PO_4), di-H orthophosphate (K_2HPO_4) and mono-H orthophosphate (K_3PO_4). All of the fertilizer was applied in a band 10 cm. directly below Yellow Granex plants set 10 cm. apart in the row (6). Two rows of onion plants, each 7-16 mm. in diameter, were planted 30 cm. apart on single 1.0 m. beds 9.8 m. long on Jan. 9, 1963. The Isagora fine sandy loam soil at Hearne, Texas used in this experiment had a pH of 6.4; 0.9% organic matter; 4 ppm P; 260 ppm K; 338 ppm Ca and a soluble salts reading of 10 mhos.

Three one kg lots of uniform onion bulbs from the $(NH_4)_2SO_4$ and KNO_3 sources of N at 0 and 112 kg/ha and the KH_2PO_4 source of P at 0 and 50 kg/ha were evaluated for CO_2 evolution every 24 h over an 8-day period at 20 °C (2). The number and weight of marketable and seedstem onion bulbs from all 81 plots were determined on 9.8 m of each 2 row bed on May 23, 1963.

RESULTS AND DISCUSSION

After an 8-day storage period at 20 °C the respiration rate of Yellow Granex onion bulbs declined from a high of 29 to 14 mg CO_2/kg/hr (Fig. 1). The use of 50 kg P/ha in the fertilizer caused a highly significant decrease in the rate of respiration on the first and all subsequent days in storage (Fig. 1). There was a highly significant source of N x rate of N interaction in the respiration rate determinations (Tables 1 and 2). As N from $(NH_4)_2SO_4$ was increased from 0 to 112 kg/ha at the 0 level of P, there was a highly significant increase in the rate of respiration (Tables 1 and 2). As N from KNO_3 was increased from 0 to 112 kg/ha at zero P there was a significant decrease in the rate of respiration (Tables 1 and 2). The highly significant rate of N x rate of P interaction shown in Tables 1 and 2 was due to a decrease in respiration rate at the 50 kg/ha rate of P application with both sources of N (Tables 1 and 2). The N source x N rate x P rate interaction is difficult to interpret (Tables 1 and 2).

The use of up to 56 kg N/ha and 25 kg P/ha in the fertilizer gave a highly significant increase in both marketable yield and size of onion bulbs (Tables 3 and 4). Ammonium sulfate and ammonium nitrate proved to be the preferred sources of N for maximum yield and size of onion bulbs (Tables 4 and 5). The use of K_2HPO_4 and K_3PO_4 as a source of P resulted in a significant reduction in the stand of marketable onions (Tables 4 and 6). The use of 56 or 112 kg N/ha gave a highly significant reduction in the number of onion bulbs producing seedstems (Tables 4 and 7).

Fifty-six kg N/ha from $(NH_4)_2SO_4$ gave the maximum size of onion bulbs showing seedstem development (Table 8). A significant source of N x rate of P interaction for size of marketable Yellow Granex onion bulbs is shown in Tables 4 and 10. Either 25 or 50 kg P/ha used in the fertilizer gave a highly significant increase in the weight of onions producing seedstems (Table 9).

The results of this experiment demonstrates that bolting in onion fields can be

minimized by proper selection of sources, rates and placement of fertilizer materials. The $(NH_4)_2SO_4$ source of N may be superior to other N sources because of the sulfur (S) in its molecule (7). Increased pungency and yield in Yellow Granex onion have been recorded from the use of S on East Texas soils (7). The striking respiratory changes brought about by the addition of nitrate or ammonium salts to plant tissues go far beyond those induced by other salts (1). A source of N which can be used in amino acid and protein synthesis sets in motion a series of events which affect many points in the respiratory cycle (1). Inorganic phosphorus also plays an important role as a reactant in both glycolytic sequences and in oxidative phosphorylation which could affect bolting in onion bulbs (1).

Table 1. Effect of rate and source of nitrogen and rate of phosphorus fertilizer on the respiration rate of Yellow Granex onion bulbs at 20 °C.

		Mg CO_2/kg/hr		
N	P	Source N		
kg/ha	kg/ha	$(NH_4)_2SO_4$	KNO_3	Avg.
0	0	17.8	22.9	20.4
112	0	25.2	19.5	22.4
	Average	21.5	21.5	21.4
0	50	18.9	19.3	19.1
112	50	16.7	19.4	18.1
	Average	17.8	19.4	18.6

Table 2. Analysis of variance of the respiration rate of Yellow Granex onions stored 8 days at 20°C.

Source	df	Mean square Mg CO_2/kg/hr
N Source (S)	1	17.70
N Rate (R)	1	12.05
PR	1	363.83**z
NS X NR	1	214.00**
NS X PR	1	38.97
NR X PR	1	116.10*
NS X NR X PR	1	507.98**
Rep X NS X NR X PR	16	14.70

z*,** significant at the 0.05 and 0.01 probability levels, respectively.

Table 3. Interaction[z] of the rate of nitrogen and phosphorus fertilizer application on the yield and size of Yellow Granex onions.

	Marketable yield MT/ha				Bulb weight (g)			
	P rate (kg/ha)				P rate kg/ha			
N rate kg/ha	0	25	50	Avg.	0	25	50	Avg.
0	11.4	17.4	17.0	15.3	82	127	122	110
56	10.5	29.2	31.7	23.8	83	194	217	165
112	11.6	21.8	22.1	18.5	85	153	156	131
				**y				*y
Average	11.2	22.8	23.6	Q L**Q**x	83	158	165	L**,Q L**,Q**

Treatment effects in rows (x) and columns (y) were significant at the 5% (*) or 1% (**) levels and were linear (L) or quadratic (Q).

[z]Interaction significant at the 1% level.

Table 4. Analysis of variance of number, yield and size of Yellow Granex onion bulbs grouped as marketable and seedstem onions.

		Mean Square					
		Marketable			Seedstem		
Source	df	Number	Yield MT/ha	Size (g)	Number	Yield MT/ha	Size (g)
Total	80						
N Source (S)	2	564.79	58326.57**	1.83**	3.72	44.68	1.45
N Rate (R)	2	318.42	158381.47**	6.71**	61.20**	28.39	4.62**
PS	2	2171.13*	14023.83	0.20	1.35	12.34	0.47
PR	2	360.98	417782.17**	18.24**	3.16	318.39**	12.03**
NS X NR	4	156.66	2822.31	0.11	6.92	17.63	1.15
NS X PR	4	168.55	19644.70	0.84*	12.05	5.20	1.18
NS X PS	4	435.09	11833.37	0.45	16.12	47.32	0.04
NR X PS	4	176.16	9975.57	0.33	7.72	19.70	0.96
NR X PR	4	401.90	51554.29**	1.82	13.03	24.73	0.84
PS X PR	4	263.50	4718.57	0.18	3.79	16.31	0.26
Row	8	2150.63**	53384.58**	1.34**	56.93**	164.13**	1.77**
Column	8	1346.55*	10885.50	0.36	30.88**	70.91**	1.73**
Error	32	466.38	11451.09	0.30	7.22	20.34	0.42

*,**Significant at the 0.05 and 0.01 probability levels, respectively.

Table 5. Influence of the source of nitrogen on the yield and size of Yellow Granex onion.

Source N	Marketable yield MT/ha	Bulb weight (g)
NH_4NO_3	19.6 AB[z]	136 AB
$(NH_4)_2SO_4$	21.6 A	149 A
KNO_3	16.4 B	121 B
Average	19.2	135

[z]Mean separation in columns by Duncan's multiple range test, 1% level.

Table 6. Influence of the source of phosphorus on the stand of marketable Yellow Granex onions.

Source P	No. bulbs/9.8 m
KH_2PO_4	146 a[z]
K_2HPO_4	131 b
K_3PO_4	130 b
Average	136

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

Table 7. Effects of the rate of nitrogen application on the number of seedstems in Yellow Granex onions.

N rate kg/ha	Number of seedstem/ 9.8 m
0	8
56	5
112	5
F value[z]	L**

[z]Treatment effects in columns were significant at the 1% (**) level and were linear (L).

Table 8. Interaction[z] of the rate and source of nitrogen fertilizer application on the size of seedstems in Yellow Granex onions.

	Bulb weight (g)			
	Nitrogen Source			
N rate kg/ha	NH_4NO_3	$(NH_4)_2SO_4$	KNO_3	Avg.
0	62	81	61	68
56	119	140	105	121
112	100	103	116	106
Average	94 b[w]	108 a	106 a	L*,Q*[y]

Treatment effects in columns (y) were significant at the 5% (*) level and were linear (L) or quadratic (Q).

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

[z]Interaction significant at the 1% level.

Table 9. Effect of the rate of phosphorus application on the weight of seedstems in Yellow Granex onion.

P rate kg/ha	Weight of seedstems g/9.8 m
0	59
25	109
50	107
F value[z]	L**,Q**

[z]Treatment effects were significant at the 1% (**) level and were linear (L) or quadratic (Q).

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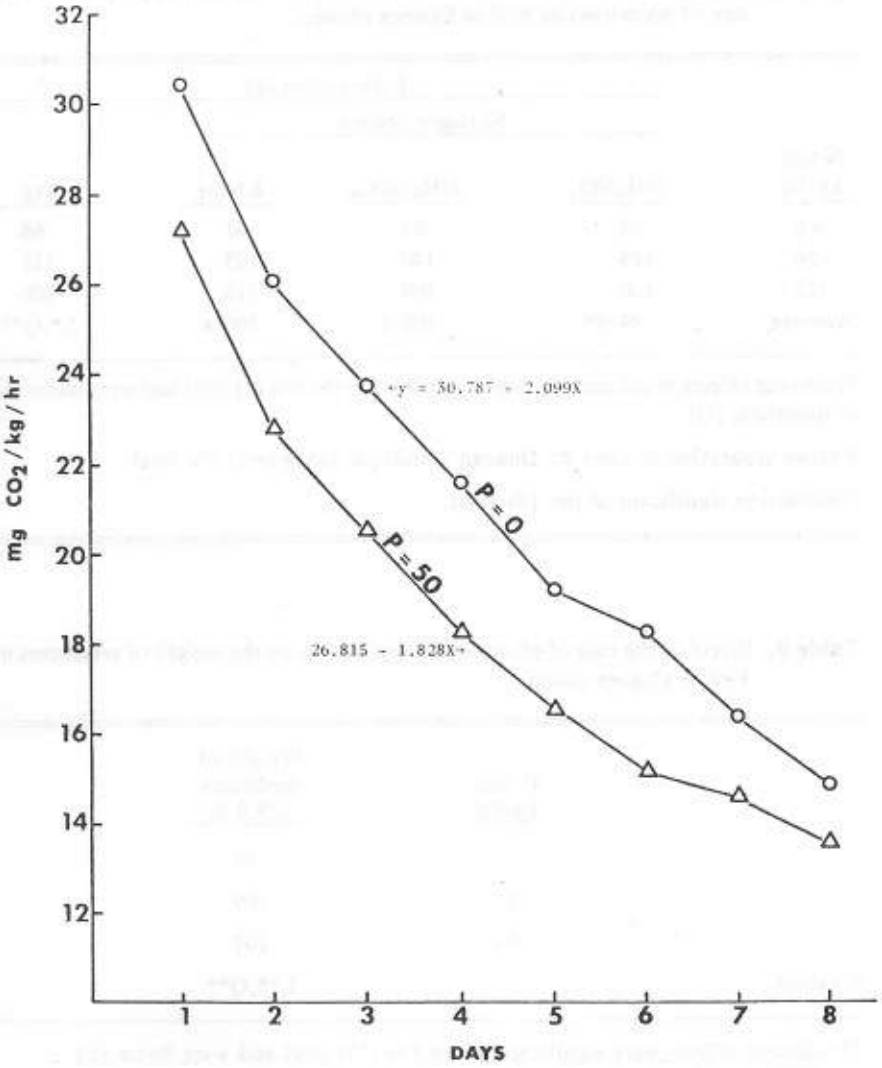

Fig. 1. Respiration rate of Yellow Granex onion bulbs at 20°C as affected by phosphorus from KH_2PO_4 applied at 0 and 50 kg/ha.

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Table 10. Interaction[z] of the rate of phosphorus and source of nitrogen fertilizer on the size of marketable Yellow Granex onion bulbs

	Bulb weight (g)			
	Nitrogen Source			
P rate kg/ha	NH_4NO_3	$(NH_4)_2SO_4$	KNO_3	Avg.
0	90	78	82	83
25	165	179	130	158
50	154	190	150	165
Average	136 AB[x]	149 A	121 B	L**,Q**[y]

Treatment effects in columns (y) were significant at the 1% (**) level and were linear (L) or quadratic (Q).

[x]Mean separation in rows by Duncan's multiple range test, 1% level.

[z]Interaction significant at the 5% level.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Germination of Illinois Bundleflower and Velvet Bundleflower Seeds

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ABSTRACT

Germination of Illinois bundleflower (*Desmanthus illinoensis*) and velvet bundleflower (*Desmanthus velutinus*) seed is restricted by impermeable seed coats. Soaking the seeds from 3 to 5 minutes in concentrated sulfuric acid increased their germination. Optimum germination ($\geq$61%) of Illinois bundleflower seeds occurred at constant temperatures ranging from 20 to 30°C, and at alternating temperatures of 15-25 and 20-30°C. Velvet bundleflower seed germination was $\geq$73% at constant temperatures within a range from 15 to 25°C, and at alternating temperatures of 10-20, 15-25, and 20-30°C. Seeds of both species germinated equally well in light and dark conditions. Percentage germination of both species was not affected by a broad range of pH values. Seed germination of both species was sensitive to an osmotic tension of -2 bars and seed germination essentially stopped at -10 bars.

Legumes are important components of natural vegetation because they can contribute nitrogen to the soil and provide food for livestock and wildlife (4). Moreover, the legumes' nutrient content is generally superior to that of grasses and other plants. Legumes can also provide green growth for longer grazing into the growing season. Numerous native herbaceous legume species are being reseeded to rangelands because overgrazing has caused them to become diminished in abundance.

Illinois bundleflower (*Desmanthus illinoensis*) and velvet bundleflower (*Desmanthus velutinus*) are perennial legumes that are being reseeded to Texas rangelands (Richard Heizer, plant materials specialist, Soil Conservation Service: personal communication). Illinois bundleflower is found most abundantly on clay soils in central and north Texas and over a large area of the central United States. Velvet bundleflower grows mostly on the limestone and caliche hills of the Edwards Plateau and South Texas Plains but is also found in New Mexico and Mexico (2). Both species are considered to be desirable plants for livestock and wildlife (1, 7). Little or no information is available about the reproductive potential of these species. The objective of this experiment was to study the seed germination characteristics of Illinois and velvet bundleflower as affected by different environmental conditions.

MATERIALS AND METHODS

Illinois and velvet bundleflower seeds were obtained from the Soil Conservation Service Plant Materials Center at Knox City, Texas. Seeds of both species were collected during the 1978 growing season. The seeds were stored at laboratory room conditions (20 to 27 °C, and 50 to 75% relative humidity). Experiments on both Illinois and velvet bundleflower were conducted with 2- to 3-year old seed.

All of the germination experiments were conducted within growth chambers with automatic temperature and fluorescent light (200 u $E/m^2/s$) controls. An 8-hr. light period was used. Unless otherwise stated or unless temperature variation was intended, velvet bundleflower seed germination experiments were conducted at a constant temperature of 20 °C, and Illinois bundleflower seed germination experiments were conducted at a constant temperature of 25 °C. An experimental unit had 100 seeds placed in a 9-cm. petri dish with two filter papers wetted with either 12 ml. of distilled water or appropriate test solution. The experiments were conducted using randomized complete block design unless otherwise stated. Each treatment was replicated four times for experiments on acid soaking, pH, and moisture tension, and 10 times for experiments on temperature and light/darkness variation. All experiments were conducted twice. Seeds with visible radicles were considered to be germinated. The number of germinated seeds was recorded 14 days after the initiation of each experiment.

Pilot experiments of both species showed that their seed germination was low because of hard seed coats. Therefore, seeds of each species were soaked in concentrated H_2SO_4 (acid scarification) for periods of 0, 1, 2, 3, 4, and 5 minutes and tested for germination at a constant temperature of 25 °C. Subsequent studies with both Illinois and velvet bundleflower were conducted using seeds scarified for 4 minutes. The scarified seeds were washed with tap water for 5 minutes before they were used in experiments.

Seeds of both species were germinated under continuous temperatures in increments from 5 to 40 °C (with an 8-hr. light period), and with alternating temperature regimes of 5-15, 10-20, 15-25, and 20-30 °C (16-hr. low temperature, 8-hr. high temperature with light). The petri dishes were randomized for each species at each temperature regime.

The effect of light and darkness on seed germination was investigated by comparing the results from petri dishes covered with aluminum foil with the results from uncovered petri dishes.

The influence of substrate pH on germination was studied by adjusting the pH of distilled water with either HCL or KOH (5). Substrate pH values of 2, 3, 4, 5, 6, 7, 8, 9, 11, and 12 were used.

Moisture stress effects were developed in distilled water (0 bar) with polyethylene glycol 6000 (6) solutions with osmotic tensions of -2, -4, -6, -8, and -10 bars. The petri dishes were placed on wet towels on large metal trays and covered with transparent plastic wrap to maintain a high humidity and to replace evaporation losses.

Germination data were transformed (Arcsin $\sqrt{\%}$) before statistical analyses. Data were subjected to the analysis of variance and student's t-test. Difference among means were compared with Duncan's multiple range test (9). All statistical comparisons were made at $p = 0.05$.

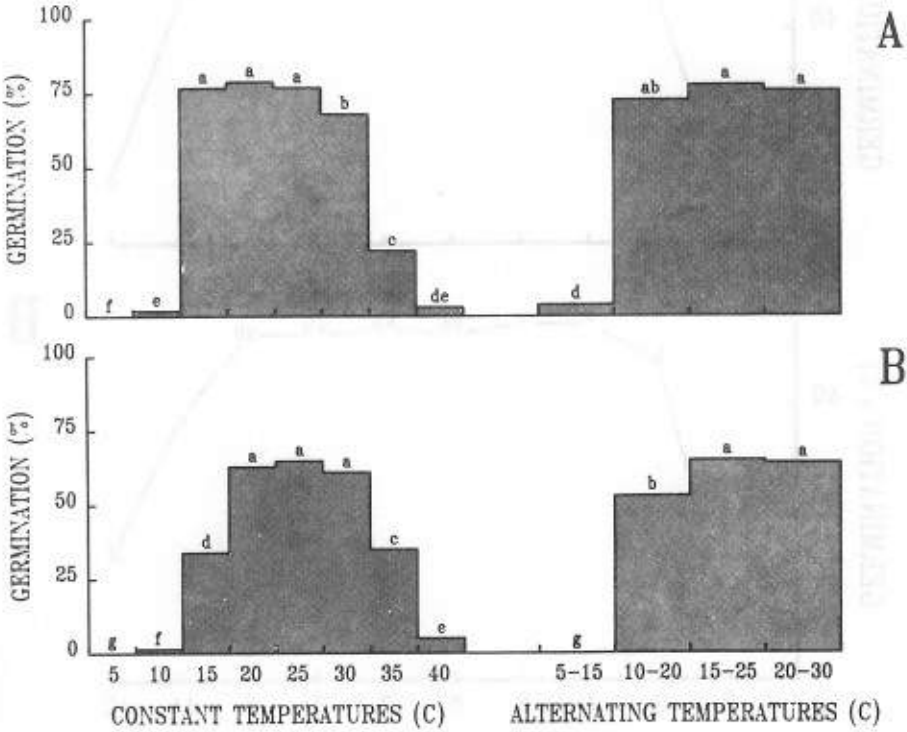

Fig. 1. Velvet bundleflower (A) and Illinois bundleflower (B) percentage seed germination after 14 days exposure to twelve constant and alternating temperature regimes. Means within an attribute with similar lower case letters are not significantly different at $p = 0.05$.

RESULTS AND DISCUSSION

Illinois and velvet bundleflower have hard seed coats that tend to inhibit moisture imbibition. The percentage germination of untreated Illinois and velvet bundleflower seeds was 15 and 12%, respectively (data not shown). Acid scarification of both Illinois and velvet bundleflower in concentrated H_2SO_4 acid from 2 to 5 minutes significantly increased germination as compared with untreated seeds or seeds scarified for 1 minute. The largest percentage germination of both Illinois (59%) and velvet bundleflower (76%) occurred when seeds were acid soaked for 4 minutes. Statistically, however, germination percentages of seeds acid scarified for 3, 4, and 5 minutes did not differ significantly.

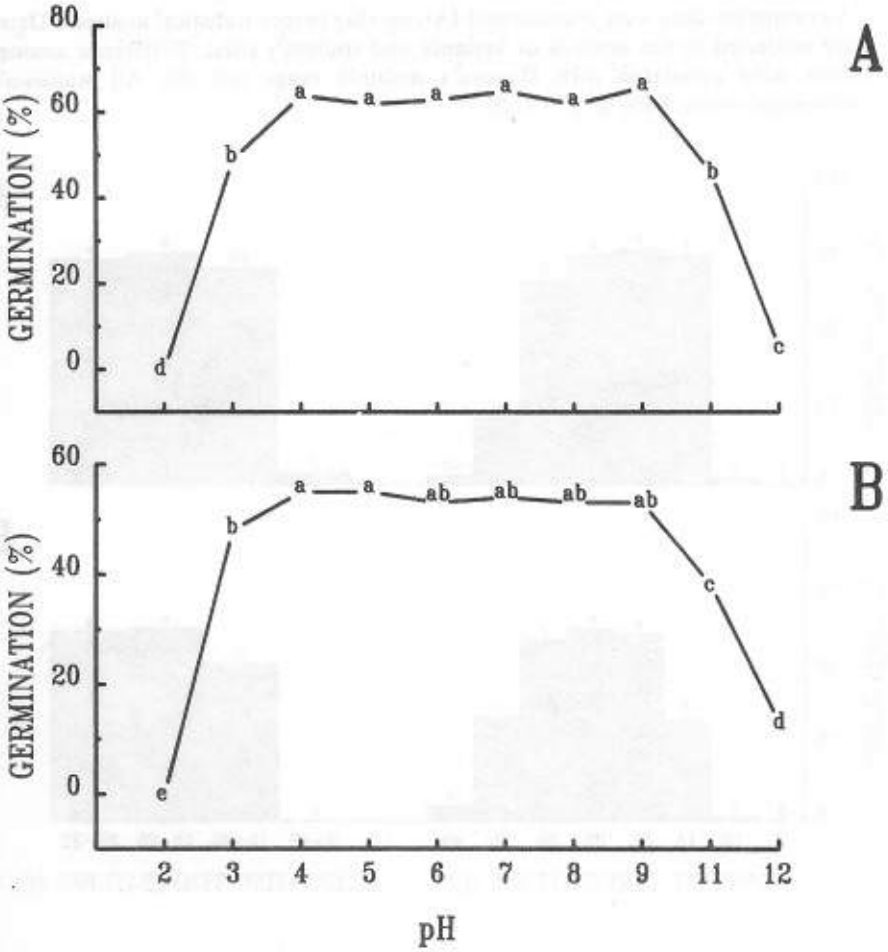

Fig. 2. Velvet bundleflower (A) and Illinois bundleflower (B) percentage seed germination after 14 days exposure to solutions of various pH. Means within an attribute with similar lower case letters are not significantly different at $p = 0.05$.

Apparently, Illinois and velvet bundleflower seed do not have specific temperature requirements for germination. Seeds of both species germinated over a wide range of constant and alternating temperatures (Fig. 1). Illinois bundleflower seed germination was apparently more sensitive to lower temperatures than that of velvet bundleflower. Illinois bundleflower seed germination ranged from 61 to 65% at constant temperatures ranging from 20 to 30 °C, and at alternating temperatures of 15-25 and 20-30 °C. Velvet bundleflower seed germination was ≥ 68% at constant temperatures ranging from 15 to 30 °C, and at alternating temperatures of 10-20, 15-25, and 20-30 °C. Seed germination of both species essentially stopped at constant temperatures of either 5, 10, or 40 °C, and at an alternating temperature regime of 5-15 °C.

Absence of light has no effect on the germination of these two herbs. Germination percentages of both species in darkness did not differ significantly from those of seeds exposed to 8-hr. periods of light daily (data not shown). However, after seed germination, many of the seedlings held in darkness had unfolded cotyledons in contrast to fully expanded cotyledons for seedlings held in light. These results agree with those reported for numerous other plant species that grow in association with these herbs (8,11,10,3).

The germination responses of both species to varied hydrogen-ion concentrations is shown in Fig. 2. Germination percentages of both species were significantly reduced at pH values of either 2 or 12, as compared with germination percentages at the other pH values. Actually, no germination occurred at pH 2 and germination was severely restricted or ceased at pH 12. Percentage germination of Illinois bundleflower did not differ significantly among pH values ranging from 3 to 9, but was suppressed at pH 11. Velvet bundleflower seeds germinated uniformly at pH values that ranged from 4 to 9, but their germination was mildly depressed at either pH 3 or 11. Since seeds of both Illinois and velvet bundleflower germinated uniformly over a broad range of pH values, soil pH is probably not a critical factor in their seed germination under field conditions.

Seed germination of both Illinois and velvet bundleflower was sensitive to polyethylene glycol-induced moisture stress (Fig. 3). Percentage germination of both species was reduced at -2 bars osmotic tension and was essentially prevented at -10 bars. These data suggest that adequate water availability is critical for optimum seed germination of these herbs. Thus, their optimum germination in the field is probably confined to periods of high soil moisture. Moreover, since seed of both species will germinate over a wide range of temperatures, managers may want to consider earlier field plantings in the cold part of the growing season, when soil moisture is usually most available for seed germination.

Although the effect of age on the viability of Illinois and velvet bundleflower seeds was not investigated, seed of both species showed a decline in germination over time. This became evident by comparing the maximum seed germination of both species in the osmotic tension experiments with their maximum seed germination in temperature studies that were conducted about 9 months earlier.

Seeds of both Illinois and velvet bundleflower can germinate over a wide range of temperatures and a generally broad range of pH, but adequate soil water content is critical. This information can be used by range and resource managers who wish to reestablish these species in ranges or other natural areas.

ACKNOWLEDGEMENTS

Special thanks is extended to the Soil Conservation Service for providing seeds for this study and to Fernando Martinez, Jr. and Mario Alaniz for their laboratory assistance.

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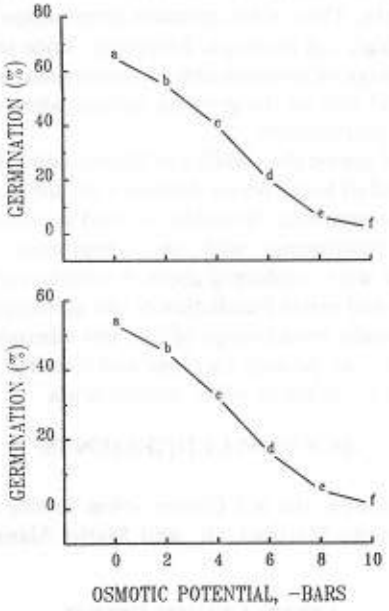

Fig. 3. Velvet bundleflower (A) and Illinois bundleflower (B) percentage seed germination after 14 days exposure to germination media of various osmotic potentials. Means within an attribute with similar lower case letters are not significantly different at p = 0.05.

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Seed Germination Characteristics of Maximilian Sunflower (*Helianthus maximiliani*) and Partridge Pea (*Cassia fasciculata*)

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ABSTRACT

Seed germination characteristics of Maximilian sunflower and partridge pea were investigated in relation to temperature, light, moisture stress, and pH. Germination of partridge pea seeds is restricted by an impermeable seed coat. Soaking seeds in concentrated sulfuric acid from 60 to 90 seconds increased germination. Maximilian sunflower seed germination was $\geq$ 60% at constant temperatures of 10, 15, and 20°C, and at alternating temperatures of 5-15, 10-20, and 15-25°C. Optimum germination ($\geq$ 56%) of partridge pea seeds occurred at a constant temperature of 20°C and at alternating temperatures of 15-25°C. Light was not required for germination of either species, but germination of Maximilian sunflower was about 15% lower in darkness. Seeds of both species had the ability to germinate well over a broad pH range. Decreased water availability reduced germination of both species; however, partridge pea seed germination was more tolerant of moisture stress than Maximilian sunflower.

Seed germination and seedling establishment are the most critical phases in revegetation of native ranges and pastures (7). To diminish the risk of seeding failure, it is necessary to better understand the factors involved in germination. Many native herbs are being reseeded to rangelands because they have decreased in abundance largely due to prolonged overgrazing. Often, these reseeding efforts fall short of desired goals because of a lack of basic knowledge on the seed germination requirements of the various species.

Maximilian sunflower (*Helianthus maximiliani*) and partridge pea (*Cassia fasciculata*) are two forbs being reseeded to Texas rangelands. Both species are widely distributed in Texas and elsewhere in the central and eastern United States (2). Maximilian sunflower, a perenSial, and partridge pea, an annual, are desirable plants for livestock and wildlife because they are palatable and prolific seed producers (1,5). Little information is available concerning their reproductive potential. The objective of this study was to investigate, in the laboratory, the germination characteristics of Maximilian sunflower and partridge pea seeds to certain environmental factors encountered in the seedbed.

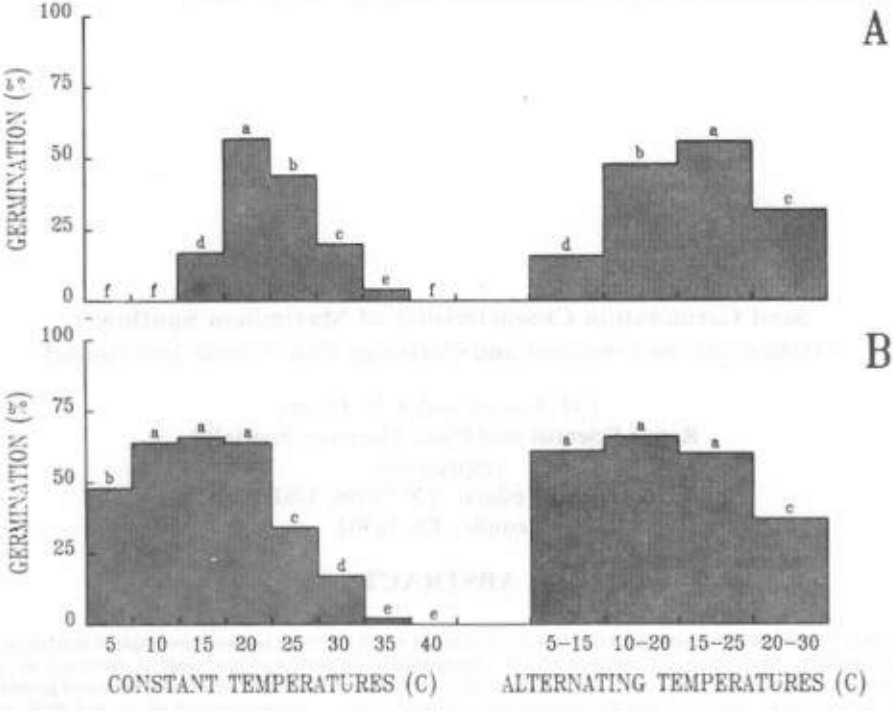

Fig. 1. Partridge pea (A) and Maximilian sunflower (B) percentage seed germination after 14 days exposure to twelve constant and alternating temperature regimes. Means within an attribute with similar lower case letters are not significantly different at p = 0.05.

MATERIALS AND METHODS

Seeds were obtained from the Plant Materials Center of the Soil Conservation Service in Knox City, Texas. Seeds were harvested from plants during the 1981 growing season. Seeds of both partridge pea and Maximilian sunflower came from plants of native origin. Only fully developed, undamaged seeds were used for germination experiments. Subsequent to use in experiments, seeds were stored at room conditions (20 to 27 °C and 50 to 75% relative humidity). All experiments were conducted when the seeds were less than 1 year old.

All experiments were conducted in small growth chambers with automatic temperature and fluorescent light (200 $\mu E/m^2/s$) controls. Unless otherwise stated or unless temperature was an intended variable, experiments with Maximilian sunflower were conducted at a constant temperature of 15 °C, while partridge pea experiments were conducted at a constant temperature of 20 °C. An 8-hr. light period was used in these experiments. An experimental unit was 100 seeds in a 15-cm. petri dish that had two filter papers wetted with 17 ml. of distilled water or an appropriate test solution. Experiments were designed as randomized complete blocks unless

otherwise stated. Treatments were replicated 3 times for acid soaking, pH, and moisture tension experiments and 10 times for temperature and light experiments, and each experiment was conducted twice. Seed with visible radicles were considered to be germinated. The number of germinated seeds was recorded 14 days after the initiation of each experiment.

Initial experiments on the germination of partridge pea seeds showed a low percent germination because of hard seed coats. Therefore, seeds were soaked in concentrated H_2SO_4 (scarification) for various time periods and tested for germination at a constant temperature of 25 °C. The seeds were acid soaked for 0, 30, 45, 60, 75, 90, and 105 seconds. Later studies were conducted using seeds scarified for 75 seconds.

Seeds of both species were germinated under continuous temperatures in 5 °C increments from 5 to 40 °C (with an 8-hr. light period) and alternating temperature regimes of 5-15, 10-20, 15-25, and 20-30 °C (16-hr. low temperature, 8-hr. high temperature with light). The petri dishes were randomized for each species at each temperature regime.

Light requirement for seed germination was investigated by comparing the percent germination in petri dishes covered with aluminum foil with the percent germination in uncovered dishes.

The effect of pH on germination was investigated by adjusting the hydrogen ion concentration of distilled water with HCL and KOH (3). Germination was evaluated with substrate pH values of 2, 3, 4, 5, 6, 7, 8, 9, 11, and 12.

Moisture stress tests on seed germination were conducted in distilled water with polyethylene glycol (PEG) 6000, at various osmotic potentials. Tables of PEG 6000 concentrations required to give selected osmotic potentials over a wide range of temperatures were developed by Michel and Kaufman (4). Their results were used to prepare solutions of -1, -2, -3, -4, -6, -8, -10, and -12 bars at 15 °C for Maximilian sunflower and 20 °C for partridge pea. Distilled water was used for a 0 bars treatment.

Percentage germination and emergence data were transformed (Arcsin $\sqrt{\%}$) before statistical analyses. Data were subjected to the analysis of variance and student's t-test. Differences among means were compared with Duncan's multiple range test (6). All statistical comparisons were made at $p = 0.05$.

RESULTS AND DISCUSSION

Partridge pea seeds do not readily imbibe moisture until the seed coats are broken. Only 6% of nontreated partridge pea seeds germinated after 14 days (data not shown). Soaking seeds in concentrated H_2SO_4 acid for 30 to 105 seconds significantly increased percent germination over that of untreated seeds. Seeds soaked for 60 to 90 seconds had significantly higher germination than those soaked for 30, 45, and 105 seconds. The highest percentage germination (49%) occurred when seeds were soaked for 75 seconds.

Germination of partridge pea seeds was more sensitive to temperature than those of Maximilian sunflower (Fig.1). Optimum germination of partridge pea seeds occurred at a constant temperature of 20 °C and at an alternating temperature regime of 15-25 °C where the germination percentages were 57 and 56%, respectively. Partridge pea seed germination was suppressed or decreased abruptly at other temperatures. None of the partridge pea seeds germinated at constant temperatures of 5, 10, and 40 °C. The germination percentages (60 to 66%) of Maximilian

sunflower seeds did not differ significantly at constant temperatures of 10, 15, and 20 °C, and at alternating temperature regimes of 5-15, 10-20, and 15-25 °C. These data indicate that field plantings of Maximilian sunflower seeds should probably be done in late winter or early spring in the southern United States to give good germination and seedling establishment, whereas partridge pea seeds should probably be planted in mid to late spring over this same geographical area.

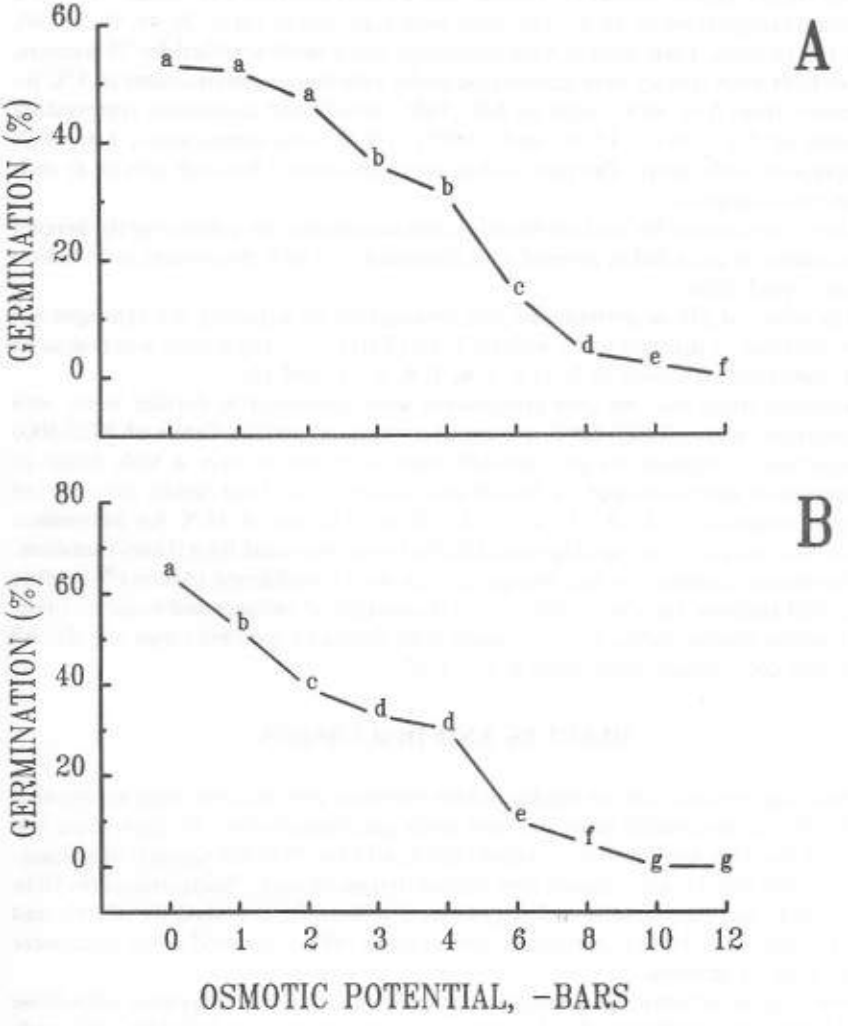

Fig. 2. Partridge pea (A) and Maximilian sunflower (B) percentage seed germination after 14 days exposure to germination media of various osmotic potentials. Means within an attribute with similar lower case letters are not significantly different at p = 0.05.

The germination percentage of partridge pea seeds germinated in darkness did not differ significantly from that of seeds exposed to daily 8-hr. periods of light, but germination of Maximilian sunflower seed was reduced by about 15% in darkness (data not shown).

Percentage germination of Maximilian sunflower seeds was significantly reduced at -1 bars tension and continued to be progressively delayed with decreasing moisture availability (Fig. 2). Only 5% of the Maximilian sunflower seeds germinated at -8 bars tension, and none of the seeds germinated at -10 and -12 bars tension. Partridge pea seed germination was not suppressed until the osmotic potential of the PEG solutions was increased to -3 bars tension, but followed a trend similar to that exhibited by Maximilian sunflower seeds as the moisture tension was increased from -3 to -12 bars. These results suggest that Maximilian sunflower seeds are more depen-

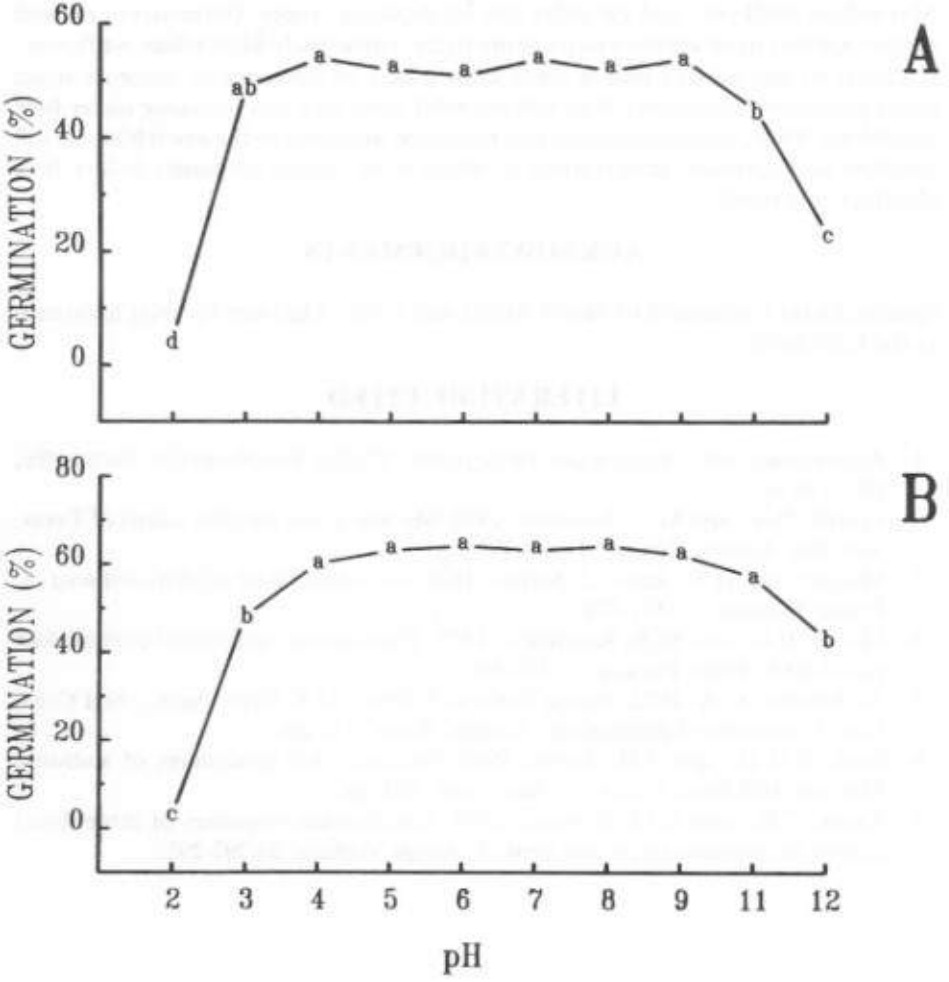

Fig. 3. Partridge pea (A) and Maximilian sunflower (B) percentage seed germination after 14 days exposure to solutions of various pH. Means within an attribute with similar lower case letters are not significantly different at $p = 0.05$.

dent on an adequate water availability for germination than are partridge pea seeds. However, Maximilian sunflower seeds will germinate under relatively cool temperatures and soil moisture is often more available during these periods.

Maximilian sunflower and partridge pea seeds germinated over a broad range of pH values (Fig. 3). Percentage germination of Maximilian sunflower seeds did not differ significantly from pH 4 to 11, but was mildly suppressed at pH 3 and 12. Germination percentages of partridge pea seeds did not differ significantly from pH 3 to 11, but germination was depressed at pH 12. Germination in both species nearly ceased in the pH 2 solutions. The ability of seeds of these two species to germinate over a wide range of pH values indicates that soil pH is probably not a critical factor in their establishment.

These results are of importance to management personnel who wish to reestablish Maximilian sunflower and partridge pea on depleted ranges. Germination of both species appears to be sensitive to moisture stress, particularly Maximilian sunflower. It should be emphasized that if seeds show a lack of tolerance to moisture stress under laboratory conditions, they will probably have even less tolerance under field conditions. Thus, managers should pay particular attention to the availability of soil moisture and optimum temperatures at which these species germinate before field plantings. are made.

ACKNOWLEDGEMENTS

Special thanks is extended to Mario Alaniz and Carlos Martinez for their assistance in the laboratory.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Use of Close-up Photography in Nondestructive Monitoring of Citrus Blackfly Cohorts

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ABSTRACT

Nondestructive counting techniques based on close-up 35 mm. B & W photography were developed to facilitate cohort studies of citrus blackfly, *Aleurocanthus woglumi* Ashby. Photographic techniques provided the following advantages over conventional (lens) methods: (1) a significant reduction in counting variability, (2) a significant increase in accuracy over all density ranges monitored, and (3) a tangible means (filmstrip) from which to verify accuracy of nondestructive insect counts. Equipment specifications and procedures are summarized.

INTRODUCTION

The establishment of *Encarsia opulenta* Silvestri (Hym.: Encyrtidae) in the Lower Rio Grande Valley during 1974-75 (2) has resulted in complete biological control of citrus blackfly (CBF), *Aleurocantus woglumi* Ashby (Hom.: Aleyrodidae), throughout the commercial citrus-production region of south Texas (3,4). The regulative impact of *E. opulenta* on CBF was evaluated in part by conventional life table analysis, based on stage-specific mortality occurring within seasonal cohorts (3). Procedures involved nondestructive sequential counts of the same individuals through time, and thus required highly accurate counting techniques. Maximum tolerable inaccuracy was arbitrarily set at + 5%.

CBF cohort studies are greatly facilitated by the tendency of 1st instar 'crawlers' to settle in the immediate vicinity of discrete egg clusters on the lower leaf surface, and sedentariness of subsequent life stages (1). While conceptually straightforward, conventional nondestructive lens counts (using 10- to 14-x hand lens in situ) proved to be unacceptably inaccurate and failed to provide a tangible means for data verification. Alternative procedures based on close-up photography were therefore developed and evaluated.

MATERIALS AND METHODS

Equipment designed to facilitate rapid in situ photography of CBF clusters on foliage consisted of a standard 35mm single-lens reflex (SLR) camera equipped with 50mm lens and 16mm extension tube, electronic flash unit, and an adjustable flange (focal frame) attached to the camera baseplate (Fig. 1). The latter served to hold leaves in a narrow plane at a predetermined distance from the lens while exposures were made (Fig. 2). Exposures were made on ASA-32 B&W negative film for maximum resolution, with preset shutter speed (1/125-sec) and minimum aperature (f/16) for maximum depth of field.

Exposed filmstrips were spooled onto reels of lightproof developing tanks inside a photographic changing bag, and were processed under normal lighting intensity and temperature ranges (18 °C-24 °C) according to manufacturer's specifications. Insect counts were made by projection of filmstrips onto a 2x2-ft. viewing screen with acetate overlay, which was marked with a grease marking pencil to avoid duplicity in counts of the same individuals.

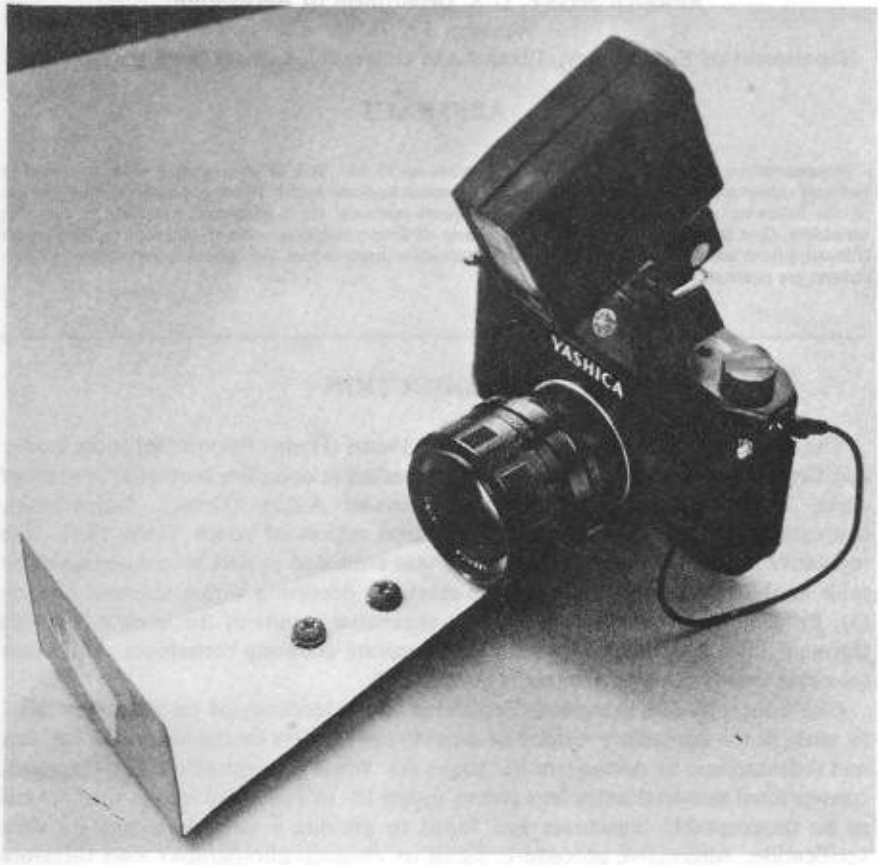

Fig. 1. Photographic equipment designed to facilitate close-up in situ photography of citrus blackfly clusters on foliage.

Efficiency and accuracy of conventional (lens) and photographic counting procedures were evaluated in a laboratory census of a 5,573-egg cohort occurring on 35 leaves (14-507 eggs/leaf). Paired counts were obtained by 6 individuals using a 10-x hand lens and photographic techniques (vide supra), in an order determined by a random numbers table. Results obtained by both techniques were compared with counts made from 8x10-in. B&W enlargements of each frame.

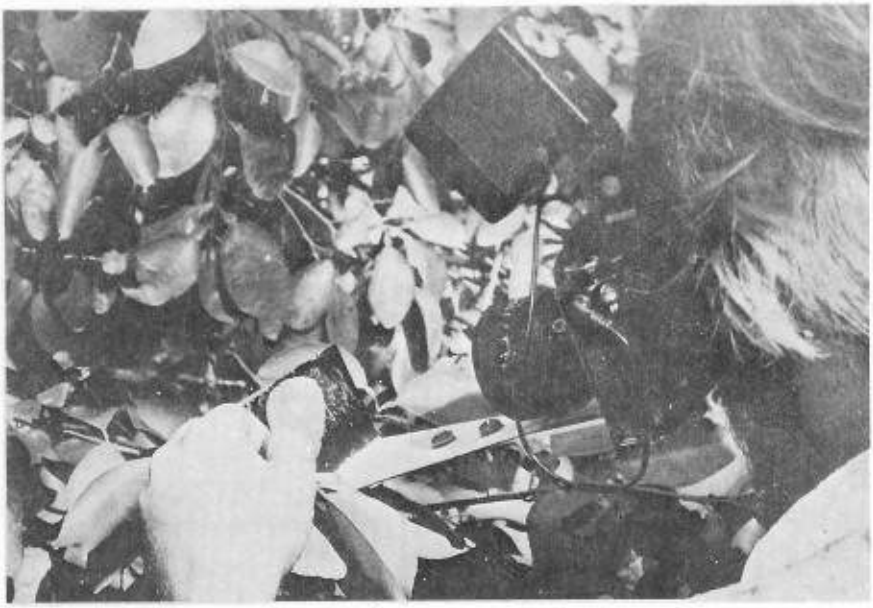

Fig. 2. Photography of citrus blackfly clusters under field conditions.

RESULTS AND DISCUSSION

Table 1 summarizes counting time (man-hrs.) and percent inaccuracy of nondestructive egg counts based on conventional lens and photographic techniques. The difference in actual counting time between the 2 techniques (lens = 1.5 + 0.1; film = 1.4 + 0.1) was not significant, although a substantially shorter data-collection time using photography (ca. 0.4 man-hrs.) represented a major advantage over conventional lens techniques, which required completion of laborious counts in situ. Counts made from filmstrips were significantly less variable than lens counts, with predicted inaccuracy within acceptable (+5%) limits over all density ranges monitored (Fig. 3). In contrast, predicted inaccuracy of highly variable lens counts indicated serious underestimation over most density ranges. Of equal significance, the filmstrip obtained using the former method provided a permanent record of egg densities on individual leaves, and thus permitted verification of counting accuracy. Lack of this provision alone precluded use of conventional lens counting methods in field collection of CBF survivorship data.

Table 1. Percent inaccuracy and time (man-hrs.) required to obtain nondestructive counts of citrus blackfly eggs on citrus foliage using conventional (lens) and photographic (film) counting procedures.[z]

	Time (Man-hrs.)[y]		Inaccuracy (%)[y]	
Method	Mean + St. error	Range	Mean + St. error	Range
Lens	1.5 + 0.1 a	1.1 to 1.9	-13.4 + 8.2 a	-24.0 to -2.5
Film[x]	1.4 + 0.1 a	1.3 to 1.6	- 2.5 + 1.9 b	- 5.4 to 1.9

[z] Replicated counts of 5,573-egg cohort occurring on 35 citrus leaves (14-507 eggs/leaf) by 6 individuals under laboratory conditions, with count-order determined by random numbers table.

[y] Tested by Duncan's multiple range test using untransformed data. Means followed by same letter not significant at 5% significance level.

[x] Estimate does not include time required to process film (ca. 10-min/roll), dependent on temperature and developer. Processing efficiency may be increased substantially by use of multi-reel developing tanks.

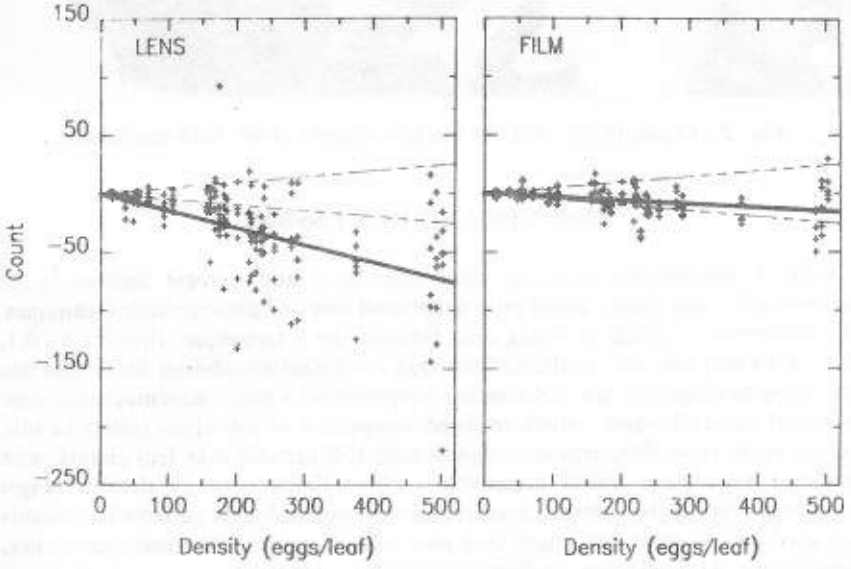

Fig. 3. Linear regression indicating predicted egg counts as a function of egg densities (solid line), using conventional (lens) and photographic (film) counting techniques. Acceptable (+ 5%) accuracy limits indicated by broken line.

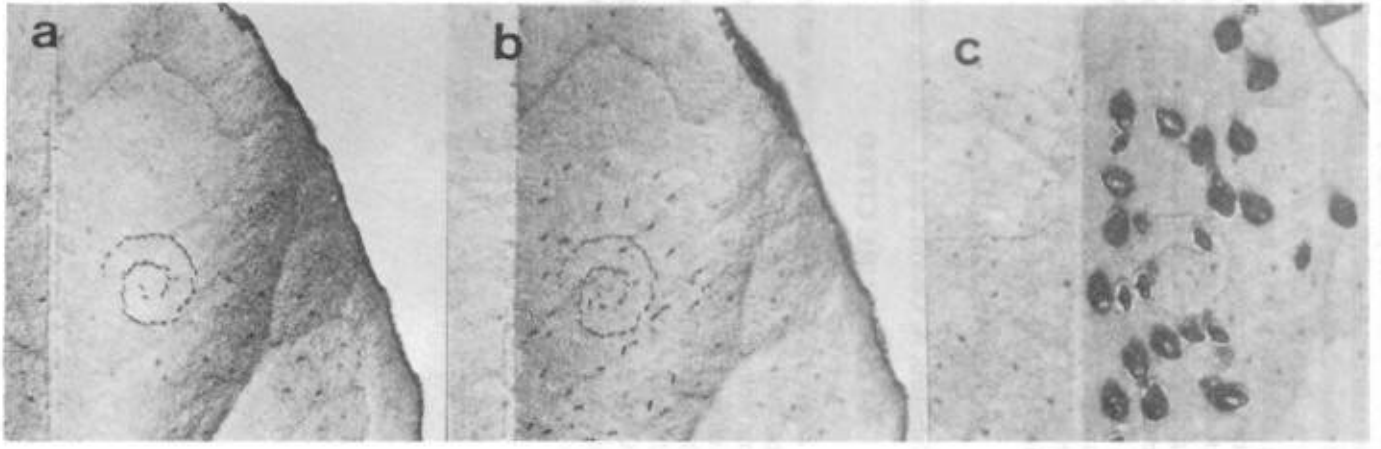

Fig. 4. Sequence of close-up 35mm photographs used to evaluate stage-specific mortality of citrus blackfly under field conditions: (a) eggs, (b) settled larvae, and (c) pupae.

In summary, use of close-up 35mm in situ photography provided a twofold advantage over conventional lens counting techniques: (1) a significant reduction in counting variability and acceptable accuracy over a wide range of insect densities, and (2) a tangible means of data verification. Costs were nominal (ca. $2.00 per 36-frame filmstrip and processing chemicals) and procedures did not require access to elaborate darkroom facilities. A sequence of close-up photographs obtained for CBF clusters monitored under field conditions (Fig. 4) permitted accurate enumeration of mortality occurring during the egg, larval, and pupal stages. Up to ca. 2,000 clusters were monitored simultaneously using techniques described herein, and development of a simple film catalog system permitted efficient retrieval of any of ca. 1,200 filmstrips accumulated during a 2-year period (3). Such techniques are amenable to quantitative studies of arthropods inhabiting a variety of substrates, e.g., bark, fruit, etc,. by simple modifications of the focal frame.

ACKNOWLEDGEMENT

The authors thank J.M. Caballero, A. Cavazos, and I. Saenz for technical assistance.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Survey for Tristeza in Texas Citrus

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ABSTRACT

In 1982 and 1983 green bark from the spring flush of selected citrus trees in South Texas orchards, dooryards, nurseries, and trees in a citrus variety planting was indexed for the citrus tristeza virus by enzyme-linked immunosorbent assay. All samples from the commercial citrus industry (orchards, nurseries, and budwood sources) of South Texas were negative for tristeza. However, tristeza was detected in some dooryard 'Meyer' lemon trees, several budwood source trees used for propagating satsuma mandarin outside the commercial citrus area, and in a navel orange, a tangelo, and a calamondin in a variety planting at Texas A & I University Citrus Center in Weslaco.

Tristeza, the most destructive of all citrus viruses, has caused serious losses of susceptible citrus throughout much of the world. Because tristeza is primarily a disease of citrus grown on sour orange (*Citrus aurantium* L.) rootstock, the Texas citrus industry, which uses sour orange almost exclusively, must maintain its tristeza-free status. Tristeza is apparently not a problem in commercial orchards at this time, but the virus has been found in 'Meyer' lemons in South Texas (5). Also, two vectors, the cotton aphid (*Aphis gossypii* Glover) and the green citrus aphid (*A. spiraecola* Patch.), are present and capable of transmitting the virus. The introduction of tristeza in budwood illegally brought into Texas from other states or countries is also a continuous threat to Texas citrus.

To assess the current distribution of tristeza in Texas, we indexed over 650 trees in 1982-83 for the virus by enzyme-linked immunosorbent assay (ELISA), a rapid and sensitive serological procedure involving a double antibody sandwich technique (1,2,4). The survey included trees used as budwood sources for Texas citrus, randomly selected orchard and dooryard trees, and most of the trees in a citrus variety block at the Texas A & I University Citrus Center in Weslaco, Texas.

MATERIALS AND METHODS

Two to four shoots from the spring flush of each tree in the survey were collected, composited and processed for ELISA (1,2,4). Shoots not processed immediately were stored in a freezer at -14°C. About 1.0 g of green bark was peeled from the shoots, diced, and homogenized in a plastic beaker containing a phosphate buffer. The bark was homogenized for 10-15 sec and filtered through cheesecloth. The samples were then applied to the ELISA assay along with positive and negative controls and scored visually or read for absorbence at 405 nm at a spectrophotometer to confirm weak reactions.

Budwood from selected trees that tested positive for tristeza by ELISA were grafted onto citrus indicator plants. Two buds from each of two budsticks from each source were graft inoculated onto at least two Mexican lime seedlings. Six months later tissue from the seedlings was processed by ELISA.

Random survey of South Texas citrus. Shoots were collected at random from three or four trees in each of 144 commercial citrus orchards across the citrus belt of the lower Rio Grande Valley of Texas. The area within the survey was approximately 25 x 90 kilometers. We also randomly selected some dooryard citrus trees with emphasis on 'Meyer' lemons.

Survey of Texas citrus nurseries. All licensed citrus nurseries were contacted for their cooperation in a survey to screen budwood source trees for tristeza. Approximately 75% of the nurseries included their trees in the survey. Nurseries which grow ornamental citrus for areas outside the commercial citrus area in Texas were also contacted.

Survey of the variety block at Texas A & I University Citrus Center. Most of the 125 selections in the variety block at the Citrus Center were included in the ELISA test. Almost all varieties are planted on sour orange rootstock. Trees in a smaller planting used for budwood sources were also included in the survey. These trees were known to be free of psorosis although many carry exocortis and xyloporosis.

RESULTS AND DISCUSSION

Random survey of South Texas citrus. All ELISA tests of tissue from the commercial citrus in South Texas were negative for tristeza (Table 1). This, coupled with the lack of any symptoms of tristeza infection, indicates that the citrus industry of Texas is probably free of tristeza or at least free of any extensive infestation. However, tristeza does exist in old-line 'Meyer' lemons planted in dooryards (Table 1).

Survey of Texas citrus nurseries. All samples from the nurseries which provide stock for commercial orchards in Texas were negative for tristeza (Table 1). ELISA tests were positive, however, for 9 of 101 samples from a nursery in the Port Neches area of Texas. All the tristeza-positive samples were from satsuma mandarin trees. This nursery provides trees for homeowners in urban areas along the upper gulf coast of Texas. Most of the trees propagated in the nursery are satsuma mandarin on trifoliate rootstock, a cold hardy and tristeza resistant combination.

Because of the faint serological reaction from these samples, the optical density was recorded. The average optical density reading for the infected satsuma mandarin trees was 1.1 while the negative control was 0.4 and the positive control was 3.1. When the virus in the satsuma mandarin budwood was graft-inoculated onto Mexican lime seedlings and retested with ELISA, the serological reaction was very strong and the optical density did not differ significantly from the positive controls. These results suggest that satsuma mandarin is a poor host for the tristeza virus.

Survey of the variety block. Three varieties, a navel orange selection, a tangelo, and a calamondin in the variety block assayed positive for tristeza (Table 1). The navel selection, chosen to be included in the variety block because of its dwarf growth habit, was planted in duplicate at the Citrus Center in 1957. Further inspection of the two infected trees revealed honeycombing of the cambium above the bud union, a typical symptom of tristeza infection. The stunted growth was probably due to tristeza. The trees originally came from budwood from an orchard in Mercedes, Texas. The orchard

was destroyed in the mid-1960's. None of the trees in the variety block surrounding the infected navel orange trees assayed positive for tristeza, indicating that the virus apparently has not spread.

The tristeza-infected tangelo selection originated from a seedling planted at the USDA experiment station in Weslaco in the early 1950's. The infected calamondin was an old-line variety which was propagated from a dooryard tree near Weslaco in 1954. There were no positive ELISA reactions with the samples taken from the budwood source planting.

Table 1. Tristeza virus infection in Texas citrus[z].

	No. of positive ELISA reactions/No. of samples			
Variety	Orchards	Nursery trees	Dooryard trees	Variety block
Oranges	0/58	0/79	0/10	1/102
Grapefruit	0/85	0/25	0/10	0/36
Meyer lemon	0/0	0/1	2/7	0/2
Satsuma mandarin	0/0	9/101	0/0	0/4
Other	0/1	0/15	0/4	2/128

[z] All orchards were in the lower Rio Grande Valley; nursery trees included budwood sources for commercial and ornamental citrus; dooryard trees were sampled only in the lower Rio Grande Valley; and the variety block was at Texas A & I University Citrus Center in Weslaco. All of the satsuma mandarin trees with positive reactions were from a nursery in Port Neches, Texas.

The commercial citrus industry in South Texas is apparently free of tristeza. However, tristeza can be found in South Texas in old-line 'Meyer' lemon trees. While these 'Meyer' lemons can be a source of inoculum that threatens the commercial acreage, movement of the virus from 'Meyer' lemons to oranges and grapefruit in orchards is unlikely for several reasons: lemons are not a preferred host of aphids; a factor exists in lemons that inhibits the transmissibility of the virus; and most of the infected 'Meyer' lemons are located some distance away from commercial plantings as dooryard plantings. Fortunately, the 'Meyer' lemons propagated today are tristeza free (6).

Although the infected navel orange, tangelo, and calamondin trees were planted in a variety planting surrounded on three sides by other orchards, no extensive spread was indicated. This suggests that few aphids feed on Texas citrus and/or they are not efficient vectors of the tristeza virus (3).

The presence of tristeza in ornamental citrus trees outside the commercial citrus area of Texas is reason for concern. Infected trees could be transported south to the lower Rio Grande Valley and planted near orchards where they would be a source of tristeza inoculum. Therefore, all trees found to carry tristeza should be destroyed. Nurseries should continue to maintain tristeza-free budwood source trees to avoid future problems with this virus in Texas citrus.

ACKNOWLEDGEMENT

We thank S.M. Garnsey, USDA-SEA/AR, Orlando, Florida, for supplying the antiserum used in the ELISA tests and Kerry Siders for technical assistance.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Relationship of Micronutrient Application to Yield in Texas Citrus

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ABSTRACT

Foliar concentrations of Fe, Zn, Mn and Cu were determined in 'Ruby Red' grapefruit (*Citrus Paradisi* Macf.) on cleopatra mandarin (*C. reshni* Hort. ex Tan.) or sour orange (*C. aurantium* L.) rootstock and in 'Marrs' orange (*C. sinensis* (L.) Osbeck)/sour orange stock.

Leaf concentration of each element fluctuated during each year but did not exhibit any definite seasonal trends. Micronutrient treatments increased the foliar concentration of the particular element and reduced or eliminated foliar symptoms of nutritional disorders but did not influence total yield or fruit size.

There is limited experimental work with micronutrient deficiencies in Texas citrus altho foliar symptoms are seen from time to time. Recently a positive yield response was reported with Star Ruby grapefruit when low or deficient manganese levels in leaf tissue were corrected by foliar sprays (5). Prior to that there were no reports of yield increases of citrus attributable to application of micronutrients. The work reported here was undertaken to determine the seasonal variation in micronutrient content of leaf tissue and the value of micronutrient treatments with respect to leaf content of the element and fruit yield.

MATERIALS AND METHODS

In order to determine the seasonal variation of several minor elements leaf samples of 100 leaves per sample were collected the first week of each month for 12 months from 10 trees of eight-year-old 'Ruby Red' grapefruit on sour orange rootstock. Trees were vigorous, productive and exhibited no foliar symptoms of nutrient deficiencies. The soil was Hidalgo clay loam. Samples were handled as previously described (4). Concentrations of Fe, Zn, Mn, and Cu were determined on an atomic absorption spectrophotometer following a nitric:perchloric acid digestion of the leaves.

Ruby red grapefruit/Cleopatra mandarin rootstock planted in 1953 on Hidalgo clay loam soil regularly exhibited foliar symptoms suggestive of Fe deficiency (2). Despite the long history of symptoms the trees, at age 16 thru 19, were averaging 333 lbs of fruit a tree or 16.6 tons an acre. Leaf samples taken during this period showed low or deficient Fe, and low Zn and Mn according to Chapman (1). Copper and all macronutrients were in the optimum range.

An experiment in a randomized complete block design with 8 replications and single tree plots was established. Treatments were: Iron sulfate, 10 lb/tree applied to the soil beneath the skirt; Iron chelate (Oxy-plex Iron, Occidental Chemical Company) 1qt/100 gal with 10 gal sprayed/tree using a hand gun at 100 psi; zinc chelate (Oxy-plex Zinc) sprayed as above; Manganese chelate (Oxy-plex Manganese) sprayed as above; and untreated control. Treatments were applied in May 1972, 73 and 74. Nitrogen was ground applied to all trees in December or January each year at 100 lb N/acre. Leaf samples for tissue analysis were taken in May each year before treatment. Fruit was harvested, weighed, and sized on an individual tree basis in December each year.

Marrs orange/sour orange rootstock planted on a 10 acre block that had been leveled the previous summer regularly exhibited foliar symptoms of nutritional disorders during their early years. The soil, of the Hidalgo series, varied from sandy clay to clay. Cuts varying from 9 to 19 inches were necessary over about 2 acres. Symptoms of trees planted in the cut area suggested insufficient Fe, Zn, or Mn to be the problem. Leaf samples taken in May 1973 revealed Zn and Mn levels to be in the low range (1); all other elements were in the optimum range.

Guard rows in the deeply cut area were used for Zn and Mn foliar spray treatments. A randomized complete block design with 10 replications was developed using single tree plots. In December or January each year the entire block received nitrogen fertilizer at the rate of 125 lb N/acre. Micronutrient sprays were applied in May, each year, 1973 thru 1976 in the form of Zn or Mn sulfate at a concentration of 1 lb/100 gal water (3) with 10 gal applied/tree using a hand gun at 100 psi. Treatments were Zn, Mn, Zn + Mn, and no micronutrients. The Zn + Mn combination was not applied in 1976. Leaf samples were taken in September 1973, 74, and 76. Fruit was harvested, weighed, and sized on an individual tree basis in December each year.

RESULTS AND DISCUSSION

In the study using 'Ruby Red' grapefruit/sour orange stock the leaf content of micronutrients did fluctuate from month to month (data not shown), however, there were no apparent seasonal trends as exist for certain macronutrients (4). Iron content of the leaf tissue ranged from 40 to 55 ppm over the year, Mn from 30 to 38, Zn from 20 to 25, and Cu from 6 to 9. The period May thru October, recommended for macronutrient evaluation, is also suitable for micronutrient evaluation.

'Ruby Red' grapefruit/cleopatra mandarin rootstock in the 1972 leaf sampling, which served as a pre-treatment uniformity trial, had all macronutrients and Cu in the optimum range. Iron, Zn, and Mn were in the low range and quite uniform across the plots (Table 1). In May 1973, one year after the initial spray application, Fe in the trees sprayed with Fe was in the optimum range. Altho soil-applied Fe increased leaf concentration by 4 ppm, the values remained in the low range. Results were essentially the same following the 1974 sampling.

Zinc concentration in the leaves one year after the initial spray remained in the low range on all treatments altho the highest values were in Zn treated plots. In May 1974 Zn levels reached the optimum range in Zn treated plots while all others continued to be in the low range

In 1973 Mn levels were in the optimum range in all except Fe treated plots, where

Table 1. Fe, Zn, and Mn concentrations (ppm) in leaf tissue of 'Ruby Red' grapefruit on sour orange rootstock as affected by Fe, Zn, or Mn treatments.

	Fe			Zn			Mn		
Treatments	1972[z]	73	74	72	73	74	72	73	74
No treatment	43	40 B[y]	43 B	23	16	18 B	24	26 A	30 A
Fe spray	39	63 A	65 A	22	17	20 B	22	19 B	21 B
Fe soil	41	45 B	45 B	21	15	18 B	22	18 B	21 B
Zn spray	42	44 B	50 B	22	22	25 A	23	26 A	25 A
Mn spray	44	39 B	44 B	22	15	24 A	22	27 A	26 A
	NS			NS	NS		NS		

[z] pre-treatment sampling

[y] means within columns followed by the same letter do not differ significantly ($p = 0.01$), Duncans MRT.

Mn was deficient. In the 1974 sample Mn was low in Fe treated plots and optimum in all others.

Visual symptoms of Fe shortage were eliminated from plots receiving foliar Fe in all growth flushes subsequent to the initial spray. Symptoms were apparent in all other plots. Symptoms of Mn shortage persisted thru 1974 in Fe treated plots while in all others symptoms were reduced in flushes subsequent to the initial spray. Symptoms of Zn shortage were eliminated from Zn-treated plots for about 10 months after the initial treatment. Following the second Zn spray symptoms were eliminated thru 1974. In all other plots symptoms persisted to some degree.

No significant differences in yield or fruit size due to micronutrient treatments were found in individual years or in the 3 yr mean. At tree ages 20-22 years yields ranged from 302 to 392 lb a tree (15-20 tons/acre). Differences between years were significant ($p = 0.01$) which was a reflection of the alternate or irregular bearing sometimes exhibited by grapefruit trees. Micronutrient sprays did have the cosmetic effect of reducing foliar symptoms but did not influence yield.

Marrs orange/sour orange rootstock in the pre-treatment sampling of May 1973 had Zn and Mn in the low range. Following the initial treatment, Zn levels, were in the optimum range (September 1973) in plots sprayed with Zn alone, in the low range in Zn + Mn plots, and deficient in all other plots (Table 2). In September 1974 and 76 Zn was in the optimum range in both Zn and Zn + Mn plots while all other plots were deficient. Differences in leaf concentrations between plots were not statistically significant in the pre-treatment sampling but were significant ($p = 0.01$) in all samplings after treatments commenced.

In the pre-treatment sample Mn levels were uniformly low with differences between plots nonsignificant. In September 73 and in all subsequent samples Mn was in the optimum range regardless of treatment. Differences between treatments were not

significant in September 73 but were significant ($p = 0.01$) at all subsequent samplings with the highest concentration in the plots treated with Mn.

In the season prior to treatment there were no significant differences in yield between plots. Likewise for the 4 crops 1973 thru 1976 there were no significant differences in fruit yield or size attributable to the micronutrient sprays. Changing leaf Zn concentration from low to optimum range in the Zn and Zn + Mn plots did not influence yield. From September 73 forward foliar Mn levels were in the optimum range regardless of treatment. Increasing the Mn concentration in the leaves did not affect yield. As with 'Ruby Red' grapefruit Zn sprays had the cosmetic affect of eliminating or reducing foliar symptoms.

There were no yield increases associated with raising the foliar concentrations of Fe, Zn, or Mn from deficient or low to optimum range. Apparently levels considered less than optimum by Chapman do not adversely affect yields in Texas.

Table 2. Zinc and Manganese concentrations (ppm) in leaf tissue of 'Marrs' orange on sour orange rootstock, as affected by foliar applications of Zn and Mn 1973 thru 1976.

	Sample Date			
Treatment	5/73[z]	9/73	9/74	9/76
		Zn		
No micronutrients	18	2[y]	11 B	14 B
Zn	22	25 A	28 A	35 A
Mn	20	12 C	11 B	15 B
Zn + Mn	20	17 B	28 A	
	NS			
		Mn		
No. micronutrients	22	34	29 B	30 B
Zn	23	32	27 B	26 B
Mn	24	35	46 A	41 A
Zn + Mn	23	35	43 A	
	NS	NS		

[z] Pre-treatment sample.

[y] means within columns, followed by the same letter do not differ significantly ($p = 0.01$), Duncans MRT.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Growth and Yield Comparison of Ten-Year-Old Red Grapefruit Trees From Field- and Container-Grown Nursery Stock

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Additional index words: citrus, nursery practices

ABSTRACT

Tree growth and productivity of container- and field-grown nursery 'Redblush' (*Citrus paradisi* Macf.) trees were compared in the 7-10 yrs. of growth. Cumulative and mean fruit yield and the increase in trunk circumference were not significantly different. The canopy volume of field-grown trees was significantly greater than container-grown trees at the end of 10 years growth. Savings in spraying, harvesting, topping and hedging can be an advantage of container-grown citrus trees.

Many citrus nurseries in Texas are taking advantage of improvements in tree production by growing container trees (1). One concern is the yield and growth of container trees compared to field-grown nursery trees. A comparison test of field and container-grown nursery trees was planted in 1972 on the Texas Agricultural Experiment Station at Weslaco.

Previously reported results of this test through six years showed no significant differences in fruit yield (2). Canopy-volume of the field-grown trees was significantly larger than container-grown trees at the end of 6 growing seasons. The test has been continued through year 10 to determine fruit yields and tree volumes of field-grown and container-grown nursery trees. Data are presented evaluating fruit yield, tree growth and canopy volume from year 7 through year 10. Year 8 (1980) data has been discarded as non-representative due to a hurricane in that year that damaged the fruit crop.

MATERIALS AND METHODS

A description of the soil and test design has been previously reported (2). Cultural practices included fertilizer at 0.45 kg N as ammonia sulfate per tree applied each February, flood irrigations, and weed control maintained by herbicides with spot treatments as needed.

Data collection and analysis were continued as reported (2). Yield data from 1980 were omitted from analysis due to wind damage to fruit in August from Hurricane Allen.

Table 1. Fruit yield from container-grown and field-grown 'Redblush' grapefruit trees.

				1979-82 Cumulative[z] Yield (kg)		1974-82 Cumulative[z] Yield (kg)	
	1979	1981	1982	Total	Mean	Total	Mean
Container Trees	106.0a[y]	164.0b	143.4a	413.5a	137.8a	791.5a	98.9a
Field Trees	87.3b	197.1a	117.9a	402.3a	134.1a	770.4a	96.3a

[z]1980 data omitted due to hurricane effect on fruit yield.

[y]Means separated in columns by T-test. $t_{.05} = 2.1$.

Table 2. Mean canopy volume and trunk circumference of 10-year-old 'Redblush' grapefruit trees grown as container and field nursery stock.

	Canopy Volume[z] (m^3)	Trunk Circumference (cm) 1978	1982	Growth Increase
Container Grown	39.33a[y]	42.22	56.86	14.63a
Field Grown	49.92b	50.13	65.76	15.63a

[z]Volume = $0.523 \times d^2h$.

[y]Means within columns with different letters are significantly different at the 1% level.

RESULTS AND DISCUSSION

Significant yield differences were found in 2 of the 3 years reported (Table 1). Container-grown trees had greater yields in 1979 and field-grown trees performed better in 1981. However, the cumulative and mean yield over the 4-year period (3 years' data) showed no significant difference between container- and field-grown trees. Mean trunk circumference increased over the 4-year period but there were no significant differences (Table 2). However, canopy volume of field-grown trees was significantly greater.

In this test, cumulative over 10 years, container-grown nursery trees have produced as much fruit as field-grown nursery trees but have maintained a smaller canopy volume. This has an advantage in harvesting, application of chemicals and delaying hedging and topping.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984

Forecasting Texas Citrus Production

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ABSTRACT

An objective method based on counting total fruit per sample tree and rating orchards by productivity and condition was used to estimate the Texas citrus crop over 4 seasons. The method, called TCOR for tree count-orchard rating, also estimated fruit size and quality. The estimates are compared to the actual production reported. Further efforts to improve or expand the traditional crop forecast will depend on its purpose and value to the Texas citrus industry.

Each year in early October the Texas Crop and Livestock Reporting Service forecasts Texas' citrus production for the ensuing season. The forecast estimates production, in 7/10 bushel cartons, for early/mid-season oranges, late oranges (Valencias) and grapefruit. Similar forecasts are made for Florida and California. The October estimate is the official answer to months of speculation and argument about the current citrus crop (6).

A review of citrus production forecasts, however, reveals divergent opinions on their purpose and value. A California report on forecasting lemon production initially says, "this information is closely followed by those in agriculture and allied industries as a basis for production and marketing decisions" but concludes, "such statistical information should (emphasis mine) be very useful to the industry during the critical months ahead" (9). A Florida publication states the U.S.D.A. citrus production and Brix estimates for oranges were never intended as absolute measures upon which industry decision makers should plan marketing strategy (3). Nevertheless, in 1978 when the U.S.D.A. forecast the orange crop at 30 million boxes less than most everyone expected, orange juice futures went up to the limit for several days and industry leaders worried that tariffs would be lowered to allow an influx of imported juice (15).

Although annual estimates of Texas citrus production began in 1919, the use and value of these estimates to the industry has not been critically reviewed (22). In view of the changes in the industry in this timespan such a review would be pertinent. The experience of other citrus producing areas suggests Texas' current, essentially subjective, system of forecasting could undoubtedly be improved and expanded (1). It remains for the Texas citrus industry to decide whether the forecast's importance merits the cost and effort of improvement.

Improvements of citrus production estimates have centered on increasing accuracy through more sophisticated sampling procedures (18,20). From the number of fruit counted on a representative limb or within a specified volume of canopy the total number of fruit per tree is calculated. Fruit size and quality information may also be recorded. From a pre-determined number of sample trees, total production is derived by extrapolation based on the most recent tree or acreage census. Several workers also investigated making fruit counts from photographs of the sample trees (2,16). The potential increase in accuracy, if any, could not justify the additional cost and time required using photography. More recently, fruit counts made from infra-red photos of trees was proposed (8). Since the technique was based on the color contrast between mature fruit and leaves, the method would have little value in pre-harvest forecasting. However, the number of fruit per tree is deemed the most important factor in estimating, so seeking an improved, more cost efficient fruit counting procedure appears justified (10).

An objective forecasting method for Texas I devised, while similar to others has three major differences. The first is that fruit numbers were obtained by counting the total number of fruit on each sample tree. With minimum practice fruit on trees of all the citrus varieties grown in Texas can be counted quite accurately in less than 4 minutes per tree. Compared to other methods, from 10 to 25 times more trees could be sampled with the same time expenditure (2, 20). In addition no other equipment or calculations were needed to get the final fruit count per tree. Statistically, by increasing the number of counts both the precision and accuracy of the estimate should improve (17). Within each sample orchard from 1 to 2% of the trees were randomly selected for counting. While counting, a visual estimate of the quality and percent of fruit in 3 appropriate size classes was made. The approximate tree spacing, size and age along with orchard acreage were also noted.

The final datum taken in each sample orchard and the second key feature in the survey method, was rating the overall condition and quality of the orchard from 1, excellent, to 5, essentially abandoned. Orchards of early/mid-season oranges, Valencias and grapefruit were sampled in proportion to total acreage of each variety and age group within each of the zones described in the 1983 Texas Citrus Tree Inventory Survey, Fig. 1 (19).

The third key feature of the survey was estimating the proportion of acreage in each age group and condition rating by varieties within zones. While driving through each zone, every orchard along a half to three-quarter mile stretch of road was classified according to the above criteria. By using the sample orchards as standards, this estimate, though rough, did provide a broad base from which the fruit count, size and quality data could be extrapolated. From the tree count-orchard rating features, I've dubbed this the TCOR method for sake of convenience and brevity.

The production forecast was completed by averaging fruit counts, size, and quality estimates for orchards within each condition and tree age class by zones. From long term fruit growth curves maintained at the Citrus Center, the pounds of fruit/tree was projected to January 1st. Using the tree populations reported in the appropriate tree survey, total production by tree age and orchard condition rating was calculated for each zone. Summarizing the totals from the zones provided the estimate for the Valley.

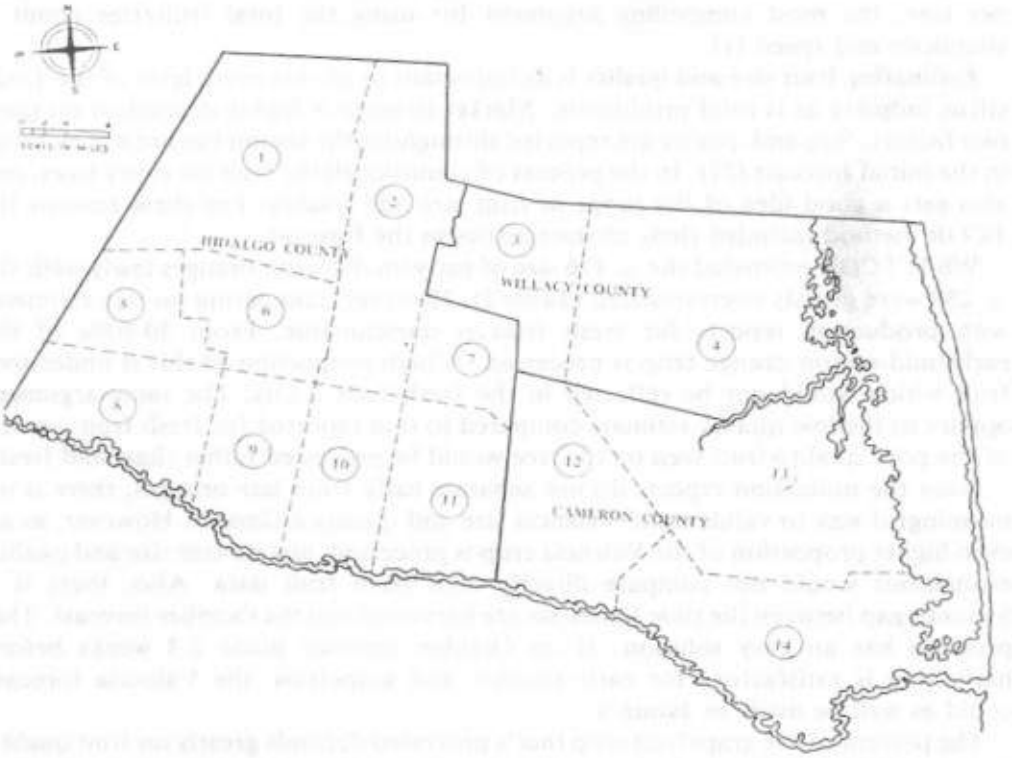

Fig. 1. Map of Texas citrus producing divided into sections used for acreage survey and production forecast (19).

Forecast and final production are compared beginning with a limited survey in th 1979-80 season. With slight refinements in subsequent years, the resultant forecast are compared to the reported production (Table 1). In 7 out of 11 times, (includin the 1982-83 early/mid-season orange revision), the TCOR October estimate wa within 10% of the final production. The average error was ± 20% (20).

The relative importance of the variables affecting orange production in Floric forecasts are: number of fruit, 45%; fruit size, 25%; fruit drop, 20%, and tr population, 10% (10). These percentages would probably apply to Texas orang and grapefruit as well. However, a ranking of these factors in ascending order available, accurate data for estimating production would be: fruit drop, number fruit/tree, fruit size and tree population. Each biennial survey of Texas citrus t numbers and acreages should provide increasingly precise estimates of actual valu Data on fruit sizing and drop, while good, can be improved considerably with m study (11,14,24). Thus fruit numbers remain the most variable factor in production forecast. In comparison to other methods, I believe counting all the f on a tree is the best system for Texas. On large trees, the number and distributio fruit makes for easy counting. On young trees, fruit tends to be clustered inside canopy. While this makes counting more difficult, it is probably still more accu

than limb or frame counts. With limb counting, requiring 2 men from 20-25 minutes per tree, the most compelling argument for using the total fruit/tree count is simplicity and speed (1).

Estimating fruit size and quality is as important to almost every level of the Texas citrus industry as is total production. Market strategy is highly dependent on these two factors. Size and quality are reported throughout the season but are not included in the initial forecast (21). In the process of counting all the fruit on many trees, one also gets a good idea of the range in fruit size and quality. For these reasons the TCOR method included these characteristics in the forecast.

While TCOR estimated the $\geq$ 176 size of early/mid-season oranges fairly well, the $\leq$ 288 were grossly overestimated (Table 2). However, comparing on-tree estimates with production reports for fresh fruit is questionable. From 30-50% of the early/mid-season orange crop is processed. A high proportion of this is undersized fruit which would not be reflected in the fresh fruit totals. The same argument applies to the low quality estimate compared to that reported for fresh fruit—much of the poor quality fruit seen on the tree would be processed rather than sold fresh.

Since the utilization reports do not separate early from late oranges, there is no meaningful way to validate the Valencia size and quality estimates. However, as an even higher proportion of the Valencia crop is processed, any on-tree size and quality evaluations would not compare directly with fresh fruit data. Also, there is a 5 month gap between the time Valencias are harvested and the October forecast. This problem has an easy solution. If an October forecast made 2-3 weeks before harvesting is satisfactory for early oranges and grapefruit, the Valencia forecast could as well be made in January.

The percent of the grapefruit crop that's processed depends greatly on fruit quality and the fresh market. Grapefruit culled for processing, while varying more from season to season than oranges, tends to be equally distributed among all fruit size classes. Consequently, the on-tree grapefruit size and quality estimate should conform more closely to the fresh fruit size and quality figures than for oranges. This seemed true for the 1979-80 and 1981-82 seasons. The quality estimates for 1980-81 and 1982-83 were accurate but fruit sizes were underestimated. This could be due to sampling error or failure to adequately account for fruit growth.

In view of the inherent discrepancy in comparing on-tree estimates with fresh fruit data, the TCOR results were sufficiently realistic to consider further refinement of this approach to forecasting production. In 1969, Israel replaced a subjective citrus forecast with an objective method similar to TCOR (4,5). With a total production twice that of Texas, the Israeli method estimated their three major citrus crops with a 5 year average error of $\pm$ 6%. The same accuracy could be achieved in Texas and even improved with additional research such as recent studies relating the effect of climate on fruit size and quality (7,12,23).

CONCLUSION

The accuracy of the annual Texas citrus crop forecast could be immediately increased by using more objective sampling and survey methods. Application of recent studies and additional research could further improve the forecast. The

Table 1. Texas citrus final production compared to the initial (October)estimate, 1979-1983.

Season	Crop	Estimate[z] (TCOR)	Production (Final)	Difference[y]
1979-80	Early/mid-season Oranges	—	—	—
	Valencia Oranges	2,114.5	1,721.5	+23
	Grapefruit	7,586.5	7,895.5	− 4
1980-81	Early/mid-season Oranges	2,557.1	2,600	−.1
	Valencia Oranges	1,903.9	1,721.5	+10
	Grapefruit	6,991.9	6,695	+ 4
1981-82	Early/mid-season Oranges	3,261.2	3,601.5	− 9
	Valencia Oranges	1,996.1	2,331	−14
	Grapefruit	10,495.5	13,883.5	−24
1982-83	Early/mid-season Oranges[x]	1,800 (3,272.8)	3,579	−50 (− 8)
	Valencia Oranges	2,405.3	2,079.5	+16
	Grapefruit	11,293	11,150	+ 1

z — figures x 1000 = field boxes: 80 lb. for grapefruit, 90 lb. for oranges. No estimate was made for early/mid-season oranges in 1979-80.

y — Difference = $\frac{\text{estimate} - \text{final production}}{\text{final production}} \times 100$

x — Sample was too small and unrepresentative for calculating estimate. Revised estimate in parentheses based on previous production and other non-formula factors (13).

question is not how, but why should the forecast be improved. Modifying the present method of estimating the crop, including the addition of fruit size and quality information, changing the forecast date and increasing cost effectiveness can only be justified when the Texas citrus industry determines for whom and what purpose the forecast is made.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Aerial Environment and Soil Water Effects on Fruit Enlargement of 'Marrs' and 'Valencia' Oranges and 'Ruby Red' Grapefruit

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ABSTRACT

The circumference of 30 fruit from 3 replications and the polar (P) and equatorial (E) diameters of 10 fruit from 1 replication were measured biweekly from early May until harvest of 'Marrs' and 'Valencia' oranges (*Citrus sinensis* (L.) Osbeck) and 'Ruby Red' grapefruit (*C. paradisi* Macf.) to compare fruit growth responses among cultivars and in relation to the aerial environment and 4 irrigation treatments. Regardless of differences in maturity dates, 85% of the variation in fruit size at harvest for all three cultivars had been determined by August 1. Fruit diameter or circumference in early August could be divided by 0.8 for grapefruit or by 0.7 for oranges to estimate their size at harvest. Rate of enlargement decreased continuously for all cultivars from May to harvest, but growth was interruped by stressful environmental conditions, especially during the period May through August. Soil water conditions that ranged from wetter than to drier than commercial grove irrigation practices were not an important factor in fruit size. The P/E diameter ratios stabilized for all cultivars by November 1. P/E ratios may help define end points of growth stages. Circumstantial evidence suggests that the number of cells formed in the fruit, which is completed within a few weeks of bloom, rather than enlargement of those cells limits final fruit size. Thus, pre- and immediate post-bloom environmental and tree conditions need to be studied as they determine number of cells produced per fruit.

Citrus fruit size at harvest varies from season to season and is affected more by climatic factors (2,4,5,6,8,10) than by water and fertility management of the groves (4,9,16). Fruit size is especially important economically for grapefruit in the Lower Rio Grande Valley of Texas because of the demand for the larger fruit sizes for the fresh fruit market and the higher prices commanded. Yield in tons per acre is also proportional to average size of the individual fruit once the crop is set. Hence larger fruit means higher yields and a better chance of profit for the producer of oranges as well as grapefruit. For these reasons effort to understand the factors involved and be able to predict the size citrus will achieve is worthwhile.

Fucik (3) reported that grapefruit weight increased about 4% per week from September to January, remained static in January and February and increased again in late March and April. Fucik and Norwine (4) related mean monthly insolation, and mean monthly maximum, minimum and average daily temperatures for the months January through October to the diameter of grapefruit in October, November, and December for the years 1965 through 1974. Insolation for the

individual months January through June was significantly positively correlated with fruit size in all 6 months with the highest product moment correlation, r, of 0.70 for April. April and May air temperatures were positively correlated with fruit size and August through October temperatures were negatively correlated with fruit size. A multiple stepwise regression equation that included 7 variables-January, March, and April average daily insolation; February and April mean minimum daily temperature; and, March and April mean maximum daily temperature-yielded a coefficient of determination, R^2, of 0.99 for fruit diameter in both October and November. Young and Shull (14) reported rapid increase in grapefruit enlargement from April to October and that soil water availability affected fruit growth during the hottest part of the growing season.

Studies from other production areas have dealt mainly with oranges. Elfving and Kaufman (2) observed irreversible growth of 'Valencia' oranges at night but found no significant relations with single environmental variables that included vapor pressure deficit and air temperature. Daytime shrinkage and expansion of the fruit was reversible. Hales et al. (5) reported that, of the climatic variables they studied, relative humidity was most closely related to the increase in circumference of 'Valencia' oranges in California. Lombard et al. (8) also reported that diurnal change in fruit volume followed relative humidity. Hilgeman et al. (6), in Arizona, reported volume increase of 'Valencia' oranges from June 15 to November 20 was predictable from 3 variables--number of fruit per tree, bloom date in days after March 30, and summation of degree days above 100°F.

Data for this study of seasonal fruit enlargement were obtained during intensive experiments to arrive at irrigation management recommendations of 'Marrs' and 'Valencia' oranges and 'Ruby Red' grapefruit under limited water supply (15,16,17,18). In those studies yield, tree growth, water use and juice quality were reported. Fruit size measurements were taken biweekly during 4 seasons, 1968 through 1971. The purpose of this article is to compare inter-cultivar fruit growth data for the 1971 season in which both polar (stem to blossom end) and equatorial dimensions (12,13) of the fruit, weather variables, and soil water conditions were measured.

MATERIALS AND METHODS

The experiment was conducted in orchards at the Valley Soil and Water Conservation Districts' Research Farm located 4 miles north of Weslaco, TX. Two-year-old scions on sour orange rootstock were planted in 1964. The soil was a Hidalgo sandy clay loam (Typic Calciustolls). The orchards incorporated a randomized block design of 4 irrigation treatments with 3 replications. 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.

Ten fruit distributed over all quadrants of the 4 yield trees of each replication were tagged for repetitive identification on May 5, 1971, and were measured biweekly until harvest. The specific dates of measurement were : May 6 and 17, June 1, 14 and 28, July 14 and 26, August 9 and 23, September 7 and 21, October 6 and 18, November 1 and 15, December 2 and 15, January 3 and 17, February 2, 14 and 28, and March 13. The equatorial circumference was measured with a flexible tape graduated in mm and the polar (P) and equatorial (E) axes were measured with a caliper graduated to

0.1 mm. The P and E measurements began on June 1 and circumference measurements began May 6. All diameter (circumference/π) data reported are the means of all 30 fruit of the 3 replications per irrigation treatment whereas the polar and equatorial dimensions are the means of 10 fruit from one replication.

At harvest, average weight of all fruit from the 4 yield trees of each replication was determined, but the weight of the tagged fruit was not determined separately.

Full bloom occurred on March 15, 1971, for the 'Valencias' and on March 24 for both the 'Marrs' oranges and 'Ruby Red' grapefruit. Harvest dates were November 22-23, 1971, for the 'Marrs' oranges, January 3-4, 1972, for the 'Ruby Red' grapefruit, and March 13-14, 1972, for the 'Valencia' oranges.

The irrigation treatments, based on the amount of plant-available water in the surface 3 ft. of soil, were (A) irrigate all cultivars year-around when 80% of the available water was depleted; (B) irrigate all cultivars year-around at 60% available water depletion; (C) irrigate all cultivars year-around at 40% depletion; 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 and from Feb. 15 through May 14 and from Aug. 15 through Nov. 14 at 60% depletion. For 'Valencia' oranges May 15 through Aug. 14 was the only period of 80% depletion; the remainder of the year irrigations were applied at 60% available water depletion. These treatments are described more fully elsewhere (15,16).

Maximum and minimum temperature, rainfall, incident solar radiation (insolation) and wind run were measured daily at a Class A weather station within 200 m of the groves. Daily potential evapo-transpiration (PET) was calculated from those observations using the equation (11)

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

wherein Tm is mean daily temperature (°F), and Rs is daily solar radiation expressed as equivalent depth of water evaporated.

RESULTS

Fruit diameter, the change in diameter between successive measurement dates (delta diameter) and the ratio of polar to equatorial diameter are displayed in Figs. 1, 2 and 3 versus time for 'Ruby Red,' 'Marrs,' and 'Valencia,' respectively. The letters A, B, C and D designate the irrigation treatments in the legend, and identify the dates of irrigation by treatment in the upper part of Figs. 1, 2 and 3. Figure 4 displays the 3-day moving average of the observed weather data and the calculated PET (mm/day) on the same time scale as the fruit size observations.

'Ruby Red'

Diameter of the grapefruit increased at a lessening rate from the time it was tagged until harvest (Fig. 1). After mid-October the fruit enlarged only slowly. Initial fruit diameter was 2.6 cm for treatments A, B, and D but average size of the 30 fruit of treatment C was 4.0 cm. From mid-June through August fruit diameter curves are nearly paralled among all irrigation treatments, so that the 3 irrigations of treatments B and C had little effect on fruit size compared with treatments A and D that were not irrigated during that time. Size of fruit from the yield trees in 1971 was not affected by irrigation (16, Table 3).

The change in diameter, designated delta diameter in Fig. 1, between biweekly

measurement dates showed irregularity in growth rate but again the various irrigation treatments responded about alike. The changes do relate quite closely to weather conditions (Fig. 4). For example, the last 10 days of May were relatively cool and insolation averaged about 500 Ly/day. In contrast the first half of June was a rainless period of increasing air temperature and insolation that averaged almost 600 Ly/day. Consequently, fruit diameter increased by about 1.3 cm, on the average, between the May 17 and June 1 measurement dates, but by only 0.5 cm between June 1 and June 14. Similarly, the fruit size measurements made September 8 followed a 3-week period of high temperature, insolation, and evaporative demand. Fruit on the nonirrigated trees (treatments A and D) actually decreased in diameter between the August 23 and September 7 measurement dates.

The polar/equatorial ratios designated by P/E in Fig. 1 show that the equatorial fruit diameter of the grapefruit equaled the stem to blossom end dimension by July 15. By harvest, the least frequently irrigated trees had fruit with the most oblate shape (lowest P/E ratio). Such fruit in grapefruit is usually heavy for its size and has a smooth, thin peel. "Sheep-nosed" fruit would have a P/E ratio larger than 1.0 at harvest.

'Valencia'

The diameter and delta diameter curves for 'Valencia' oranges (Fig. 2) were generally similar in shape to those of grapefruit. Fruit diameter at harvest averaged 7.5 cm. The growth curves are longer for the 'Valencias' because they were not harvested until mid-March, 1972. The delta diameter curves indicate that they enlarged at a continuously lessening rate after mid-October. Average rate of enlargement from mid-January to harvest was only about 0.4 mm per biweekly interval, so they enlarged only slightly the last 2 months they were on the trees. The P/E ratio differences that existed among treatments at the time the fruit were tagged generally persisted throughout the crop season. The P/E ratio differed somewhat among 30-fruit samples representing the various treatments, but within samples stabilized by Nov. 1.

Fruit size at harvest differed among the irrigation treatments of 'Valencia' in 1971 (16) in the same order as in Fig. 2. The difference is attributable to an alternate bearing pattern that first appeared in treatments C and D in 1971. The fruit load of treatment C (539 per tree) compared with treatments D (370 per tree), B (379 per tree), and A (414 per tree) (16) is probably the reason treatment C fruit are smaller than those of the other treatments.

'Marrs'

The diameter versus time curves for 'Marrs' oranges document that they enlarged at a faster rate and were as large at harvest as the 'Valencia' oranges (Fig. 3). Within a month of harvest they were still enlarging at between 1 and 2 mm per biweekly period. Fruit size was not significantly different among irrigation treatments (16). Like the 'Valencias,' the relative P/E ratios among treatments that existed at the time fruit were tagged (May 5) persisted throughout the season. Delta diameter curves are very similar to those for 'Ruby Red' and 'Valencia' indicating that all 3 cultivars responded alike to aerial environmental conditions.

Correlations of Fruit Diameter on All Dates with Initial and Harvest Date Fruit Diameters

The coefficients of determination are presented in Fig. 5 for fruit diameter when tagged versus their diameter on every observation date, and also the coefficient of determination for their diameter at harvest versus their diameter on every observation date. The coefficients of determination decrease rapidly from unity for the observations correlated with the initial size (forward-looking correlations) and increase but approach unity asymptotically for final size correlated with size on earlier dates (backward-looking correlations).

The data were analyzed this way to determine how early in the season 80 to 85% of the variation in final size could be accounted for. The curves for the harvest size correlations with earlier observations show clearly that for all cultivars 85% of the variation in final size is accounted for by August 1. This indicates that conditions after August 1 are relatively unimportant in determining fruit size, even for 'Valencia' that will remain on the trees for another 6 to 9 months. One can estimate grapefruit size at harvest by dividing either the diameter or circumference observed in early August by 0.8 whereas for oranges the diameter or circumference attained by early August divided by 0.7 estimates their size at harvest.

The coefficients of determination for both the forward- and backward-looking correlations change most-dropping from unity to about 0.6 and rising from the range 0.2 - 0.4 to 0.6 - 0.8, respectively-during May and June. Environmental conditions are evidently affecting fruit size appreciably in July, also, but less than in either May or June.

The coefficients of determination change more rapidly during the period May through July for 'Marrs' oranges and 'Ruby Red' grapefruit than for 'Valencia' oranges. This seems to be in agreement with the slower, steadier enlargement of 'Valencias' over a longer time period (upper curve, Fig. 2) compared with 'Ruby Red' grapefruit and 'Marrs' oranges (upper curves Figs. 1 and 3, respectively).

DISCUSSION

The correlation between initial and final fruit sizes--the beginning points of the backward-looking coefficient of determination curves, and the end points of the forward-looking coefficient of determination curves of Fig. 5--was quite variable among cultivars. It was 0.20 for 'Marrs' oranges, 0.10 for 'Ruby Red' grapefruit, and 0.45 for 'Valencia' oranges. Variation among treatments within a cultivar may be partially due to inclusion of fruit of variable physiological age in the samples. This tends to be supported by the fact that, except for treatment B of the 'Marrs' oranges, fruits from the treatments that had the largest fruit at tagging (Figs. 1, 2, and 3) had the highest correlation with final fruit size (Fig. 5). Number of fruit per tree, however, affected final fruit size (16) and can also affect correlations between fruit size early in the season and at harvest.

The backward-looking correlation coefficients are more meaningful in terms of estimating final fruit size than the forward-looking correlations. However, there appears to be relatively little the manager of an orchard can do to affect fruit size, except leave the fruit on the trees longer (3,14) once the final fruit size is predictable. On the other hand, forward-looking correlations drop rapidly through July,

suggesting that grove managers should emphasize the period from bloom through July in using the fertilizer, water, and other resources available to them.

The diameter and delta diameter data presented show that the aerial environment stressed the fruit more than soil water deficits. The potential evapotranspiration calculated from temperature and insolation reduces these two variables to one. Superposition of the PET curve (Fig.4) on the diameter and delta diameter curves (Figures 1, 2 and3) results in a good correspondence between them. However, the saturation deficit of the air is a very important factor in plant and fruit water relations (7) and accounts for the strong effects of relative humidity on diurnal fruit size 5,8). The mild saturation deficit in South Texas, compared with Arizona and California, permits the fruit to enlarge under rather dry soil conditions. In this study, treatment C (40% plant available water depletion in the surface 3 ft. of soil at irrigation) received 6 irrigations in all cultivars during the period May through November whereas treatment A (80% depletion) trees were not irrigated in any of the cultivars. Irrigations did help maintain enlargement through stressful aerial environmental conditions, but over the duration of the season the fruit attained the same size whether irrigated or not.

Bain (1) has identified 3 growth stages of 'Valencia' orange in Australia: Stage 1, the initial 4 weeks after bloom when the major portion of cell division occurs and enlargement is slow; Stage 2, from the 5th to 34th week after bloom during which cell enlargement is rapid and the fruit enlargement rate is nearly uniform; and, Stage 3, the maturation phase that extends to 59 weeks. Since the growth period in Australia and here appear to be about the same length, we may suppose that similar growth stages occur in the Lower Rio Grande Valley of Texas. If so, since the recorded date of full bloom for the 'Valencias' of this study was March 15, Stage 1 had ended before the measurements were begun, and the number of cells in the fruit had been determined.

Thus, if potential fruit size is determined more by number of cells per fruit than by the size the individual cells achieve at fruit maturity, then the main effect of temporary aerial environmental stress on fruit size in Stages 2 and 3 is temporary interruption of cell enlargement. Relief of the stressful environmental condition results in resumption of cell sizing and consequently of fruit enlargement. Thus the changes in fruit diameter shown in Figs. 1, 2 and 3 respond to aerial environmental conditions. On a day-to-day time scale, the fruit is enlarging erratically depending on dehydration and rehydration and growth. Kaufman and co-workers (2,7) provide considerable insight about tree and fruit water relations of citrus in response to the aerial environment.

Assuming comparability between the Lower Rio Grande Valley and Australian (1) growing seasons, the 34th week after bloom would be about November 10 for the March 15 bloom date observed for 'Valencia.' By mid-November or the beginning of December the fruit diameter of the 'Valencia' oranges changed very slowly, and P/E ratio had stabilized near the value it would be at harvest. In spite of this apparent agreement with Bain's growth stages, it remains that fruit size at harvest was largely determined by August 1. Our data do suggest the possibility of identifying growth stages in terms of the P/E ratios.

The methodology of studying fruit size that both we and Fucik and Norwine (4) used misses the most crucial part of the growing season for determining fruit size at harvest. (Measurements should begin right after petal fall even though many of the

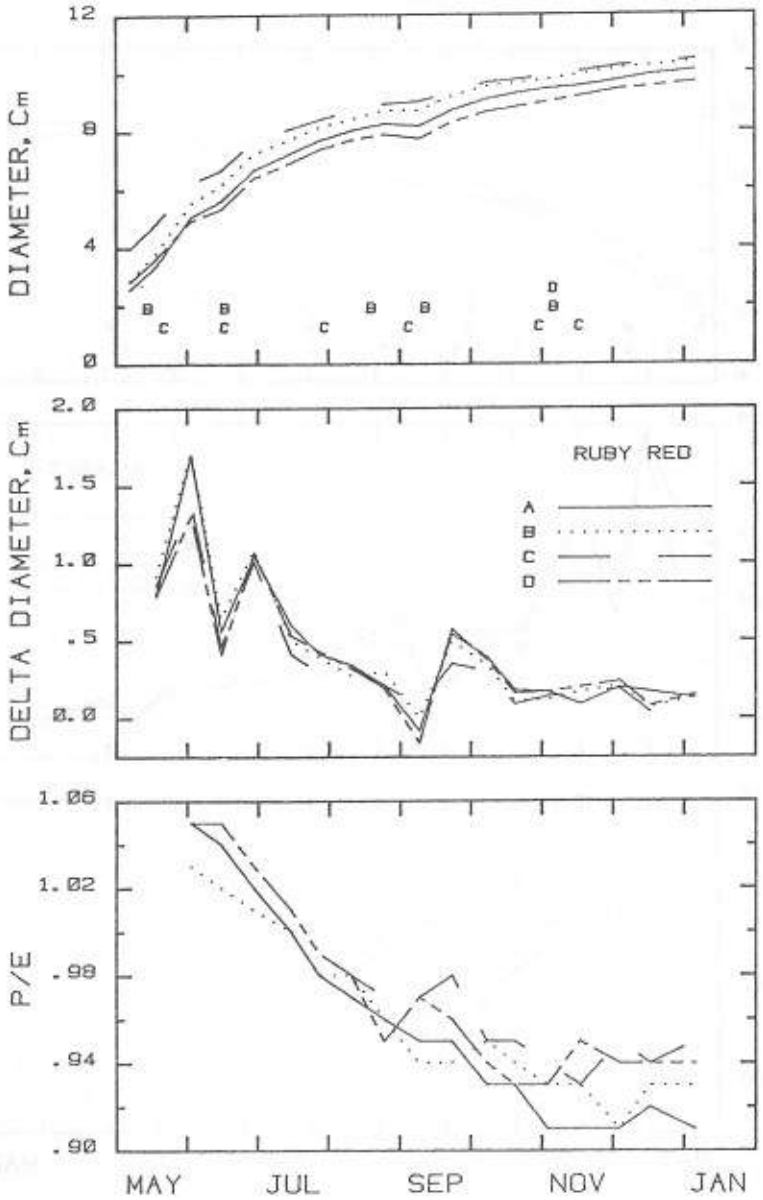

Fig. 1. Diameter of 'Ruby Red' grapefruit, change in diameter of the fruit during successive biweekly intervals (delta diameter), and polar/equatorial axes ratio (P/E) versus time from date of tagging if the fruit 'til harvest. Letters A, B, C and D designate the irrigation treatments in the legend, and identify the dates of irrigation by treatment in the upper part of the figure. See text for irrigation treatments.

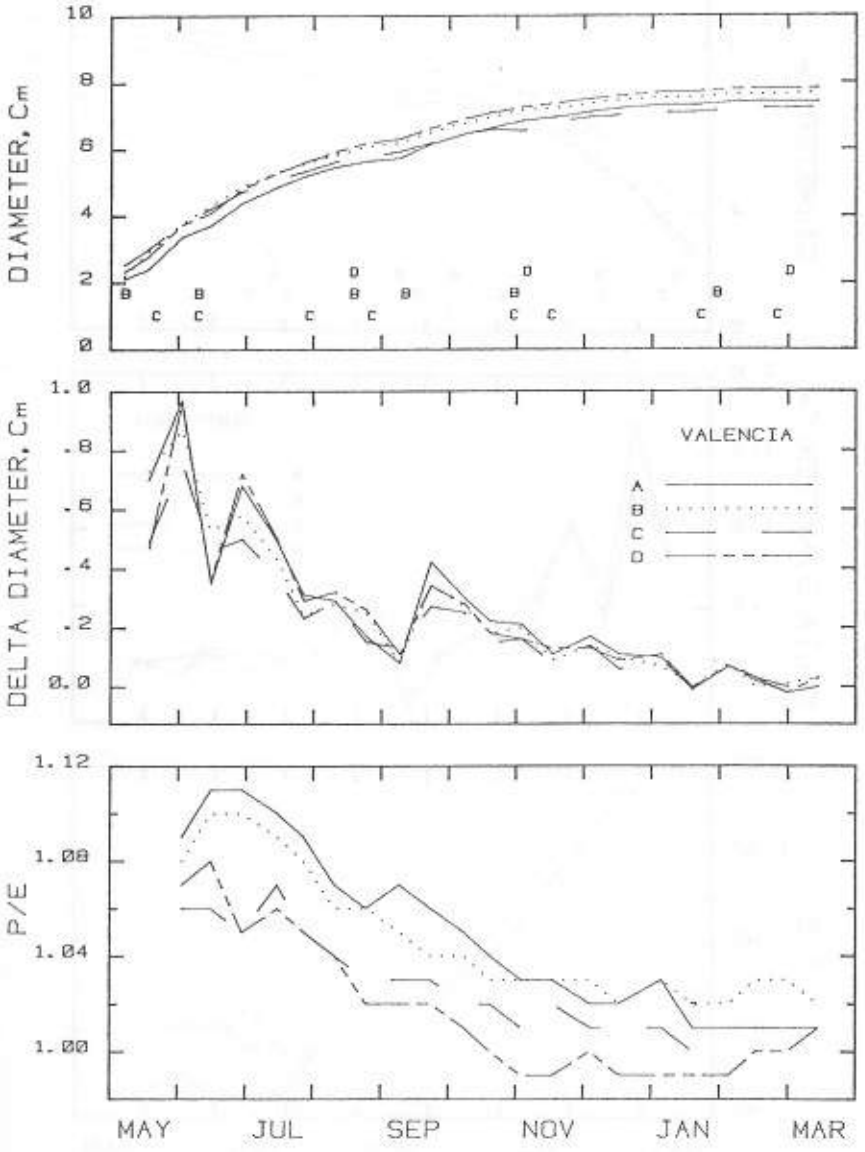

Fig. 2. Diameter of 'Valencia' oranges, change in diameter of the fruit during successive biweekly intervals (delta diameter), and polar/equatorial axes ratio (P/E) versus time from date of tagging of the fruit 'til harvest. Irrigation designations as in Fig. 1.

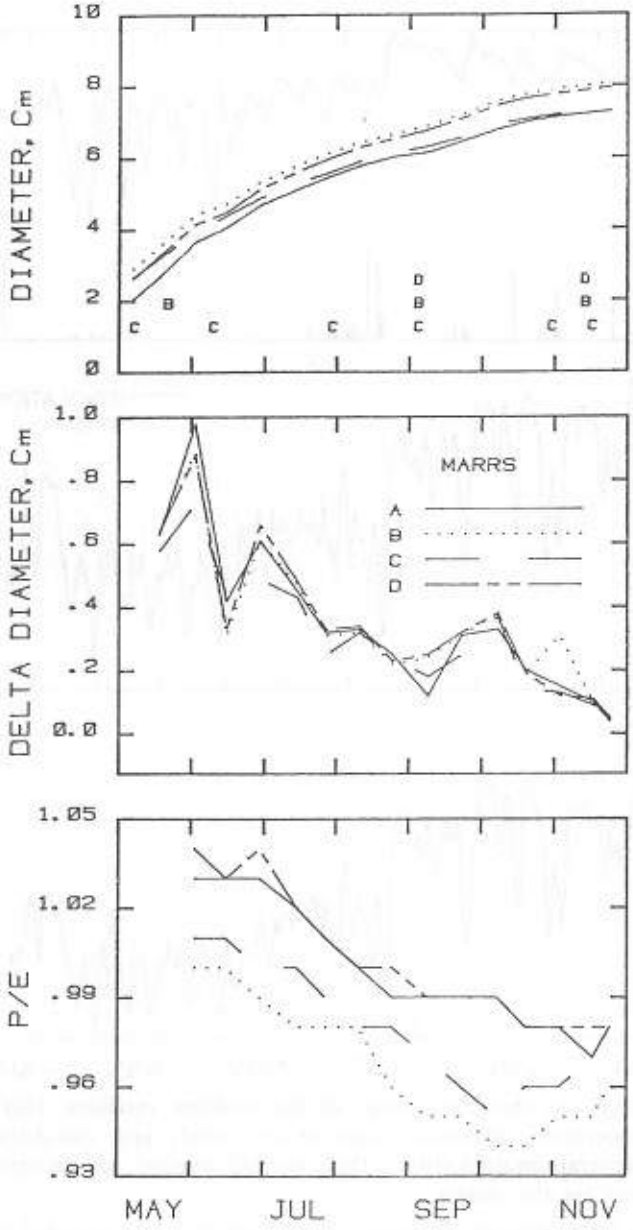

Fig. 3. Diameter of 'Marrs' oranges, change in diameter of the fruit during successive biweekly intervals (delta diameter), and polar/equatorial axes ratio (P/E) versus time from date of tagging of the fruit 'til harvest. Irrigation designations as in Fig. 1.

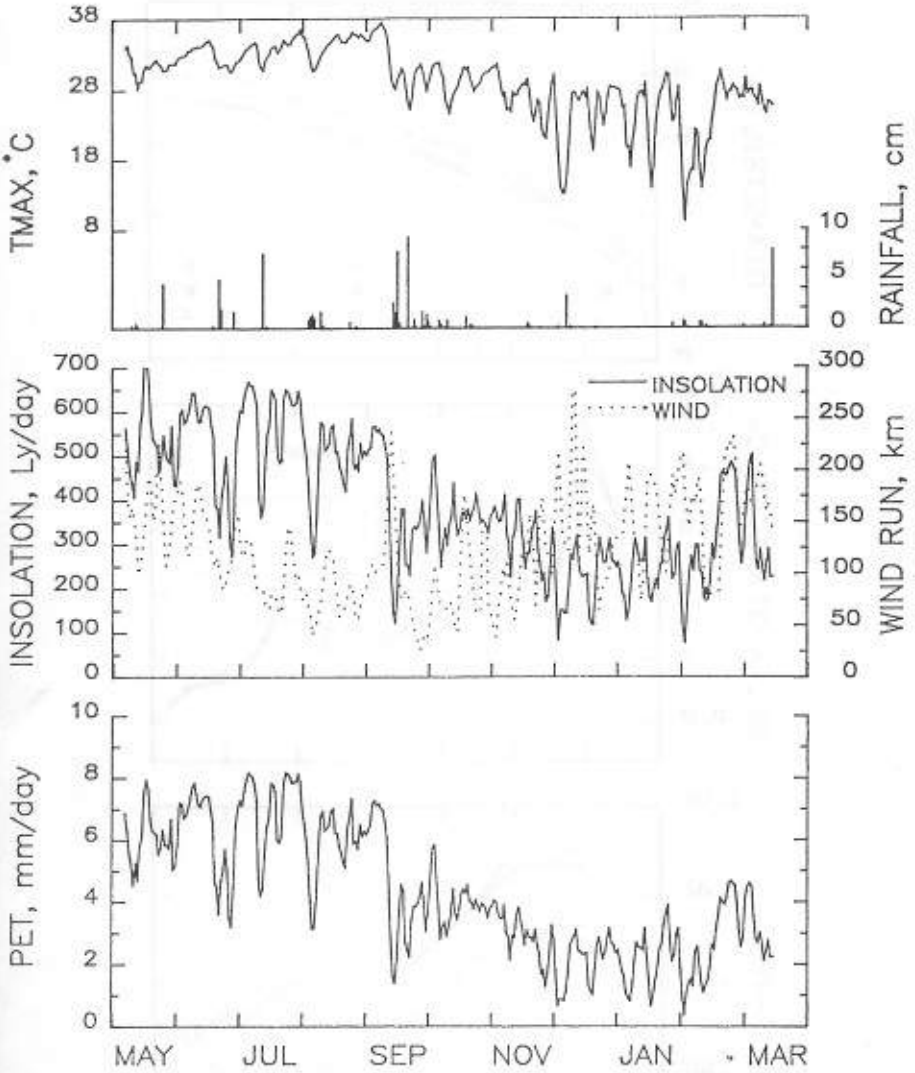

Fig. 4. Three day moving average of the weather variables daily maximum temperature, insolation, run of the wind, and calculated potential evapotranspiration (PET). Daily rainfall amounts on the dates of occurrence are also shown.

fruit would later abscise). However, Fucik and Norwine included the weather variables for the prebloom and fruit set period, January through April, in their multiple regression analyses and these accounted for practically all the variation in final fruit size. Evidently, then, number of cells formed per fruit depends in some way on temperature and insolation during the prebloom and early set periods of the crop season, and cell size within a cultivar at maturity is relatively constant from year to year. It remains to explain how and why environmental conditions prior to bloom and soon after bloom determine the number of cells per fruit.

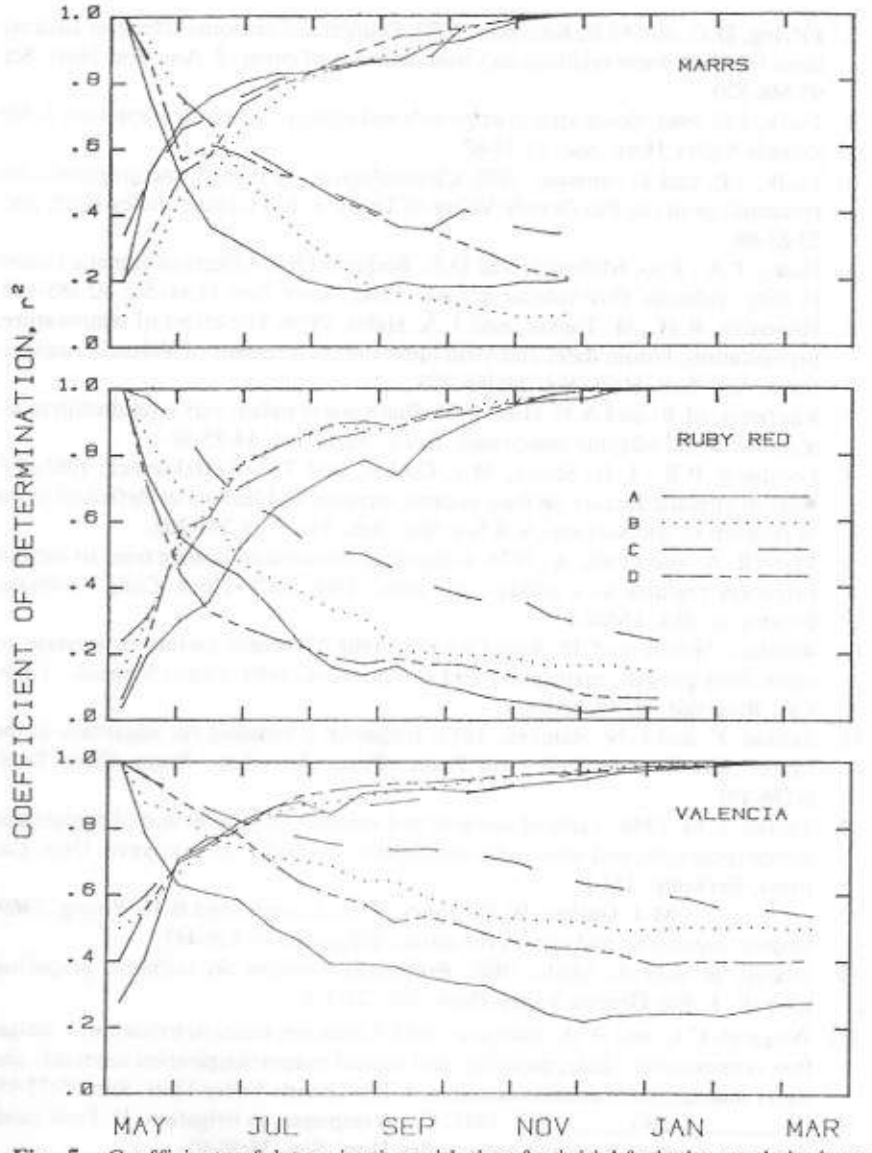

Fig. 5. Coefficients of determination with time for initial fruit size vs. their size on every observation date (forward-looking correlations), and for their final size vs. their size on every observation date (backward-looking correlations) for each irrigation treatment of each cultivar.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Comparison of Numbers of *Tylenchulus semipenetrans* Cobb on Six Citrus Rootstocks in South Texas

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ABSTRACT

Numbers of the citrus nematode extracted by Baermann funnel from the soil around grapefruit trees on Troyer citrange, Morton citrange, of Sunki mandarin rootstocks were significantly lower than the numbers of nematodes in soil around trees on sour orange, Cleopatra mandarin or Columbia sweet lime rootstocks. The fewest numbers of female nematodes embedded in feeder roots were found on Morton citrange roots and the highest numbers were on Cleopatra mandarin roots. No differences were found among sour orange, Troyer citrange, or Sunki mandarin rootstocks.

The citrus nematode, *Tylenchulus semipenetrans* (Cobb), decreases fruit yield in South Texas citrus, resulting in significant monetary losses to the industry (10). Sour orange rootstock, which is highly susceptible to the citrus nematode, is used almost exclusively in Texas. Reducing yield loss to the citrus nematode by using resistant rootstocks has not been investigated in South Texas.

Since much of the soil in the lower Rio Grande Valley is fine-textured and calcareous, many rootstocks are not adaptable (9). However, in certain soils rootstocks other than sour orange have been tried in experiments with favorable results (13,14). This study compares numbers of nematodes associated with 'Star Ruby' grapefruit (*Citrus paradisi* Macf.) trees on six different rootstocks. The test trees are located at the Texas A & I University Citrus Center in Weslaco. The early performance of the block with respect to certain cultural characteristics other than numbers of nematodes associated with the trees has been reported (9).

MATERIALS AND METHODS

Six of the original nine rootstock varieties planted in the block were included in this study: sour orange (*C. aurantium* L.), Cleopatra and Sunki mandarin (*C. reticulata* Blanco), Columbia sweet lime (*C. limettioides* Tan.), and Troyer and Morton citrange [*Poncirus trifoliata* (L.) Raf. x *C. sinensis* (L.) Osb.]. Trees on each rootstock were planted in 4-tree plots replicated 4 times in a randomized complete block design. The trees were planted in 1974 at a spacing of 7.6 x 7.6 m. Soil at the orchard site varied from Hidalgo sandy clay to clay, with a pH of 7.4. Other details on soil characteristics and cultural practices were previously published (9).

Table 1. Numbers of the citrus nematode in soil associated with six different rootstocks[z].

	No. of nematodes (in 1000's)/100cm^3 soil	
Rootstock	First sampling date	Second sampling date
Sour orange	6.8 b	8.5 b
Columbia sweet lime	6.5 b	13.4 c
Cleopatra mandarin	8.8 b	8.3 b
Troyer citrange	3.1 a	4.5 a
Morton citrange	3.7 a	2.2a
Sunki mandarin	3.3 a	4.7 a

[z] Mean separation by Duncan's multiple range test, 1% level.

Table 2. Numbers of female citrus nematodes on the feeder roots of six different rootstocks[z].

	No. of nematodes/1cm of root	
Rootstock	First sampling date	Second sampling date
Sour orange	1.8 b	2.6 b
Columbia sweet lime	2.6 b	4.2 c
Cleopatra mandarin	3.9 c	5.3 d
Troyer citrange	2.6 b	1.7 ab
Morton citrange	0.5 a	1.3 a
Sunki mandarin	1.5 ab	2.1 b

[z] Mean separation by Duncan's multiple range test, 1% level.

Numbers of citrus nematodes were determined in soil samples collected from each rootstock and on feeder roots cut from the trees. To estimate the population in the soil, four samples (each consisting of four cores) were collected from each 4-tree plot of each rootstock. Each soil core was collected near the drip irrigation emitter of each tree at a depth of about 15 cm. The four cores were homogenized and a 50 cc sample was placed on tissue paper in a Baermann funnel. After a 24 hr incubation period in the dark, a 15 ml aliquot was drawn. The citrus nematodes were then counted in each of three 0.5 ml samples, averaged, and expressed as the number of

citrus nematodes in 100 cc of soil. To determine extraction efficiency, a known population of the citrus nematode was equally distributed into 50 cc of sterile field soil (in triplicate) and extracted with methods described above. The efficiency of recovering a known population in the soil with this technique was 26%.

Another estimation of the numbers of the citrus nematode associated with the various rootstocks was made by counting mature females embedded in feeder roots. Roots were sieved from soil samples collected as described above, gently washed in water, and placed in water in an ultrasonic cleaner for 15 min to further remove soil and debris from the roots. The roots were then stained in acid fuchsin/lactophenol and cleared in lactophenol for observation (7). The mature females (swollen due to the development of reproductive organs) were counted under a dissecting scope on ten 1 cm long root tips from each sample.

Soil samples were collected on July 21, Aug. 22, and Sept. 14 during 1983 (results from two dates are presented) and root samples were collected on the latter two dates.

RESULTS AND DISCUSSION

Numbers of citrus nematodes in the soil around Troyer citrange, Morton citrange and Sunki mandarin were consistently lower than numbers around sour orange, Cleopatra mandarin, and Columbia sweet lime (Table 1). Significant differences among rootstocks on the third sampling date (data not shown) were identical to those on the first sampling date. On the second sampling date, the number of nematodes from soil associated with Columbia sweet lime rootstock was at least 57% greater than the numbers in soil around other rootstocks (Table 1).

The number of female citrus nematodes on Cleopatra mandarin root segments was significantly greater on both sampling dates than the number of nematodes on any other rootstock (Table 2). On one sampling date numbers of nematodes on Columbia sweet lime were greater than those on all rootstocks other than Cleopatra mandarin. The number of nematodes on Morton citrange roots was lower than those on sour orange, but the difference between the number on sour orange and Troyer citrange or Sunki mandarin was not significant.

It is estimated that annual losses to the citrus nematode in Texas amount to over 13 million dollars, presuming no treatment (10). A nematode resistant rootstock could obviously result in substantial savings to the Texas citrus industry. Of the commonly used citrus rootstocks, *P. trifoliata* and many of its hybrids possess resistance to the citrus nematode (2,3,4,6,8). This is in agreement with the results of the soil populations in this test, which indicated reduced numbers of nematodes in soil around roots of Troyer and Morton citrange. However, numbers of female nematodes in feeder roots on Troyer citrange were not lower than those on sour orange, which suggest impaired reproduction or development of immature nematodes rather than a defensive response of the root. Sunki mandarin may also have more resistance to the citrus nematode than sour orange since soil populations were consistently low around Sunki mandarin compared to sour orange. These are preliminary observations and only indirect indications of the susceptibility of certain rootstocks to the citrus nematode. Tolerance to damage caused by the citrus nematode depends on tree vigor, root growth dynamics, and other factors (5,11,12). Furthermore, many biotypes of the citrus nematode have been identified (1,8) and biotypes may develop that can infect previously resistant varieties. Further studies

are needed to determine whether any rootstocks in South Texas are sufficiently resistant to the citrus nematode for an economic advantage.

ACKNOWLEDGEMENT

I thank Howard S. Wilhite for technical assistance.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Coffee Bean Weevil, *Araecerus fasciculatus* (DeGeer),[1] Found on Texas Grapefruit

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ABSTRACT

The coffee bean weevil (CBW), *Araecerus fasciculatus* (DeGeer), has been found attacking on-tree 'Star Ruby' and 'Ruby Red' grapefruit in the Lower Rio Grande Valley (LRGV) of Texas. During a late summer 1982 pest survey, coffee bean weevils were identified in seventeen bearing grapefruit orchards throughout the LRGV. Infestation levels varied from 1 to 5 weevil-infested fruit per 1000. Coffee bean weevil larvae fed and developed in the albedo at the calyx end of the fruit and caused gumming, premature coloring and fruit abscision.

The most recent pest to invade citrus in the Lower Rio Grande Valley (LRGV) is the coffee bean weevil (CBW), *Araecerus fasciculatus* (DeGeer). First identified attacking grapefruit in an orchard just west of McAllen in August 1982, the CBW was subsequently found in other grapefruit orchards in western, mid and eastern LRGV locations. CBW is also a relatively new pest of citrus in Florida (2,6,7,10) which together with the LRGV, are the only two areas in the world where CBW is currently a citrus pest. CBW is principally a pest of stored products (3,10). In Florida, 'Hamlin' orange is the citrus cultivar most commonly attacked, but CBW have been recovered from 17 other cultivars including grapefruit (3,5,7). CBW is currently not a primary citrus pest in Florida.

Since CBW is unfamiliar to Texas citrus growers, this communication provides information on: CBW identification, life cycle, type of injury, cultivars affected, and distribution of LRGV citrus orchards in which CBW were found during 1982.

COFFEE BEAN WEEVIL IDENTIFICATION. Adult CBW are dull to dark brown and mottled with dense yellow and brown pubescence (Fig. 1 A). They are ovate and convex in shape and ca. 2-5 mm (0.1-0.2 inch) long. The head has a short broad beak (rostrum) and a pair of prominent antennae, each with a distinct apical 3-segmented club. The hardened outer wings (elytra) have 10 longitudinal rows of finely impressed punctures (1,8,9,10). The immature CBW is a curved, creamy white, legless grub with a distinct brownish-yellow head (Fig. 1 B). The body bears numerous setae and the dorsal folds of the abdominal segments have short, parallel longitudinal wrinkles (8,9,10).

[1]Coleoptera, Anthribidae.

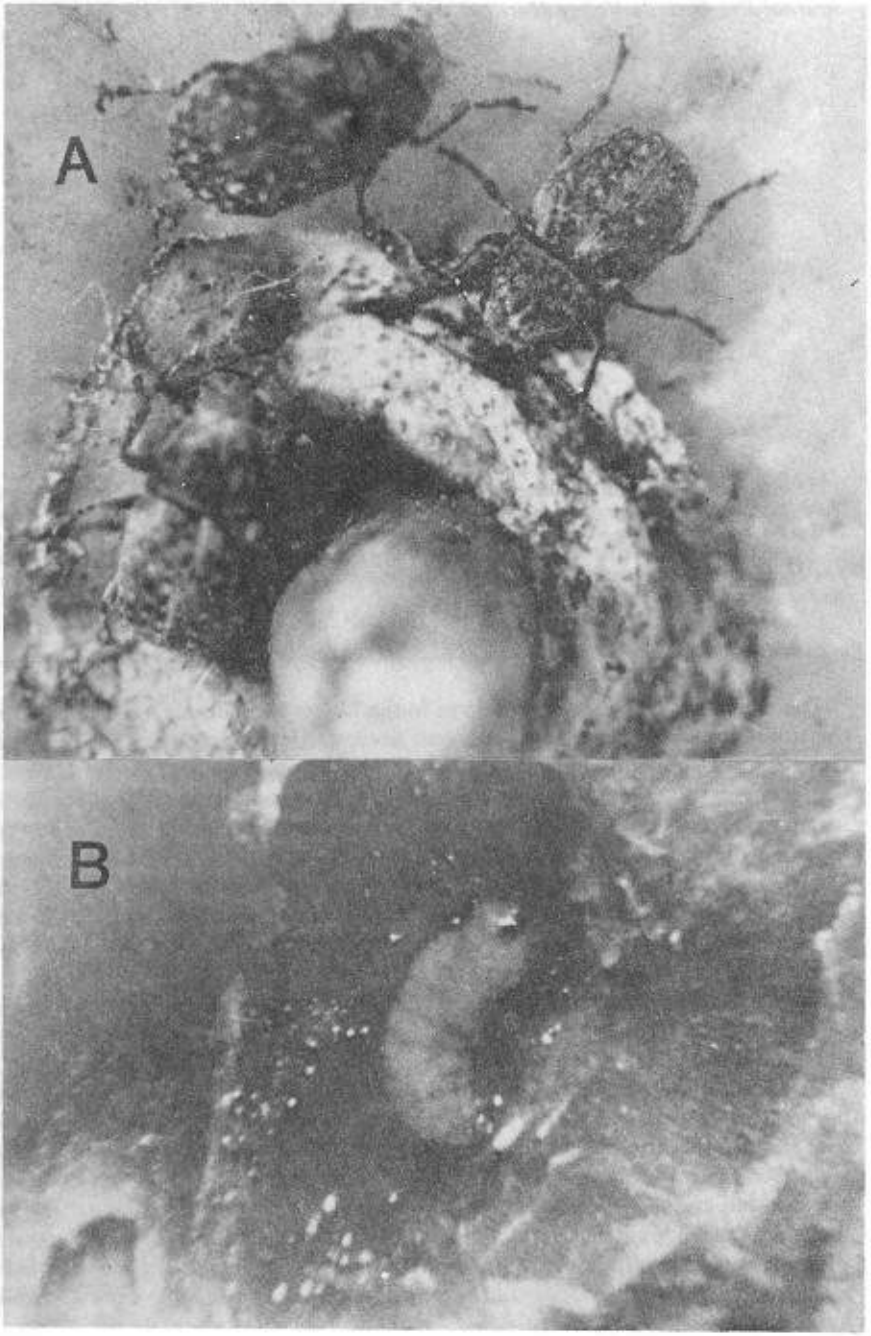

Fig. 1 A) Adult coffee bean weevils adjacent to fruit button, 10X.
B) Coffee bean weevil larva tunneling in grapefruit albedo, 18X.

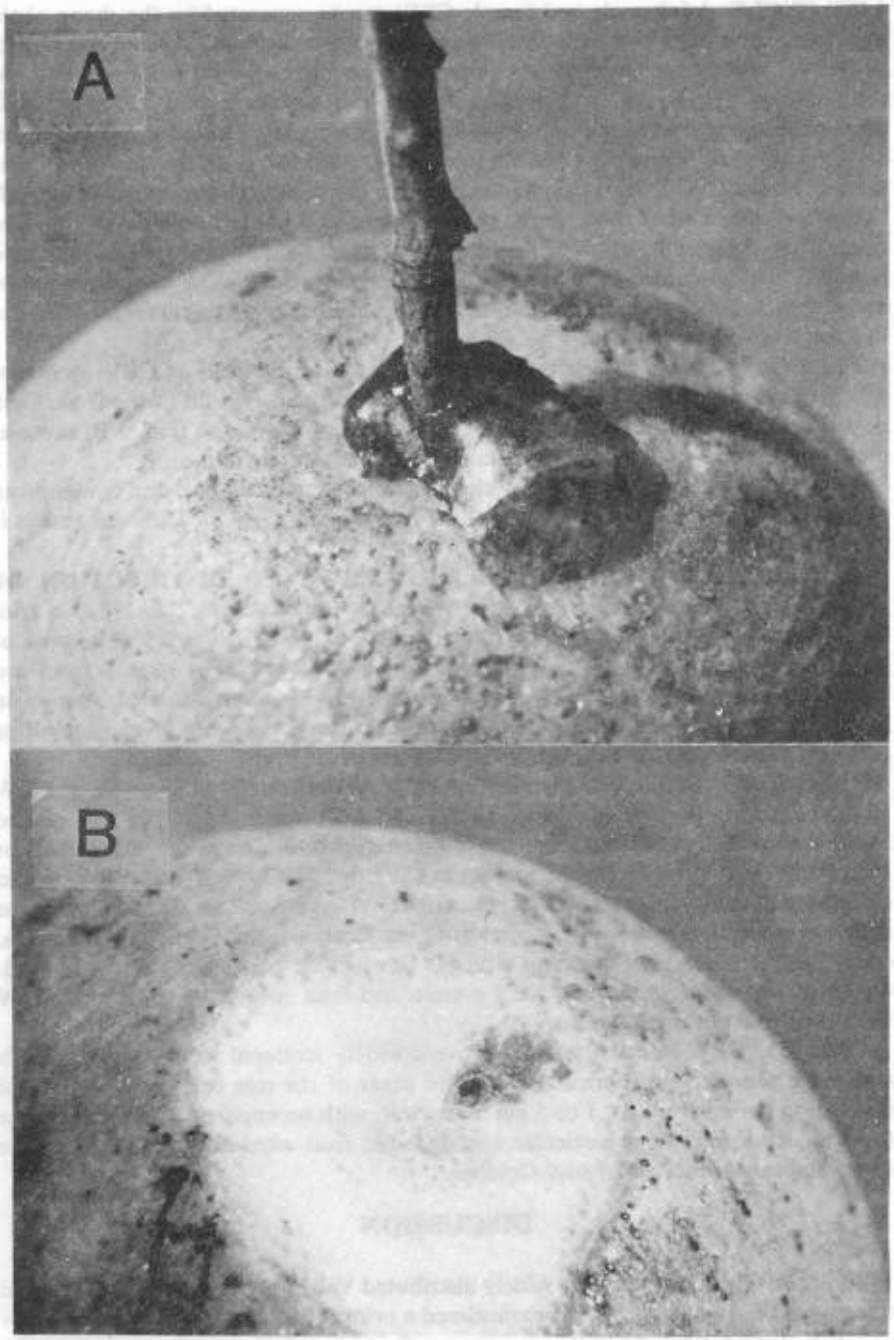

Fig. 2 A) Gum deposit on grapefruit resulting from attack by coffee bean weevil.
B) Coffee bean weevil larval feeding injury and resulting necrosis in grapefruit albedo.

LIFE CYCLE. Adult male and female CBW can be separated by the shape of the abdomen: the male's is broadly rounded, the female's distinctly tapered or pointed. A female, newly emerged from the pupa, requires about 6 days before mating and initiation of egg laying. A fertilized female can deposit up to 125 eggs, with maximum laying during the first 2 weeks after mating (6). On citrus the female inserts the eggs just beneath the peel, in the albedo. The larva feed, develop and pupate within the fruit, with emerging adults chewing exit holes. Duration of various life stages are: egg, 3 to 15 days; grub, 18 to 66 days; and pupa, 5 to 8 days (3,6). The time required for completion of the life cycle is dependent on host, temperature and humidity. Under controlled laboratory conditions (86 °F and 90% humidity) and on an acceptable host, a generation can be completed in 28 to 35 days and an adult can live for 10 to 12 weeks (6).

TYPE OF INJURY. Injury to grapefruit in Texas is principally by CBW larva tunneling in the albedo and underlying juice vesicles at the calyx end of the fruit. Gum deposits around the button (Fig. 2 A) and necrosis of the tissues (Fig. 2 B) occur as the larva develop. Affected fruit usually color prematurely and drop.

Adult weevils also cause injury by chewing holes in the fruit peel and tender green twigs. Gumming is usually evident at these feeding sites (Fig. 3). Die-back results if twigs are girdled.

CITRUS CULTIVARS ATTACKED BY CBW AND DISTRIBUTION OF INFESTED ORCHARDS. CBW larva were first found August 23, 1982, in fruit from a 9-yr-old 'Ruby Red' grapefruit orchard on Taylor Road 2.5 miles west of McAllen. Additional CBW finds were confirmed a few days later in fruit from two grapefruit orchards (19 and 25-yr-old, respectively) 3 miles north of Alamo on Minnesota Road. Prematurely colored fruit scattered on trees in each of these orchards was the first indication of CBW attack.

Removal and microscopic examination of fruit confirmed the presence of CBW larva. Following the initial finds, a survey of LRGV orchards during August and September revealed 14 additional CBW infestation sites. All were 'Ruby Red' or 'Star Ruby' grapefruit orchards, varying in age from 4 to 30 years and distributed in eastern, mid and western LRGV (Fig. 4). CBW were not found attacking citrus cultivars other than grapefruit. A total of 47 randomly selected bearing orchards (ca. equal numbers of grapefruit and orange) throughout the Valley were surveyed. Orchards were transversed in a "Z" pattern and fruit suspect of containing CBW were confirmed in the laboratory.

Generally, CBW-infested grapefruit were widely scattered in affected orchards and more prevalent in shaded and interior areas of the tree canopy. The level of infestation varied from ca. 1 to 5 per 1000 fruit, with no apparent CBW preference for fruit from trees of a particular age. Infested fruit were easily pulled from the stem, and most abscised by mid October.

DISCUSSION

While the CBW was found in widely distributed Valley citrus orchards and caused some drop of grapefruit, it is not considered a primary citrus pest. Infestation levels of CBW during 1982 did not warrant specific sprays for control, or addition of chemicals to existing pest management programs. Moreover, certain chemicals currently labelled and used for control of other citrus pest species have shown efficacy

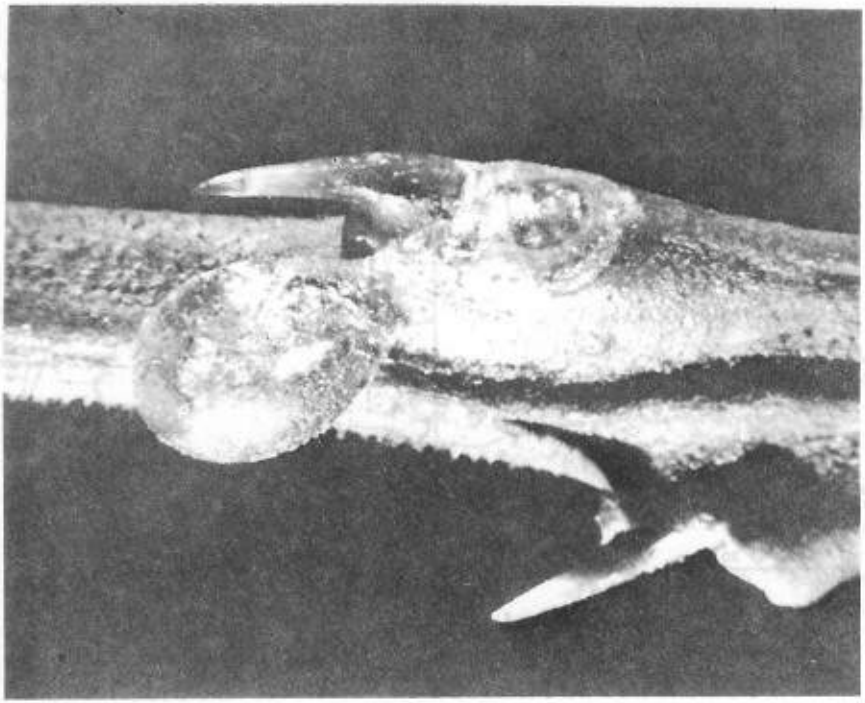

Fig. 3 Adult coffee bean weevil feeding injury to green twig.

against CBW. Results of screening trials in Florida (4) showed that included among the more promising insecticides were: azinphosmethyl (Guthion); phosmet (Imidan); oxamyl (Vydate); and methidathion (Supracide).

CBW were undoubtedly present in Valley citrus orchards for sometime prior to detection, probably developing in decaying and dried fruit on the ground. In Florida, dropped and dried 'mummified' oranges, as well as fruit of the non-citrus host, chinaberry, *Melia azedarach* L., serve as oviposition and developmental sites for CBW (3,7). We successfully reared high numbers of CBW from chinaberry fruit collected on and beneath trees near Progresso and Weslaco, Texas in the spring of 1983. Thus, chinaberry growing in or near citrus orchards is also a likely source of CBW in Texas.

More intensive monitoring of LRGV orange and grapefruit orchards for CBW, as well as a search for other potential alternative CBW hosts, will be conducted throughout 1983. Since CBW has numerous citrus and non-citrus hosts in Florida, expansion of the host range is also likely in Texas. Studies on CBW biology are also underway.

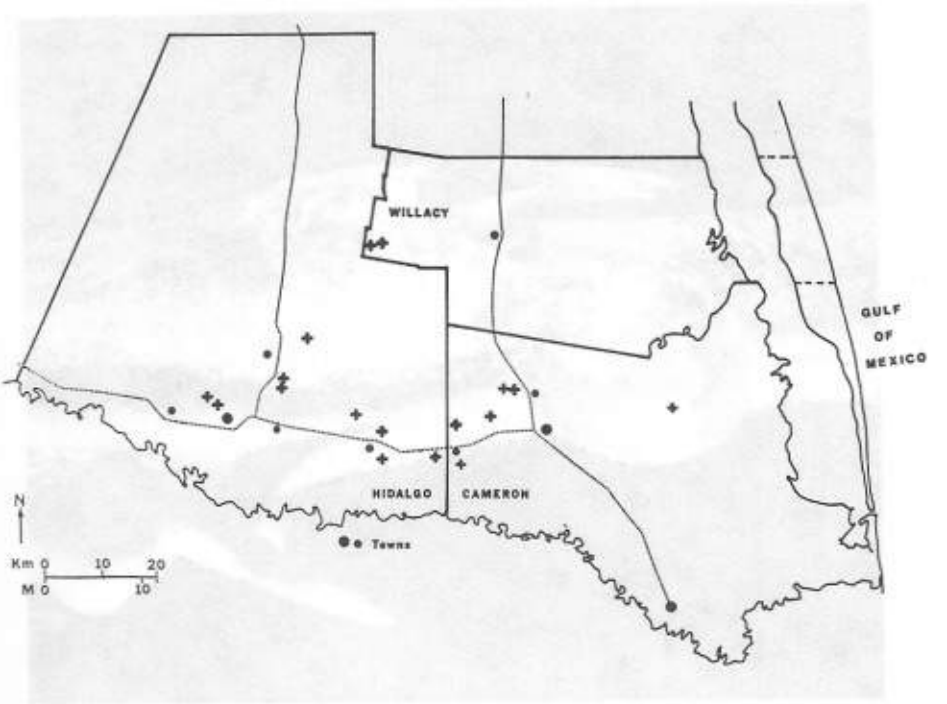

Fig. 4 + represent orchard locations where coffee bean weevil infested fruit have been identified. Circles are valley towns from east to west: Brownsville, Harlingen, Combes, Raymondville, La Feria, Weslaco, San Juan, Edinburg, McAllen and Mission.

ACKNOWLEDGEMENTS

The authors wish to thank Drs. Donald M. Anderson and Richard E. White of the USDA-ARS Systematic Entomology Laboratory, Beltsville, Maryland for identification of coffee bean weevil larva. We would also like to thank Mr. Edward V. Gage, entomologist, FMC Corp. San Antonio, Texas for taking some of the photographs used in this paper.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Evaluation of Two Commercially Available Biostimulants on Citrus

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ABSTRACT

The biostimulants Agrispon[R] and Ergostim[R] did not significantly reduce the time for germination of sour orange seeds or enhance the growth and development of seedlings following germination. Development of the seedling top or roots was not significantly influenced by the products. In a field experiment, total yield, fruit size, percentage juice in fruit, Brix, acid and Brix-acid ratio were also not influenced by the biostimulants.

Several organic compounds are now being marketed as biostimulants to increase the rate of seed germination and plant growth, to improve fruit setting, and increase yields on cereal, vegetable and fruit crops. Two products, Agrispon[R] [1/] and Ergostim[R] [2/], are used as soil supplements and/or foliar nutrient solutions. Agrispon is a mixture of organic and inorganic compounds including cytokinin, gibberellin and trace elements (Technical Data, SN Corp). Ergostim is a biostimulant growth regulator and nutrient solution (Technical Data, Montedison USA) of the amino acid L-cysteine and the vitamin folic acid (1).

A two-part research study was initiated in the spring of 1982 involving a nursery seedling experiment and a field orchard experiment. The nursery experiment was designed to determine the effect of the biostimulants on the growth and development of citrus seedling roots and top. The field experiment was designed to determine the effect of the biostimulants on fruit yield, fruit size and juice quality of producing grapefruit trees.

1/ Organic proprietary soil supplement and seed treatment manufactured by SN Corp and SnWn Associates, 3601 Garden Brook, Dallas, Texas USA 75234.

2/ A product of Montedison S.P.A. Milam, Italy, marketed by Montedison USA, Inc., 1114 Avenue of the Americas, New York, N.Y. 10036.

Mention of a trademark or a proprietary product does not constitute a guarantee or a warranty of the product by The Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that also may be suitable.

MATERIALS AND METHODS

In the nursery experiment, seed of sour orange (*Citrus aurantium* L.), the standard Texas rootstock, were treated with Agrispon and Ergostim by mist, dip, soak and/or media leaching and/or foliage mist following germiantion. Treatments were as follows for Agrispon:

1. Seed misted @ 1:10 recommended dilution
2. Seed dipped 5 minutes @ 1:10 recommended dilution
3. Seed soaked 3 hrs @ recommended dilution
4. Seed planted and medium leached @ 1:100 dilution
5. Seed misted @ 1:10 and medium leached @ 1:100 dilution
6. Seed misted @ 1:10 and medium leached @ 1:100 dilution plus foliage mist
7. Seed rinsed with distilled water plus foliage mist

Treatments for Ergostim were as follows:

8. Seed misted @ 5%, formulated product, spreader + pH adjusted to between 3 and 5 with H_3PO_4
9. Seed dipped 5 minutes @ 5%, formulated product, spreader + pH adjusted to between 3 and 5 with H_3PO_4
10. Seed soaked 3 hrs @ 5%, formulated product, spreader + pH adjusted to between 3 and 5 with H_3PO_4
11. Control seed rinsed with distilled water + spreader and pH adjusted with H_3PO_4.

All treatments included the non-petroleum wetting agent Tween 20. Foliage mist treatments at 1:100 dilution were applied at 50, 78 and 106 days after planting.

Seedlings were grown in containers (growing tubes) containing a potting mixture of peat, perlite, vermiculite and composted pine bark. A water soluble complete nutrient solution (N, P, K plus minors at 300 ppm N) was applied weekly.

A count of seedling germination was recorded at 5-day intervals from 20 through 50 days after planting. No seed germinated before 20 days after planting.

In October 1982, the experiment was terminated. Measurements recorded were shoot length, root system total dry weights and top growth total dry weights.

Experimental design consisted of 12 replications of each treatment. Each replication consisted of 2 seedlings of each treatment. Measurements reflect the mean of the 2 seedlings for each treatment, or the measurement of one seedling if one of the pair died or did not germinate. Statistics were run at the 5% level of significance.

The field study design was 20 replications of 2-tree plots of producing 'Redblush' grapefruit (*Citrus paradisi* Macf.) trees. Statistics were run at the 5% level of significance.

Ergostim was applied to the foliage at the rate of 500 ml/acre. Applications were made during early bloom (March 5, 1982) and again at the end of bloom (March 24, 1982) with a 3rd application April 7, 1982. Agrispon was applied to the foliage and soil with an FMC John Bean 357 speed sprayer at the rate of 5.7 L/10 acres. Lower nozzles were directed at ground. Applications were made during early bloom (March 11, 1982) and again in early summer (June 15, 1982).

Tractor speed was 1.0 mph which allowed the mix to be applied until runoff. Tank mix consisted of water, spreader, phosphoric acid to adjust pH to between 4.0 and 5.0 and biostimulant. Control trees were sprayed with the tank mix minus biostimulant.

Table 1. Effect of biostimulants on percentage of sour orange citrus seed germinated between 20 and 50 days after planting.

	Percentage of seed germinated						
	Days after planting						
Treatments	20	25	30	35	40	45	50
1	0	53[z]	82	88a	94	100	100
2	0	40	60	80a	85	95	100
3	0	60	93	100b	100	100	100
4	0	16	75	83a	83	92	100
5	0	24	71	100b	100	100	100
6	0	42	74	95a	95	95	95
7	0	57	71	93a	93	93	100
8	0	26	68	79a	95	95	95
9	0	35	55	90a	90	100	100
10	0	50	89	89a	94	100	100
Control	0	42	66	75a	83	92	100
		NS	NS		NS	NS	NS

[z]Mean separation within columns by Duncan's Multiple Range Test, p = 0.05.

All fruit was harvested from the test trees in December 1982. Fruit were sized in 3 categories as either undersize, minimum commercial, or standard commercial 96 and larger. Fruit quality was measured as percentage juice, Brix (total soluble solids), acid and Brix-acid ratio.

Soil samples were taken from the first and second foot depth at 4 locations around the dripline of each tree. Extracts from samples were analyzed by standard techniques for nitrogen as nitrate (NO_3), phosphorus, potassium and by atomic absorption spectroscopy for Mg, Mn, Zn and Fe.

Leaf samples of 50 leaves from each tree taken in August and selected randomly around the tree were analyzed for N, P, K, Mg, Mn, Fe, Zn.

RESULTS AND DISCUSSION

In the nursery experiment no significant difference was found between the control and any Ergostim treatments nor most Agrispon treatments for increasing seedling germination over the duration of the experiment (Table 1). An advanced number of seed germinated at 35 days in treatment 3 (seed soaked 3 hrs.) and treatment 5 (seed misted and media leached). Although treatment 3 did not shorten the time for germination, it did allow the seed to germinate over a shorter time span. This treatment may have allowed Agrispon to penetrate the seed where it could be effective. Concerning treatment 5: since treatment 6 was similar to treatment 5 but not significantly

different from the control, and since treatment 5 had one of the lower percentage seed germinated at 25 days, treatment 5 was not considered to be a real significant enhancement to germination.

Table 2. Effect of biostimulants on shoot and root growth of sour orange citrus seedlings.

Treatments	Shoot Lengths (cm)	Total dry weights (g)	
		Shoots	Roots
1	21.7[z]	1.65	0.58
2	21.8	1.61	0.61
3	23.8	1.73	0.65
4	17.7	1.01	0.36
5	22.9	1.63	0.58
6	24.0	1.80	0.67
7	23.4	1.79	0.68
8	21.2	1.52	0.52
9	22.1	1.54	0.60
10	24.0	1.82	0.68
Control	21.9	1.56	0.55

[z]There were no significant differences between treatments according to Multiple zRange Test, p = 0.05.

No difference in shoot length nor shoot or root dry weight was found between any of the treatments and the control at the termination of the experiment. Data showed no significant difference between treatments and control (Table 2).

In the field experiment, these biostimulants at recommended rates showed no significant differences from non-treated controls with respect to total yield, fruit size, percentage juice in fruit, Brix, acid or Brix-acid ratio (Table 3).

No significance was found for any of the nutrients analyzed in the first nor second foot depth when compared to controls (Table 4). Had significance been found in the second foot or even top foot, the meaningfulness should be questioned, and no importance made in reporting the findings. Values for the more readily-leached nutrients such as nitrogen, potassium and for the micro-nutrients manganese, zinc and iron are not meaningful, as correlation between yield responses and levels of the elements in the soil has not been established.

There were no significant differences in leaf analysis between means for treatments and control (Table 5).

In summary, data obtained in these experiments did not show these biostimulants to significantly reduce the time for germination of sour orange citrus seed or to enhance the growth and development of the seedling following germination. In a

field experiment in which young producing orchard trees were treated and data collected for total yield, fruit size, percentage juice in fruit, Brix, acid and Brix-acid ratio, no significant difference was found from non-treated controls.

Table 3. Effect of Agrispon and Ergostim on total yield, fruit size and fruit quality of 'Redblush' grapefruit.

Treatments	Total Yield (kg)	Fruit Size (% of yield) <112	112	≥ 96	Juice %	Brix	Acid	Brix/Acid
Agrispon	154.5[z]	68	12	20	48.2	10.4	1.3	8.0
Ergostim	158.2	62	14	24	48.0	10.0	1.3	8.0
Control	152.8	63	15	22	48.2	10.2	1.6	7.5

[z]There were no significant differences between treatments according to Duncan's Multiple Range Test, p = 0.05.

Table 4. Results of analysis of soil samples from the first and second foot depths.

Treatments	Depth (ft)	Nutrients (ppm) N	P	K	Mg	Mn	Zn	Fe
Agrispon	0-1	8.0[z]	27.7	314	80	9.7	.28	2.7
	1-2	8.9	17.2	309	84	6.8	.14	1.5
Ergostem	0-1	9.3	29.1	306	80	8.3	.27	2.4
	1-2	10.2	20.8	324	84	7.0	.15	1.6
Control	0-1	7.0	27.9	285	84	7.8	.24	2.1
	1-2	7.4	16.2	276	80	5.6	.16	1.5

[z]There were no significant differences between treatments according to Duncan's Multiple Range Test, p = 0.05.

ACKNOWLEDGEMENTS

The author gratefully acknowledges support of this research by grants-in-aid from SN Corp, Dallas, Texas and Atlantic International, Bellevue, Washington.

Table 5. Nutrient analysis of citrus leaf samples.

Treatment	N(%)	P(%)	K(%)	Mg(%)	Mn(ppm)	Fe(ppm)	Zn(ppm)
Agrispon	2.19[z]	0.112	0.93	0.34	35	68.6	17.0
Ergostim	2.20	0.109	0.84	0.37	33	71.1	18.4
Control	2.21	0.111	1.03	0.38	37	68.5	24.3

[z]There were no significant differences between treatments according to Duncan's Multiple Range Test, $p = 0.05$.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Release of Sterile Mexican Fruit Flies for Control of Feral Populations in the Rio Grande Valley of Texas and Mexico[1]

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ABSTRACT

The Mexican fruit fly, *Anastrepha ludens*, Loew, has been detected in the Rio Grande Valley citrus producing area annually from the late 1920's until the present. Quarantines and regulatory fumigation with ethylene dibromide have been established to insure that shipment of fruit contaminated by live fruit fly forms will not occur. As an alternate to fruit fumigation, a pilot sterile insect release program with releases throughout the shipping season of sufficient proportions to suppress fly reproduction was initiated. In Texas, from October 3, 1982 thru the week of July 24, 1983, 509 feral Mex-fly adults were trapped in the sterile fly release zones while 1,090 feral flies were trapped in the non release zones.

The Mexican fruit fly, *Anastrepha ludens*, Loew, has been detected in the Rio Grande Valley citrus producing area annually from the late 1920's until the present. Fruit fly trapping records from 1971 to the present indicate that flies begin appearing in South Texas groves in November and December and reach peak populations in late April or early May. Adult flies may persist until harvest is completed (usually by June 15). Populations decrease to low or undetectable levels in the summer months apparently due to the lack of suitable oviposition sites and/or due to the extended periods of hot, dry weather present during these months.

Quarantines and regulatory fumigation with ethylene dibromide (EDB) have been established to insure that shipment of fruit contaminated by live fruit fly larvae will not occur. Most citrus harvested in Texas and shipped to or through California, Arizona, Florida, Hawaii, southern Louisiana, Puerto Rico and the Virgin Islands must be fumigated. (Movement of citrus fruit is regulated by USDA Quarantine No. 64.) Fruit going to Japan and other East Asian export markets travel through California and therefore, must be fumigated. Because the future of EDB for fumigation of citrus is presently uncertain, and an alternative fumigant is not available, Texas producers could lose those markets. Ultimately, this diverts fruit to local markets depressing fruit prices and limits fruit shipments to states presently quarantined.

[1]Presented at the 37th Annual Institute of the Rio Grande Valley Horticultural Society.

As an alternative to fruit fumigations, a pilot sterile insect release program with releases throughout the shipping season of sufficient proportions to suppress fly reproduction was proposed. The program was implemented in January 1981. Data collected for the 1980-81 citrus producing season were insufficient in quantity for statistical analysis. Data collected for the 1981-82 season did not indicate significant suppression of feral flies in the sterile release zones. Results of the sterile release program for the 1982-83 program thru the week of July 24, 1983 are reported herein.

MATERIALS AND METHODS

Mexican fruit fly to be released are reared and sterilized (as pupae) at the Monterrey, Mexico, USDA Mexican Fruit Fly Re)ring Laboratory. With the present laboratory space available 6.5 to 7 million sterile flies per week can be reared for the releases outlined herein. The sterilized pupae are shipped in cooled, styrofoam containers via air conditioned vehicle to Moore Air Base, Mission, Texas weekly. Here the pupae are gently rolled in a florescent orange dye and placed in the bottoms of number 6 modified paper grocery bags for eclosion. Five thousand pupae are placed in each bag.

Following the bagging of pupae, the opening of the bag is loosely stapled closed in two areas, one staple each, one third of the distance from the edge of the bag to the center. Five of these bags are then positioned within individual sections of a Tanaka Box. This box is used as an eclosion (emergence) unit. Within the eclosion box (2 ft long x 1 ft deep x 14½ inches wide) situated horizontally above the section dividers is a screen "tray". Both food (sugar) and water (agar block) are placed on this tray to provide nourishment for adult flies following eclosion. The tray is attached to the sides of the Tanaka box with polyvinyl chorlide clips to prevent Mexfly escape (Fig 1).

After filling of the Tanaka boxes with pupae is completed the boxes are placed in temperature controlled rooms at 80-85 °F (26.6-29.4 °C) and 60-90% relative humidity. In 2-3 days the major portion of the Mexfly have eclosed in the Tanaka boxes and temperature in the chamber is reduced to 35-42 °F (1.6-5.5 °C) which immobilizes the adults so they can be collected and placed in aerial release machines. The release machines, modified versions of those used in the California Mediterranean Fruit Fly Erradication Program (April 1979-September 1982), are then loaded into an airplane. The flies are dropped free fall equally over the release area of Texas and Mexico.

The release area in Texas for the 1982-83 season consisted of approximately 38,550 acres of commercial citrus divided into 2 zones (Fig 2), an area of 345 square miles. This includes commercial citrus, citrus plantings in urban areas, and hosts located in rural areas close to the Mexican border. Correspondingly, the non-release area, also divided into 2 zones, consists of 31,500 acres of commercial citrus or 785 square miles. The sterile release area in Mexico (adjacent to the border) includes a linear distance of ca. 60 miles. This area encompasses about 120 square miles in a zone from 1 to 8 miles wide. Releases are made over all urban areas and rural areas where any hosts are present. Commercial citrus is limited to a few orchards on both the eastern and western portions of the release area. The present non-release area in Mexico consists of ca. an area equal to that in the release area. However, no commercial citrus is located in this area, and only urban and rural citrus is established.

In Texas, 5,000 McPhail traps (Fig. 3), divided equally between the 4 zones, were set at densities of 5/square mile in commercial and urban or rural citrus. When a square mile had both urban and commercial citrus, the traps were placed in the urban area,

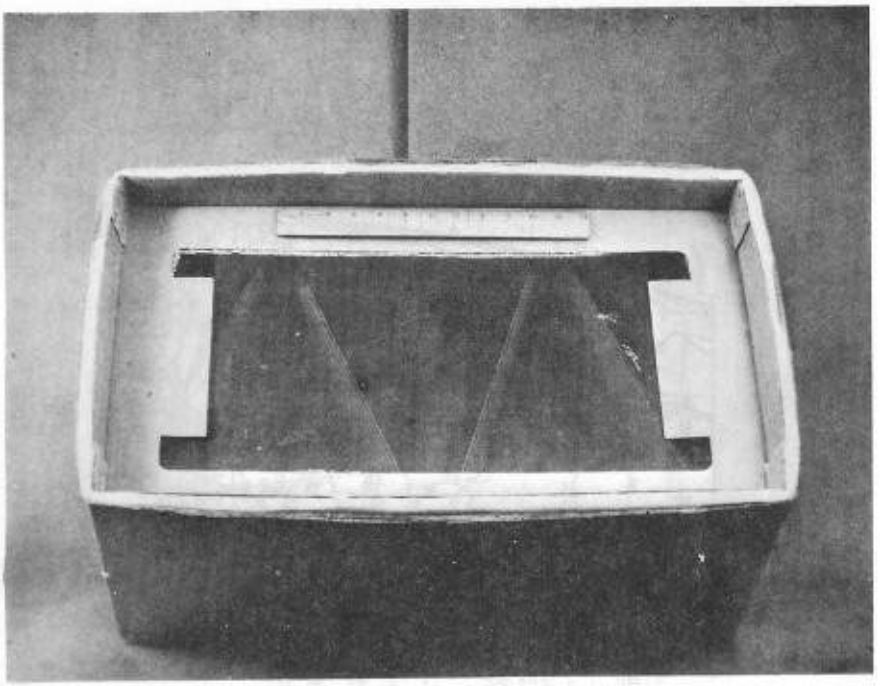

Fig. 1. A Tanaka box used for holding eclosed *Anastrepha ludens*, Loew. Note the paper bags containing pupae prior to eclosion.

unless the survey inspector determined that commercial citrus plantings dominated the square mile. However, traps were increased to a density of 50/square mile within a 1 mile radius of a detection (1 adult male, or non-gravid female), and 20 traps/square mile within a 1½ mile radius of the detection. In Mexico, 487 traps (290 traps in the sterile release zone and 191 traps in the non-release zone) were placed more densely around fruit markets and dumps (up to 4/square mile) than in residential plantings or citrus orchards. Traps were increased in a similar manner as was done in Texas when one or more feral flies were detected.

Fruit fly specimens trapped in Texas are identified as to trap number and square mile block from which they originate. There are 1,000 square mile blocks covering the entire Valley starting with number 1 at the eastern edge of the Valley and ending with number 1,000 at the western edge of the Valley. Fruit fly specimens caught in traps from Mexico are identified as to the location of the fly by using a trap number only.

When a fruit fly specimen is removed from a trap in Texas it is placed in a vial of 70 percent alcohol, with the appropriate trapping data, and taken to the Mexfly facility in Mission, Texas for identification. If the fly has been determined to be *Anastrepha ludens*, it is then observed for the presence of the orange dye in the ptilinum portion of the head capsule by extracting the ptilinum and viewing it under ultra-violet illumination. If dye is present, the fly is considered as sterile. If no dye is present, the male or female gonads must be removed and observed under magnification. If no irradiation damage is evident, the fly is considered to be feral (non-sterile native). If the female fly is feral and eggs are present in the ovaries, the 3 spermatheca are removed and observ-

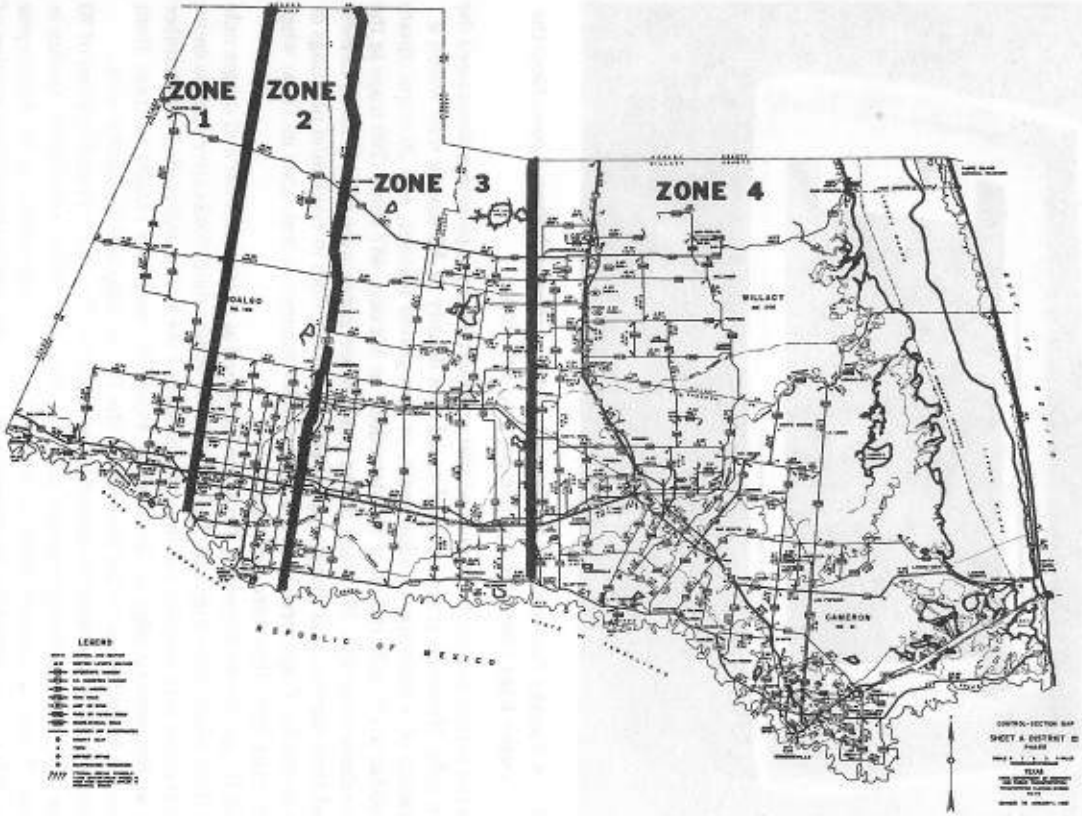

Fig. 2. Map of the Lower Rio Grande Valley citrus producing area. Zone 1 and 2 are sterile release zones, Zones 3 and 4 non-release zones.

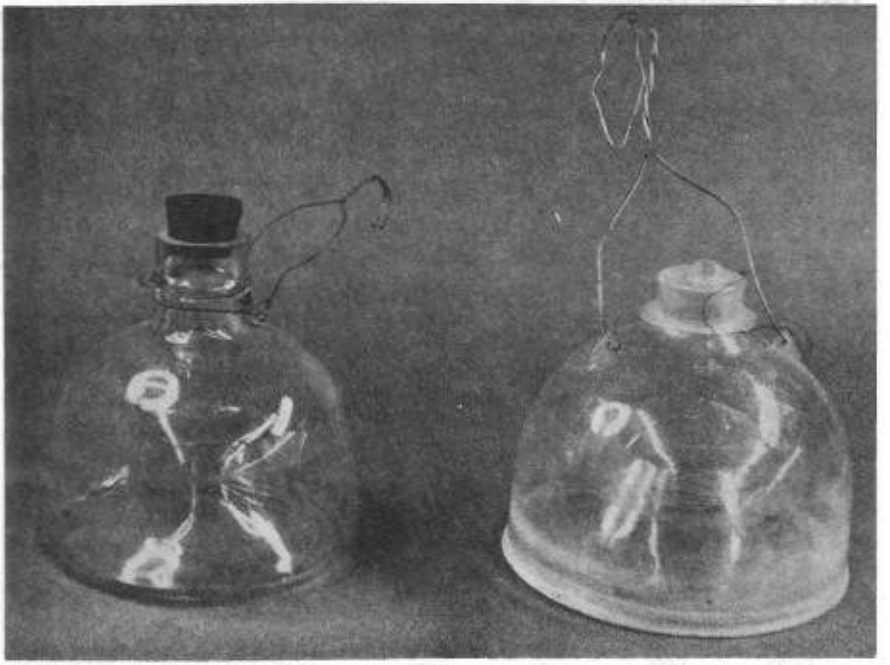

Fig. 3. The standard glass McPhail fruit fly trap (right) and a experimental plastic McPhail trap (left).

ed for the presence of sperm. When sperm is present, the fly is considered gravid. If no sperm is found, the fly is assumed to be non-gravid. At present, a determination cannot be made if sperm found in the spermatheca of a feral female is that of a sterile or native male.

Flies trapped in Mexico must first be directed through the local Mexico Sanidad Vegetal's (PPQ equivalent) research laboratory in Matamoros. After Sanidad Vegetal personnel view the fly for the florescent dye in the ptilinum (without removing the ptilinum) it is taken to Mission for examination using the predescribed techniques.

RESULTS

The results presented herein have not to date been statistically analyzed. Data presented is thru the week of July 24, 1983. The sterile release program for the 1982-83 season was initiated October 3, 1982 and will terminate on September 30, 1983. Due to publication deadlines information for the remaining 10 weeks is not available. The fact that this data is lacking, however, should not influence significantly the results reported herein. Therefore, the only intent here is to present the data as collected and elaborate on why these results may have occurred.

As of this writing, ca. 140,500,000 sterile flies have been field released in Texas and ca. 11,500,000 in Mexico. This averages ca. 3.4 million and 544,000 per week for Texas and Mexico, respectively, (Releases of sterile flies over Mexico is inconsistent due to either availability or difficulty in receiving the necessary permitting for US owned aircraft to fly over Mexico). Of the flies liberated over the release zones in Texas and Mexico, 0.1483 and 0.0443 percent were recovered in traps, respectively.

Table 1. Feral Mexican fruit fly, *Anastrepha ludens*, Loew, trapped during the 1982-1983 citrus producing season in the Rio Grande Valley of Texas at trap densities of 5 per square mile.

Month Week Year	STERILE RELEASE ZONES					
	ZONE NO. 1			ZONE NO. 2		
	Number of traps	Number of adults	No. adults per trap per week	Number of traps	Number of adults	No. adults per trap per week
10-3-82	1020	0	.0000	978	0	.0000
10-82	1055	0	.0000	1053	0	.0000
17-82	1121	0	.0000	1175	0	.0000
24-82	1250	0	.0000	1250	0	.0000
31-82	1250	0	.0000	1250	0	.0000
11-7-82	1250	0	.0000	1460	1	.0007
14-82	1250	0	.0000	1460	0	.0000
21-82	1250	0	.0000	1460	0	.0000
28-82	1250	0	.0000	1460	0	.0000
12-5-82	1250	0	.0000	1460	0	.0000
12-82	1250	0	.0000	1460	0	.0000
19-82	1250	0	.0000	1460	0	.0000
26-82	1250	1	.0008	1460	0	.0000
1-2-83	1460	1	.0007	1460	0	.0000
9-83	1670	0	.0000	1250	0	.0000
16-83	1670	0	.0000	1250	0	.0000
23-83	1670	0	.0000	1250	0	.0000
30-83	1460	0	.0000	1250	0	.0000
2-6-83	1460	0	.0000	1250	0	.0000
13-83	1460	0	.0000	1250	0	.0000
20-83	1460	1	.0007	1250	0	.0000
27-83	1460	0	.0000	1250	1	.0008
3-6-83	1250	3	.0024	1250	1	.0008
13-83	1250	9	.0072	1250	3	.0024
20-83	1250	26	.0208	1250	15	.0120
27-83	1250	72	.0576	1250	48	.0384
4-3-83	1250	35	.0280	1250	25	.0200
10-83	1250	27	.0216	1250	14	.0112
17-83	1250	4	.0032	1250	11	.0088
24-83	1250	6	.0048	1250	4	.0032
5-1-83	1250	3	.0024	1250	4	.0032
8-83	1250	12	.0096	1250	16	.0128
15-83	1250	25	.0200	1250	19	.0144
22-83	1250	10	.0080	1250	20	.0160
29-83	1250	9	.0072	1250	8	.0064
6-5-83	1250	11	.0088	1250	2	.0016
12-83	1250	3	.0024	1250	1	.0008
19-83	1250	7	.0056	1250	8	.0064
26-83	1250	1	.0008	1250	7	.0056
7-3-83	1250	2	.0016	1250	2	.0016
10-83	1250	1	.0008	1250	2	.0016
17-83	1250	24	.0192	1250	4	.0032
24-83	1250	0	.0000	1250	0	.0000
Accum. Totals	55,716	293	.0053	55,096	216	.0040

Table 1. (cont'd)

Month Week Year	NON-STERILE RELEASE ZONES					
	ZONE NO. 3			ZONE NO. 4		
	Number of traps	Number of adults	No. adults per trap per week	Number of traps	Number of adults	No. adults per trap per week
10-3-82	694	0	.0000	450	0	.0000
10-82	870	0	.0000	872	0	.0000
17-82	1192	0	.0000	1130	0	.0000
24-82	1250	0	.0000	1250	0	.0000
31-82	1250	0	.0000	1250	0	.0000
11-7-82	1250	0	.0000	1250	0	.0000
14-82	1250	0	.0000	1250	0	.0000
21-82	1250	0	.0000	1250	0	.0000
28-82	1250	0	.0000	1250	0	.0000
12-5-82	1250	0	.0000	1250	0	.0000
12-82	1250	0	.0000	1250	0	.0000
19-82	1250	0	.0000	1250	0	.0000
26-82	1250	0	.0000	1250	0	.0000
1-2-83	1250	0	.0000	1250	0	.0000
9-83	1250	0	.0000	1250	0	.0000
16-83	1250	0	.0000	1250	0	.0000
23-83	1250	0	.0000	1250	0	.0000
30-83	1250	0	.0000	1250	0	.0000
2-6-83	1250	0	.0000	1250	0	.0000
13-83	1250	0	.0000	1250	0	.0000
20-83	1250	1	.0008	1250	2	.0016
27-83	1250	1	.0008	1250	0	.0000
3-6-83	1250	9	.0072	1250	3	.0024
13-83	1250	9	.0072	1250	9	.0072
20-83	1250	31	.0248	1250	9	.0072
27-83	1250	42	.0336	1250	26	.0208
4-3-83	1250	46	.0360	1250	12	.0096
10-83	1250	22	.0176	1250	12	.0096
17-83	1250	7	.0056	1250	6	.0048
24-83	1250	4	.0032	1250	5	.0040
5-1-83	1250	7	.0056	1250	9	.0072
8-83	1250	35	.0280	1250	24	.0192
15-83	1250	131	.0992	1250	55	.0440
22-83	1250	72	.0592	1250	45	.0360
29-83	1250	61	.0488	1250	25	.0200
6-5-83	1250	33	.0264	1250	55	.0440
12-83	1250	32	.0256	1250	31	.0248
19-83	1250	30	.0240	1250	36	.0288
26-83	1250	19	.0152	1250	19	.0152
7-3-83	1250	6	.0048	1250	22	.0176
10-83	1250	16	.0128	1250	15	.0120
17-83	1250	19	.0152	1250	21	.0168
24-83	1250	8	.0064	1250	8	.0064
Accum. Totals	52,756	641	.0122	52,453	449	.0086

Feral Mexican fruit fly trapped during the 1982-83 citrus producing season (thru July 24) for the release area of Texas totaled 509, or 0.0046 flies per trap. Feral flies trapped for the same period in the non-release area totaled 1,090 or 0.0104 flies per trap. Stated in percentages, 31.83 percent of the 1,599 flies trapped were from the sterile release zone and 68.79 percent of the flies trapped were from the non-release zone. In both the release area and non-release area of Mexico only 4 feral flies were trapped in each area, although a total of 32 flies were trapped both south and west of the sterile/non-sterile area (Table 1). This is an appreciative drop in trap catches from the 1981-82 season when 20 flies were trapped in the sterile release area and 32 flies were caught in the non-release area.

The mean native fly to sterile fly ratio for the 1982-83 citrus producing season in Texas based on trap catch (thru July 24) is 1:409. The range is 0:5539 - 1:101. This is a substantial increase over that ratio observed for the 1981-82 season when a mean of 1:69 native to sterile fly ratio was recorded (January 1982 thru September 1982). The ratio (means) of native to sterile flies trapped in Mexico was recorded as being 1:1266 (4 native flies to 5,064 steriles). This compares with a 1:30 ratio (32 natives to 953 steriles) for the 1981-82 season (December 1981 thru September 1982). At no point during the 1982-83 season did the sterile to native fly ratio drop below 100 to one as was determined (hypothetically) to be the ratio necessary to suppress native populations in the Rio Grande Valley of Texas and Mexico.

DISCUSSION

Keeping in mind that the program test will not officially be completed until September 30, 1983, and without the benefit of statistical analysis, no definite statement can be made regarding the suppression or non-suppression of feral *A. ludens* in the sterile release zone of Texas. However, the results appear to indicate that a high degree of control of feral populations did occur. Further evidence supports this. Beginning in January 1983 (unpublished), J.L. Davidson supervised the collection of 12,500 fruit from each zone, each month, through May. Most were grapefruit but some sweet and sour oranges were also collected. A total of 250,609 fruit was collected, cut and examined (following a 2 week holding period) for the presence of *A. ludens* larvae. Of that total, 47 fruit were found infested with 320 larvae. Forty five of the infested fruit were collected from the non-release zones; only 2 infested fruit were collected from the sterile release zone.

Results for the 1982-83 Texas citrus producing season to date are the complete opposite from those obtained in the 1981-82 season. The primary reason for this reversal lies in the quality of the sterile fly released in the 1982-83 season as compared with the previous season. This is most evident in the sterile fly recovery percentages in traps from one season to the next. The mean sterile fly recovery for Texas (and also Mexico) was greater for this season's trapping as compared with last season, indicating that fly activity has greatly increased over that in 1981-82. This is also apparent in the percent of native fly population suppression observed between the two test seasons. Apparently, by improving our handling methods, a more competitive fly is now being released. We expect the quality of flies to increase substantially in the near future when a new rearing/eclosion facility becomes operable.

Success of the sterile release program this season as compared to last may also be directly related to the periods in which sterile flies were or were not released. Prior to the 1981-82 season, sterile flies were not released during the summer months. Release of sterile flies were made prior to the 1982-83 season (June-September) which may

have reduced the native fly populations to a level which could be ultimately suppressed using continuous sterile releases during peak adult activity. Likewise, it is possible that releases prior to this season may have only slightly reduced the native population in the release area when compared to population densities present in the non-release zone. In other words the 1982-83 fly populations at the beginning of the citrus producing season may have been nearly equal for both the release and non-release zones. Consequently, success or failure of the sterile insect technique could be measured accurately.

Apparent also from the results reported herein is the successful application of the hypothetical native to sterile release ratio formula. Staying at or above the 100 sterile flies to 1 feral fly ratio, suppression of the native fly population for at least the past season appears evident. If native Mexican fruit fly populations in the Rio Grande Valley of Texas in subsequent years are similar to the 1982-83 season, then we should expect similar suppression. In Texas, the Rio Grande Valley is the northern most boundary for appreciable reproduction of the Mexican fruit fly. Trap records for the past 10 years have been generally consistent for the number of flies caught per trap. Therefore, the present release rate of sterile flies seems adequate for USDA/Texas program needs.

No definitive conclusions are evident from the data collected in the sterile and non-sterile areas of Mexico. Whether or not release in Mexico adjacent to the sterile release zones of Texas is actually advantageous is questionable. There is so little commercial citrus that if a serious fruit fly outbreak does occur, it may be more advisable to treat the infestation with a bait-spray. If the Mexican fruit fly migrates into the citrus areas of Texas from urban and rural plantings of citrus, the resulting infestation would appear negligible when compared with native fly infestations. In the future, we may reassess the need for releases in Mexico adjacent to Texas citrus.

USDA in cooperation with the State of Texas and Sanidad Vegetal personnel in Mexico intends to continue the test project into the 1983-84 citrus producing season. If successful in again suppressing feral populations in the existing release zones, the possibility of expanding sterile releases into the present non-release zones of the Rio Grande Valley will be reviewed. Most important, if the sterile insect technique is to be a credible alternate to EDB fumigations, an additional year of data, similar to that reported herein, is necessary.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the professional assistance of Mr. Albert Guenthner and Ms. Joanne Marty. Likewise we would like to acknowledge numerous field technicians who spend countless hours servicing the traps from which the data are generated for this publication.

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Salination — A Threat to Valley Agriculture[1]

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One of the most serious threats to the future of agriculture in the Lower Rio Grande Valley is the accumulation of salts in irrigated fields, making them unsuitable for commercial production. There is ample precedent for this occurrence; in recorded history a number of civilizations based on irrigated agriculture faded due to salination of their land. Today we have the knowledge and technology to control salination, but it will require considerable investment and education.

There are a number of mechanisms by which salts accumulate in soils. The weathering process which breaks down soil parent material releases salts. Some of these salts are leached and carried away in groundwater or surface runoff. Plant roots take up tremendous volume of soil water but screen out most salts, an action which concentrates salts in soil. Evaporation from soil, rivers and lakes further increases salt in the remaining water.

The activities of modern man also increase the salt load of river systems. Damming of the Rio Grande has slowed the movement of the river, increasing evaporation. Municipal and industrial waste water contain tremendous salt loads, as does runoff from agricultural enterprises, particularly in this area of heavy fertilizer usage.

Before the advent of commercial agriculture the Rio Grande Valley naturally maintained a salt balance. There are slightly more than 400,000 acres of land in Cameron and Willacy Counties that contained high levels of salt which had originally been deposited by the Gulf of Mexico. This connate salinity rendered the land unsuitable for agriculture. The rest of the Valley soils were relatively non-saline because the main mechanisms for salt accumulation, breakdown of parent material and evapotranspiration of the natural vegetation, was balanced by the leaching effect of rainfall and periodic flooding of the river. Flooding also deposited a new layer of fertile, relatively non-saline topsoil.

Irrigated agriculture fundamentally changed this balance. The creation of reservoirs to supply water also reduced the occurrence of flooding. Tremendous quantities of moderately saline river water (often more than 3 acre-feet per year) were added to soils. The crop plants grown had dramatically higher evapotranspiration rates than native vegetation. The use of high rates of chemical fertilizers contributed to the problem.

[1]Summary of a presentation at the 37th Annual Institute of the Rio Grande Valley Horticultural Society.

To give an idea of the amount of salt added by these practices consider the example of a field cropped consecutively with fall cabbage and spring peppers. Total fertilizer usage would be on the order of 350 lb. nitrogen and 150 lb. phosphorus per acre. Routine irrigation practices would use at least three acre-feet. At current water salinity levels (1200-1500 ppm) the total salt load added would exceed 5 tons per acre. Removal of salt by the crops would be less than 1/20 that total.

Obviously a considerable portion of this salt would leach through to the ground water and be carried away, but therein lies a major problem. Many Valley soils have poor drainage characteristics. This results in high retention of salts (poor leaching) in a given field and rising groundwater tables Valleywide. Fine textured soils pull groundwater upward by capillary action, drawing salts back into root zones. A survey by the Soil Conservation Service in 1967 revealed that approximately 150,000 acres had developed salinity and/or high water table problems since irrigated production began. Additional land is affected each year.

The main mechanism by which soil salinity influences plant growth is the osmotic depression of soil water potential. Adding salt is analogous to drying soil since both reduce the amount of water a plant can take up and the rate at which that uptake occurs. In extreme circumstances salinity can prevent water uptake even when the soil is at field capacity.

Table 1. Influence of soil salinity on percent yield reduction of selected crops[z].

	Soil salinity level (PPM)			
Crop	1300(2)	2600(4)	3900(6)	5200(8)
Cotton	—	—	—	5
Sugarcane	—	15	25	35
Pepper	5	30	65	100
Onion	10	40	70	100

( )Indicates salt index in DS/m

[z]Source: Hoffman, G.J., et al. 1980. Salinity in irrigated agriculture. *In* Design and operation of farm irrigation systems, edited by M.E. Jensen. ASAE Monograph No. 3.

Plants differ in their tolerance to salinity. Cotton and bermuda grass are relatively tolerant while corn, sugarcane and most vegetables are quite sensitive. The visual symptoms of excessive soil salinity are marginal leaf burn, chlorosis, or leaf drop; wilting may occur under extreme conditions. It is important to remember that significant reductions in growth rate and yield can occur without visual symptoms. Table 1 gives a comparison of salinity related yield reductions of some important Valley crops.

There are several ways to minimize the effects of soil salinity on stand establishment. By planting in the furrows one can escape the zone of accumulated salt at the bed top. Planting on the side of a peaked bed will allow the salt front to be drawn to the peak and away from the seed row Unfortunately altering bed geometry can interfere with other cultural practices. A more widely applicable approach is the use of sprinkler ir-

rigation. Sprinkling will drive most salts below the germinating seedlings as well as decrease the physical resistance of the soil crust.

Preventing salt buildup in the profile of a given field requires the addition of enough water to supply crop demand as well as to provide leaching of salts out of the root zone. Given the quality of our irrigation water adequate leaching would require the application of 15-30% in excess of crop need. Unfortunately much of the Valley's irrigated land lacks sufficient internal drainage to accomodate this leaching. The installation of drain tiles or well point systems are required, particularly on fine textured soils. There are some clay soils, particularly in the Harlingen and Grulla series, where the cost of providing adequate drainage is not economically feasible. Such areas are candidates for permanent pasture or some other salt tolerant crop.

Whereas salinity control on a given field may be relatively simple, combating the salt problem Valleywide is a complex, costly undertaking. The key is an efficient drainage system that is capable of carrying to the Gulf approximately the same amount of salt that is applied to our cropland by irrigation. This is not the forum, nor I the authority, to examine the specific engineering aspects of such a drainage system. It is clear that hard choices must be made and significant resources committed if agriculture in the Rio Grande Valley is to survive. The combination of an efficient drainage system, judicious water use and intelligent crop selection will enable us to beat the spectre of salination.

CITRUS CANKER UPDATE

The canker outbreak in Mexico that currently has the US citrus industry on the alert is the first canker infestation in North America since the disease was declared eradicated from the US in 1947.

Growers of Mexican limes in Colima, Mexico reported spots on leaves of their trees in December, 1981. These were identified as a bacterial disease several months later. In July, 1982 the U.S. Department of Agriculture was informed by Mexico's plant protection agency, Sanidad Vegetal, of the presence of a citrus disease, possibly citrus canker, in Colima. On July 23 the USDA prohibited the entry of all citrus fruit from Mexico into the U.S. until more was known about the disease. Dr. E.L. Civerolo, an authority on this bacterium, immediately conducted host range and serological studies and concluded that the organism attacking Mexican limes in Colima was not the virulent A strain of canker and was serologically related to but not identical with the known canker strains.

Over the ensuing months the canker situation became somewhat of a political football. Many of the statements appearing in the press or voiced on television or at various meetings seemed to lose all sight of the science involved.

The by-laws of the Society prohibit the Society from engaging in partisan politics (Article VI, paragraph 4). Therefore in an effort to remove the canker situation from the political arena, Dr. E.L. Civerolo, Plant Physiologist, USDA, Beltsville, MD, a world recognized authority on bacterial canker of citrus, has been invited to present a review of the scientific knowledge of bacterial canker of citrus on the following pages.

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Bacterial Canker Disease of Citrus

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ABSTRACT

Citrus bacterial canker disease (CBCD), one of the most serious diseases of citrus, is endemic in the Orient and may have originated in India and Java. Worldwide distribution of CBCD is increasing with occurrences in citrus-growing areas of Africa, Asia, Oceania, and South America. Widespread occurrence of CBCD is a major concern of citriculture worldwide and is a continuous threat for reintroduction of the disease into the United States. At lea't three forms of CBCD, caused by pathogenic variants of *Xanthomonas campestris* pv. *citri*, are currently recognized: the Asiatic form of CBCD severely affects grapefruit, limes, sweet orange, and sour orange; Cancrosis B occurs most commonly on lemon in Argentina, Paraguay, and Uruguay; 'Mexican' lime cancrosis affects only 'Mexican' lime in Brazil. The Asiatic form of CBCD is currently the most serious threat to citriculture. Exclusion of the pathogen is the primary strategy for preventing establishment of the disease into previously CBCD-free areas. Prompt detection and eradication of CBCD-affected trees are also essential for containing the disease and preventing its establishment following introduction of the pathogen into disease-free areas. In areas where CBCD is endemic, effective management of the disease can be achieved by using integrated systems of compatible cultural practices and phytosanitary measures. Components of such systems include use of resistant or moderately resistant hosts, disease forecasting systems, removal of inoculum sources, phytosanitation, properly designed windbreak systems, leaf miner control, timely application of protective copper and/or antibiotic sprays, and quarantine and regulatory programs. Properly designed and implemented CBCD eradication programs have generally been effective in preventing establishment of the disease following introduction into disease-free areas. Development of commercially acceptable citrus cultivars depends upon improved techniques for identification and evaluation of CBCD-resistance in *Citrus*, as well as on a better understanding of the nature, mechanism(s), and heritability of resistance to infection by *X.c.* pv. *citri*. Serological techniques, such as immunofluoresence and enzyme-linked immunosorbent assay, and pathogenicity tests are the basis for rapid detection and identification of *X. c.* pv. *citri*.

Citrus bacterial canker disease (CBCD), or citrus canker, is a destructive disease that seriously affects most commercially important citrus cultivars (2,3,7,83,98,101). The most CBCD susceptible plants are members of the genus *Citrus* and closely related genera. Widespread occurrence of CBCD is a threat to citriculture worldwide. Currently, CBCD occurs in four countries in South America, eight countries in Africa, 22 countries in Asia, and six countries in Oceania (2,23). Increased occurrence of CBCD in Reunion since the beginning of 1980 may be a factor limiting further citriculture development there (2,7). All young, developing aerial parts of the citrus plant are affected. Conspicuous lesions develop on leaves, fruit, twigs, and stems (6,23,69,98). Severe infection results in defoliation, dieback, blemished fruit, reduced fruit quality, and premature fruit drop (6,53,83,98).

Movement of infected plants, seedlings, budwood, and fruit is undoubtedly the primary means of widespread distribution of the CBCD pathogen and occurrence of

the disease. Between January 1971 and June 1983, nearly 5,800 interceptions of citrus fruit with CBCD and CBCD-like lesions were made at selected United States ports of entry (USDA, APHIS, PPQ data supplied by R. Kahn, personal communication).

HISTORY

The origin of CBCD is not known for certain. The disease may be indigenous in China (20,99). However, CBCD was identified at the Herbarium of the Royal Botanic Gardens, Kew, England (21) on *Citrus medica* leaves collected in northwestern India, possibly between 1827 and 1831, and on *C. aurantifolia* leaves from Java, collected sometime between 1842 and 1844. Based on herbaria specimen records in England and the United States, Fawcett and Jenkins (21) suggested that CBCD probably originated in India and Java from where it spread to other parts of the Orient and to other citrus-growing areas around the world. The disease that is endemic in Asia is referred to as the Asiatic form of CBCD.

Although the first occurrence of CBCD in Japan is not conclusively known, symptoms that were undoubtedly CBCD lesions were observed on Washington navel orange leaves in a nursery in 1899 in Fukuoka Prefecture (55,99). While no infections were observed on Satsuma mandarin (*C. reticulata*) trees, other species including Natsudaidai (*C. pardisi* hybrid (?)), Yamabuki-Mikan (*C. aurantium*) and trifoliate orange (*Poncirus trifoliata*) were slightly affected (99). A description of these symptoms was published in 1904, although neither the disease nor the causal organism was referred to by name. Nevertheless, this was the first recognition of CBCD as a distinct disease (99). By 1921, susceptible citrus varieties in all citrus-producing areas in Japan were severely affected by the disease.

In 1914, the disease seriously affected *C. aurantifolia* in the Philippines (20), but was not recognized as CBCD until 1915. The disease also occurred on *C. hystrix* and *C. medica* in the Philippines between 1916 and 1919 (21).

CBCD was probably introduced into the United States in 1910 on trifoliate orange seedlings and Satsuma orange trees shipped from Japan to Texas, Mississippi, Alabama, and Florida (13,20,83,98). CBCD also developed on trifoliate orange trees shipped from Texas to Florida (20). Nurseries were established in Texas and Florida with CBCD-affected trees from Japan. Young, infected trees were subsequently shipped to Alabama, Georgia, Louisiana, and South Carolina, as well as within Florida and Texas (13,20).

In the United States, as in Japan the disease was initially considered to be an unusual form of scab disease. It was not recognized as a new disease until 1913 and not a serious threat to citriculture until 1914 (13,20). In 1915, the causal agent of the disease was identified as a bacterium, and designated *Pseudomonas citri* (37).

Thus, by 1914, CBCD was recognized in several Gulf Coast and southeastern states. Copper sprays, pruning, and defoliation did not effectively control the disease (13,98). Destruction of trees by on-site burning was the only successful means of controlling the disease (13).

In South America, CBCD was known to occur in Corrientes, Missiones, and Santa Fe provinces in Argentina in 1923 on *C. limon* (12,14,83). By 1937, the disease occurred throughout the Litoral region of Argentina including Corrientes and Entre Rios provinces, and in parts of Santa Fe and Buenos Aires (14,83). The disease occurred primarily on *C. limon* and *C. aurantifolia*, but also affected *C. aurantium* and

C. grandis. *C. sinensis* was only rarely affected and *C. paradisi* was not affected (14,20,83). This form of the disease is variously known as false canker, South American canker, or cancrosis B (14,83). The Asiatic form of CBCD was first recognized in Argentina in Missiones province in 1972 and was widespread in Corrientes and Entre Rios provinces by the late 1970's (12).

CBCD was first identified in Brazil in 1957 on *C. aurantifolia* and *C. sinensis* in Alta Sorocabana, a non-commmercial citrus area in the state of Sao Paulo (5,10,83,98). It was probably introduced via infected budwood originating in Japan (5,83). CBCD, affecting *C. sinensis*, was found in non-commercial areas of the states of Mato Grosso in 1958 and Parana in 1959 (83). In 1979, an outbreak of the Asiatic form of CBCD occurred in the area of commercial citrus production for export in Sao Paulo state (10) affecting primarily *C. aurantifolia*, although some symptoms occurred on a few *C. sinensis* and *C. latifolia* trees (10). This infestation was eradicated (98).

A type of CBCD affecting only *C. aurantifolia* in Brazil, recognized since 1963 (83), is distinguished from the Asiatic and cancrosis B types of CBCD based on the restricted pathogenicity of the pathogen to Mexican lime (71,83,98).

CBCD was first recognized affecting *C. limon* in Uruguay in 1949 (1) in a lemon grove in Salto near the Uruguay River adjacent to the Entre Rios province of Argentina. Unfortunately, the affected trees were not destroyed at the time. By the early 1960's, the disease occurred on other trees within the original affected orchard and on lemon trees in an adjacent property. By the mid-1970's, CBCD was known to occur in other parts of the department of Salto and in the northern part of the department of Paysandu. These infestations affected only *C. limon* and were considered to be the cancrosis B type of CBCD. In 1979, three *C. paradisi* trees affected by the Asiatic type of CBCD occurred for the first time in Uruguay in the department of Salto (1). In 1981, almost 600 grapefruit and orange trees at four locations were affected by CBCD-A. CBCD in Uruguay is currently restricted to the Salto-Northern Paysandu area.

CBCD-like lesions on *C. aurantifolia* leaves collected in Paraguay in 1932 were identified as cancrosis B (20,83). Subsequently, the disease also occurred on *C. limon, C. jambhiri*, and *C. medica* (5,83). The Asiatic type of CBCD affecting *C. sinensis, C. reticulata, C. limon,* and *C. paradisi* in Paraguay was identified in 1968 (83).

In 1981, a disease affecting Mexican lime (*C. aurantifolia*) occurred throughout the lime-growing region of the Mexican state of Colima (100). Lesions resembling CBCD occurred on leaves and twigs but no lesions associated with the disease were recognized on fruit in the field. The causal agent of the disease was identified as a bacterium. However, the etiology of this disease is not completely understood yet.

Importation of Unshiu orange into the United States from Japan where CBCD is endemic was strictly prohibited before 1968 because Satsuma mandarin was not considered to be sufficiently resistant to the disease and CBCD epidemics occurred frequently in Japan (55). Production of CBCD-free Satsuma mandarin in disease-free areas in six citrus prefectures was initiated. All citrus trees, except Satsuma mandarin, were removed to eliminate sources of inocula and protective chemical sprays were applied to prevent further infection. In 1967 United States quarantine regulations were revised to allow limited exportation of Satsuma mandarin to the United States. Since 1968, when quarantine restrictions against importation of citrus

fruit from Japan were removed, Satsuma mandarins have been permitted into Alaska, Hawaii, Idaho, Montana, Oregon and Washington (23,55,98).

The safeguards designed to prevent the reintroduction of *X. c.* pv. *citri* into the United States via Satsuma mandarin fruit from Japan include: 1) fruit must be grown and packed in areas determined to be free of CBCD by Japanese and U. S. plant pathologists; 2) Satsuma mandarin, a host moderately resistant or resistant to CBCD, is the only type of citrus that can be grown in the zone of fruit production for export to the United States; 3) CBCD-free Satsuma mandarin production areas must be surrounded by a buffer zone in which no citrus or citrus relative plants are grown; 4) groves and fruit are determined to be CBCD-free before and during harvest by inspections by Japanese and U. S. plant pathologists; and 5) in the packinghouse, fruit are surface-disinfested by a bactericidal dip. A bacteriophage test to detect *X. c.* pv. *citri* on pre- and post-harvest fruit was originally used to verify that fruit were pathogen-free; however, this test is no longer used. Since 1968, no CBCD outbreak resulting from Satsuma mandarin fruit imported from Japan has occurred in the United States.

TYPES OF CBCD

There are at least three distinct types of CBCD based on differential pathogenicity of the pathogen to citrus hosts (7,83,98). Asiatic canker, true canker, canker A, or cancrosis A (CBCD-A) is the most widely distributed form of the disease and affects many rutaceous and non-rutaceous hosts (22,24,39,40,53,56,57,58,62,77,78,79,83,94). CBCD-A affects most *Citrus* species and hybrids. Grapefruit, *P. trifoliata*, sour oranges, 'Mexican' lime, lemons, tangelos and tangerines are severely affected (7,83,98). Cancrosis B, false canker, or canker B (CBCD-B) affects primarily lemon in Argentina, Uruguay, and probably Paraguay (7,14,83,98). 'Mexican' lime, sour orange, Rangpur lime, sweet lime, citron and occasionally sweet orange and mandarins can also be affected by CBCD-B (7,14). 'Mexican' lime cancrosis (CBCD-C) affects only *C. aurantifolia* and is known to occur only in Brazil (7,14,98).

SYMPTOMATOLOGY

Characteristic lesions develop on all aerial parts of trees, particularly young leaves, twigs and fruit (2,6,13,69,83,98). Lesions on immature tissues in nature are usually visible about seven days after infection and appear initially as small, glazed, slightly swollen watery dots similar to foliar oil glands (13,98). Subsequently, CBCD lesions resemble symptoms of a variety of other citrus diseases including sweet orange and sour orange scab (*Elsinoe fawcettii, E. australis*), anthracnose (*Colletotrichum gloeosporioides, C. limetticolum*), leaf spots (*Cercospora angolensa, Mycosphaerella citri*) black spot (*Guignardia citricarpa, Phoma citricarpa*), alga spot (*Cephaleuros virescens*), and leprosis (2,83,84).

On young leaves, lesions are generally visible on the lower surface first but eventually appear on both leaf surfaces. Lesions appear as small, round, slightly raised or blister-like eruptions. These are white or pale yellow initially and become tan or brown. Corky tissues develop and lesions may become crater-like as the epidermis on both leaf surfaces covering developing lesions ruptures. Old lesions, of variable size, may be irregularly shaped, hard, corky, and appear roughened on both surfaces. As the lesion

extends, the margin of the erumpent tissue has a water-soaked, greasy or oily appearance. Leaf lesions are commonly surrounded by yellowish halos. Lesions may become 3 to 5 mm in diameter and may coalesce into larger areas.

Lesions on young fruit generally resemble those on leaves and may be 2 to 5 mm in diameter. The yellow halo may or may not be apparent, although the oily-appearing margin is present and the corky, crater-like appearance is promient. The rough spongy eruptions involve tissue of the surface layers and some deeper tissues in the rind; however, fruit infections do not extend into the vessels (6,13,69). Lesions that develop on mature fruit appear as minute (0.1 to 0.15 mm) or small (0.6 to 1.5 mm) greenish spots (43).

Twig lesions are also similar to leaf lesions and may occur more commonly on susceptible than on resistant hosts (20). The lesions on older twigs are more prominent than on younger twigs. On susceptible hosts, lesions may occur on branches up to 8 cm in diameter (6) and on trunks of mature trees.

Roots of citrus trees are susceptible to infection by *X. c.* pv. *citri* by artificial inoculation; however, CBCD lesions do not occur on or are extremely rare on underground roots (20, 1936).

CBCD PATHOGEN STRAINS

Nomenclature. Currently all recognized forms of CBCD are considered to be caused by pathogenic variants of *Xanthomonas campestris* pv. *citri* (7,16,23,37,83,98), a rod-shaped, gram-negative bacterium with a single polar flagellum. Physiologically distinct bacterial strains isolated from CBCD-affected lemon and sweet orange trees were designated *X. citri* f. *atypica* (83). The bacterium associated with CBCD-C in Brazil was designated *X. citri* n.f.sp. *aurantifolia* based on its distinct pathogenicity, phage sensitivity, physiological characteristics and serological characteristics (71,72,73). Although distinct pathogenic variants of *X. c.* pv. *citri* are associated with CBCD-A, CBCD-B, and CBCD-C (98), little is known about the nature of the distinctive pathogenicity of these variants.

Colony variation. Small or punctiform, opaque colony variants of some *X. c.* pv. *citri* strains associated with CBCD-A are generally less virulent than the wild-type large smooth colony forms of wild-type parent isolates (59,102). CBCD-B strains of *X. c.* pv. *citri* grow more slowly and form smaller colonies than CBCD-A strains (33,93).

Physiological variation. Two biotypes were distinguished among 65 isolates of *X. c.* pv. *citri* in Argentina based on growth on media with carbohydrates, acid production in litmus milk, and colony appearance on Wakimoto's medium (18). Biotype I strains were more virulent than biotype II strains (17,18). Reduced virulence of *X. c.* pv. *citri* strains isolated from lemon and orange in Argentina was associated with slow rate of starch hydrolysis and inability to liquify gelatin (17,18). Differential use of mannitol, mannose and lactose were not associated with pathogenicity or virulence of CBCD-A strains (24,74,88,101). However, strains capable of utilizing mannitol were isolated from naturally infected *C. natsudaidai*,lemon, and navel orange trees, while strains incapable of utilizing mannitol were isolated from Satsuma mandarin trees (24). CBCD-A and CBCD-B strains were distinguished by differential use of lactose, maltose, and malonate, and by optium growth temperature and mean generation time (33).

Bacteriophage sensitivity. Fifteen strains of *X. c.* pv. *citri* were divided into si three groups based on differential rates of gelatin liquefaction and starch hydro respectively (41). However, these may not be reliable characteristics for delim strains of a bacterial phytopathogen. Generally, CBCD-A strains are susceptib lysis by CP1 or CP2 while CBCD-B strains are susceptible to lysis by (24,28,29,72,74,75,101). Some CBCD-A strains are resistant to lysis by both and CP2 (31,33,72,101). Although phages capable of lysing CBCD-C strains expected to exist, none have been reported. A filamentous phage, Cf, was rece isolated from a CBCD-A strain of *X. c.* pv. *citri* (11).

Serological relationships. CBCD-A, CBCD-B, and CBCD-C strains of *X. c.* *citri* appear to be serologically related but distinct (3,4,8,33,64,66,73). Using antis prepared against heat-stable somatic antigens and against lipopolysacchari CBCD-A strains were differentiated from CBCD-B and CBCD-C strains agglutination, Ouchterlony double diffusion (ODD) and enzyme-linked immunosc bent assay (ELISA) tests and by immunoelectrophoresis (3,4,33,64,73). CBCD- strains, but not CBCD-A strains, were differentiated from CBCD-C strain IBBF-51 in ODD tests and by indirect immunofluorescence (IF) (64,66,67). Although specif antigenic components were associated with CBCD-A and CBCD-C strains, th serological relatedness of these strains was indicated using several technique (3,4,8,9,78). In contrast, CBCD-A strains IBSP-132 and IBBF-501 and CBCD- strain IBBF-503 were not related in ODD tests (4). In comparative ELISA tests several CBCD-A strains were readily differentiated *in vitro* and *in planta* from CBCD-B and CBCD-C strains while the CBCD-B and CBCD-C strains were ndistinguishable (3,4,8,9).

Two serogroups were recognized among 17 strains of *X. c.* pv. *citri* isolated from BCD-affected lemon, orange, mandarin and grapefruit trees in Argentina in ODD sts using antisera prepared against whole cells (86). Strains in one group, contain- g isolates from lemon and orange, were less virulent than those in the other group.

Pathogenic variation. Distinct pathogenic strains of *X. c.* pv. *citri* are associated th CBCD-A, CBCD-B and CBCD-C (33,71,93). In addition to specific forms of BCD, pathogenic variation of *X. c.* pv. *citri* strains has been evaluated by reactions artificially inoculated leaves of various *Citrus* species, hybrids, and relatives ,18,33,41,68,71,82,86,88,93,100). Pathogenic strains among 15 strains of *X. c.* pv. *i* were characterized as 'severe,' 'mild;' and 'avirulent' based on the reaction of *rraya exotica*, a non-citrus host, following wound inoculation of leaves (41). Based the number and size of lesions that developed on *C. natsudaidai*, Satsuma ndarin, several sweet orange cultivars, lemon, and grapefruit leaves following ulation by wounding or by injection-infilration, CBCD-B strains were less virulent aggressive than CBCD-A strains (33,93,98). Following wound-inoculation with D-C strains, lesions developed extensively on 'Mexican' lime, and slightly on t lime, 'Tahiti' lime, and lemon leaves (71). When inoculations were made without nding, small lesions developed only on 'Mexican' lime after a prolonged incuba- period (71). No lesions developed on grapefruit, sweet orange, sour orange, lemon ngpur lime leaves following inoculation with or without wounding (71). Never- s, a CBCD-C strain induced hypersensitive-like reactions in 'Duncan' grapefruit ng leaves following injection-infiltration (93). The limited pathogenicity and siveness of *X. c.* pv. *citri* strains associated with CBCD-B and CBCD-C reduce hreat to citriculture (7,98). Therefore, reliable differentiation and identification

of bacterial strains associated with CBCD are important for disease management strategies and regulatory policies.

EPIDEMIOLOGY

Under natural conditions, infection of susceptible tissue by *X. c.* pv. *citri* occurs primarily through stomates, other natural openings, and wounds (19,20,24,43,44, 45,46,47,48,52). Resistance of leaves to stomatal infection increases with maturation (19,24,95,103); however, mature leaves are susceptible to wound infection (95,98). The period of susceptibility to wound infection may be longer than that of stomatal infection, depending on the cultivar. Resistance to infection by *X. c.* pv. *citri* due to differential structure, number, distribution and/or function of stomates may be related to the relative ease with which water-soaking of uninjured leaves occurs. Infection of citrus foliage by *X. c.* pv. *citri* during the year is generally associated with growth flushes that occur during warm wet weather (24,47,48,54,89,92,96,98). Leaves of several *Citrus* species and cultivars with different degrees of resistance were most susceptible to infection 14 to 21 days after shoots began to develop (92,94,95,97).

Fruit are generally susceptible to infection by *X. c.* pv. *citri* during the period of enlargement (22,43,76,87). Under natural conditions in Argentina grapefruit were highly susceptible when 3 to 6 cm in diameter (97).

Temperature and moisture are the most important environmental factors for *X. c.* pv. *citri* infection and CBCD development (20). Bacterial multiplication *in planta* occurs at 14 to 36 C with the optimum temperature being 25 to 30 C (20,44,78,79). The maximum and minimum temperatures for growth of *X. c.* pv. *citri in vitro* are about 37 and 5 C, respectively; however, infection by *X. c.* pv. *citri* may not occur below 20 C. The incubation period between infection and lesion development in susceptible tissue ranges from about 4 days at 30 C to several weeks at 15 C. Relatively long-term survival of *X. c.* pv. *citri* at 10 C on spray-inoculated *C. natsudaidai* leaves may occur without multiplication of the bacteria in host tissues.

Free moisture, such as dew or rainfall, is also an important factor for dissemination and survival of the pathogen. Thus, CBCD is most likely to develop in areas where abundant rainfall occurs during a period when the mean temperature is greater than 20 C (20). CBCD is not economically important in areas characterized by high temperatures and low rainfall (98).

Long distance dissemination of *X. c.* pv. *citri* occurs primarily by means of infected plant material; infested personnel, clothing, equipment, tools, packing boxes and other items associated with harvesting and post-harvest handling of fruit are also potential sources of *X. c.* pv. *citri*. The epidemiological significance of long distance dissemination of *X. c.* pv. *citri* by animals, birds, and insects which may occur, is not clearly understood.

Short distance tree-to-tree and within-tree dissemination of *X. c.* pv. *citri* occurs primarily by wind-driven rain, especially when the wind velocity exceeds 8m/sec (55,89,92). In Argentina, the bacterium was disseminated further during a light rain accompanied by strong wind than during heavier rain (96). During the summer months, *X. c.* pv. *citri* was detected in rainwater collected 16 to 32 m from diseased trees (96). In Japan infection of Satsuma mandarin seedlings 5 to 6 m from an inoculum source occurred when a typhoon was associated with 6.8 cm of rain and a strong wind (12.0-17.3 m/sec) (89).

Approximately 10^5 to 10^7 viable *X. c.* pv. *citri* cells occur in leaf, fruit, and twig lesions under natural conditions and in those on artificially inoculated leaves (24,27,43,45,46,96). The number of viable cells in overwintered lesions may be 100 times less (96). On grapefruit, the population of viable *X. c.* pv. *citri* in leaves, fruit, and twigs are similar and are independent of lesion size (96). *X. c.* pv. *citri* populations were similar in lesions on orange and grapefruit leaves, and were not related to varietal resistance (96).

In Argentina, the concentration of *X. c.* pv. *citri* in rainwater was inversely related to the distance from the tree (96). Rainwater collected from diseased trees and under or 1 m away from diseased trees can contain 10^5 to 10^6 and 10^2 to 10^4 viable *X. c.* pv. *citri* cells/ml, respectively (96). Some strains of *Erwinia herbicola, bacillus subtilis* and *Pseudomonas syringae* which are antagonistic to *X. c.* pv. *citri in vitro* are associated with the pathogen in naturally-occuring lesions (32,38,92). However, the relationship between saprophytic microorganisms present in naturally-occurring CBCD lesions and *X. c.* pv. *citri* in CBCD is not clearly understood. However, yellow erwiniae are probably the most common and dominant secondary organisms in CBCD lesions. *E herbicola* did not affect the growth of *X. c.* pv. *citri in planta* (32).

X. c. pv. *citri* survives and multiplies primarily in naturally-occurring lesions (24,43,47,48,96) and in symptomless bark tissues of citrus trees (26). Saprophytic survival of *X. c.* pv. *citri* in soil in the absence of plant tissue or debris has not been conclusively established. It is possible that bacteria from soil can be dispersed during rain or irrigation to infection sites on susceptible citrus; however, the minimum level of *X. c.* pv. *citri* for infection of wounded *C. natsudaidai* seedling leaves from infested soil or plant material in simulated rain experiments was about 10^2 colony forming units (CFU)/gm of sample (25,28,29,35). Generally, *X. c.*pv. *citri* populations decline very rapidly in soil, in lesions on defoliated leaves and dropped fruit, and in infested host roots (*C. natsudaidai*) or non-host tissue (*Z. macrostachya*) rhizomes, rice straw mulch. The longevity and level of epiphytic survival of *X. c.* pv. *citri* associated with non-citrus plants may depend on the type of plant.

The primary inoculum sources for spring infections are lesions on shoots and leaves resulting from infections the previous fall and in which the pathogen overwinter, while current season lesions are sources of inocula for secondary spread of the pathogen. The bacterium probably also survives epiphytically at lower population levels on citrus hosts without symptom development (26). *X. c.* pv. *citri* is also known to be saprophytically associated with non-citrus weed and grass hosts, such as *Vetiveria zizanioides, Zoysia japonica* in Japan (25,28,29), *Trichachne insularis* and *Panicum maximum* in Brazil (80,81), and *Cenchrus* sp., *Solanum* sp. and an unidentified broad-leafed weed plant in Argentina (92,96). Long-term saprophytic survival of *X. c.* pv. *citri* probably occurs primarily in association with the roots and rhizosphere of citrus and non-citrus plants. However, the epidemiological significance of the survival of *X. c.* pv. *citri* in association with non-citrus hosts is not completely understood.

HOST RANGE

The host range of *X. c.* pv. *citri* based on lesion development following artificial inoculation is wide, including *Citrus* species, hybrids, and relatives within the Rutaceae and two non-rutaceous hosts (6,20,39,40,41,53,56,57,58). The susceptibility of *Citrus* species, hybrids, cultivars, and relatives to CBCD differs widely (53). *Poncirus trifoliata* is the only *Citrus* relative that is highly susceptible to CBCD, although

CBCD-like lesions developed on *Microcitrus australis, Aegle glutinosa,* and *Murraya exotica* (6,41,53). Small, atypical lesions developed on naturally-infected *Hesperthusa crenulata, Fortunella hindsii, F. margarita, F. japonica,* and *M. australis.*

Typical CBCD lesions developed on *E. latifolia, E. ridleyei, Xanthoxylum fagara, X. clava-hercules, Melicop triphylla, Casimiroa edulis, Paramignya longipedunculata, P. monophylla, Citropsis schweinfurthii, Atlantia citrioides, A. disticha, A. ceylonica, F. japonica, F. marginata, F. crassifolia, Eremocitrus glauca, M. australisca* var. *sanguinea, Feronia limonia* and *Feroniella lucida* following artificial inoculation. The only non-rutaceous hosts that are susceptible to *X. c.* pv. *citri* infection following artificial inoculation are *Lansium domesticum* and *Murraya exotica.* Generally, grapefruit (*C. paradisi*), limes (*C. aurantifolia, C. limettioides*), and *P. trifoliata* are highly susceptible to CBCD (6,53); sweet oranges (*C. sinensis*), sour oranges (*C. aurantium*), lemons (*C. limon, C. jambhiri*) and Mediterranean sweet oranges are moderately susceptible; and thick-skinned East Indian pummelos, mandarins and tangerines are resistant or moderately resistant (2,6,20,53,83). Generally, calamondin, citron, kumquats, *C. madurensis* and *C junos* are highly resistant to CBCD (6,20,53).

In Argentina, CBCD-A occurred more extensively on Valencia orange trees on rough lemon rootstock than on those on trifoliate orange rootstock (12). Similarly, the numbers of lesion/cm^2 on naturally-affected orange and grapefruit leaves were significantly less on trees on Sampson tangelo than on rough lemon (103). In both cases, increased susceptibility to CBCD infection was attributed to the availability of susceptible tissue resulting from the timing, duration, frequency, and/or intensity of vegetative growth as influenced by the rootstock.

HOST—PARASITE INTERACTIONS

Populations of *X. c.* pv. *citri* associated with susceptible hosts early in the season are higher than those associated with resistant hosts (47,48,54,96). Bacterial multiplication occurs extensively while lesions increase in size but decreases when lesion extension ceases. Lesions on susceptible plants extend rapidly for a longer period of time than those on resistant plants. Lesions on susceptible plants, therefore, are epidemiologically more significant as inoculum sources than those on resistant plants (53).

Distinct cytopathic effects are associated with infection of susceptible and resistant hosts by *X. c.* pv. *citri* (34,36,45,46,50). Following injection of *X. c.* pv. *citri* into young leaves of susceptible *C. natsudaidai,* bacteria remained intact and continued to multiply. Within 24 to 48 hr. after inoculation the thickness of the plant cell wall increased near the bacteria. The outer surface of the cell wall subsequently became detached. Bacterial multiplication occurred between the detached outer cell wall surface and the plasmalema. Bacteria were not immobilized and there was no accumulation of electron-dense material around the bacterial cells. Degeneration of the cell wall occurred 2 to 4 days after inoculation. Other cytopathic effects in the susceptible host 4 to 5 days after inoculation included appearance of fibrils in the intercellular spaces originating from the cell wall, increased ribosomes in the cytoplasm matrix and on the endoplasmic reticulum of mesophyll cells, enlargement of nucleoli and vacuoles, separation of plasmalemma from the cell wall, appearance of small vesicles between the cell wall and separated plasmalemma, and disintegration of the tonoplast and cellular organelles.

In resistant *C. junos* and *C. hassaku,* bacteria within the intercellular spaces were immobilized and encapsulated in fibrillar material four days after inoculation.

Deteriorated bacterial cells became electron dense. In addition to fibrillar encapsulation of bacterial cells, the resistant host reactions included the appearance of granules and small vesicles in the spaces between the cell wall and separated plasmalemma, and development of electron-dense cytoplasm.

HOST RESISTANCE

CBCD resistance among *Citrus* species, hybrids, and cultivars is variable (2,49,51, 53,94,95,103). Factors related to CBCD susceptibility or resistance include the pathogen strain (51,53,92,93), plant tissue age (19,51,76,94,95), tissue type (51), stomate number, distribution, size, type, structural characteristics, and activity of stomates (2,24,61,63,103), environmental factors (47,48,55,98,103), occurrence of wounds (52,53,92), and rootstock-scion combinations (12,103). Host resistance is directly related to lesion extension, the ability of lesions to support bacterial and phage multiplication, and encapsulation and immobilization of bacteria soon after infection (50,53,54). In addition to external resistance factors, resistance to infection by *X. c.* pv. *citri* is associated with the mesophyll of mature leaves (95,103).

Resistance to CBCD can be evaluated by inoculum dose-host response analyses of infectivity titrations in which low inoculum doses are infiltrated into uniformly selected host tissue under controlled environmental conditions (95). The slopes of regression lines are inversely related to CBCD resistance. Based on such analyses using nine orange cultivars, leaves of Westin, Hamlin, and Petropolis were more susceptible than those of Sucral Vive and Natal; leaves of Enterprise, Valencia Wood, Valencia Frost, and Sanguinella Vil were the least susceptible (95).

DETECTION AND IDENTIFICATION OF *X. c.* pv. *citri*

Rapid and accurate diagnosis of any disease is a prerequisite for adequate management. Symptoms of many other citrus diseases, pests, or injuries are similar to CBCD symptoms (2,84). Specific biochemical and physiological tests are generally not available for reliable detection and identification of *X. c.* pv. *citri*. However, some simple, rapid, sensitive, and specific procedures for *X. c.* pv. *citri* detection and identification have been developed.

Pathogenicity. The only unequivocal method for identifying *X. c.* pv. *citri* is by the development of characteristic lesions on artificially inoculated, susceptible plant tissue, such as leaves. Injection-infiltration (30) and needle prick wound inoculations (42) of intact or detached leaves to specifically detect living *X. c.* pv. *citri* are based on the ability of the pathogen to grow selectively in susceptible tissue in the presence of other saprophytic microorganisms. Leaf injection-infiltration is generally more sensitive than wound inoculation; however, wound inoculation may be more suitable for detecting the pathogen in certain types of samples, such as soils.

Wounded and unwounded leaves of 20 day-old 'Marsh' grapefruit and 'Parson Brown' sweet orange seedlings grown aseptically on Murashige-Skoog medium specifically developed characteristic CBCD lesions after inoculation with *X. c.* pv. *citri* (60). A technique based on the selective enrichment of compatible phytopathogenic bacteria in detached host leaves (90) may also be useful for detecting low levels of *X. c.* pv. *citri*.

Serology. Serodiagnostic tests for *X. c.* pv. *citri* are based on the occurrence of

specific antigens. The pathogen can be specifically detected within one to two days in clinical samples directly by ODD, indirect IF, and ELISA without prior isolation of the pathogen. However, presumptive identification of *X. c.*pv. *citri* must be confirmed by pathogenicity tests. The sensitivity of these serological techniques to detect *X. c.* pv. *citri* is similar to that of methods based on pathogenicity, but serodiagnostic techniques are more rapid. However, serodiagnostic methods do not distinguish between living and dead cells. Further improvement in the sensitivity and specificity should increase the reliability of these techniques for serodiagnosis of *X. c.* pv. *citri*.

Bacteriophage. Generally, incubation of a bacteriophage in the presence of a susceptible bacterium results in an increase in detectable phages. However, the use of citriphages such as CP1 and CP2 specifically to detect *X. c.* pv. *citri* may be limited. Although fewer than 10 *x. c.* pv. *citri* CFU/ml may be detected by CP1 under appropriate conditions, detectable increases in CP1 and CP2 may require at least 10^5 *X. c.* pv. *citri* CFU/ml. Some *X. c.* pv. *citri* strains are resistant to infection and/or lysis by the test phage. Citriphages may also replicate in and lyse bacteria other than *X. c.* pv. *citri.* Nevertheless, CBCD-B strains may be identified by their susceptibility to lysis by citriphage CP3.

CBCD MANAGEMENT

Current methods for management of CBCD, especially on susceptible cultivars under favorable disease development conditions, are not adequate for commercial citrus production. The most effective management of CBCD is by supplementing the use of resistant cultivars with integrated systems of compatible cultural practices and phytosanitary measures, including quarantine and regulatory programs. Basic strategies of the specific methods include avoidance, exclusion, or eradication of the pathogen; reduction of the amount of inoculum available for infection; minimizing dissemination of the pathogen; and protection of susceptible tissue against infection. Inoculum suppression may be most effectively achieved at times when natural pathogen populations are low as result of suboptimal environmental conditions.

Commercially acceptable or horticulturally desirable citrus cultivars that are CBCD-resistant need to be developed. This depends upon developing methods for selecting resistant individuals in seedling populations, identifying sources of resistance and understanding the nature and mechanism(s) as well as the inheritance of resistance to *X. c.* pv. *citri* infection (23,51,53).

CBCD incidence is reduced when properly designed windbreak systems consisting of trees or netting are used or when orchards are located in areas that are naturally protected from strong winds (55). In such cases dissemination of the pathogen and pathogen invasion facilitated by watersoaking in wind-driven rain and by wounding caused by whipping of shoots in strong winds are reduced.

Removal of overwintering inoculum sources by pruning infected late summer and autumn shoots effectively reduces infection the following spring. Defoliation of CBCD-affected citrus trees with a contact herbicide may also be an effective CBCD management practice to reduce the amount of inoculum available for further infections (70).

Populations of *X. c.* pv. *citri* are reduced and CBCD control can be achieved by the timely application of protective bactericidal sprays. Bactericides that contain copper (Bordeaux mixture, copper hydroxide, basic copper chloride, copper

oxychloride, and tribasic copper sulfate) as the active ingredient are the most effective bactericidal sprays for protecting leaves and fruit against CBCD (55,97). Under some conditions, an additive such as $CaCO_3$ may be needed to reduce the phytotoxicity of some copper-containing formulations and to prolong residual copper effects. Antibiotic sprays, such as streptomycin and terramycin, alone or in combination with copper-containing compounds in CBCD spray programs may be effective in some situations, but their use may be limited by their cost and biohazards associated with their accumulation in the environment.

The timing, effectiveness, and phytotoxic effects of bactericidal sprays for different *Citrus* species and cultivars under different environmental conditions need to be determined. These will probably vary depending upon CBCD susceptibility and on differential growth characteristics (97). However, protective copper-containing sprays applied at the proper time to immature growth of the first leaf flush in the season and when inoculum is naturally low or suppressed are important factors for preventing inoculum buildup (87,97,98). Effective protection against leaf infection can be generally achieved by application of two to six protective spray applications at the proper times during the growing season (55,97) depending upon the relative susceptibility of the specific host to CBCD. In Japan the first spray is applied to protect the new spring flush foliage against early spring infections. Additional sprays may be applied to new flushes when the leaves are one-half to fully expanded or 7 to 14 days after shoots begin to develop. Subsequent sprays are generally applied at petal drop when the fruit is about 2 cm in diameter and again when the fruit is about 4 to 6 cm in diameter (55,97). Sprays are also applied to reduce infections associated with strong, wind-driven rains in the summer and autumn. Commercially acceptable control of CBCD-A on grapefruit leaves in Argentina was achieved with a schedule that included spray applications before and 14 days after shoots began to grow (97). One or two subsequent sprays at 2-week intervals during the period of maximum susceptibility also provides increased protection of leaves against infection by *X. c.* pv. *citri* (97). Chemical spray schedules in areas where the disease is endemic may be determined by a CBCD forecasting system based on the analyses of CBCD occurrence the previous year, analyses of current season climatic factors such as rainfall and temperature, CBCD-lesion occurrence in the initial stages of disease development, and general disease progress (55).

Significantly less CBCD on fruit resulted when copper-containing sprays were applied to grapefruit in Argentina in the spring to protect the first flush of growth and small fruit (97). The period of susceptibility of fruit to infection by *X. c.*pv. *citri* is longer than that for leaves (22,43,76,87,97), and generally corresponds to the period of fruit enlargement (97). Difficulty keeping fruit covered with copper during this period may limit the effectiveness of sprays to control CBCD on fruit (97).

Phytosanitary measures which limit the distribution of CBCD by restricting dissemination of the pathogen include: regular inspections of commercial citrus nurseries and groves, as well as home gardens; certification of CBCD-free propagating material and fruit; eradication of infected and adjacent trees; disinfestation of personnel, vehicles, packinghouse and plant equipment, field boxes, and other field equipment; restricted movement of vehicles into and between groves; restricted movement of plant material and vehicles from CBCD-infested to non-infested area; and embargoes on picking fruit from symptomless trees in CBCD-infested areas.

Eradication of CBCD-affected trees is the most effective means of protecting commercial citrus from the disease (1,10,13,23,55,69,83,85,98). Diseased trees are

destroyed in place and surrounding disease-free trees are destroyed or at least defoliated. Eradicated areas need to be carefully reinspected. The area must be kept free of new citrus sprouts, new citrus seedlings from germinated seed and newly appearing weeds by herbicide application. Protective copper-containing sprays should also be applied to trees surrounding an eradicated area. No citrus or other crop should be replanted for a specific period of time on land from which CBCD-affected trees have been eradicated. It is expected that *X. c.* pv. *citri* survival in bare soil under natural conditions would be very limited.

Quarantine and regulatory measures prohibiting or restricting intra- and international movement of citrus materials are designed to protect citriculture in CBCD-free areas. This includes phytosanitary certification of CBCD-free nursery trees, propagating material, and fruit.

ERADICATION PROGRAMS

CBCD eradication programs are generally successful in protecting commercial citrus (1,10,20,83,97). The effectiveness of CBCD eradication programs to contain the disease and prevent its establishment depends upon prompt detection of affected trees, pathogen identification, and rapid diagnosis of CBCD.

In 1914, a program was organized in Dade County, Florida (6,13,20,97), to eradicate CBCD and to restrict movement of citrus material from infested areas. The program was extended statewide in 1915. Also in 1915, the Federal government joined the program and it was extended to other Gulf Coast states (6,13,97). The eradication program was based on regular inspections for new outbreaks, quarantine measures, and on-site tree destruction (97).

By 1927, CBCD appeared to be eradicated from Florida and the disease was declared eradicated from the state in 1933 (6,20,97). The last known occurrence of CBCD in the United States was on *P. trifoliata* hedge trees in Texas in 1943 (13,97). No CBCD was found in extensive surveys in Texas in 1947 and in Louisiana in 1949 (6,13,97). Thus, by the late 1940's, CBCD was considered to be eradicated from the United States (6,13,97).

CBCD was also eradicated from South Africa (6,20,97), Australia (20,97) and New Zealand (14,97) where infestations were not as extensive as in the United States. In Japan, CBCD was eradicated from several prefectures (55). Despite active eradication programs in Brazil and Uruguay, periodic outbreaks of CBCD occur in these countries. The CBCD eradication program in Brazil has been reviewed (83,85). When the disease was detected in Sao Paulo state in 1957, the infested area was delineated by disease survey, a quarantine area defined, and the disease contained by prohibiting the movement of citrus plants and products from the area. Infected and non-infected trees or plants of all citrus and citrus relatives in the quarantine area were also destroyed. Nevertheless, diseased trees were subsequently detected outside the quarantine area. Initially, all citrus trees were destroyed in any area where CBCD was found. However, only the infection foci plus all citrus trees within a 1 km radius were destroyed. Regulatory measures prevented transport of fruit, plants, or living parts of citrus trees to Sao Paulo. The herbicide 2,4,5-T is used in the neighboring states of Parana and Mato Grosso to kill citrus trees, to prevent resprouting, and to eliminate weeds.

By 1968, no citrus trees were left in the original eradication zone nor in other counties where infection foci had been found previously. Following reinspection part of the northwestern area of the original eradication zone was declared free of CBCD. Small experimental plots were planted in the initial eradication zone in 1968. Since 1963, only 'Mexican' lime trees have been destroyed when diseased trees were found. Between 1969 and 1974 CBCD reappeared in the initial eradication zone on the replanted trees and these small experimental plots were destroyed. The CBCD eradication program currently involves surveying and re-inspecting trees in the affected areas on a regular basis, keeping the area free of citrus sprouts, no replanting of citrus on land from which citrus trees have been removed, and embargo of fruit from symptomless trees in affected areas. Extensive phytosanitary and certification measures have been implemented which include: disinfestation of personnel, vehicles, and equipment; wearing special protective clothing which is handled with special precautions and regularly washed; carrying fruit out of orchards to trucks; disinfecting field boxes before returning to the field; and applying copper sprays as a preventive measure.Thus, periodic outbreaks of CBCD in Sao Paulo have been contained by eradication programs. However the disease has become permanently established in other areas, such as in Parana and Mato Grosso, where attempts to eradicate CBCD were unsuccessful.

Surveying and eradication activities related to CBCD were extended to all citrus-growing regions in Brazil in 1974 under the National Citrus Canker Eradication Campaign.

In 1979, an outbreak of CBCD-A appeared for the first time in two counties in Sao Paulo state in the zone of commercial citrus export (10). However, only Mexican limes were affected. A total of about 124,000 trees, approximately 10% of which were actually diseased, were destroyed. More than 250,000 nursery trees in the affected area were also destroyed. Outbreaks of CBCD in 1980 in Rio Grande do Sul state bordering on Uruguay was reportedly eradicated (V. Rossetti, personal communication).

In Uruguay, a Campaign to Prevent and Eradicate Citrus Canker (CPECC) was implemented in 1977 (1). Initially, annual inspections of lemon orchards were made in the northern citrus-growing areas of the country. The CPECC continued to expand its activities in subsequent years to include more frequent surveys and inspections of all citrus species and varieties, as well as inspections of nurseries. In addition, the CPECC has established regulatory procedures to restrict the importation of citrus into the country. Some phytosanitary measures to restrict pathogen distribution have been established as well as extension programs. Diagnostic procedures for CBCD, based on pathogenicity tests and serological analyses, are used to confirm field observations. While CBCD has not been detected in Uruguayan citrus nurseries (1) possible occurrence of the pathogen in nurseries needs to be conclusively determined.

The number of CBCD-B affected trees was reduced from nearly 2,500 in 1977 to 23 in 1982. Between 1979 and 1982, the numbers of cancrosis B affected trees each year ranged from 23 to 66 (F. Canale and G. Arocena, personal communication). Many of the CBCD infestation foci detected by the CPECC since 1978 are probably reinfections.

Following the eradication of the original CBCD-A focus in 1979, no CBCD-A affected trees were found in 1980 (1). However, nearly 600 CBCD-A affected trees were detected in four locations in 1981. Three foci involved grapefruit trees and one focus involved orange trees. In 1982, 125 Asiatic CBCD-A affected trees were found.

Over the six years the CPECC has been active CBCD in Uruguay has not been eliminated but, the disease is being contained. Nevertheless, the occurrence of CBCD-A and the possible occurrence of CBCD outside of the Salto-Paysandu region are significant developments that must be considered in the future.

National and provincial CBCD eradication programs in Argentina were only partially successful and were abandoned in 1978 (97). In Paraguay, a CBCD eradication program was developed and destruction of trees was reportedly initiated in 1967 (83). However, no systematic CBCD eradication program is currently known to exist in Paraguay (97).

FUTURE OUTLOOK FOR THE UNITED STATES

CBCD is a constant concern for citriculture in the United States. Despite strict regulatory and quarantine measures, introduction of the CBCD pathogen into United States is considered likely (23,97). CBCD interceptions are continually being made at United States ports of entry (23,97). Unshiu oranges are imported under a number of safeguards into the United States from Japan where the disease is endemic. In South America the occurrence of CBCD is epidemic (97). In Reunion CBCD occurrence has increased since 1980 (2). A disease resembling CBCD affecting *C. aurantifolia* occurs in Mexico (100).

Occurrence of a source of *X. c.* pv. *citri* inoculum with susceptible citrus cultivars in a suitable environment, such as in the Gulf Coast states, can be expected to result in CBCD development in the United States. Since most of the citrus trees planted in the United States are susceptible to CBCD (97) exclusion of the pathogen by quarantine and regulatory activities will continue to be the primary strategy for protecting U. S. citriculture. Rapid detection of CBCD and identification of the pathogen, containment of any infestation, and prompt eradication of infected trees will be essential for preventing re-establishment of the disease in the United States should the pathogen be reintroduced. State and federal eradication plans have been developed (97).

CONCLUSIONS

CBCD is a potentially hazardous threat to citriculture as widespread distribution of the disease increases worldwide with the most serious threat being from the Asiatic form of the disease. Re-introduction of *X. c.*pv. *citri* into the United States could lead to re-establishment of CBCD in the United States (97).

In areas where the disease is endemic, the most effective management of CBCD is based on the use of resistant or moderately resistant citrus species and cultivars and integrated systems of compatible cultural practices and phytosanitary measures that are supplemented by quarantine and regulatory programs. CBCD management measures are not available or are inadequate for commercial production (55,97) of susceptible and highly susceptible citrus.

Strains of *X. c.* pv. *citri* associated with CBCD vary widely with respect to cultural,

physiological, biochemical, serological, and pathogenic characteristics and properties. A better understanding of the pathogenicity and apparent pathogenic specialization of *X. c.* pv. *citri* strains associated with different forms of CBCD is needed. This could be important for developing new CBCD-resistant cultivars and for designing CBCD eradication and quarantine programs. Development of CBCD-resistant cultivars should be based on a better understanding of the nature, mechanism(s), and heritability of resistance to infection by *X. c.* pv. *citri*. The epidemiological significance, role, and behaviour of epiphytic *X. c.* pv. *citri* needs to be clarified.

Significant progress has been made recently in detection, identification and differentiation of *X. c.* pv. *citri* strains based on pathogenicity and serology. New serological and molecular biological techniques are currently being developed and adapted for more rapid, sensitive, and reliable pathogen detection and identification, as well as for differentiation of strains of the CBCD pathogen(s). In addition new information about CBCD was obtained in Argentina through a cooperative project at the Instituto Nacional de Tecnologia Agropecuaria in Bella Vista, Correintes, involving scientists from Argentina and the United States (98). This program was uniquely beneficial for the United States in that research on epidemiology, control, and hosts of CBCD was done with different types of citrus and pathogen strains in an environment similar to that in Florida. Information was obtained concerning *X. c.* pv. *citri* populations in lesions and rainwater, dissemination of the pathogen, survival of the pathogen in association with non-host plants, the relative susceptible of several citrus cultivars to CBCD under field conditions, and the timing of chemical spray applications for controlling CBCD on leaves and fruit (97). Based on this recent research in Argentina, as well as on information from previous CBCD eradication programs in Brazil, Argentina, and the United States, a CBCD eradication plan in Florida and a federal CBCD action plan have also been developed. These plans provide guidelines for implementing eradication procedures and preventing spread of the pathogen to other locations after an outbreak of CBCD is identified. Revisions in these plans can be made as new technology is developed. Prevention of the re-establishment of CBCD in the United States depends upon prompt and early detection and diagnosis of the disease. Prompt eradication of diseased trees is essential for containing any infection focus and preventing further distribution of the pathogen.

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LETTER FROM THE EDITOR

Historically the Journal has published research papers reporting experimental work and also the texts of talks presented at the Annual Institutes.

From time to time the Board of Directors has discussed the merits of adding a section in which information of a less technical nature would be published. This would be material written by growers, orchard care people, amateur horticulturists or backyard gardeners. The discussions never resolved the matter but each time merely decided to maintain the status quo for the present.

With Volume 37 of the Journal the editor has taken it upon himself to institute a Popular Section. On the following pages there are 5 papers in the popular vien. Whether or not such a section is continued in future volumes is left to the readership. Your comments on the popular, or non-technical, section are invited. The voices raised in approval or condemnation, one or the other, will carry the day.

Robert Leyden

Editor

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Transplanting Papayas

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Additional Key Words: *Carica papaya,* hydro-transplanting, culture of papaya.

ABSTRACT

Survival of directly transplanted papaya plants is low if the same technique is used as for most other plants. But if the soil is soggy wet at both the growing site and transplant site from water just applied or water applied simultaneously with lifting and setting operations--be it from garden hose, container, or flood irrigation--survival rate is good. Variations on the procedure for transferring plants to pots and for moving plants with stem diameters up to 2 cm. are described.

Papayas (*Carica papaya* L.) are popular yard plants in the Lower Rio Grande Valley of Texas (1,2). Because seeds emerge from only very shallow depths of planting, a common source of seedling trees is plants that emerge near the base of bearing trees from fruit that has fallen to the ground. These volunteer plants typically need to be moved to new sites to provide adequate space between plants and to preserve a planned landscape.

Unlike vegetable plants such as tomatoes or cabbage, however, papayas wilt almost immediately when pulled or spaded from dry soil. The purpose of this paper is to describe a "hydro-transplanting" technique that I've found works well. If it has been described elsewhere for garden or yard plants, I'm unaware of it.

THE METHOD

While applying water slowly via garden hose to the root zone of the plant to be transplanted, lift it from the ground with a shovel. Then, if the removal site is within hose reach of the transplant site, move the garden hose and transplant to the new site and be applying water while placing the plant in the soil at its new site. Plants moved by this method and kept wet thereafter for several days usually don't even wilt.

It is often inconvenient to move the hose and the plant at the same time. In that case the transplant site should be recently wetted and water should be applied as soon as the plant has been "set" at its new site. For removal and transplant sites inaccessible by hose, the same results can be achieved by having water waiting in a container to use at both the removal and transplant sites when ready to transfer the plant.

TWO VARIATIONS

There are also variations on this technique. For the person who has an excess of plants and wants to pot them to give away or use at organizational plant sales, the plants are removed from soggy wet soil as before and immediately transferred to pots containing a wet potting medium. Then the pots are placed in dishpans, buckets, or other containers with water about 10 cm. deep. The plants can be left standing in the water as long as a day before removal (longer if done in the spring or fall when air and water temperatures are below 30 °C (86 °F).

For those who have access to flood irrigation of their yards and gardens, the best time to transplant papayas is when the yard is flooded. Simply spade out a hole for it at the transplant site, then go to the plant to be transferred and lift it out with a shovel. Carry it on the shovel to the new site, lower it in the hole, and add soil from that removed to make the hole, to cover the roots and restore the surface to ground level.

Under flood'd yard conditions, I've successfully transferred plants as large as 2 cm. in diameter. For plants this size, all leaves except for a rosette of four or five at the terminal of the plant should be removed-either before or right after the transplanting is accomplished. There is no need to remove leaves from plants as large as 1 cm. in diameter.

On July 4, just passed, in mid-afternoon I successfully transferred 20 plants to pots using the described technique without "losing" any. So any of these variations is commended to the homeowner, gardener, or nurseryman who would like to propagate papayas but has had difficulty getting them to survive transplanting.

Like other plants, the root zone of transplanted papayas should be rewetted at least once daily for about three consecutive days after transplanting. After watering twice more at about three day intervals, the papayas should not require watering oftener than once per week.

The name hydro-transplanting was selected (there was no contest and no prizes) to describe the generous use of water in the transplanting operation. Evidently, it is successful because enough of the root system is transported with the plant to supply the plant's water needs. Thereby tissue dessication and, consequently, death are avoided. This hypothesis is supported by the following observation: When pulled (heaven forbid) or spaded from dry soil, little more than the tap root accompanies the above ground part of papaya plants; however, when removed from soggy wet soil by spading, many fine rootlets accompany the rest of the plant to its new environment and are able to supply the plant's water and nutrient needs.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Orchids for the Rio Grande Valley: A Guide for the Beginner

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Orchids, once thought to be very delicate, are proving to be quite hardy and easily grown at home. They are rapidly gaining popularity with home growers.

The first concern for any new grower is often price. Orchid plants once demanded high prices, but new propagation techniques have rapidly reduced prices. Some orchids can still demand a price of $5,000, but most blooming size plants can be purchased for $10 to $50, depending on the variety.

Humidity is another concern. When the first orchids were imported from Central and South America to England and Europe, they were literally showered with humidity in a mistaken attempt to duplicate conditions of the tropical rain forest. This very high humidity killed many plants and caused others to not bloom. Orchids generally require a humidity of 40 to 50 per cent, which is easily obtained in the home or outside in the Rio Grande Valley. Low humidities can be changed by frequent mistings and/or growing the plants over water filled trays.

Fig. 1 A spike of sixteen phalaenopsis flowers and buds.

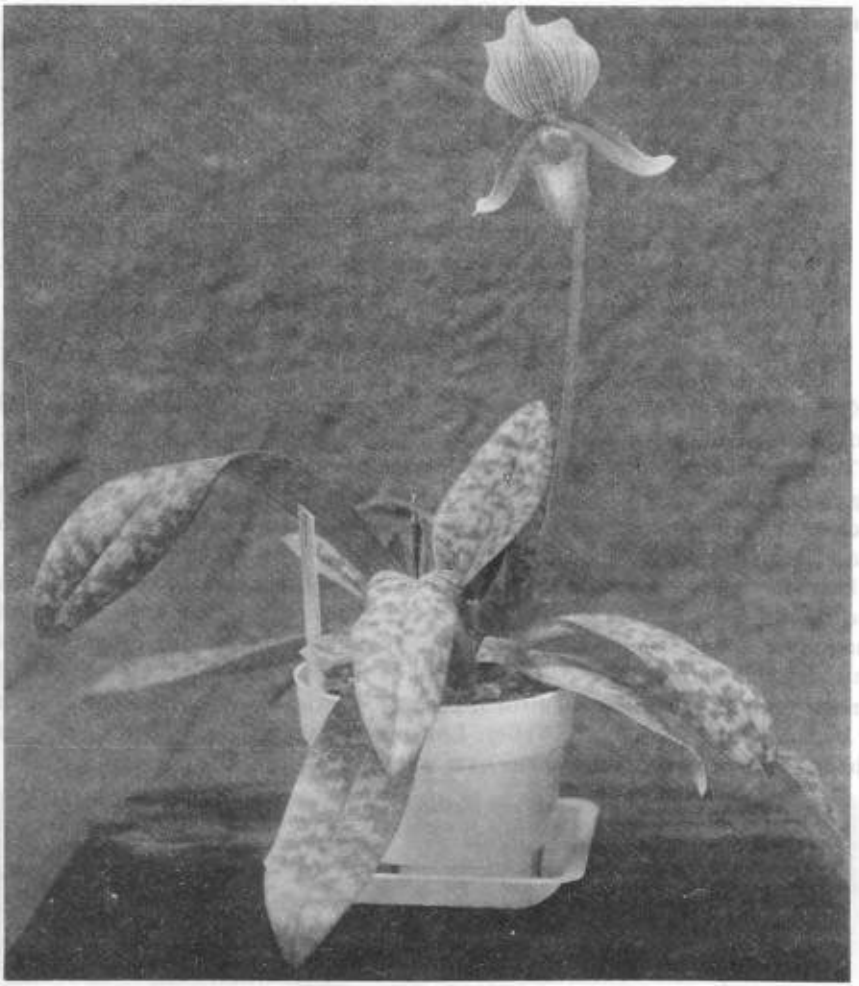


Fig. 2 A paphiopedilum plant.

Orchids generally are epiphytes, that is, plants that grow on, but do not receive nourishment from, another plant. They are not parasites such as mistletoe. This fact leads to the use of inert materials such as osmunda fiber, bark, volcanic rocks, and charcoal for the growing of orchids. Orchids grown in potting soil will quickly lose their roots and eventually die.

ORCHIDS EASY FOR THE BEGINNER TO GROW

Cattleyas called the 'Queen of Orchids', are most commonly known as the flowers in corsages. Cattleyas can be grown outside on a bright (3000-5000 foot candles), protected porch. They can be humidified by misting or sprinkling two or three times a day.

Several new minature cattleyas have been developed for the windowsill grower. They have two to three inch flowers and grow only eight inches tall.

Blooming size cattleyas range in price from $10 to $40 depending on variety.

Phalaenopsis orchids, which grow in similar conditions as do african violets, can provide sprays of up to 20 blooms. A single spike may last six months from the opening of the first flower to the closing of the last one. These 'moth orchids' which are usually found in bridal bouquets, can be grown in an east, west, or south window out of direct sun or under lights (2000 foot candles). They should be kept evenly moist and misted two or three times a day. Phalaenopsis are the easiest orchid to grow in the home. Their price will range from $20 to $40 depending on the variety.

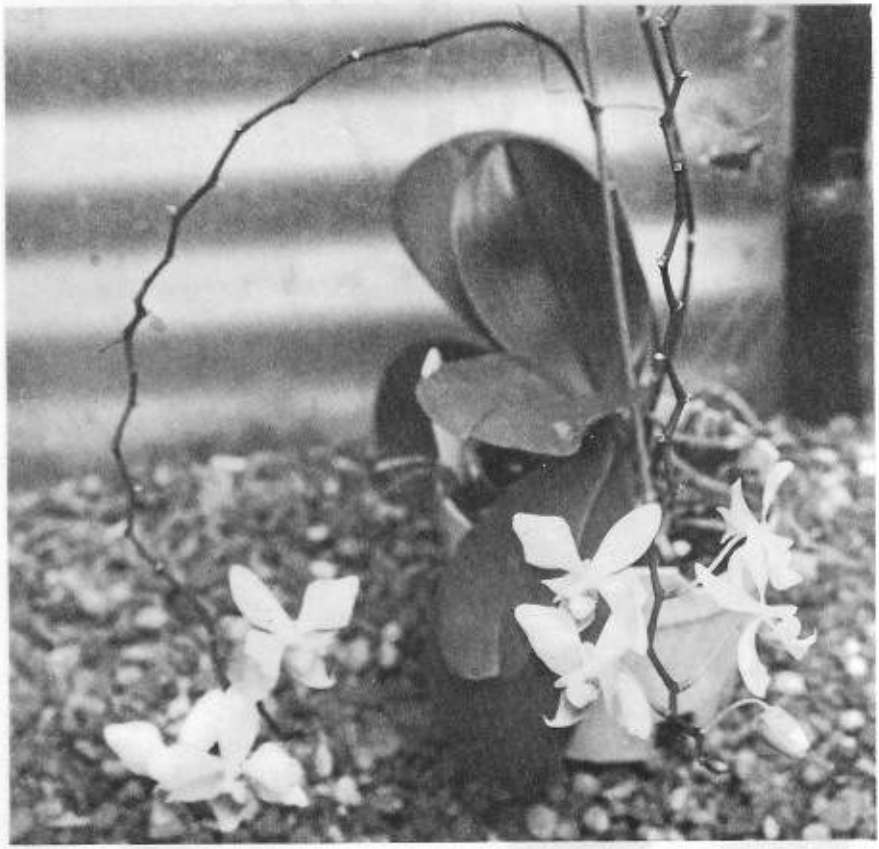


Fig. 3 A phalaenopsis plant with eight flowers remaining. This plant had a total of 42 blooms.

Paphiopedilums are called 'lady slipper' orchids due to the shape of the flower. They have the same requirements as the phalaenopsis orchids. The best types to grow at home are the variegated or mottled leaf types which can take extremes easier than the solid leaf types. These orchids range in price from $10 to $30 depending on the variety.

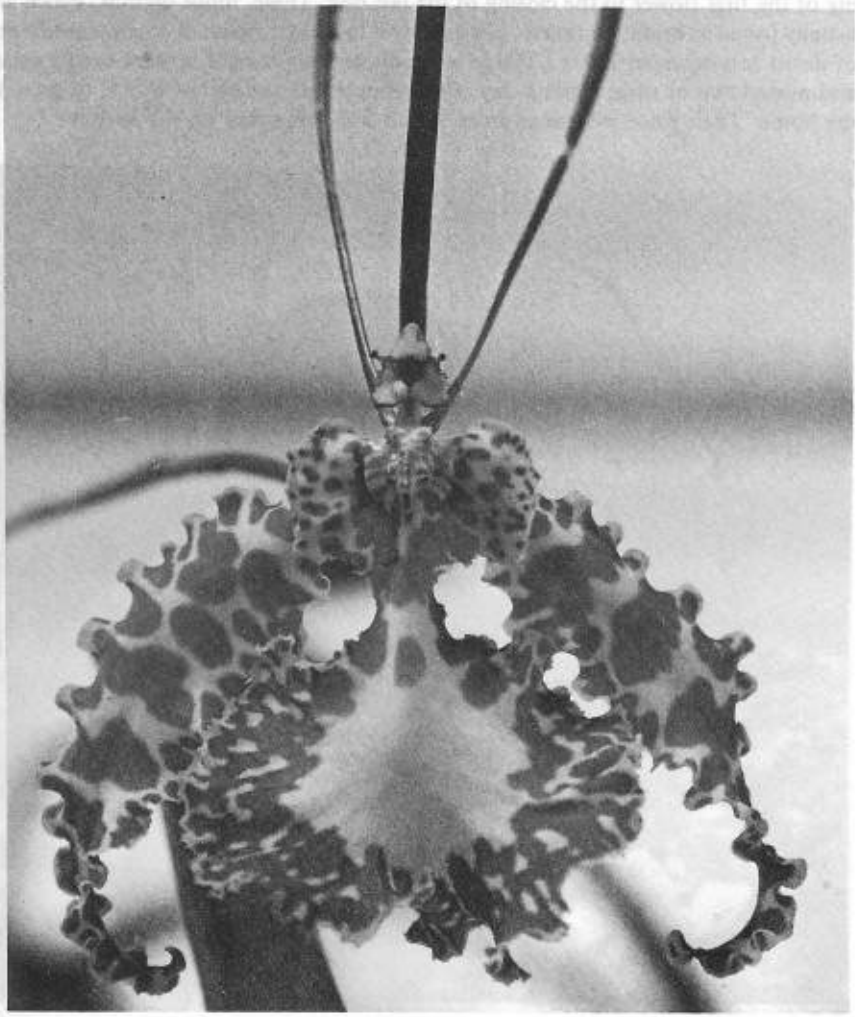


Fig. 4 A 'butterfly' oncidium.

Species Orchids. There are several types of orchids that can be grown on a sunny window sill or under trees outdoors. These orchids are found in Mexico, Central and South America. The easiest and best to grow in this area are: Oncidiums (dancing lady orchids), Epidendrums, and Encyclias. They require occasional mistings and waterings and will provide sprays of many brightly colored flowers. Prices vary widely: from $5 at a local flea market to $50 for a highly bred species.

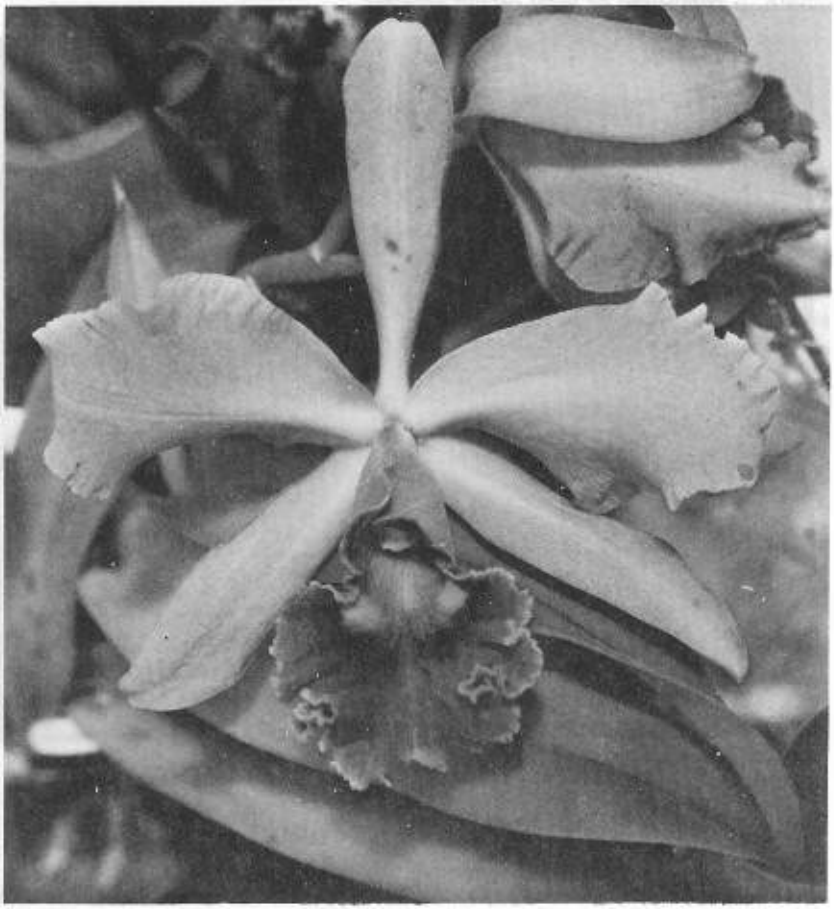


Fig. 5 A laeliocattleya flower.

WHERE TO GET INFORMATION ON ORCHIDS

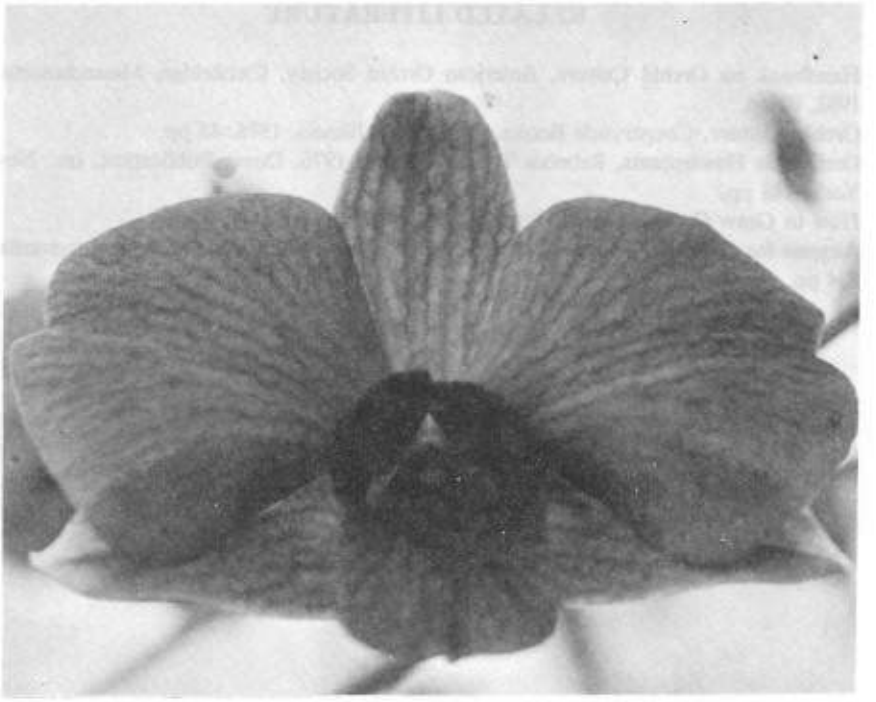
Your local public library will typically have a few informative books on orchids. More information can be obtained from: American Orchid Society, Inc. (A.O.S.), 84 Sherman Street, Cambridge, Massachusetts, 02140. The Tip of Texas Orchid Society, which meets at the Harlingen Public Library on the first Sunday of each month, is comprised of local orchid growers.

Fig. 6 A brasslaeliocattleya flower, a cross having a large, ruffled lip.

WHERE TO OBTAIN ORCHIDS

Many local growers will be happy to sell to or advise new people on where to buy orchids. A list of names can be obtained by sending a self-addressed, stamped envelope to Howard Wilhite, P.O. Box 431, San Juan, TX 78589. Addresses of commercial growers can be obtained from orchid books or from the A.O.S.

While requiring a little more care than the normal houseplant, orchids are hardy and easy to grow. The flowering of your orchids will more than repay the extra care required by these plants. How proud you will be to say: "I grew that orchid myself."



Fi. 7 A dendrobium-phalaenopsis flower.

Fig. 8 An encyclia flower shown life size.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Operation of the Texas A&M University-Hoblitzelle Farms Citrus and Avocado Nursery

Daniel Fernandez, R.E. Rouse and N.P. Maxwell
Texas A&M University-Hoblitzelle Farms, and
Texas Agricultural Experiment Station, respectively

The Texas A&M University-Hoblitzelle Farms in Mercedes, Texas is a self supporting farm receiving no state funding. The farm has become a diversified unit for the purpose of commercial production of citrus, avocado, vegetables, and grain, while maintaining cooperative research and demonstration functions with the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service.

HISTORY

Hoblitzelle Farms' original property of 36 acres was purchased in 1921 by Karl St. John Hoblitzelle, a prominent banker in Dallas with investments throughout the state of Texas. The first citrus planting was established in 1933 and consisted of white and red grapefruit along with navel and Hamlin oranges. In 1942 the farm was expanded to 750 acres through the purchase of additional land. Part of this was several sand hills adjoining the farm.

Dr. Rafael Cintron assumed the position of manager in 1946. The acreage continued to be increased with land purchases to its present size of 1,151 acres. Citrus comprises 325 acres and with new planting it is expected to reach 500 acres. Following the death of Mr. Hoblitzelle in 1967, Dr. Cintron continued full management of the farm under the Hoblitzelle Foundation. Through the efforts of Dr. Cintron, the Hoblitzelle Foundation donated the farm and facilities to Texas A&M University on June 8, 1972, for the purpose of developing a research and demonstration farm for the Rio Grande Valley of Texas.

CITRUS NURSERY

The Hoblitzelle Nursery has two objectives: 1) to produce new trees for the farm in the form of resets and new plantings and, 2) to make available to the citrus industry and the public a research and demonstration unit making available new cultural practices and nursery propagation techniques.

In order to plant new acreage, replace groves no longer economical and recover after occasional freezes, the citrus nursery becomes the major component in a citrus management replant and rehabilitation plan. Under the Hoblitzelle citrus management plan, 15 to 20 acres of citrus are planted each year either as new plantings in areas where groves have been removed or on new acreage.

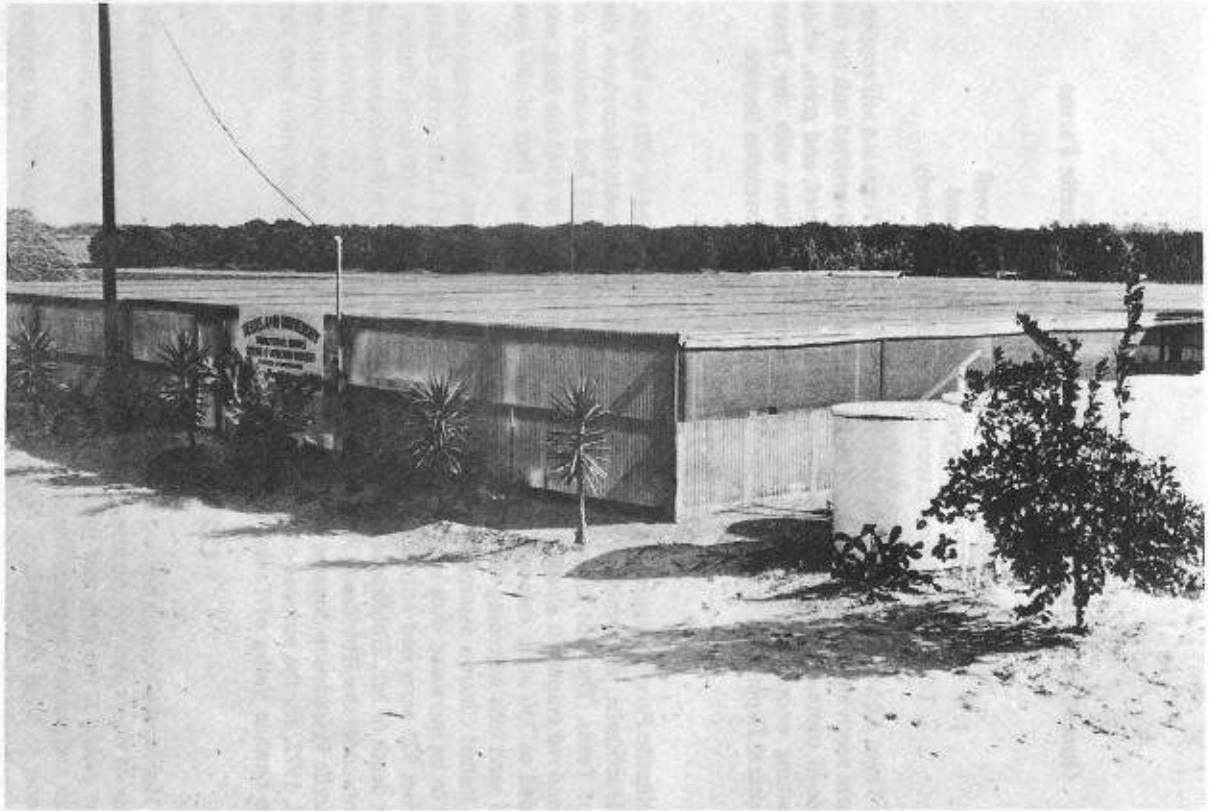

Fig. 1. Hoblitzelle Farms Nursery structure with shade cloth covered area in foreground and windbreak grow-off area behind.

Historically, citrus nursery trees are in short supply for several years following a severe freeze. Under such conditions, the Hoblitzelle nursery production can be doubled and trees produced ready for the field in 12 to 15 months.

The original Hoblitzelle nursery proved to be too small to produce the quantity of trees required annually. A complete new nursery was established in 1977. The latest technology in production of nursery trees was considered in the design. Research and technology will continue to change future imputs for maintaining and improving efficiency of production.

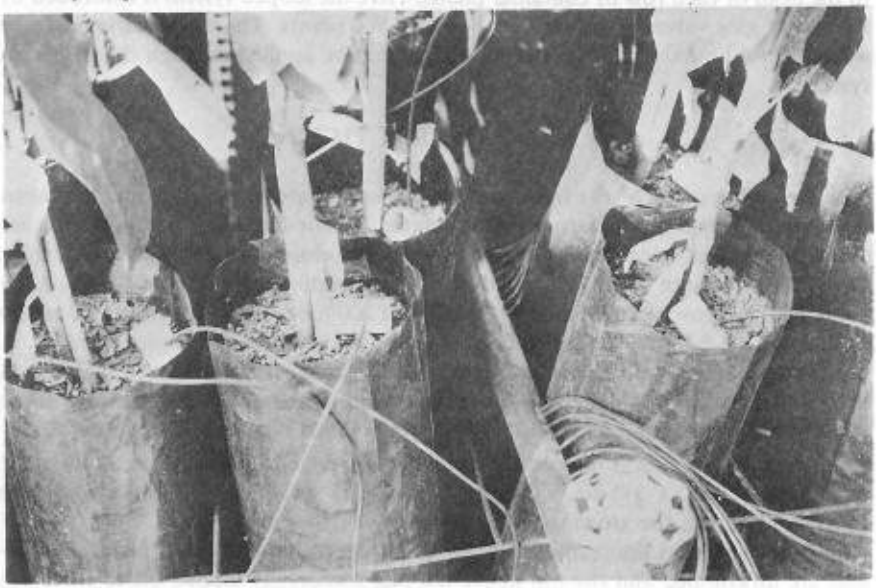

Fig. 2. Irrigation system with individual emitter in each container.

Optimum use of available land is achieved at Texas A&M University-Hoblitzelle Farms citrus nursery by growing plants in containers. Several advantages of container grown citrus are: 1) the same nursery site can be used each year when container plants are grown. 2) at all stages the trees are protected from cold, strong winds and sun. 3) the need for heavy or specialized equipment is reduced or eliminated. 4) labor can be efficiently managed. 5) tree nutrition and water relations are easily monitored. 6) insect problems are easily spotted and controlled. 7) disease problems in the nursery are easily avoided or controlled. 8) tree time in the nursery is shortened. 9) when field planting the trees, nematodes, weed seed, foot rot or other diseases are not transferred to the new grove site due to the use of sterilized soil, clean nursery tools and selected graft wood. 10) trees begin growth rapidly when planted in the field due to an undisturbed root system.

The Hoblitzelle nursery structure (Fig. 1) consists of a 1,600 square foot shade house with the capacity of handling approximately 6,500 container plants and an adjoining fiberglass enclosed windbreak area with a capacity of 6,500 plants.

The shade house structure is covered with polypropelene mesh fabric rated at 55% shade. The north and west wall exposure are completely covered with fiberglass panels for wind and cold protection. The south and east exposure is fiberglass to 4 feet above ground level with shade cloth to the 7 ft. 6 inch high top. Water and elec-

trical outlets are available throughout the house. Cold protection during winter is provided by 4 mil polyethylene plastic suspensed by guide wires. Two butane heaters with fans are located on the north wall. When required, trees in the windbreak area are protected by covering each tree row with 4 mil polyethylene.

Irrigation of container citrus plants is accomplished by use of 0.06 inch microtube emitters, one per container and attached to a ¼ inch polyethylene line (Fig. 2). City water is used to fill five 500 gal tanks. Water is pumped with a 1.5 H.P. electric pump to the head of each row of container plants. Here the looped system is controlled by a series of gate valves with each row handling 700 plants. The entire nursery can be watered in 4 hours. Fertilizer and fungicides can be applied through the irrigation system.

ANNUAL PRACTICES

In December of each year fresh seed for rootstocks are extracted from fruit taken from selected trees on the farm. Seed is planted in cone-like tube containers that are 6 inches long and 1 inch diameter and tapered and closed at the bottom with drain holes. The medium used is a combination of peat, perlite and sand (1:1:1 by volume). The growing tubes are held in trays of 200 tubes with 16 trays (3,200 tubes) placed in a 4 x 8 foot enclosed wooden growth box with a clear plastic sealed lid. A heating coil and fan force warm air around the base of the tubes to maintain a temperature of approximately 85°F for optimum germination and growth. These self-contained seedling boxes can be placed in a shade house or greenhouse.

After approximately 3 months the seedlings are ready for transplanting to larger containers (17 in. x 3½ in. x 3½ in. 6 mil black poly bags). The seedlings are transplanted from the growing tubes without disturbing the roots.

In May the plants are ready for budding. Fourteen days after budding the seedlings are unwrapped and the top above the bud completely lopped off to force the bud. Trees are grown-out and headed at 16-18 inches in full sun in a windbreak area. The finished tree is ready for fall planting or may be held in the nursery through the winter for planting in the spring. The finished tree has been produced from seed in 12 to 15 months.

Cleft grafting as described (2) has proven successful during the winter and growth begins early in the spring. The graft union is approximately 6 inches above soil line, wrapped with plastic, secured with rubber bands for tension and placed under clear 4 mil plastic tents. The grafting procedure can be extended into the spring if each graft is covered with its own small plastic bag instead of using the tent. These 2 methods of covering the grafts have improved graft survival by maintaining an optimum level of heat and humidity.

Once new growth has begun and shoot development is observed, the tents are removed and the grafts later unwrapped as the plant begins vigorous growth. The plants remain in the shade house until mid-April or May at which time they are moved to the windbreak area to harden off to full sunlight. By fall of the second year the trees are ready for field planting and have attained a height of 3 feet and a diameter approximately ½ to 9/16 inch (Fig. 3).

Fig. 3. Finished tree ready for field planting.

AVOCADO PROPAGATION

Avocado tree propagation and production is done on a limited scale. The grafting technique is similar to that described for citrus, but the growing and handling are considerably different (1).

Those individuals interested in more detailed information on the citrus research and demonstration nursery should contact the Texas A&M University-Hoblitzelle Farms, Manager, Mercedes, Texas 78570: Telephone: (512) 565-2152.

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Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Selecting Roses for the Lower Rio Grande Valley[1]

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Virtually no other plant comes close to matching the beauty, practicality, and versatility of the rose. Stated in clinical terms, a rose is a flowering shrub. But it is remarkable shrub, encompassing a great variety of growth types and flower and foliage forms, a wide range of colors, and here in the Valley, a year-round growing and blooming season. When people come into the nursery looking for a plant that will tolerate both full sun and full exposure to the cold, and still provide year-round color, nothing fills the bill as well as the rose.

Today, the rose is certainly our most popular flower. Over 50 million American families have at least one rose bush in their yard. In order to grow roses successfully, in the Valley or anywhere, three basic requirements must be met:

1. Select healthy #1 plants in suitable varieties and rootstock.
2. Locate and plant them properly.
3. Supply their four basic needs: water, nutrients, pruning, and pest and disease control.

This article will deal primarily with the first of these requirements.

Before choosing your roses know what type of blossom and growing habit you want. There are many different types of roses, but the three best-selling general classifications are hybrid tea, floribunda, and grandiflora. Hybrid teas are far and away the most popular class, outselling all others combined. These are the roses of the formal garden, the cutting bed, and the greenhouse. They produce large, spectacular blossoms, one bloom to a stem, on long stems which make them very suitable for cutting. Thousands of varieties of hybrid tea roses are known, and many new ones are developed each year, so no one dealer can hope to stock them all. We at Waugh's generally stock just over one hundred different varieties. While this is just a small percentage of those available it keeps us quite busy. The second classification, Floribundas, have blossoms somewhat smaller than most hybrid teas but borne in large clusters with many blooms to a stem. Most floribundas are hardy, disease-resistant, and heavy bloomers. Their compact growth habit, combined with profuse blooming, make them the best selection for landscape use, such as borders or informal hedges. Grandifloras, the third general class, are vigorous plants sometimes eight to ten feet high, with hybrid tea-like flowers borne singly or in long-stemmed clusters. They are particularly valuable for their mass color effect in the garden and for their large numbers of cutting flowers.

Roses are available for purchase in both bare root and potted forms. Bare root roses are generally not sold in the Valley by reputable dealers because of our warm climate, and the distances involved in shipping. By the time rose bushes reach the

[1]Summary of a presentation at the 37th Annual Meeting of the Rio Grande Valley Horticultural Society, Evening Session.

Valley from their growing fields and encounter our warm Valley days, they tend to think that it is spring and sprout almost immediately. The artificial inhibition of this sprouting by refrigeration or waxing often causes the roses to lose much of their vitality. Also, the planting of a waxed rose bush under our hot Valley sun can be disastrous. Therefore, be sure to select only potted, growing rose bushes which can be planted immediately with no ill effects, and which will produce blossoms in only a few weeks.

It is important to select only number one bushes. All roses are graded as number 1, 1½, or 2—based on the size and number of the canes. If you want the best, insist on Grade Number One plants with three or four heavy canes at least 3/8 inch in diameter. After a few seasons of growth, grade 1½ plants may catch up, but you miss those first years of good bloom quality. Number Two bushes are usually the runts of the crop, and will probably never give you good bushes or blossoms.

Of equal importance is the selection of roses having the proper rootstock. The "rootstock" or "understock" of a rose bush is a well-rooted cutting of a particular species of rose, into which growth eyes or buds of the desired rose are inserted. Rootstocks are used because the rose bush which produces the most desirable flower does not necessarily produce the most vigorous root system. So roses are budded to provide the best of both worlds: a heavy-blooming bush with beautiful flowers on top; and a vigorous, disease-resistant root system to supply it with its foundation and nutrients. As yet, no rootstock has been found that is suitable for all regions of the country. We believe the best one for the Valley is a cross between the "Dr. Huey", a semi-double maroon-red climber with short dormancy requirements, and the "Mexican root stock", developed from a wild Mexican rose. This rootstock seems to be best able to tolerate our year-round blooming season, our alkaline soils and waters. Tyler roses are generally not suitable for the Valley because they are grown on a rootstock adapted to areas with a definite dormant period, and for more acid soil and water conditions.

Nearly any variety of rose bush can be grown in the Valley if it is on the proper root stock. As a general rule, however, the brighter, deeper colors seem to stand up to our hot summer somewhat better than the paler colors. Yellow roses are particularly difficult here, as the blooms tend to fade and shatter rapidly during our long, hot days. White roses have similar problems, although to a lesser degree. If you do want roses in the yellow range, "Oregold" and "Summer Sunshine" are two of the best. There are also a great many roses in the apricot-to-orange range which do very well here, from pale colors such as "Medallion", to deeper shades like "Tropicana". In the whites, "Louisiana" has proven to be an excellent year-round rose. There are also many blends, such as "Peace" and "Garden Party", which can help fill the yellow and white color ranges, and have better lasting quality than their pure-toned cousins.

No matter how dedicated you are to your roses, it will be difficult to be completely successful unless these general guidelines are kept in mind when you make your selections. Paying attention to what you are buying, knowing what you need, and dealing with people you know and trust can make rose-growing easier and more rewarding, and can fill your home and your garden with fragrance and color year-round for many years to come.

Journal Rio Grande Valley Horticultural Society, Vol. 37, 1984.

Native Plant Project...for the Preservation, Utilization and Appreciation of the Native Plants of the Lower Rio Grande Valley

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Since 1500 A.D. the world has recorded the extinction of about 200 species of animals. Saving other endangered species has engaged the effort of numerous conservation and naturalist groups. Less well known is that almost as many plant species are lost forever **each year!**[1] There are fewer spokesmen for plants, especially for those wild and assumed economically unimportant specimens which exist in habitats or locations coveted by man. The problem is that the potential of a vanished plant can never be appreciated or realized.

The Native Plant Project was organized in the spring of 1982 to serve the cause of the native plants of the Lower Rio Grande Valley. At 26°N. latitude the Valley, with its mixture of semi-tropical and semi-arid climates and assortment of alluvial, windblown and residual marine soils, has a unique range of ecological niches. From the Gulf seashore west to the caliche ridges of Starr County and from the banks of the Rio Grande north to the chapparal brush country exist a diversity of plant species found nowhere else within the United States. Through the early years of this century the plant and animal ecology of the Valley remained fairly stable. In the last few years, however, accelerated population growth, agricultural expansion, and urbanization have destroyed or drastically altered over 95% of the native brush and other natural areas.

PRESERVATION...A DUAL THRUST

The preservation of threatened or endangered native plants is a major goal of the Native Plant Project. Besides supporting efforts to preserve the Valley's unique biotic communities and set aside areas as nature reserves, the organization has put considerable effort into developing a nursery for native plants. These plants will be used to revegetate cleared land destined for reversion to a natural state. In the process of propagating and raising native plants the Project is accumulating and organizing information on their culture. When large numbers are needed, the natural way of propagation and distribution of plants can be very inefficient and inconsistent. To rely on nature to reestablish or maintain a plant population in today's environment could well spell doom for many species or even whole plant communities.

[1]Koopowitz, Harold and H. Kaye. Plant Extinction: A Global Crisis. Stone Wall Press, Inc. Washington, D.C. 1983.

Cultural information is important for the second preservation goal of the Native Plant Project, which is to encourage the utilization of native plants in private and commercial landscapes. Currently, inclusion of native plants in a landscape usually means transplanting them from the natural state. Unless extreme care is provided, the plant has little chance of surviving. Thus, to encourage using native plants without having an available source is only hastening their demise in the wild. The answer is to provide native stock through local commercial nurseries. Several Valley nurserymen have agreed to cooperate with the Project in raising native plants. The problem is that data pertinent to the commercial propagation and culture of most native plants are practically non-existent.

The Native Plant Project hopes to help fill this void. We know that if more native species are planted around homes and businesses not only will they be preserved, but the appreciation of their value and beauty will be increased.

PUBLIC INFORMATION AND SERVICE PROGRAMS

The Native Plant Project is focusing public attention on native plants through diverse approaches, groups and locations.

A series of newspaper articles written by members of the group features a native plant or some aspect about the Valley's natural vegetation. The articles note unusual characteristics, landscape value, or uses of local plants, as well as how plants interact with other facets of Valley life.

In addition to the published articles, several members of the Project are regularly called on to speak to interested groups about native plants and the concerns and objectives of our organization.

In cooperation with the staff at the Santa Ana Wildlife Refuge, the Native Plant Project is building a collection of seeds of native plants. While the shapes, sizes and colors of seeds make an intriguing display of themselves, such a collection has another important role in wildlife research and management. A common method of studying the feeding habits of birds and animals is through analysis of droppings or stomach contents. By comparing the kind and amount of seeds thus found, the significance of native plants in the diet of both migrant and indigenous wildlife species can be determined. Such knowledge, in turn, is useful in establishing plantings or revegetation projects designed to attract or sustain wildlife.

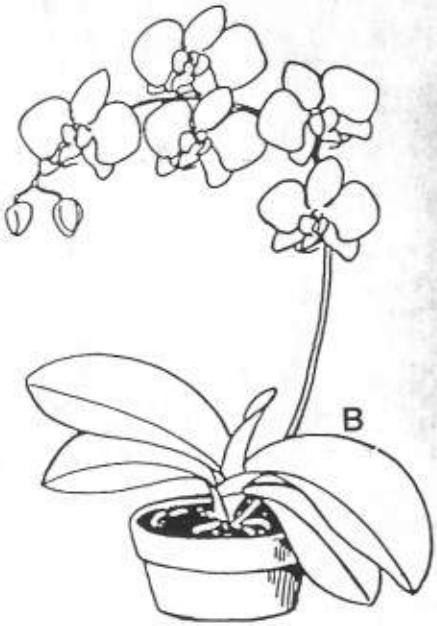
The group has assisted in several landscaping projects involving the use of native plants. In one case a small park in Weslaco is being redesigned to provide a collection of native plants and their representative habitats. When completed the park will serve to preserve and display native plants as well as being a source of education and appreciation of the Valley's natural botanic heritage.

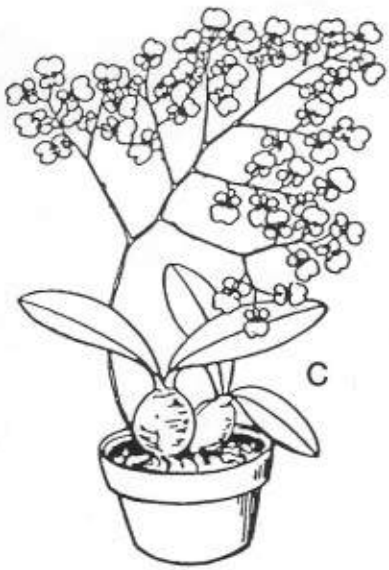
Underway is a landscape plan developed for the parking area of the Santa Ana Wildlife Refuge. The design will feature native plants utilized in traditional roles such as hedges, shade trees, specimens, ground covers, and flowering shrubs. The completed project will emphasize the advantages of native plants... adaptibility, ease of maintenance, and freedom from serious pests and diseases.

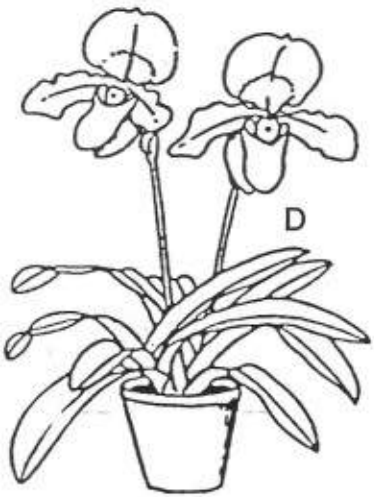
CLEARINGHOUSE, RESOURCE, ADVOCATE

Underlying all the activities of the Native Plant Project is the desire to serve as a local clearing house and resource for information activities relating to our native plants. While we strive, along with other groups, to save vanishing plant species or habitats, the development of an appreciation for our native flora and the realization of their potential requires effort along a much broader front. As the organization grows and becomes better known, it hopes to fulfill all these functions.

Information on the Native Plant Project and membership details can be obtained by writing to: Native Plant Project, Box 8121, Weslaco, TX 78596.







ON THE COVER

ABOVE: Line drawings showing the growth and infloresence of four common orchids (A) cattleya (B) phalaenopsis (C) oncidium and (D) paphiopedilum.

FRONT: A pure white cattleya flower, a very popular variety.

Close-up of a cattleya flower.

A cattleya plant.