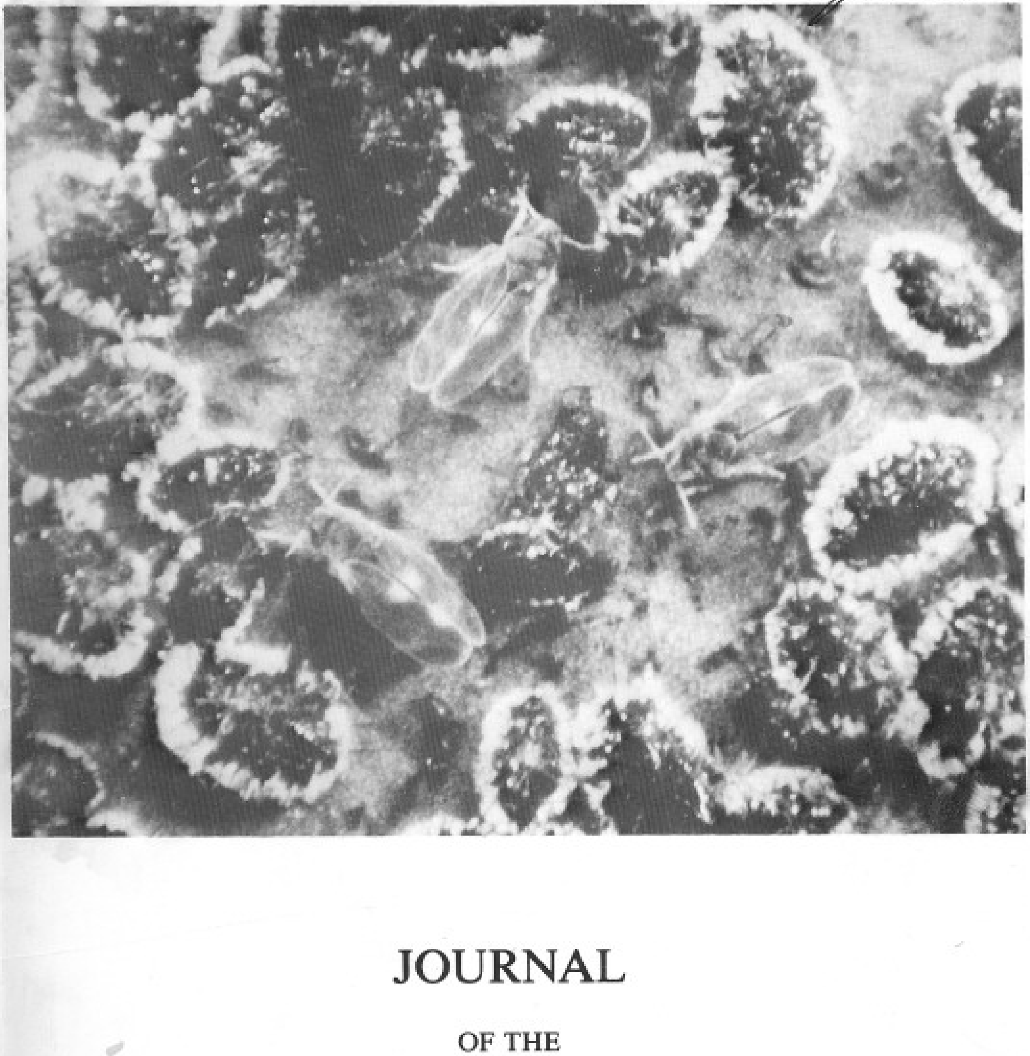
Wiedenfeld



JOURNAL

OF THE

RIO GRANDE VALLEY HORTICULTURAL SOCIETY

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VOLUME 41, 1988

Published by

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

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 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.

Call for Papers

Papers are requested for inclusion in Volume 42, 1989 of the Journal of the Rio Grande Valley Horticultural Society. Manuscripts of a scientific or practical nature pertaining to horticulture will be considered for publication. All papers, including written versions of presentations from the Annual Institute, will be subject to review. Separate guidelines for the preparation of research and non-research papers are printed in the back of this issue. The deadline for submission of papers for Volume 42, 1989 is 1 July 1989. Manuscripts for publication in the Journal may be sent to:

Journal Editor
Rio Grande Valley Horticultural Society
P.O. Box 107
Weslaco, Texas 78596

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History of the Arthur T. Potts Award

When the Rio Grande Valley Horticultural Society decided to establish an award recognizing outstanding horticultural work in this area there was little doubt as to who would be the first recipient. Arthur T. Potts of Harlingen was chosen and his name has been given to the award.

Arthur T. Potts worked in the field of citriculture in Texas long before the establishment of a commercial citrus industry. Born in Weatherford, Texas, he graduated from Texas A and M College with a Bachelor of Science degree in horticulture and went to the Beeville Experiment Station as superintendent in the early years of this century. At the Beeville station during the period 1909 - 1912 he determined that satsumas and kumquats could be grown in South Texas. Citrus in that area was grown on trifoliata rootstock which is susceptible to citrus canker. Citrus canker and freezes finally eliminated most of the citrus trees along the Gulf Coast. The citrus industry then moved southward and by 1921 most of the citrus trees in the state were located in the Lower Rio Grande Valley.

Meanwhile Potts joined the Extension Service and traveled over the state locating experiment substations including the one at Weslaco. By 1924 Potts had received master's degrees in horticulture from the University of California and Texas A and M. At that time he moved to the Lower Rio Grande Valley to become a partner with Sam Baker in the Baker-Potts Nursery Co. He later bought out his partner's share in the business and has been closely identified with the development of the citrus industry in the Valley ever since. He also helped in the development of several large citrus tracts including those at Bayview, Progreso and Adams Gardens. Mr. Potts was instrumental in formation of the Texsun Citrus Exchange and served in many civic capacities.

GUIDELINES FOR SELECTING THE RECIPIENT OF THE ARTHUR T. POTTS AWARD

1. The Arthur T. Potts award is to be given to an individual for outstanding contributions to the Horticultural Industry of the Lower Rio Grande Valley. The recipient may be from Industry, State or Federal agencies and need not reside in the Rio Grande Valley nor have been a member of the Society.
2. The members of the selection committee are to be appointed by the President no later than 1 July. The committee will consist of at least four members from the membership of the Rio Grande Valley Horticultural Society. At least one representative from some phase of production horticulture, ie., chemical sales, consultant, producer or supplier, must be a member of the committee. In addition, one member must be a carryover from the previous year to insure continuity within the committee.
3. The committee is to select a candidate for the award and to submit the candidate's name to the Board of Directors for approval by 15 October so that pictures and biographical sketch of the recipient can appear in the Journal of the Rio Grande Valley Horticultural Society the same year the award is presented. In the event the Board of Directors rejects the candidate, the selection committee must then select another candidate and submit this selection to the Board.
4. The committee is to solicit names of candidates for the award from the membership each year. The newsletter may serve as a satisfactory agent of solicitation by including in it a statement indicating that the committee is accepting nominations for the award from the membership.
5. The committee is to keep records of all meetings; these records to include a list of candidates considered for the award and this list passed on to the selection committee the following year. These candidates may then be reconsidered for the award. The Secretary of the Society is responsible for maintaining a file of these records.
6. The committee is responsible for providing a biographical sketch of the recipient, determining the appropriate wording for the plaque and having it ready in time for the Annual Institute.
7. The committee is responsible for purchasing the plaque for the following year in order to insure that a plaque is always available for engraving. The Secretary shall be responsible for storing the plaque.
8. The Arthur T. Potts Award shall be presented to the recipient at the Annual Institute by the President or his appointed representative.

PREVIOUS POTTS AWARD RECIPIENTS

1955 Arthur T. Potts
1956 Wilson Popenoe
1957 E.M. Goodwin
1958 J.B. Webb
1959 G.H. Godfrey
1960 W.C. Cooper
1961 Lon C. Hill
1962 W.H. "Bill" Friend
1963 Paul W. Leeper
1964 Stanley B. Crockett
1965 Harry Foehner
1966 Sam D. Taylor
1967 O.F. Marrs
1968 P.W. Rohrbough
1969 Arthur V. Shull
1970 Frank J. Schuster
1971 Guy W. Adriance
1972 George R. Schulz
1973 Bailey Sleeth
1974 Raphael H. Cintron
1975 J.B. Corns
1976 Henry E. Link
1977 R.T. "Mayo" Correa
1978 A.H. "Dutch" Karcher, Jr.
1979 Charlie Rankin
1980 Glenn G. White
1981 Walter H. Baxter, Jr.
1982 Raymond Cowley
1983 Norman P. Maxwell
1984 Noel E. Ryall
1985 Richard A. Hensz
1986 George Pletcher, Jr.
1987 Herbert A. Dean
1988 Stanley B. Crockett, Jr.

Wayne Showers

1989 Recipient of the Arthur T. Potts Award

Wayne Showers, President of Griffin & Brand of McAllen, Inc., was born in Vernon, Texas. He graduated from Mission High School in 1949 and obtained B.Sc. degrees in Horticulture in 1953 and in Entomology in 1958, and a M.Sc. degree in Entomology in 1958 from Texas A&M University. Mr. Showers served with the Armed Services from 1954 to 1956. His wife, Reba, is from College Station and they have two daughters, Gay Showers Hargis and Brenda Showers.

Mr. Showers is a noted alumnus and avid supporter of education and agricultural research. He has devoted many hours of his personal time in consultation to help develop research and education priorities and opportunities in the state of Texas. His efforts devoted to developing education and research programs in the Horticultural sciences have resulted in tremendous increases in awareness and support of agriculture in south Texas. He serves as a member of the Board of Regents, Texas A&M University System. He previously served as a Vice President of Public Relations with the Texas A&M Association of Former Students (1981-1983); Vice Chairman for Agriculture for the Target 2000 Project (Texas A&M Univ.); as a member of the Development Council, College of Business Administration, Texas A&M Univ.; Board Member of the Aggie Club, College Station; and a past member of the Advisory Committee of Texas A&M Research and Extension Service.

Mr. Showers has been very active in the development of the agricultural industry of south Texas. He was Chairman and Co-founder of the Texas Citrus and Vegetable Insurance Exchange (1978) and served as President of the Texas Citrus and Vegetable Growers and Shippers Association (1978-1979) and Board of Directors, United Farmers Cooperative. He was a former Chairman of the Produce Recovery Fund Board and past member of the Texas Department of Agriculture Food and Fiber Council. He is currently a member of the South Texas Onion, Lettuce and Melon Committees and the Texas Valley Citrus Committee. He is a member of and active participant in several professional societies including American Society of Horticultural Science and Entomological Society of America.

This award is presented to Wayne Showers in recognition of his active role in leadership and interest in developing education and research opportunities that have benefited the horticultural sciences and industry of south Texas.

Officers of the Rio Grande Valley Horticultural Society 1988

PRESIDENT	Craig Bovee
PRESIDENT ELECT	Paul Wright
VICE PRESIDENTS	
Fruit	John Fucik
Vegetables	Clyde Bogle
Ornamentals	Yin-Tung Wang
Garden and Landscape	Will Klement
DIRECTORS	
Fruit	Irene Eubanks
Vegetables	Cliff Chambers
Ornamentals	Carl Baney
Garden and Landscape	Tim Weber
At Large	Larry Chandler
	Dan Fernandez
SECRETARY-TREASURER	Paul Teague
JOURNAL EDITORS	Tina Teague
	Bob Leyden
	Harold Browning
Associate Editors	Roger Albach
	Larry Chandler
	Vic French
	John Fucik
	Bob Rouse
Newsletter	Dan Fernandez
	Lenore Cadena

By-Laws of the
Rio Grande Valley Horticultural Society

ARTICLE I. NAME

This organization shall be known as the Rio Grande Valley Horticultural Society.

ARTICLE II. PURPOSE

The purpose of this Society shall be the advancement and development of horticulture from a scientific and practical standpoint in the Lower Rio Grande Valley of Texas. The horticultural crops shall include citrus, vegetables, ornamental plants, and special fruits such as avocados, grapes, peaches, berries and nuts.

ARTICLE III. YEAR

The fiscal year shall begin January 1 and close December 31.

ARTICLE IV. MEMBERSHIP AND DUES

1. *Eligibility and Election.* Any person or firm interested in any of the phases of horticulture may become a member of this Society upon payment of prescribed annual dues to the Treasurer.

2. *Classification.* There shall be four classifications of annual active membership: Individual, Sustaining, Patron, Special Contributor. Upon payment of dues such members are entitled to vote and to receive publications of the Society for the calendar year.

3. *Dues.* Annual dues shall be:

Individual	$ 7.50
Sustaining	25.00
Patron	50.00
Special Contributor	100.00

Dues are payable at the time of application for membership and become due and payable in January each year.

4. *Good Standing.* Only members whose dues are paid shall be entitled to vote at meetings of the Society, and only such shall be eligible for office.

5. *Termination of Membership.* The membership of any member may be terminated for cause by a two-thirds vote of the members of the Board of Directors, and the accused shall be given an opportunity to appear before the Board of Directors to give reasons why his membership should not be terminated, prior to final action by the Board.

6. *Honorary Membership.* Individuals who have made outstanding contributions to the science and practice of horticulture or to the Society may be elected to honorary membership upon recommendation of the Board of Directors and

approval by two-thirds of the members present and voting at any regular meeting of the Society. Such honorary members shall be exempt from payment of dues.

7. *A.T. Potts Award Recipient.* Each year a distinguished horticulturist may be elected to Honorary Membership in the Society and presented with The Professor A.T. Potts Life Membership Annual Award, consisting of an appropriate plaque, at the Annual Horticulture Institute. These persons shall compose the list of A.T. Potts Award Recipients as well as being on the list of *Honorary Members.* The award recipient being an honorary member shall be exempt from the payment of dues.

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.

2. Other Sections may be added at any annual meeting by an affirmative majority vote of the membership present when such has been approved and recommended by a majority of the entire Board of Directors.

ARTICLE VI. MEETINGS

1. An Annual Horticultural Society Institute shall be held, preferably in January, to present the latest developments in scientific and practical horticulture to all interested persons.

2. The schedule for other meetings shall be developed by the President and a majority of the Board of Directors.

3. The various Sections of the Society will be in charge of the programs throughout the year. Ample notice of meetings shall be given to the members of the Society.

4. The meetings of the Society and the Annual Horticultural Society Institute shall be devoted to horticultural topics from scientific and practical standpoints (ARTICLE II). The presiding officer shall rule out of order all motions, resolutions, and discussions tending to commit the Society to partisan politics or commercial ventures.

5. Twenty-five members entitled to vote shall constitute a quorum at any meeting of the members of the Society for the transaction of business. In matters of procedure, unless otherwise indicated in the by-laws, Roberts Rule of Order shall be observed.

ARTICLE VII. DIRECTORS AND OFFICERS

1. *Board of Directors.* The government of this Society, the direction of its work, and the control of its property and funds shall be vested in a Board of Directors

consisting of eleven members. These members shall include the President, President-elect, a Vice-President and a Director from each Section and a Director-at-large for a total of eleven.

2. *Nomination.* The President, not less than thirty days before the Institute, shall appoint a nominating committee of five persons, including one from each Section. This committee shall make nominations for officers and Directors at the annual meeting of the Society. Such nominations by the committee, however, shall not preclude nominations from the floor.

3. *Election.* The President-elect and the Directors shall be elected by a majority vote of the members present at the Annual Institute and shall assume duties following termination of the Institute.

4. *Term of Office.* The term of office of President shall be for one year. The President-elect shall serve for one year prior to assuming office as president. A Director of each Section shall be elected for a term of two years. His second year in office shall be as Vice-President of his Section. Thus each year there shall be elected one Director for each Section. Directors-at-large shall serve two years. Directors' term of office shall be staggered so that one-half will be elected in each year in order to provide a continuing Board of Directors.

5. *Secretary and Treasurer.* The Board of Directors shall elect a Secretary and a Treasurer who may or may not be a Director and who shall hold office during the pleasure of the Board.

6. *Journal Editor and News Letter Editor.* The Board of Directors shall elect a Journal Editor and a News Letter Editor who shall hold office subject to the pleasure of the Board of Directors.

7. *Gratis Members.* In appreciation for services rendered the Society, the following appointive officers are gratis members during their terms in office: Secretary, Treasurer, Journal Editor, and News Letter Editor.

8. *Succession.* The Board of Directors shall appoint a line of succession of Vice-Presidents.

9. *Meetings of the Board.* The meetings of the Board may be called at any time by order of the President, or by the Vice-President first in succession, acting in his absence, and shall also be called at the request in writing of three members of the Board. A majority of the Board of Directors shall constitute a quorum.

ARTICLE VIII. DUTIES OF THE OFFICERS

1. *President.* The President shall preside at all meetings of the members of the Board of Directors. The President shall preside over all meetings of the Society and submit an annual report of the doings of the Board of Directors and officers and operation of the Society during the preceding year, at the annual meeting.

2. *Vice-President of the Sections.* Each Vice-President shall be a member of the Board of Directors, shall serve as a member of the program committee for meetings, and shall recommend to the Board of Directors the appointment of a sectional committee which he deems desirable to carry on the work of his Section.

3. *Treasurer.* The Treasurer shall be the financial officer of the Society. He shall collect the dues of the members, receive all monies that may be paid to him by virtue of this office, have charge of the funds and make a report of receipts and disbursements at meetings of the Board of Directors and a complete report to the members at the annual meeting of the Society.

4. *Secretary.* The Secretary shall have charge of general correspondence, keep minutes of the meetings, and other secretarial duties. He shall be authorized to hire secretarial help at the discretion of the Board.

ARTICLE IX. COMMITTEES

1. *Nominating Committee.* (prescribed in ARTICLE VII, Section2.)

2. *Editorial Committee.* The President, with the approval of the Board of Directors, shall appoint an Editorial Committee consisting of an Editor, who shall serve as Chairman of the Committee, and one or more Associate Editors. This Committee shall be responsible for assembling and publishing an annual proceedings (JOURNAL) of the Society. The Journal shall include reports of Committees and articles of scientific and practical nature pertaining to horticulture. The Journal shall provide a continuing record of progress in horticulture in the Rio Grande Valley.

3. *Sectional Committees.* These Committees, appointed by each Vice-President with the approval of the Board of Directors (ARTICLE VIII, Section 2), shall consist of three or more members and shall carry on the work of the Sections including the arranging of programs for meetings held under the auspices of the individual Sections. These Sectional Committees shall be known as the Citrus and Special Fruits Committee, the Vegetable Committee, the Ornamentals Committee, and the Gardening and Landscape Committee, etc.

4. *Annual Horticultural Society Institute Committee.* This committee shall be appointed by the *President* of the Society (ARTICLE VI, Section 4). This committee shall plan the activities of the Annual Institute and shall appoint such sub-committees as shall be deemed necessary.

5. *Advisory Committee.* The President, with the approval of the Board of Directors, may appoint an Advisory Committee to the Board of Directors consisting of certain members of State and Federal Agencies concerned with research, education, extension, and regulatory matters in Rio Grande Valley horticulture.

6. *Publicity Committee.* The President, with the approval of the Board of Directors, shall appoint a Publicity Committee consisting of certain members of the Press, Radio and TV, and other people who may be helpful.

7. *Auditing Committee.* The President, with the approval of the Board of Directors, shall appoint an Auditing Committee which Committee shall confer with the Treasurer in preparing an audit to be presented by the Treasurer at the annual meeting.

8. The President shall appoint such other committees as may be deemed desirable and advisable by the Board of Directors and approved by the Board of Directors.

ARTICLE X. AMENDMENTS

These by-laws may be changed or amended at any regular meeting of the Society by a two-thirds vote of all members present at such meeting when approved by the Board of Directors.

The above revised by-laws were approved 18 January 1983 by the Horticultural Society.

RIO GRANDE VALLEY HORTICULTURAL SOCIETY MEMBERSHIP, 1988

HONORARY

R.H. Cintron, Mercedes
R.T. Correa, Weslaco
Raymond Cowley, Weslaco
Stanley B. Crockett, Jr.
Herbert A. Dean
George Godfrey, Prescott, AZ
R.A. Hensz, Weslaco
A.H. Karcher, Jr., Edinburg
Paul Leeper, Weslaco
Norman Maxwell, Weslaco
Charlie Rankin, Edinburg
Noel E. Ryall, Los Fresnos
George D. Schultz, McAllen
A.V. Shull, Edcouch
Bailey Sleeth, Weslaco

SPECIAL CONTRIBUTORS

Bentsen Development Co., Mission
Edinburg Citrus Association, Edinburg
Kinney Bonded Warehouse, Donna
Mid-Valley Chemicals, Weslaco
Stuart Place Nursery, Harlingen

PATRONS

Barbee-Neuhaus Imp. Co., Weslaco
Ciba-Geigy, McAllen
Crockett Groves, Inc., Harlingen
Magic Valley Savings & Loan, Weslaco
Rhone Poulenc, El Campo
Rio Farms Inc., Edcouch
Sharyland Orchard & Nurseries, Inc., Mission
Tex-Ag Co., Inc., Mission
Texas Commerce Bank, McAllen
Tide Products, Inc., Edinburg
Union Carbide Corp., McAllen
Valley Garden Center, McAllen

SUSTAINING

Alamo Bank Of Texas, Alamo
Alamo Transplants, Alamo
Am-Ag, Inc., Edinburg
Asgrow Seed Co., Weslaco
Bayview Orchard Service Inc., Los Fresnos
Mr. Herbert J. Bickel, Dallas

SUSTAINING (Cont'd.)

Burton Auto Supply, Inc., Weslaco
Caldwell Jungle Nursery, Raymondville
K.P. Caskey Estate, Weslaco
Cherrington Nursery, Harlingen
Citrus Management Corp., Mission
Compton Grove Care, Mission
Country Farm Nursery, Edinburg
Crest Fruit Co., Alamo
Curltex Citrus Nursery, Edinburg
D's Plants, La Feria
Davidson, C.E. and Mary, Mission
Donald Thompson Grove Care, Weslaco
Edinburg Improvements Assn., Edinburg
Esco Ltd. Co., Pharr
Eubanks Nursery, McAllen
Everhard Nursery, McAllen
First National Bank, Mission
First State Bank & Trust Co., Edinburg
First National Bank of Mercedes, Mercedes
FMC Corporation, San Antonio
Forever Aloe Plantation, Harlingen
Freeway Drive-In Nursery, Edinburg
Gene's Ornamental Farms, Los Fresnos
Green Valley Sales, San Benito
Guerra's Inc., Mission
Gulf Distributing Co., Weslaco
Gulfstream Green Houses, Los Fresnos
Hammar Greenhouses, Donna
Harlingen Garden Club, Harlingen
Heaton Implement Co., Inc., Edinburg
Hertzler Hess Nursery, San Juan
Hidalgo County Farm Bureau, Pharr
Hidalgo Bank & Trust, Mercedes
Hidalgo Soil & Water Cons., Edinburg
Hidalgo Savings & Loan Assn., Edinburg
Interstate Fruit & Veg. Co., La Feria
J.S. McManus Produce Co., Weslaco
Jeske's of Alamo, Alamo
Jimmy Hill, McAllen
Albert H. Karcher
Knapp-Sherrill Canning Co., Donna
I. Kunik Co., McAllen
K-Y Farms, Harlingen
La Laguna Nursery, Mission
Janie B. Lee
Lewis Nursery, Pharr
Llano Grande Nursery, Mercedes

SUSTAINING (Cont'd.)

Lily Research Lab., Mission
Longwell Farms, Inc., Hargill
Lone Star Floral, McAllen
Lynn Jones Farms, Inc., Mission
M & W Fruit Co., Edinburg
Magic Valley Elec. Corp., Mercedes
Magic Valley Nursery, Pharr
McAllen State Bank, McAllen
McNar Farms, McAllen
Mid-Valley Chemicals, Weslaco
Mid-Valley State Bank, Weslaco
National Bank of Commerce, Edinburg
Pan American Bank, Brownsville
Patio Plantation, Edinburg
Pletcher's Wholesale Nursery, Inc., Harlingen
Plier's Greenhouse, Harlingen
Precision Orchards, Mission
Pride of the Citrus of TX Inc., Mission
Resaca Nursery, San Benito
Roeder, Judy K., Weslaco
Rio Properties, Inc., Edinburg
Rohm & Haas Co., Memphis, TN
Semco, Pharr
Smiley Grove Care, Mission
Southland Care Co., Edinburg
South Texas Tropical Foliage, Harlingen
Stauffer Chemical Co., Weslaco
Stuart Place Nursery, Harlingen
Sun-Up Growers, Mission
Sunrise Tropicals, Donna
Sun World International, Coachella, CA
Texas Citrus Exchange, Mission
Texas Citrus Mutual, McAllen
Texas Valley Citrus Comm., McAllen
Texas Plant & Soil Lab, Edinburg
TexaSweet, McAllen
Texsun Corporation, Weslaco
Townsend Implement Co., McAllen
Tropical Nursery, McAllen
Valco Chemicals, Harlingen
Valley Gardens, McAllen
Valley Prod. Credit Assn., Harlingen
Valley National Bank, McAllen
Vic's Nursery, McAllen
W.T. Ellis Company, Mission
Walter Baxter Seed Co., Weslaco
Waugh's Fruit Ranch, McAllen

SUSTAINING (Cont'd.)

Weaks Martin Imp. Co., Inc., Mission
Willacy Soil & Water Con. Dist., Raymondville
Wood Implement Co., Inc., Donna

REGULAR

Albach, R.F., Weslaco
Amador, Jose, Weslaco
AM-AG, Edinburg
Anderson, N.L., San Benito
Arnall, Mrs. N., Weslaco
Arpaia, Mary Lu, Riverside, CA.
Ausmus, W.V., McAllen
Bailey, L.L., Kingsville
Baney, Carl, Linn
Barnes, L.W., College Station
Barrett, B., Alamo
Barron, Jorge Elizondo, Victoria, Tamaulipas, Mex.
Barter, Darlene, Mercedes
Bentzinger, H.A., Edinburg
Bevil, Lancer, Edinburg
Bibbs, Melissa, Mission
Blessington, Tom, Weslaco
Bogle, Clyde, Weslaco
Bogue, J., McAllen
Boren, R., McAllen
Boulton, G.A., Mission
Bovee, Craig, Edcouch
Bowlin, V., La Feria
Brabham, C.C., Jr., Lyford
Bravo, E., Mexico
Bromiley, Adele, Brownsville
Browning, Harold, Weslaco
Buford, W.R., Harlingen
Burger, David, Davis, CA.
Camp, Thomas, Weslaco
Carpenter, M., Mission
Carter, W.W., McAllen
Castle, W., Lake Alfred, FL.
Chambers, Cliff, McAllen
Chandler, K., Edinburg
Chandler, L.D., Weslaco
Chavez, Juan E., Mexico
Christian, John E., Raymondville
Clark, E.W., Olmito
Coltharp, Sharon, McAllen
Connolly, C.C., McAllen
Corona, E.R., Primera
Cox, E., Weslaco
Crane, R.H., McAllen
Crawford, J., Sugerland
Crawford, R.K., McAllen
Cruse, R.R., Weslaco
Cunningham, Gary, McAllen
Davalos, G., Mexico
Davidson, Tom, Corpus Christi
Davis, Frank, Harlingen
Dean, H., Weslaco
Duos, Gene, Los Fresnos
Eckhardt, R., McAllen
Edelson, J., Weslaco
Elizondo, A., McAllen
Escobar, Mrs. R.S., Pharr
Eubanks, Irene K., McAllen
Everitt, J.H., Weslaco
Fankhauser, G.H., Mission
Fankhauser, H.I., Mission
Fankhauser, D., Mission
Farrald, Carol, Elsa
Felker, P., Kingsville
Ferguson, James, FL.
Fernandez, Daniel, Mercedes
Flowers, Jud, Mission
Flowers, S., McAllen
Foerster, C.O., Elsa
Folger, D., Mission
Forever Aloe Plantation, Harlingen
Franco, Arturo Diaz, Progreso
Frazier, S., Harlingen
French, J.V., Weslaco
Fucik, J., Weslaco
Gage, Ed, San Antonio
Gallasch, P., Australia
Garza, G., Mexico
Gerberman, A.H., Edcouch
Gibbs, Melissa, Weslaco
Gibson, F.A., McAllen
Goff, Mrs. J., Harlingen
Goldsberry, Dennis, Donna

Gonzalez, C.L., Weslaco
Gonzalez, E.G., McAllen
Gonzalez, Ramiro, Mexico
Goode, J.P., Weslaco
Goodwin, G., Mission
Griffin, James, Texarkana
Grossman, D., McAllen
Hammar, Mary T., Donna
Harding, G., Raymondville
Harmon, Jay, Brownsville
Hartz, Tim, Weslaco
Heald, C.M., Weslaco
Hearn, J., Edinburg
Hefley, Ed, Weslaco
Henderson, S.W. Jr., Edinburg
Hensz, R.L., Harlingen
Hertz, A.E., Harlingen
Hertzler, B.M., San Juan
Hertzler, K., San Juan
Hill, Jimmy, McAllen
Hoelscher, Nick, Pharr
Holcomb, Blaine, Mission
Holler, T., Mission
Hopkins, E., Elsa
Jacobs, J., Harlingen
Jeske, D.L., Alamo
Jeske, Glen, Alamo
Jones, L.F., Mission
Jones, Whitley, Mission
Karle, F.G., McAllen
Kersten, M., Donna
Klement, Jon, McAllen
Klement, Will, Mission
Kutzenburger, J., Harlingen
La Gow, H., Silver Spring, MD
Larson, L.V., Sherman, TX.
Laruick, H.E., Wisconsin
Lattimore, Mrs. K.C., Edinburg
Laverty, J.A., Los Fresnos
Lee, J., Brownsville
Leidner, T.G., Edinburg
Lewis, L., McAllen
Lime, B.J., Weslaco
Longwell, Don, Hargill
Longwell, Eldin, Edinburg
Love, Glenn and Beth, Weslaco
Magyar, T., Harlingen
Marguleas, H.P., CA.
Mart, Marion, Raymondville
Martinez, Jose, Weslaco
Mayeux, Herman, Harlingen
McCrate, Sean, Weslaco
McFarland, W., Edinburg
McLarty, Michael, Mission
McNar, Farms, McAllen
Meier, A.C., Mission
Menges, R., Weslaco
Meyerdirk, D., Riverside, CA.
Miller, J.C., College Station
Miller, M., Weslaco
Mitchell, R., Donna
Moreno, D.S., McAllen
Murray, A., McAllen
Murray, C.E., McAllen
Neal, J.R., Mission
Nelson, Darrell, Donna
Netz, C.J., Brownsville
Newcomb, D.A., Palm Springs, CA
Nishuira, M., Japan
Nixon, P.R., Weslaco
Nunn, R.E., Edinburg
Orr, E.B., La Feria
Oswald, P., McAllen
Pape, J., Mission
Parker, Willette, San Benito
Paterson, D., Overton
Pehrson, J.E., CA.
Petta, Jimmy, Corpus Christi
Phillips, Mike, Bryan
Pierce, L., College Station
Pospishil, J., La Feria
Pratt, J.B., FL.
Psarros, N., Greece
Ramirez-Diaz, J., Mexico
Reinking, R.B., Harlingen
Rice, H.E., La Feria
Robacker, K., Mercedes
Rocha, M., Mexico
Rockers, D., Mission
Roeder, A., Weslaco
Roth, J., Weslaco
Rouse, R., Weslaco
Ruby Red Grove Service, Mission
Sakai, Mitsoru, McAllen

Saldana, G., Weslaco
Sauls, Julian, Weslaco
Schultz, Marvin E., Mankato, MN
Schuster, F., Alamo
Scott, Andy, Edcouch
Scott, Bernard, Mission
Seal, Tommy, McAllen
Seifried, Ed, McAllen
Serna, R.R., Mexico
Sherman, D.R., Michigan
Skaggs, W., La Feria
Sluis, N., Edcouch
Smiley, R., Mission
Smith, Dorothy, McAllen
Smith, G.B., Harlingen
Smith, L., Edinburg
Smith, R.C., Donna
Snider, B.B, Harlingen
Spaulding, W., McAllen
Srdar, F., Minneapolis
Stein, E., Weslaco
Summy, K.R., Alamo
Swietlik, D., Weslaco
Taylor, J.L., Edinburg
Teague, P., Edcouch
Teague, T., Edcouch
Thomas, D., Weslaco
Thomas, J.R., Weslaco
Timmer, P., Lake Alfred, FL.
Tredemeyer, T.R., La Feria
Van Meter, C.L., San Benito
Vargas, J., Progreso
Villalon, B., Weslaco
Von Arnim, A.G., Sri Lanka
Wallace, D.K., Weslaco
Wallace, Ed., La Feria
Wang, Yin-Tung, Weslaco
Warren, D.G., Edinburg
Warren, W., McAllen
Whitlock, L., McAllen
Wiedenfeld, R., Weslaco
Wiegand, C., Weslaco
Wilhite, H., San Juan
Willacy Soil & Water Con. Dist., Raymondville
Wilkerson, M.C., College Station
Williams, J.L., Los Fresnos
Williams, R.R., McAllen
Williamson, D.L., Harlingen
Willis, P., Brownsville
Witbank, W., Gainsville, FL.
Wood, R., Weslaco
Woodall, Bill, Lansing, MI
Work, Alice, Harlingen
Wright, Paul O., Brownsville
Wutscher, H., Orlando, FL.

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Vegetable Crop Fertilization[1]

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Additional Index Words: nitrogen

ABSTRACT

Vegetable nutrition generates much interest because fertilization is absolutely necessary for maximum production, yet it is impossible to come up with an exact answer on rates, timing and methods of application. Since nitrogen (N) goes through such a wide variety of possible transformations and movement over time, there is currently no soil test which can accurately predict responses to N fertilization under subtropical conditions. The information that a grower can use to determine fertilizer needs is generated by various fertility studies, and his own previous experience on a particular field. The most important time to apply fertilizer to vegetables is early during the growing season, either preplant or at thinning, even though crop demands are greatest during later stages of growth. Early applications can be placed in a location that is more accessible to the plant than later applications. Apparently N losses are not as great as originally predicted. Slow-release fertilizers have been found to be effective on long-, cool-season crops having high N requirements and grown under conditions prone to soil N losses. Foliar fertilization is effective only for applying micronutrients which are unavailable due to the calcareous nature of these soils. Foliar fertilization is not an effective means of applying major nutrients, particularly N, since only a small fraction of plant requirements can be satisfied. Fertilizer research continues to make steady progress toward identifying fertilizer needs and developing efficient and economical fertilizer practices.

Fertilization of vegetables is a topic which generates a great deal of interest and occasional controversy because fertilizer application is an absolute necessity and constitutes a major cost of producing vegetables. There is not, however, a clear, exact answer about how much of what to apply, when to apply, or by what method. Whenever you ask an "expert" what fertilizer should be applied the answer you get is "It all depends.....". Then he will proceed to describe all types of factors that influence nutrient availability and uptake by a crop. We are quite certain that a cabbage crop will use between 5½ and 6 lbs N/ton, or an onion crop will use about 6 lbs N/ton. The critical questions are how much of that will be supplied by the soil and how much needs to come from the fertilizer? If conditons for N uptake are favorable, there is little leaching, the rate of crop growth is high and the field's natural fertility in terms of N is low, then the crop will use about half of the applied fertilizer N. This figure could be, and usually is, much less. Therefore, most of the N fertilizer applied is not used by the current crop, and we tend to over-apply in order to compensate for this low recovery.

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[1] Presented at the 42nd Annual Institute of the Rio Grande Valley Horticultural Society, January 25, 1988.

What information can be used in making fertilizer decisions? It seems reasonable to be able to take a soil sample and perform a chemical analysis to determine the level of a plant nutrient present. Again, we already know that a typical Rio Grande Valley soil contains about one ton of N per acre in the top foot. This is organic N contained in decomposing plant residues. Since plants take up N mostly in the nitrate (NO_3^-) form, why not just measure the available nitrates? In some cases this approach has been satisfactory (2), but usually there values vary tremendously depending on climatic conditions, cultural practices, etc. This is because N undergoes rapid transformations from organic to mineral forms and vice versa. Therefore, the NO_3^--N level at any one point is a poor indicator of the amount of N that will become available during the growing season. This situation is aggravated by the Valley's subtropical climate which further speeds up N transformations and they occur during a much longer period than in a moderate climate due to the extended growing season. At this point, some sort of mineralization index appears to be the most feasible soil test that would give an indication of the amount of N fertilizer to apply. However, such a test would be time consuming requiring the incubation of the soil sample over a long time, adding considerably to the expense.

Presently, the best information available to growers on fertilizer rates can be found in the reports on fertilization studies which have been conducted over years on various crops and under various conditions. These studies have been summarized in the Rio Grande Valley Soil Fertility Handbook (1). The interpretation and consequent application of such information requires considerable knowledge and experience since it is unlikely that the same conditions under which the fertility trials were run will reoccur. This is where the extension specialists and consultants are vital, since it is very difficult for growers to be aware of all the research being conducted, and to have a mastery of the various principles involved. Finally, past experience is an extremely important part of the information needed to make fertilizer decisions. How has this particular field performed in the past, and how much fertilizer did it require? Incorporation of all these various elements into a decision on the most economical level of fertilizer to apply is really an art as much as a science.

Now let's review some of the areas where attempts are being made to improve fertilization efficiency.

Timing of application has always been considered extremely important. It is widely accepted that not only can soluble fertilizers be rather quickly lost to leaching, but also to other transformations as well. Multiple or split applications have, therefore, been widely adopted as a way to insure adequate availability throughout plant growth. First of all, research studies have shown that immediately following tillage and bedding operations, there is an increase in available soil NO_3-N(3). Apparently, the soil mixing and warming, as well as an increase in available moisture from irrigation, accelerate mineralization and causes an increase in NO_3-N, even where no N fertilizer was applied. Having pondered this finding, let us now consider that vegetable crops have been shown to benefit most from early N fertilization (4,5) rather than late applications. This could be interpreted to indicate that the crop needs more N during early growth than later in the season; but this does not make much sense because we know that N uptake increases over time as the rate of crop growth increases (Fig. 1). A crop like celery puts on 50% of its total weight in the last two weeks of growth. This leads to the conclusion that early applications must be more accessible and more available to the crop than later applications or that at later dates the soil can naturally satisfy crop demand. Also, where the commodity produced is a reproductive or storage organ for the plant, excess nutrient availability from a soluble fertilizer applied late in the season could result in luxury consumption causing the plant to partition photosynthates into vegetative rather than reproductive parts, thus lowering yields.

Fertilizer placement is another important consideration. Early applications (preplant or at thinning) can be placed in close proximity to the root system. Later applications must be placed outside the already developed root system to avoid injury, then rely on water to move the fertilizer to the plant. This is an inefficient transfer because irrigation water moves in many directions, not just in a path from the fertilizer band to the roots. Rainwater could be even less efficient since it is quite possible for the direction of flow within the bed to move the fertilizer down and out toward the furrow away from the roots. Injection of fertilizer directly into irrigation water is also inefficient because of the problems stated above and because infiltration patterns from flood irrigation are very uneven. Approximately twice as much water infiltrates the soil near the supply end of a field compared to the tail end.

If all the fertilizer is applied early to insure maximum availability, what about all the losses we expect? Evidence continues to accumulate indicating that, except in unusual circumstances, N fertilizer losses are not as large as originally anticipated. Losses may be concentrated primarily in the center of the furrow, and much lower through the part of the bed containing the roots and fertilizer. Studies have shown that single preplant fertilizer application produces maximum yields, and split application provides no additional benefits on most spring vegetable crops, such as peppers or melons (4). Special situations may occur such as unusually heavy rainfall which will leach out fertilizer N, requiring additional applications, but this is rare in the spring. Such events are more likely to occur in the fall when cool season crops such as cabbage and onions are in the field and take much longer to mature. These winter crops are, therefore, less likely to be able to achieve maximum yields on a single preplant application of a soluble fertilizer.

Slow-release fertilizers offer promise of overcoming several of the problems described above. These products are not new. Tennessee Valley Authority developed sulfur-coated ureas over 25 years ago. Today, a wide variety of these materials are used in special situations. These fertilizers retain the N against loss while gradually making the N available to the crop in a pattern which hopefully matches crop requirements. The question arises: Is the use of slow-release materials going to result in increased yield or quality and/or increased returns to a grower? In many situations, such as ornamental production, turfgrass maintenance or on other high value horticultural crops, the answer to these questions is yes. In the Valley, vegetable crops that are grown in the spring, have a relatively short growing season, and do not have a particularly high N requirement will almost never benefit from slow-release fertilizers. Under such conditions, the losses these products are intended to prevent generally never occur. Longer season crops with higher N requirements which are grown under conditions prone to N losses from the soil are more likely to benefit from slow-release fertilizers. Studies have shown increased yields for a single early application of a slow-release fertilizer, compared to delayed, split applications of a soluble fertilizer at the same rate (5). The problem is that we are considering using a more expensive fertilizer to control losses that occur to different degrees each year. This reduces the decision to a cost-benefit analysis based on probabilities. Most slow-release fertilizers available in the past have been granular materials, but since vegetable-producing areas, like the Valley, are very strongly oriented toward the use of liquid soluble fertilizers, companies are now developing and testing slow-release liquids and suspensions that are compatible with the distribution, storage and application systems currently in use.

Another topic that often generates considerable interest is foliar application of plant nutrients. This is a very attractive concept because, in theory, you eliminate the inefficient intermediate step of going through the soil and roots to get nutrients into the plant. Instead the nutrients move directly into the plant through the leaves. In practice, however, it doesn't always work that well. First, only a fraction of the nutrients applied are actually absorbed through the leaf. The rest misses the foliage or gets washed off. Absorption is an active metabolic process and certain forms of various nutrients are selectively taken up more readily than others. The next problem is that only a very low concentration of fertilizer can be applied safely to leaves - higher levels cause leaf injuries. Safe levels for such nutrients as N are considerably lower than the total amount the crop will typically require. This means that multiple applications of fertilizer will be required which is an expensive proposition. Various factors such as crop condition, air temperature, and humidity are all very critical. To increase uptake efficiency, very fine droplet size, a sticker/spreader agent, and possibly even other additives such as urea-N to improve micronutrient uptake are necessary. The usual conclusion is that a crop's normal N requirement should be met using a soil application program. Only in an unusual situation would foliar application of N serve as a temporary emergency remedy. This might be where heavy rains have leached available N and the situation needs to be corrected quickly. Foliar fertilization to correct micronutrient deficiencies when they are identified has been found to be effective. This is particularly true for nutrients that are made unavailable due to the high pH of Valley soils. However, the economics of correcting micronutrient deficiencies using foliar sprays are not clear at the moment.

Research work is continuing in the Valley and in other vegetable growing areas to improve the ability to identify fertilizer requirements and to meet those needs as efficiently and economically as possible. Unfortunately, plant nutrition research does not lead to glamourous breakthroughs. We build little by little on the hard work of those who have gone ahead of us; and if you look at the overall progress in this area, improvements in fertilizer management have contributed substantially to the tremendous increase in production that many of us today take for granted.

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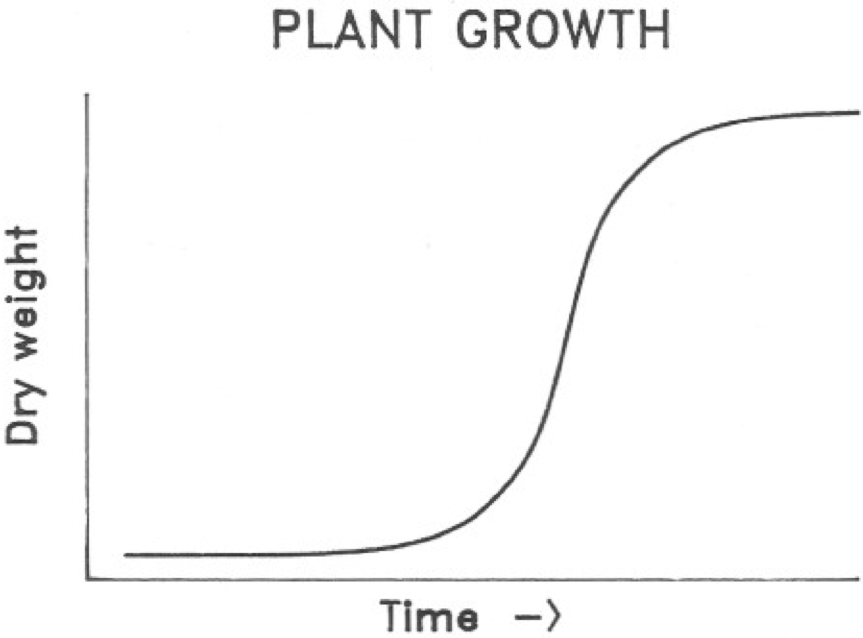

Fig. 1. A typical pattern of plant growth over time for many vegetable crops.

Plant Water Relations: Effect on the Growth of Woody Ornamental Plants

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Water Quantity and Quality. Water is a precious commodity to the nursery industry. Increasing urban population pressure for water directly affects nursery production and landscape usage. In the large nursery producing states such as California, Texas, and Florida water quantity and water quality are problems the nursery industry must face. Last year there were drought problems in the southeast, and this year the northwest has water availability problems. All nursery producing areas face drought problems either on a regular or periodic basis.

Water relations in the nursery industry starts in the beginning stages of plant propagation. Selecting cuttings early in the day from nonstressed stock plants is critical for cutting survival and insuring that propagule turnover time to liner stage, container and/or field production stage proceed as rapidly as possible without the loss of plant momentum and quality.

Problems Confronting the Nursery Industry. There are a number of problems confronting the nursery industry which include: 1. increased production costs, 2. the need to develop more economic and efficient production systems, 3. increased government regulations affecting water usage, fertilizer (high soluble salts) and pesticide runoff and 4. the need to introduce new species. Nursery plant water relations plays a role in all of the four outlined problem areas. Economics and water availability will continue to play a larger role not only in the minimum amount of water we can use in producing and maintaining a landscape plant, but also in more efficiently utilizing water to limit nursery runoff.

Overhead Irrigation. To date the most cost effective method for applying irrigation water has been with an overhead sprinkler such as a rainbird #25 and other available makes and models. Overhead irrigation is inefficient due to such factors as: 1. heat which can cause twenty percent or greater evaporative losses, 2. wind, which causes poor, uneven and wasteful distribution of water, and 3. the canopy effect of foliage which shields/prevents both irrigation water and fertilizer (fertigation) from reaching the media and root system of the container. It has been estimated that the canopy effect causes water and fertigation losses of fifty to seventy percent.

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[1] Summary of a talk presented at the 42nd annual Horticultural Institute January 26, 1988.

How Much Water To Apply. Teaching employees when and how to water remains more an art than a science. There is a need to establish more scientific procedures for making water management decisions. It is difficult to measure the moisture status of landscape plants produced in high organic media used in conventional production. Buoycous gypsum blocks and soil psychrometers, which have been used in field mineral soils, are inadequate for the bark media that industry uses in container production. Soil tensiometers also present problems in organic media.

Water relations is also an important criteria for selecting desirable landscape plants. Plant resistance to drought and the ability to tolerate lower water regimes are important breeding and selection criteria for new and useful landscape plants.

Water Research Objectives. One of the objectives in water relations research is to identify landscape plant that are water-use efficient. It is important to note that there are differences between drought resistance and water-use efficiency. Certain desert plants are very water-use inefficient and will use high amounts of water when available; however under drought conditions when water is limited, these plants cease growth and become dormant. We need to establish for the nursery industry which plants are efficient and which are inefficient in water usage. Currently, we are evaluating plant species considered by the industry to have varying water efficiencies in order that recommendations for water management decisions be based on factual and repeatable data, and not solely on personal observations.

How Landscape Plant Resist Drought. One of the first areas we need to address in evaluating and making recommendations is how landscape plants resist drought. Two such mechanisms are drought avoidance and drought tolerance. Drought avoidance can include wilting of leaves, closing of stomates, leaf abscission (drop) and temporary cessation of growth. Drought tolerance includes certain physiological and cellular mechanisms such as solute accumulation or increased tissue elasticity. As an example, *Ligustrum japonicum* uses drought tolerance to resist drought. This landscape plant accumulates greater concentrations of carbohydrates in leaf cells so that photosynthesis can continue even under lower soil moisture regimes. Ligustrum is one of the most water efficient plants that we have evaluated to date.

Another objective of our research is to determine the minimum amount of water needed to produce a nursery crop without quality loss. This information is needed for all nursery producing regions in the U.S.

An integrated approach is needed from production to landscape site in determining water use efficiency. How plants utilize water in a container with a restricted root system can be quite different from their response in the landscape. Crape myrtle (*Lagerstroemia indica*) is one of the most water inefficient plants when grown in containers; it wilts rapidly and uses large quantities of water. Yet, when established in a landscape with its extensive root system developed, crape myrtle has good resistance to water stress and is one of the most successful summerblooming landscape plants in the southern U.S. In container production the natural ability of crape myrtle to avoid drought with an extensive root system is lost, but is regained after establishment in the landscape.

Another goal is to develop research techniques that a nursery producer can use in evaluating landscape plants for water efficiency.

Research Parameters For Measuring Water Efficiency. Currently, we have been using 4 parameters to test landscape plants for water efficiency. This includes plant evapotranspiration which is measured by the gravimetric method of weighing container grown plants. Another technique is to measure stomatal conductance and transpiration with an autoporometer. A pressure chamber, which measures the water potential of leaves and stems is a useful tool for determining internal plant water stress. Pressure chambers are being used by the forestry industry for seedling production. By monitoring internal water status, management decisions can be made on controlling seedling growth, height, dormancy and other important parameters. Control of the water relations of horticultural crops has been used for some time to influence such factors as flowering, height, hardiness and dormancy; yet the science of water management is still to be fully developed. Another parameter studied is root hydraulic conductivity which is the ability of the root system to take up water and the actual flow of water through plant roots.

New Plant Materials. An interesting concept that integrates water use efficiency with low maintenance plants is the development of Meidiland^R roses from Europe. These roses are not meant to compete with the high maintenance, showy and more disease susceptible hybrid-T roses. Instead Meidiland roses have been developed and marketed as low maintenance, disease, temperature and water stress resistant for landscape, park and highway plantings.

Ways to Improve Plant Water Relations. Most means of reducing plant stress improves plant water relations. In studies we have conducted in containers high temperature always adversely affected plant water relations. Possible ways to reduce water loss include:

1. utilize water-use efficient plants.
2. use can-tight spacing of container where appropriate.
3. use border rows of media filled containers or larger sized plants to shield interior rows from wind and temperature extremes.
4. use shade cloth, saran, or lath structures to reduce light intensity and heat load.
5. use companion plantings of shrubs and smaller sized plants in the understory of larger specimen plants to more efficiently utilize nursery space and reduce heat load.
6. manipulate air drainage so that adequate air movement occurs to minimize disease problems but sufficient wind protection exists to help minimize dessication and evapotranspiration.
7. mulch and insulate container media-root systems and landscape plantings. Artificial mulch systems of waxed cardboard and plastics to line the top surface of exposed containers can cut water loss 20 to 30%.
8. use low volume irrigation equipment such as drip irrigation micro spray emitters, fan jets, mini or micro spot sprinklers.
9. to minimize evaporative water losses irrigate early or late in the day.

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The Effect of Dropp (Thidiazuron), a Urea Derivative with Cytokinin Activity, on Sour Orange Seedlings and Field-grown Grapefruit Trees[1]

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ABSTRACT

In two greenhouse experiments sour orange (S.O.) seedlings were foliar sprayed with thidiazuron (TDZ) (N-phenyl-N-1,2,3-thiadiazol-5-ylurea) at 0.125-2.00 ppm a.i. concentration. TDZ reduced shoot growth for 2 weeks but compensatory growth during successive 2 weeks offset the effect. TDZ induced leaf and stem chlorosis, axillary bud swelling, and bi- and trifoliate leaf formation. Leaf stomatal conductance increased 3 weeks after treatment and persisted for a further 3 weeks. Lateral shoot formation, leaf area, plant dry weight, and root:top ratio were unaffected. S.O. responded similiarly to two formulations of TDZ. Foliar sprays with TDZ to field-grown 'Rio Red' grapefruit trees at 8 or 56g a.i. ha^{-1} rate induced responses in developing leaves such as puckering, increase in area, dry weight, specific leaf weight, and caused chlorosis on leaves of all ages. Visual symptoms resembled those suspected of being caused to grapefruit by TDZ spray drifts from cotton fields. In the following spring, bud-break, flowering, and fruit set were reduced and growth flush delayed. Responses were positively related to TDZ rate and growth flush intensity at time of treatment.

Spray drifts of the cotton defoliant, Dropp 50% (thidiazuron, N-phenyl-N'-1,2,3, -thidiazol-5-ylurea) (NOR-AM Chemical Company, Wilmington, Del.) widely used in the Lower Rio Grande Valley of Texas have been suspected of having a significant effect on citrus manifested by leaf distortion and chlorosis. Exploratory greenhouse and field experiments were conducted at the Texas A&I University Citrus Center in Weslaco to ascertain the nature and consequences of foliar-applied Dropp (TDZ) on greenhouse-grown sour orange (*Citrus aurantium* L.) (S.O.) seedlings and field-grown grapefruit (*Citrus paradisi* Macf.) trees.

[1]Presented at the 42nd Annual Meeting of the Rio Grande Valley Horticultural Society, January 26, 1988.

GREENHOUSE STUDIES

Two greenhouse experiments, both of 9 weeks duration, were designed to: investigate the effects of foliar sprays with TDZ at concentrations ranging from 0.125 to 2.00 ppm on S.O. seedlings in terms of formative effects on leaves, growth of shoots and roots, dry matter production, and water status; examine whether the reported cytokinin-like properties of the compound (Mok et al., 1982) had any potential for practical use as a growth regulator. The responses of S.O. to two different formulations of TDZ (Dropp 50% and technical grade 98%) at equimolar concentrations were compared. In both experiments each treatment consisted of 6 plants (replicates) arranged into completely randomized blocks. Foliar-sprays were applied on July 14 and September 18, 1987 in Experiment 1 and 2, respectively. Results were analyzed using polynomial regression analysis for replicated experiments. Statistical significance of linear, quadratic, and cubic models were tested using the F-test.

Concentrations ranging from 0.125 to 2.00 ppm of both TDZ formulations were to some degree phytotoxic, causing leaf puckering and chlorosis. Initial pilot studies indicated that concentrations of 2.00 ppm and less were non-injurious. This attests to the extreme sensitivity and variability in the responses of S.O. to TDZ.

Leaf and stem chlorosis were only obvious on those parts of the plant present at the time of application indicating that injury occurs only to those plant tissues which are involved in TDZ absorption; tissues formed post treatment showed no symptoms. This phenomenon suggests that TDZ is either not translocated or is translocated in quantities insufficient to cause injury due to dilution in new growth. It is also possible that the compound is metabolized into inactive metabolites (Mok and Mok, 1986).

TDZ had a negative effect on shoot growth 14-30 days after treatment but it was offset by compensatory growth 31-46 days after treatment (Table 1). Total root length was decreased by TDZ treatment but only at concentrations of 0.25 ppm and higher. No differences in the root:top dry weight ratios were observed. Branching was not affected by TDZ treatment indicating that bud-break, reportedly induced by the compound on other plant species (Wang et al., 1986), did not occur on S.O. seedlings. Slight swelling of axillary buds was noticed on many treated plants as well as the formation of bi- and trifoliate leaves and the production of leaves from thorns. Leaf area, dry weight, and specific leaf weight (SLW) of leaves formed after TDZ treatment were unaffected.

At TDZ concentrations of 0.25-2.00 ppm, leaf chlorosis was severe enough to cause a decline in stomatal conductance (gs) soon after treatment. Stomata on leaves formed after spraying and unaffected by chlorosis showed no response. On plants treated with 0.125 and 0.24 ppm TDZ, leaves present at the time of spray were only mildly affected by chlorosis and gs increased about 3 weeks after treatment with the effect persisting for a further 3 weeks (Table 2). This elevated gs was not accompanied by lowering of stem water potential which suggests increased stem and/or root hydraulic conductivity.

In terms of gs and growth, TDZ (technical grade) elicited similar reactions to that of Dropp indicating that TDZ was responsible for the responses observed.

None of the effects noted in these two studies can be considered of practical benefit to citriculture. The incidence of chlorosis observed at the concentrations of TDZ used, preclude any positive recommendations. Further research will have to determine whether foliar applications with lower concentrations of TDZ or alternative application methods can elicit any beneficial effects in the absence of injuries.

Table 1. Increases in total shoot length (terminal + lateral) on young sour orange seedlings foliar-sprayed with TDZ on July 14, 1987.

TDZ	Shoot growth (cm)				
	Days after treatment				
(ppm)	0-14	15-30	31-46	47-61	Total
None	9.1	30.7	7.7	14.1	61.5
0.25	17.0	22.5	13.6	14.8	67.8
0.50	13.1	16.7	14.9	11.7	56.3
0.75	16.6	13.2	13.2	11.5	54.6
1.00	19.5	18.6	16.1	12.7	67.0
1.25	14.0	19.0	18.6	19.1	70.7
1.50	15.3	17.3	10.3	15.3	58.1
1.75	11.6	14.4	9.5	14.1	49.6
2.00	17.2	10.1	11.9	11.7	50.9
Significance					
Linear	NS	***	NS	NS	NS
Quadratic	NS	NS	*	NS	NS
Cubic	NS	**	NS	NS	NS

NS; *; **; ***; non-significant; or significant at 5% (*); 1% (**) or 0.1% (***) levels.

Table 2. The effect of foliar-sprayed Dropp (TDZ-D) or TDZ technical grade (TDZ-T) on stomatal conductance of fully expanded leaves on sour orange seedlings.

Concn	Stomatal conductance (cm s^{-1})					
(ppm)	TDZ-D	TDZ-T	TDZ-D	TDZ-T	TDZ-D	TDZ-T
	3 Wks post treatment		4 Wks post treatment		5 Wks post treatment	
0	0.19	0.19	0.19	0.19	0.42	0.42
0.125	0.27	0.23	0.30	0.22	0.64	0.58
0.24	0.26	0.35	0.32	0.35	0.49	0.68
Significance						
Linear	NS	***	*	***	NS	***
Quad.	NS	NS	NS	NS	*	NS

NS; *; **; ***; non-significant; or significant at 5% (*); 1% (**) or 0.1% (***) levels.

FIELD STUDIES

Two field experiments were conducted on 2-year-old 'Rio Red' grapefruit trees which were foliar-sprayed at two TDZ rates: 8 and 56g a.i. ha^{-1}. The highest rate, 56g ha^{-1}, equates with that applied, on an area basis, for the defoliation of cotton while the other, 7 times lower, was applied to simulate spray drift. Treatments were applied to the trees during a late summer flush of growth - mid August and early September; the period during which cotton is defoliated in the Lower Rio Grande Valley. In the first experiment, the trees experienced a less intense growth flush than in the second; an average of 15 vs 49 flushing branches per tree, respectively. The objectives were to determine the effects of TDZ on grapefruit with specific reference to leaf injury and formative effects, leaf and shoot growth reponses shortly after application; and growth, blossoming, and fruit set in the spring following treatment. In both experiments each treatment consisted of five trees (replicates) arranged into completely randomized blocks. Results were analyzed using polynomial regression analysis for replicated experiments. Statistical significance of linear and quadratic models were tested using the F-test.

Leaf formative effects such as puckering and 'bumpiness' were only evident on shoots that were actively growing at the time of treatment. Leaf chlorosis was not limited to developing leaves but a mild effect was noticeable on some leaves that were mature or fully expanded at the time of spray application. These two kinds of leaf symptoms increased in severity with increasing TDZ rate (Table 3).

Leaf area, dry weight, and SLW of leaves that were expanding at the time of treatment were significantly increased with increasing TDZ rate (Table 4). This may have a positive effect on net photosynthesis but needs to be confirmed. The distinct formative effect of TDZ on young actively growing but not mature leaves indicates that leaf physiological age at the time of exposure to the chemical is a major factor. This implies that if trees are subject to TDZ contamination during a growth flush then the effects will be readily noticeable, however, should no flush be present, then it is possible that the incidence of TDZ spray drift will go unnoticed by growers unless leaf chlorosis develops.

In the spring following TDZ application, the new flush of growth supported by shoots that were actively growing at the time of treatment was delayed and the percentage bud-break reduced (data not shown). Reduced blossom production was observed with increasing TDZ rate on shoots that were actively growing or mature at the time of treatment although in the latter case only a trend was suggested (Table 5). Fruit set was reduced on shoots in the actively growing category and a decreasing trend noted on shoots that were mature at the time of treatment (Table5). All of these negative effects were more pronounced in Experiment 2 since at the time of treatment the trees experienced a more intensive late summer flush than the trees in Experiment 1. This fact points out that the amount of flush present at the time of TDZ contamination is an important criterion in determining tree response. The effects on flower and fruit production indicate that economic loss may be sustained by citrus growers if grapefruit trees are repeatedly exposed to TDZ spray drift or by drifts equating to a rate of 8g ha^{-1} or higher.

The results of the field experiments provide evidence that the magnitude of responses in terms of growth, flowering, and fruit set are positively correlated with the rate of TDZ applied, the intensity of the growth flush at the time of TDZ treatment, and the physiological age of affected shoots. Additional research is required to further elucidate these effects.

Table 3. Leaf area affected by distortion (Dist.) and chlorosis (Chl.) on individual shoots that were actively growing or mature at the time of TDZ treatment of 2-year-old 'Rio Red' grapefruit trees. Treatments applied September 4, 1987; evaluation performed November 3, 1987.

	Actively Growing		Mature	
TDZ	Dist. (%)	Chl. (%)	Dist. (%)	Chl. (%)
None	0.2	0.1	0.2	0
8g ha^{-1}	18.0	0	1.8	0.1
56g ha^{-1}	63.8	0.6	5.0	1.6
Significance				
Linear	***	*	NS	**
Quadratic	NS	NS	NS	NS

NS; *; **; ***; non-significant; or significant at 5% (*); 1% (**) or 0.1% (***) levels.

Table 4. Leaf area, dry weight, and specific leaf weight (SLW) of leaves from shoots that were actively growing at the time of TDZ treatment on 2-year-old 'Rio Red' grapefruit trees. Treatments applied September 4, 1987; fully developed leaves collected October 25, 1987.

TDZ	Area of 20 leaves (cm^2)	Dry weight of 20 leaves (g)	SLW (mg/cm^2)
None	555.9	6.3	11.8
8g ha^{-1}	714.9	8.6	11.9
56g ha^{-1}	1072.4	13.9	12.9
Significance			
Linear	***	***	***
Quadratic	NS	NS	*

NS; ***; non-significant; or significant at 0.1% (***) level.

The field experiments were of an exploratory nature and as such confirmed TDZ to be responsible for the development of leaf symptoms that prior to the study were only suspected of being caused by this compound. Also, the data pointed out that there is potential for economic loss due to TDZ spray drifts provided that the rates applied are high enough. Greenhouse experiments revealed that TDZ affects stomatal movement but no promising growth regulator properties were noted. That aspect, however, should be studied in the future using lower concentrations of TDZ than reported here and possibly other citrus species e.g., sweet orange and/or grapefruit.

Preliminary studies, under greenhouse conditions, have also indicated that applications of TDZ with another cotton defoliant Def 6 (S,S,S-tributyl phosphorotrithioate), greatly accentuates the effects of TDZ. The former is frequently used in combination with the latter for the purpose of cotton defoliation in the Lower Rio Grande Valley but the nature of the synergism between the two is unknown at present. The effects of TDZ + Def 6 on citrus warrants further investigation.

ACKNOWLEDGEMENT

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Table 5. The effects of TDZ on flowering and fruiting characteristics of individual shoots that at the time of treatment were actively growing or of mature age, on 2-year-old 'Rio Red' grapefruit trees. Treatments applied September 4, 1987; measurements taken March 15, 1988.

TDZ	Percent original shoots supporting spring flushes with flowers	Number of flowers supported by a single original shoot	Percent original shoots supporting fruit	Fruit set per original shoot (No.)
Actively growing shoots				
None	82.0	68.0	28.0	0.37
8g ha^{-1}	64.6	44.2	20.0	0.23
56g ha^{-1}	5.0	1.4	2.0	0.03
Significance				
Linear	***	**	**	**
Quadratic	NS	NS	NS	NS
Mature shoots				
None	66.0	11.8	42.0	0.70
8g ha^{-1}	40.0	8.4	38.0	0.72
56g ha^{-1}	33.6	6.2	24.5	0.60
Significance				
Linear	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS

NS; **; ***; non-significant; or significant at 1% (**) or 0.1% (***) levels.

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Tropical Adapted Peach Cultivars for Commercial Production in South Texas.

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Additional Index Words: *Prunus persicaa,* low-chilling, subtropical

ABSTRACT

Low-chilling subtropical peaches [*Prunus persica* (L.) Batsch] with characteristics acceptable in U.S. markets are being produced in the Lower Rio Grande Valley. Cultivars that ripen in April and May are being grown commercially for the fresh market. Approximately 280 ha (700 acres) have been established since 1984 and plantings are expected to reach 400 ha (1,000 acres) when nursery orders for new trees are filled in January, 1989. The adapted cultivars being grown are EarliGrande, Flordaprince, FlordaGrande, TropicSweet, and TropicBeauty. Fruit have firmness and quality not previously available in cultivars requiring 200 or fewer chilling units. Two new selections will be planted for commercial trial in January, 1989. RGV 83-1, to be named 'ValleGrande', is a selection from 'EarliGrande' with similar fruit and tree characteristics that matures about 7 days after 'EarliGrande'. Fla. 82-7 is similar to 'Flordaprince' and ripens about 5 days before 'Flordaprince'.

Peach trees, like other deciduous fruit trees, require cool temperatures during the winter for leaf and flower bud dormancy to be satisfied and for the resumption of normal growth in the spring. The optimum temperature for chilling in most peach cultivars is 7 °C (2, 11, 12), but subtropically adapted, low-chilling peach cultivars acquire chilling at higher temperatures (3, 9). Normally 200 or fewer hours of temperatures below 7 °C occur during the winter in the Lower Rio Grande Valley. Therefore, peach cultivars grown elsewhere in the United States that require 400 to 1,200 chill units (11) are not adapted to the Lower Rio Grande Valley. The Texas Agricultural Experiment Station, Weslaco, has been testing low-chilling peaches and nectarines for adaptation in the Lower Rio Grande Valley where no peach industry was previously successful due to the lack of adapted cultivars suitable for commercial markets (5). The purpose of this article is to summarize findings to date.

Peach cultivars developed since 1980 are being commercially produced in the Lower Rio Grande Valley of Texas (1, 4, 6, 7, 8, 10). Approximately 280 ha (700 acres) of low-chill peaches have been established since 1984. The packinghouse facility operated by the South Texas Peach Growers Cooperative Association accounted for shipments of 3,500, 14,330, and 20,393 bushels in 1986, 1987, and 1988, respectively. These figures do not include packinghouse culls, local sales and shipments by individuals. The demand and price of the 1988 crop have stimulated growers to increase their planting. Orders for new trees for planting in January, 1989, will increase plantings to greater than 400 ha (1,000 acres).

Currently used and recently released peach cultivars considered promising are listed in Table 1. The cultivars possess fruit quality and shipping characteristics acceptable in U.S. markets and ripen in April or early May. Flower bud-set in cultivars Flordaprince, TropicSweet, TropicBeauty, and TropicSnow is high and fruit thinning at 20 to 25 cm (8 to 10 inches) apart is necessary to obtain 5.7 to 7.0 cm (2.25 to 2.75 inch) diameter fruit. Fruit size of 'Flordaprince' has been disappointing to growers. Intensive fruit thinning and older trees have not increased fruit size much above 5.0 cm (2.0 inch). Fruit size of 'Flordaprince' has been 5.7 cm (2.25 inch) and above in such areas as Hermosillo, Mexico and the Imperial Valley of California (Tim Gerdtz, Burchell Nursery, personnel communication). Fruit of 'Flordaglo' and 'TropicSnow' have firm white flesh with acceptable size and high quality, but may be limited to local markets until commercial markets in the U.S.A. accept white peaches.

RGV 83-1 is a selection from 'EarliGrande' that was observed in 1983 to mature fruit about 6 to 8 days after 'EarliGrande'. Trees of RGV 83-1 are vigorous, large and upright. They show only slight susceptibility to disease except for rust [*Tranzschelia discolor* (F. Chl) Tranz and Litn]. Trees are moderately resistant to bacterial spot [*Xanthomonas campestris* pv. *pruni* (Smith) Dye]. Fruit are slightly larger than 'EarliGrande,' probably due to being on the tree longer, and range from 5.7 to 6.4 cm (2.25 to 2.5 inch) in diameter. Fruit has yellow, fine textured, well-flavored flesh with slight red color next to the pit and little to no protrusion at the apex. The moderately firm flesh is semicling at full ripeness. Fruit surface varies in red blush from 50 to 75 percent and has medium pubescence; suture is smooth; pits average 2.75 cm length; and flowers are non-showy. Harvest normally begins the third week of April and about 6 days after 'EarliGrande'.

Fla. 82-7 has a parentage similar to 'Flordaprince'. Trees are vigorous and semi-unright, susceptible to rust, and moderately susceptible to bacterial spot. Trees set a large number of flower buds and require considerable thinning. Flowers are large, showy and medium pink. Trees are fully self-fertile. Fruit average 5 cm diameter (2.0 inch) at maturity. Harvest period begins in early to mid-April, about 5 days before 'Flordaprince' and concurrent with 'EarliGrande'. Fruit are slightly oblong with little or no tip, medium pubescence, semicling with little separation of the flesh at the pit when soft ripe. Flesh is melting, yellow, and firm with good quality, excellent flavor and strong peach aroma but of slightly coarse texture with some red near the peel when fruit are allowed to soften on the tree. External fruit appearance is characterized by a red blush over 80% of the fruit surface including attractive dark red stripes over a yellow ground color.

Certain advantages and differences have been noted when comparing fruit and tree characteristics of a particular cultivar for several seasons at Weslaco, Texas (26°09'N, 97°58'W) in the subtropical Lower Rio Grande Valley and at Gainesville, Florida (29°38'N, 82°21'W). Many times the chilling requirement for low-chill cultivars is often determined in areas that receive more than adequate chilling. At Weslaco selections can be evaluated near their extreme lower limits for acquiring chilling. 'EarliGrande' was released in 1980 as a peach requiring 275 chill units, but after testing at Weslaco it has been more accurately identified as 200 chill units. The optimum temperature for chilling in cultivars TropicSweet, TropicBeauty, and TropicSnow is thought to be near 13 °C (3), but trees have been observed to set and mature a full crop when about half the required chilling units occurred.

Table 1. Peach cultivars and selections adapted to subtropical climatic areas as evaluated in the Lower Rio Grande Valley.

Cultivar	Estimated chill units	Leaf glands	Bacterial leaf spot resistance^z	Flower Type	Fruit: Bud set^z	FDP^y (days)	Size (g)	Pit^x	Color: Red(%)	Color: Ground^w	Shape^z	Firm^z	Taste^z	Flesh: Texture^z	Browning^z	Color
EarliGrande	200	globose	10	nonshowy	6	75	98	SC	40	Y	7	6	7	7	8	yellow
Flordaprince	150	reniform	4	showy	10	78	85	SF	80	Y	9	8	8	7	7	yellow
FlordaGrande	75	reniform	9	showy	9	100	98	F	60	DY	8	8	8	8	8	yellow
Flordaglo	150	reniform	7	showy	10	87	124	SC	80	CW	9	9	9	8	9	white
TropicBeauty	150	reniform	6	showy	10	89	110	SF	80	Y	10	10	8	8	9	yellow
TropicSnow	175	reniform	9	showy	10	93	140	F	90	CW	7	9	9	8	10	white
TropicSweet	175	reniform	6	showy	10	95	111	F	70	DY	9	9	9	9	9	yellow
RGV 83-1	200	globose	10	nonshowy	6	82	120	SF	60	Y	8	8	8	7	9	yellow
Fla 82-7	150	reniform	5	showy	10	72	90	SC	85	Y	7	9	8	9	9	yellow

^{z}Rated on a 1 to 10 scale where 10 is most desirable, and 10 is functional immunity in the case of bacterial spot.
^{y}Fruit development period from full bloom to ripe.
^{x}F = free, SF = semifree where pit is loose when soft ripe, SC = semicling where pit is not loose when soft ripe.
^{w}Y = yellow, DY = dull yellow, GY = greenish yellow, CW = cream white.

The fruit development time from bloom to harvest in the Lower Rio Grande Valley is normally 5 to 10 days less than at Gainesville, depending on the year. This has been attributed to warmer daily mean temperatures from bloom to fruit ripening resulting primarily from warmer nights. In years when bloom is earlier in the Lower Rio Grande Valley than in Gainesville, fruit harvest of a specific cultivar may be 2 weeks or more ahead of Gainesville. Fruit of 'FlordaGrande' grown in Gainesville has a small blossom-end protuberance (point) which is absent when grown in the Lower Rio Grande Valley. This characteristic, which has been observed every season since 1983, is apparently associated with the rapidly warming temperatures following bloom that persist throughout fruit development. External red color is enhanced in the warm, subtropical climate. The red blush normally observed on a particular cultivar will be 10 to 20% greater on locally grown fruit compared with that of the same cultivar grown in cooler or slower to warm areas.

After being evaluated in the subtropical climate of the Lower Rio Grande Valley, several cultivars are now considered obsolete or unsuitable (Table 2). Some of these cultivars are being grown successfully in other areas. Among these are 'Desertred' whose fruit are too small and mature too late for the market window of the Lower Rio Grande Valley. Cultivars Rayon, Hermosillo, Flordabelle and Newbelle, have acceptable size but ripen in late May, also too late in our market window. 'Newbelle' is the name given to selection Fla. 1E-138 which is similar to 'Flordabelle' but does not suffer from uneven ripening or green ground color of the latter. Cultivars McRed and San Pedro are too soft for commercial shipment. Recent releases are superior to 'Flordagem' which has a large suture bulge and approximately 250 chill unit requirement that is not satisfied in some years in the Lower Rio Grande Valley. A 1988 Florida release, 'FlordaStar' did not size well nor have good flavor when grown in south Texas. Another recent release, 'Flordacrest' has a 400 units chilling requirement making it better suited to other areas. Cultivars 'Gulf Queen' and 'Gulf Pride' have also been evaluated and found to require more chilling than normally occurs in the Lower Rio Grande Valley.

A commercial quality nectarine adapted to the subtropical climate of the Lower Rio Grande Valley has not been released. Several are being tested and some offer promise. Stylar-end scarring by thrips has been a problem every year with nectarines, but insecticide sprays during bloom may control the problem. The only available cultivar, 'Sunred', is suitable only for home landscape planting.

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Table 2. Peach cultivars currently obsolete or not commercially suitable to the subtropical climatic area of the Lower Rio Grande Valley.

	Estimated		Bacterial	Flower		Fruit								Flesh		
	chill	Leaf	leaf spot		Bud	FDP[y]	Size		Color							
Cultivar	units	glands	resistance[z]	Type	set[z]	(days)	(g)	Pit[x]	Red(%)	Ground[w]	Shape[z]	Firm[z]	Taste[z]	Texture[z]	Browning[z]	Color
Desertred	175	globose	5	nonshowy	10	90	88	SF	90	Y	10	9	8	8	9	yellow
Flordabelle	150	reniform	7	showy	8	105	135	F	70	GY	7	8	8	9	8	yellow
Flordagem	250	reniform	8	showy	9	90	140	SC	80	BY	6	8	9	8	10	yellow
Flordastar	200	globose	10	showy	10	69	80	SC	70	BY	8	9	5	7	10	yellow
Hermosillo	200	globose	7	showy	10	106	97	SF	80	GY	9	8	7	8	8	yellow
Maravilha	200	reniform	6	showy	8	80	70	SF	90	CW	10	8	8	9	6	white
McRed	225	reniform	8	showy	7	90	80	SF	70	Y	7	6	7	7	6	yellow
Newbelle[v]	150	reniform	7	showy	6	110	140	F	70	Y	8	8	8	7	9	yellow
Rayon	150	reniform	9	showy	10	105	100	SC	80	DY	8	8	7	7	10	yellow
San Pedro	200	reniform	7	showy	6	88	130	SF	60	Y	7	7	7	7	7	yellow

[z] Rated on a 1 to 10 scale where 10 is most desirable.
[y] Fruit development period from full bloom to ripe.
[x] F = free, SF = semifree where pit is loose when soft ripe, SC = semicling where pit is not loose when soft ripe.
[w] Y = yellow, BY = bright yellow, DY = dull yellow, GY = greenish yellow, CW = cream white.
[v] Name given selection Fla. 1E-138, similar to Flordabelle but without green ground color or uneven fruit ripening.

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Effect of Irrigation Regimes on Susceptibility of Bean to *Macrophomina phaseolina*

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Additional Index Words: *Phaseolus vulgaris,* charcoal rot, irrigation

ABSTRACT

Three bean cultivars, Fe-30 RB, Pinto 114 and Negro Huasteco, planted in land naturally infested with *M. phaseolina* were managed under three irrigation regimes, 1) preplant irrigation; 2) preplant irrigation plus two irrigations afterwards; and 3) preplant irrigation plus three irrigations afterwards. The water applied in each irrigation was 15 cm per acre. Infected plants were counted every ten days after emergence. Significantly higher percentages of healthy plants and yield resulted with either three or four irrigations. Plant survival was similar among cultivars, although significantly the highest yield was obtained with Fe-30-RB.

Charcoal rot of dry beans (*Phaseolus vulgaris* L.) is caused by *Macrophomina phaseolina* (Tassi) Goid., a soilborne fungus that attacks many crops of economic importance in warm regions (3,5). Mortality of 85-100% in dry beans has been reported in Tamaulipas (3) and Sonora (4), Mexico. Due to this disease, the production area of this legume is now reduced in these states. The high incidence of *M. phaseolina* diseases is related to low soil moisture (1,2,5,7,9) and low water potential (6,8), therefore, water management may be manipulated to reduce the mortality of bean plants. The objective of this work was to study the effects of irrigation and cultivars of dry bean on susceptibility to *M. phaseolina.*

MATERIALS AND METHODS

The experiment was established on March 14, 1986 in a naturally infested field (clay soil) at Rio Bravo Experiment Station. Three irrigation regimes and three cultivars were evaluated in a split plot design with four replicates. The irrigation regimes were: a) one irrigation at pre-planting; b) first irrigation at preplanting, second at third trifoliate leaf (V4) and third at pod formation (R7); c) the same as b and one additional irrigation at pod filling (R8). In all cases the water applied was 15 cm per acre. Cultivars were Negro Huasteco, Pinto 114 and Fe-30-RB. Plot size was 8 rows of 8 m separated by 80 cm. The yield was taken from the four central rows and the charcoal rot incidence, as the percentage of final healthy plants, was estimated from the row next to each side of the harvested area. Fifty plants per row were marked after emergence and every 10 days were examined for infection according to disease signs (3). Data from each plot were subjected to analysis of variance. Treatment means were separated using Duncan's multiple range test ($p = 0.05$). The percentage of final healthy plants in each treatment was regressed with mean yield (kg/ha).

RESULTS AND DISCUSSION

When rain was registered in the third week of May (7 cm), the plants were in physiological maturity (9). Observations of mortality in bean plants determined that the main infection was caused by *M. phaseolina* in 95% of the cases.

Significant differences in the percentage of healthy plants and yield were found between irrigation regimes. Plant survival and yield were higher in plots receiving three and four irrigations, although there were not significant differences in plant survival and yield when comparing the treatments with three and one irrigations (Table 1). No significant differences in final healthy plants were found among the three cultivars, nevertheless, the cultivar Fe-30-RB yielded significantly more than the other (Table 2). On the other hand, even though the maximum percentage of mortality was around 20%, the incidence of disease was correlated with yield and a statistically significant ($p = 0.05$) regression co-efficient was calculated describing a positive linear relationship ($y = -2935 + 43.6x$, $r = 0.842$, $n = 9$) between yield in kg/ha (Y) and the final percentage of healthy plants (X) (Fig. 3).

The results suggest that susceptibility of dry bean to *M. phaseolina* was inversely related to soil mositure. Apparently low soil moisture influenced stress in bean plants, increasing their susceptibility to the pathogen. This agrees with work on sorghum (7) and sunflower (2, 9), which have reported that increasing rates of irrigation water produced a significant decrease in the incidence of charcoal rot.

Cultivars showed similar grade of susceptibility to the pathogen, but Fe-30-RB had high yield potential. This cultivar is probably better adapted because of the site-specific selection.

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Table 1. Effect of different irrigation regimes on charcoal rot incidence and yield in bean cultivars, Fe-30-RB, Pinto 114 and Negro Huasteco.

Irrigation regime	Final healthy plants (%)	Yield (kg/ha)
One irrigation	79.8 b[1]	469 b
Three irrigations	89.5ab	849ab
Four irrigations	92.8a	1,043a

[1]The values followed by the same letter are not significantly different ($p = 0.05$) according to Duncan's Multiple Range Test.

Table 2. Effect of irrigation regimes on disease incidence and yield of three bean cultivars.

Cultivars	Final healthy plants (%)	Yield (kg/ha)
Fe-30-RB	90.8a[1]	1,104.1ab
Pinto 114	84.3a	613.8 b
Negro Huasteco	87.4a	642.9 b

[1]The values followed by the same letter are not significantly different ($p = 0.05$) according to Duncan's Multiple Range Test.

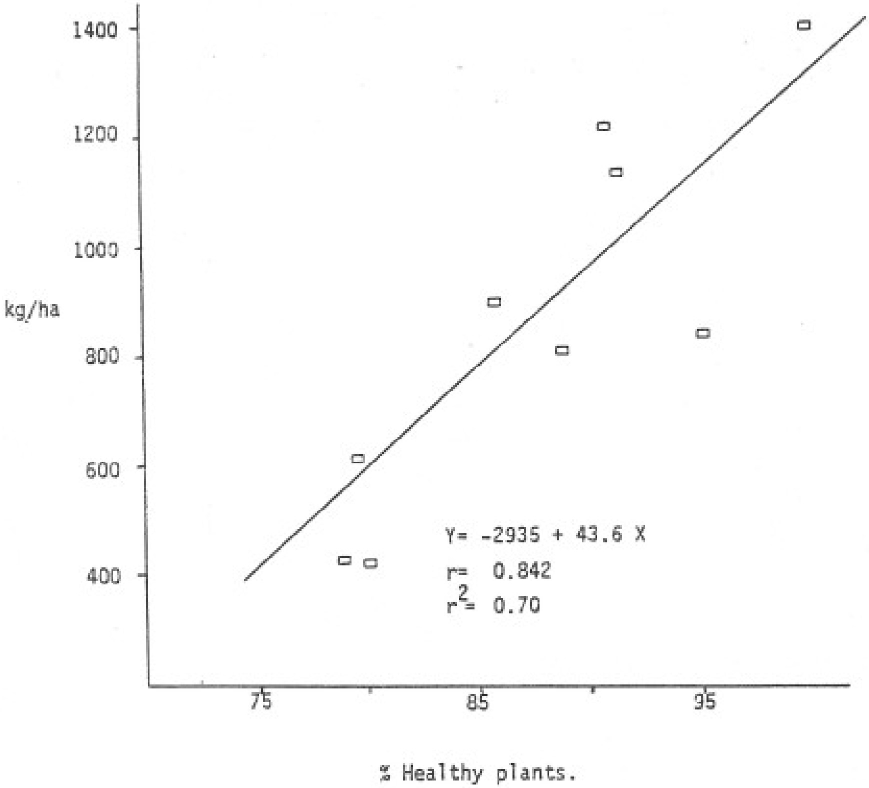

Fig. 3. Relation between yield and percentage of final healthy bean plants in field infested by *M. phaseolina*.

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Effects of Plant Density and Harvesting Methods of Guayule on Rubber and Resin Production Under Dryland Conditions

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ABSTRACT

Production of guayule rubber and resin yields under different plant densities and harvesting methods were investiaged under dryland conditions in south Texas. Higher rubber and resin yields resulted from the highest plant populations due to the production of higher biomass. Production was not always significantly different among densities for various whole and top clipped plants harvested over a 41-month period. Harvesting whole older plants including roots one time only was found to be more productive than harvesting top of plants plus their regrowth every one or two years.

The world need of natural rubber, of which more than 93% is from Asian countries, continues to increase. Since the output of Hevea tree rubber from tropical countries is not expected to increase significantly, alternative sources of natural rubber must be found. An excellent source of natural rubber is the xerophytic shrub, guayule (*Parthenium argentatum* Gray). Guayule, a semi-desert shrub native to the drylands of north central Mexico and to the adjacent Big Bend areas of Texas, was successfully grown in south Texas and other areas during the Emergency Rubber Program (ERP) during World War II. This shrub was a commercial source of natural rubber in the first part of this century, providing 10% of world supply in 1910 (9). Shrubs grown without irrigation have the highest rubber percentage. This shrub has produced rubber under dryland culture with annual rainfall of 38 to 64 cm. Recent economic and political trends encourage reexamination of guayule as a potential domestic natural rubber source (8).

Guayule has been reported to increase in rubber content with maturity (5). Native stands in west Texas have been reported to have as much as 16-20% rubber. However, the age of these plants was not determined (7,9). Lloyd (1911) estimated that most guayule found in the wild is at least 12-years old. Environmental and heredity factors influence rubber content, which varies greatly among shrubs with values up to 26% reported in Mexico (8).

This study evaluated rubber and resin production from native guayule plants harvested at different ages from plant tops, whole plants, including roots, and plant regrowth at different plant densities grown on dryland in south Texas.

MATERIALS AND METHODS

Study Area. This study area is on the southern edge of the Rio Grande Plain, about 12 km north of Rio Grande City, Starr County, Texas. Long-term average annual precipitation is 43 cm and is exceeded by potential evaporation four times (10). Most precipitation occurs as thunderstorms that are unevenly distributed both geographically and seasonally. Occasionally, tropical disturbances produce heavy rains; thus September has the highest long-term monthly rainfall average with another peak in late May or early June from squall-line thunderstorms. Summer temperatures are high, and daily maximum temperatures in July and August are usually 38 °C or higher. Fall freezes occur 7 out of 10 years, and spring freezes occur 9 out of 10 years. The average length of the growing season is 305 days (10).

The study area is a sandy loam range site with level to sloping topography (0 to 5%). The associated soil types are Brennan and McAllen sandy loams, which are soils with noncalcareous fine sandy loam surfaces and sandy clay loam subsoils. The Brennan series is a member of the fine-loamy, mixed, hyperthermic family of Aridic Haplustalfs; the McAllen series belong to the hyperthermic family of Aridic Ustochrepts. The fine sandy loam surface ranges from about 25 to 50 cm deep, while the permeability of the subsoil is moderate. The water holding capacity and fertility of these soils are high; thus, this site has a high production potential.

Treatments. Ten-week-old seedlings of a Mexican native guayule cultivar were transplanted using a 2-row mechanical transplanter on Sept. 22, 1981. Treatments included 3 plant populations: 55,000, 42,000, and 32,000 plts/ha planted on 102 cm beds. Each plot consisted of 6 rows, 15 m long. The design was a randomized complete block replicated 9 times.

Immediately following planting, all plots were sprinkled irrigated with about 1.5 cm of water. Two and a half cm of rainfall was received 8 days following planting and 10 cm more was received 30 days later. Overall plant survival averaged 67%, 30 days after planting. After replacement plants were planted the final stand was 85%. All plots were maintained weed free by occasional hoeing and tractor cultivation.

All plots were fertilized with 50 units of N and P every spring from 1982 to 1984. Samples for total rubber and resin determination were obtained every year starting in February 1983 by harvesting 3 whole plants including roots, or clipping tops of 3 plants in each plot. Regrowth of plant top harvested previously were also harvested every year. Rubber and resin contents were determined using near infrared reflectance spectroscopy (1).

RESULTS AND DISCUSSION

In this study, rubber percentage remained about the same for both clipped and whole harvested plants in 1983, 84, and 85 (Table 1). In some cases the younger plants (17 months, 1983 harvested) showed a higher trend in rubber than those harvested in 1984 and 1985. The rubber percentage found in these samples was generally low. However, it must be kept in mind that plants used in this study were nonimproved native plants that possibly had a high ratio of natural interspecific hybridization with mariola (*Parthenium incanum*), which reduces rubber production potential.

Resin percentage (Table 2) showed a decreasing trend from 1983 to 1985; a reduction of about 2%. Thus as the plants get older the ratio of resin to rubber decreases. This very interesting phenomenon occurs mostly on guayule shrubs grown on

Table 1. Rubber percents from whole plants and top parts of plants.

Density	Rubber					
	First clipped plants			Whole plants		
	1983	1984	1985	1983	1984	1985
plts/ha	-------------------------------------- %			--------------------------------------		
55,000	4.84a[1]	3.54a	4.31a	3.95a	3.38a	3.61a
42,000	5.91ab	4.74a	4.63a	5.26b	4.06a	4.57a
32,000	6.38b	5.53a	5.79b	4.97ab	5.65b	5.02b

[1] Means followed by the same letters are not significantly different at the 0.05% level according to Duncan's multiple range test, for each year's harvest.

Table 2. Resin percents from whole plants and top parts of plants.

Density	Resin					
	First clipped plants			Whole plants		
	1983	1984	1985	1983	1984	1985
plts/ha	-------------------------------------- %			--------------------------------------		
55,000	5.86a[1]	5.30a	3.79a	5.52a	5.80a	3.53a
42,000	5.83ab	5.36a	3.99a	5.76a	5.56a	3.89a
32,000	6.64b	5.75a	4.01a	5.80a	5.69a	3.69a

[1] Means followed by the same letters within columns are not significantly different at the 0.05% level according to Duncan's multiple range test.

dryland conditions. The opposite has been reported for guayule grown under irrigated conditons (2,3,4).

Rubber production (kg/ha) from whole and clipped harvested plants from 1983 to 1985 were slightly different among plant density treatments each year (Table 3). Total rubber yield increased as the plants increased in age. From 1983 to 1985, total rubber better than doubled in all plant density treatments for both whole harvested plants. Whole harvested plants produced more total rubber which was caused by a higher biomass since roots were included. The highest plant density treatment (55,000 plts/ha) produced the most rubber in all years harvested, although the difference was not statistically significant.

Table 3. Rubber production from whole plants and top parts of plants harvested for 3 years.

Density	Rubber							
	First Clipped Plants				Whole Plants			
	1983	1984	1985		1983	1984	1985	
plts/ha	----------------------------------			kg/ha	----------------------------------			
				X̄				X̄
55,500	364a [1]	517a	916a	599	436a	689a	923a	683
42,000	296ab	411a	613b	400	279a	620a	874a	591
32,000	255b	460a	659b	458	296a	645a	830a	590
X̄	305	464	729		337	651	876	

[1] Means followed by the same letters within columns are not significantly different at the 0.5% level according to Duncan's multiple range test.

Resin production changes were very similar to rubber production the first 2 years, 1983 and 1984 (Table 4); however in 1985, resin production did not change much from 1984. In most treatments, the higher amounts of resin were produced in 1984, 2-year-old plants. After plants reached 2 years of age resin concentrations decreased (Table 2), which also caused resin production to decrease. Similar results have been reported in other studies (3,4).

Rubber and resin percentage in regrowth from clipped harvested plants was generally 1% lower than from tops of first time harvested plants (Table 5) compared with Tables 1 and 2. Percent rubber of one-year regrowth was about the same as that of 2-years regrowth (Table 5). The lower plant density treatment (32,000 plts/ha) showed a higher trend in rubber concentration in some years. This was probably attributed to larger or healthier plants due to less competition for moisture and plant nutrients. Percent resin was higher in 1983 (one-year regrowth) than in 1984 and 1985.

A comparison of cumulative rubber and resin production of 41-month-old guayule plants harvested by alternate methods indicated that differences can be accounted for by the time of regrowth and method of harvest.

In all cases the final harvest (Feb. 1985) included the roots for the plants regardless of earlier harvests (Table 6). A clipped harvesting of 17-month old plants followed by 2-years regrowth generally showed the lowest rubber and resin production. The clipped harvesting of 29-month old plants plus 1 year's regrowth was slightly higher than the total rubber and resin production of the plants having 2-years regrowth. The single whole plant harvesting of 41-month-old plants resulted in the highest rubber and resin production. Based on these data it appears that a one time harvest produced more rubber and resin than multiple harvests of clipped plants followed by a whole plant harvest. Harvesting work and cost would undoubtedly be less for a single harvest as compared to a number of clipped harvests. Total resin production was less variable than rubber when all the alternate methods of harvest were compared.

Since guayle plants will be grown for several years before final measurements can be made, a recommendation for dryland guayule is that whole plant harvesting every 3 years could be the most practical economical means to obtain the highest yields.

Table 4. Resin production from whole plants and top parts of plants harvested for 3 years.

				Resin				
Density	First Clipped Plants				Whole Plants			
	1983	1984	1985		1983	1984	1985	
plts/ha				kg/ha				
				$\overline{X}$				$\overline{X}$
55,500	438a	815a	821a	691a	633a	1240a	935a	936a
42,000	314b	451c	535b	433b	325b	789b	751b	622b
32,000	274b	556b	450b	427b	303b	720b	756b	593b
$\overline{X}$	342	607	602		420	916	811	

[1]Means followed by the same letters within columns are not significantly different at the 0.5% level according to Duncan's multiple range test.

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Table 5. Percent rubber and resin from guayule plant regrowth.

Density	Rubber			Resin		
	Second clipping		Third clipping	Second clipping		Third clipping
	1983-84[1]	1984-85[2]	1984-85[3]	1983-84	1984-85	1984-85
plts/ha	%					
55,500	3.5a[4]	4.1a	3.7a	5.0a	3.5a	3.1a
42,000	3.7a	4.0a	4.2a	4.9a	3.4a	3.0a
32,000	4.6a	4.6a	4.1a	5.3a	3.2a	3.4a

[1] Feb. 1983 to Feb. 1984 - regrowth of 1983 clipped harvested plants.
[2] Feb. 1984 to Feb. 1985 - roots of 1984 clipped harvested plants.
[3] Feb. 1984 to Feb. 1985 - regrowth and roots of clipped plants initially harvested in 1983.
[4] Means followed by the same letters within columns are not significantly different at the 0.5% level according to Duncan's multiple range test.

Table 6. Total rubber and resin production of 41-month-old guayule plants harvested by different time intervals.

	Rubber			Resin		
Density	Two clippings[1]	One clipping[2]	Single harvest[3]	Two clippings	One clipping	Single harvest
plts/ha	kg/ha					
55,500	672a[4]	720a	923a	815a	984a	935a
42,000	677a	600a	874a	674b	606b	751b
32,000	534a	629a	830a	585c	684b	756b

[1] First clipping (Feb. 1983) & second clipping (1983-84 regrowth) final harvests (1984 to 85 regrowth & roots).
[2] First clipping (Feb. 1984) & final harvest (Feb. 1984 & 1985 regrowth & roots).
[3] Single whole plant harvest (Feb. 1985).
[4] Means followed by the same letters within columns are not significantly differnt at the 0.5% level according to Duncan's multiple range test.

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Cultivar, Culture and Freeze Damage Effects on Post-Freeze Recovery of Texas Grapefruit

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Additional Index Words: *Citrus paradisi,* cvs Ruby Red, Star Ruby.

ABSTRACT

The relationship of freeze damage ratings to long-term tree performance, is not well documented. Certain pre-and post-freeze cultural factors and freeze damage ratings are related to canopy regrowth and yields of two grapefruit cultivars 4 years after the freeze of 1983. Pre-freeze factors which affected the degree of damage, canopy regrowth and yield were: cultivar-'Star Ruby' sustained more damage than 'Ruby Red'; location in the orchard - trees on the east side had less injury and recovered better than those on the west side and; irrigation method - trees under drip irrigation suffered less injury than those flood irrigated but only in 'Star Rubies' was this reflected in less canopy growth and lower yields. Freeze damage ratings did not correlate with canopy regrowth for either cultivar but was positively correlated to 'Star Ruby' yields.

Freeze damage to citrus is typically expressed by the amount of defoliation and wood killed (Fucik, 1974; Maxwell, 1967; Rohrbaugh and Maxwell, 1950). Evaluation of damage usually involves some type of rating system based on the amount and condition of post-freeze shoot growth (Davies, Jackson, and Rippetoe, 1984; Rohrbaugh and Maxwell, 1951; Young, 1963; Young and Peynado, 1963). The degree of freeze injury may be influenced by soil cover and moisture, air drainage, tree age, physiological condition, nutrition, dormancy and other factors (Krezdorn and Martsolf, 1984; Turrell, 1973; Swietlik and LaDuke, 1985; Wheaton et al, 1986; Young and Peynado, 1963). Others use yields or tree condition several years after the freeze as evidence of differential freeze injury (Leyden, 1965; Wiegand and Swanson, 1985). Lacking in most reports are sound correlations between initial post-freeze injury ratings and long term tree recovery and performance. The 1983 Christmas freeze provided the opportunity and incentive to address this problem.

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MATERIALS AND METHODS

Plots in a 10-year-old irrigation experiment of 'Star Ruby' and 'Ruby Red' grapefruit on sour orange rootstocks were selected so that the effects of drip vs. flood irrigation as well as orchard location could be studied. There were 16 plots, 8 of each cultivar, of 6 trees each. The trees were healthy and bearing well although they were growing on Mercedes clay, a soil considered unsuitable for citrus. (Jacobs, 1981). Insofar as physical constrictions of irrigation method, cultivar and location allowed the plots were randomly distributed as shown in Fig. 1. The data from all plots were used in analyses of cultivars and location effects (Table 1) but only the plots on the west were used to evaluate irrigation effects.

The initial freeze damage evaluation was made in November, 1984. Each tree was rated according to the following criteria:

Rating	Description
1	Whole tree, scion and rootstock, dead.
2	Top, scion variety, dead, some sprouting from rootstock.
3	A few sprouts above graft union; trunk extensively damaged; scaffold limbs are all dead.
4	Majority of scaffold limbs dead; remainder have 80% or more dead wood; a few weak shoots on scaffolds; considerable splitting in crotches and trunk.
5	Trunk essentially sound; moderate to heavy damage on crotches and scaffolds which have fair new shoot growth but more than 50% dead wood.
6	Trunk, crotches and majority of scaffolds sound; many new shoots on scaffolds which have less than 50% dead wood.
7	Trunk, crotches and all scaffolds basically sound; vigorous growth of new shoots on all scaffolds with few having more than 10% dead wood; high potential for 100% recovery.

Although the trees had some production in 1986-87, work schedules did not permit yields and canopy sizes to be measured until the 1987-88 season. Canopy volumes were calculated from the tree heights (h) and the average of 2 diameters (d), one parallel to and the other perpendicular to the row line. the equation, $V = .524\ hd^2$, is a modification of the formula for the volume of a prolate spheroid. Both analysis of variance and regression were used in the statistical analysis as appropriate. Means were separated by the Waller-Duncan k ratio test (Chew, 1977).

RESULTS AND DISCUSSION

The more severe damage suffered by the trees in the west half vs. the east half of the orchard would presumably be due to greater exposure of the former to the extremely cold 10 to 20 mph NW winds which accompanied the '83 freeze (Table 1). These differences in freeze damage were not reflected by any significant differences in canopy volumes. Even though the 'Star Ruby' trees were located in the sheltered south half of the orchard, they suffered significantly more damage than the 'Ruby Reds' (means of locations, not given in table). While 'Star Rubies' are generally less

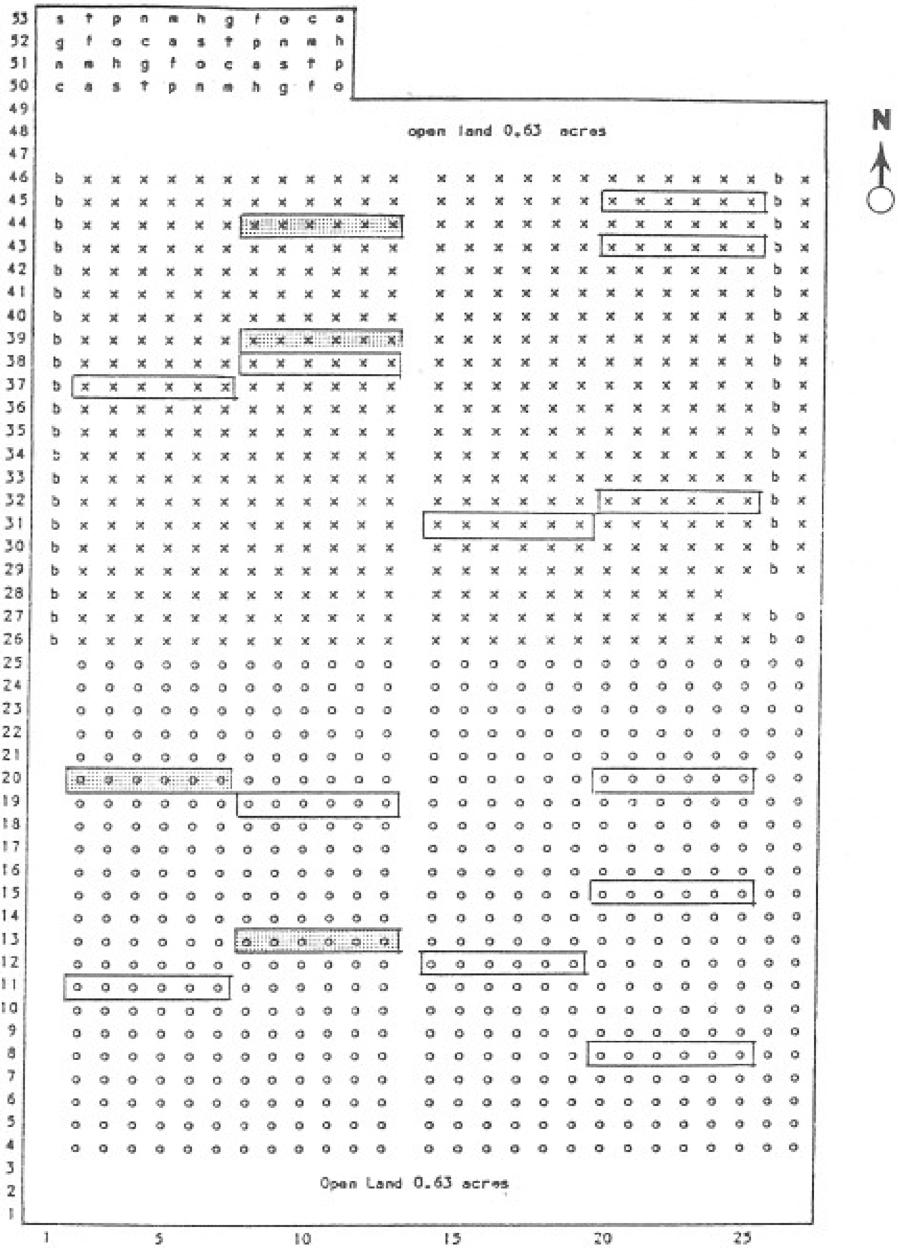

Fig. 1. Experimental orchard with plots of 6 trees outlined. Tree designation: o = Star Ruby, x = Ruby Red. Stippling indicates drip irrigated plots, open plots were flood irrigated. Vertical axis = row numbers, horizontal axis = tree numbers. (Letters in NW corner identify a variety planting).

fruitful than 'Ruby Reds' of the same age and vigor, the yields of the two cultivars and especially those associated with location suggest that freeze damage, if not responsible, at least accentuated the cultivar's yield differences.

Trees under drip irrigation sustained less damage than their counterparts under flood irrigation (Table 2). Our records show that throughout the month of December, 1983, the drippers were delivering 50 to 60 gals water/tree/week. While this amount of water would provide little freeze protection if compared to Florida's experience with microsprinklers (Buchanan, Davies, and Harrison, 1982; Davies, 1980; Parsons, Wheaton and Stewart, 1985; Parsons, Wheaton, and Whitney, 1982) the greater amount of water retained by the heavy soils under these trees probably offered some protection via direct heat transfer and microclimate moderation under the canopy of these large trees (Rieger, Jackson and Davies, 1987; Parsons, Wheaton and Whitney, 1982). The more significant factor, however, was the negative influence of the flood irrigation. The weather preceding the irrigation and up to the freeze was very mild but dry. Such conditions did not induce much cold hardiness into the trees (Yelenosky, Hearn and Hutchinson, 1984). Irrigating 17 days before the freeze probably intensified the problem by (1) stimulating growth (2) preventing any induction of cold hardiness through water stress and (3) allowing sufficient soil drying to minimize the potential heat source of a wet, clay soil (Krezdorn and Martsolf, 1984; Yelenosky, 1978, 1985; Davies, Buchanan and Anderson, 1981).

Another indication of how cultivar, location and irrigation method influenced freeze damage, canopy recovery and yields is to determine what proportion each factor contributed to the overall variability associated with these three characteristics (Table3). For example, in the analysis of cultivar vs. location in Table 1, 19% of the variability in freeze damage was due to the difference between cultivars and 10% was due to location in the orchard. The 0% for the cultivar x location interaction indicates that the east-west effect was the same for both 'Star Ruby' and 'Ruby Red' trees. More than half the variability in freeze damage was due to differences between cultivars, irrigation method and their interaction (Table 3). While canopy recovery was not much influenced by cultivar or location alone, irrigation method and its interaction with cultivar accounted for nearly 40% of canopy volume variability. The contribution of location and cultivars and irrigation method and cultivars to yield variability was similar to freeze damage ratings for the former and canopy volume for the latter pairs of factors.

From the results of this study, the question "Can freeze damage ratings based on the extent of wood injury and new shoot growth predict subsequent canopy regrowth and yields of freeze-damaged grapefruit trees?" can be partially answered. The regression analysis of yield against freeze damage rating (Fig. 2) was positive and significant for 'Star Ruby' grapefruit ($r = .33^{**}$, Standard Error of Estimate ± 15 lbs/tree) but not for the 'Ruby Red'. Freeze damage rating was not correlated with canopy volume for either cultivar. Most likely the rating/yield correlation would have been significant for the 'Ruby Reds' if there were enough rating/yield comparisons to define the lower portion of the curve e.g. ratings 1 to 3, or there were more rating categories, e.g. 10 to 12 instead of only 7, to be paired with yields at the upper end of the curve. In either case, with additional refinement, the potential of predicting tree recovery and performance using a freeze damage rating system seems quite promising.

CONCLUSIONS

Under the conditions of this study there is little doubt that 'Ruby Red' grapefruit had less freeze injury than 'Star Ruby' and that trees of both cultivars located on the

Table 1. Relationship of cultivar and location in orchard to freeze damage, canopy regrowth and yield of grapefruit[z].

Cultivar	Location	Damage Rating[y]	Canopy volume (ft^3)	Yield (lb/tree)
Ruby Red	East	6.5C[x]	806[x]	222C[x]
	West	5.8B	642	196BC
Star Ruby	East	5.4B	701	165B
	West	4.1A	681 n.s.	103A

[z]Canopy size and yields are for 1987-88 season.
[y]Ratings run from: 1 = completely dead to 7 = no trunk damage, scaffolds no more than 10% dead wood.
[x]Means separated by Duncan-Waller k ratio test, k = 500 (ca. 1% level).

Table 2. Relationship of cultivar and irrigation method to freeze damage, canopy regrowth and yield of grapefruit[z].

Cultivar	Irrigation Method	Damage Rating[y]	Canopy volume (ft^3)	Yield (lb/tree)
Ruby Red	Drip	6.6C[x]	176B[x]	188B[x]
	Flood	5.9B	173B	195B
Star Ruby	Drip	5.9B	212B	230B
	Flood	3.5A	36A	38A

[z]Canopy size and yields are for 1987-88 season.
[y]Ratings run from: 1 = completely dead to 7 = no trunk damage, scaffolds no more than 10% dead wood.
[x]Means separated by Duncan-Waller k ratio test, k = 500 (ca. 1% level).

west side of the orchard suffered more injury than trees on the east side. The timing of a pre-freeze irrigation coupled with the intervening mild, dry weather probably prevented cold hardening which resulted in heavier damage to the trees under flood irrigation. The overall response of the 'Star Ruby' so evident in this study supports observations of this cultivar's super-sensitivity to adverse cultural and climatic factors (Fucik, 1976).

However the factors contributing to Texas grapefruit trees' freeze tolerance are orchestrated, continued use and validation of some form of freeze damage rating system seems the most useful means of evaluating the trees' post-free performance (Fucik, 1980).

Table 3. Percent of total variability associated with freeze damage, canopy volume and yield due to cultivar, location in orchard and irrigation method.

	Freeze Damage		Canopy Volume		Yield	
Variable	Location[z]	Irrigation[y]	Location[z]	Irrigation[y]	Location[z]	Irrigation[y]
Cultivar	19	24	.1	5	12	6
Location or Irrigation Method	10	21	1.2	16	4	15
Interaction between variables	0	8	0.5	21	1	17

[z]Calculated from A. N.O.V.A. for Table 1; % variability = $\frac{\text{Variable} \times 100}{\text{Total variability}}$
[y]Calculated from A. N.O.V.A. for Table 2.

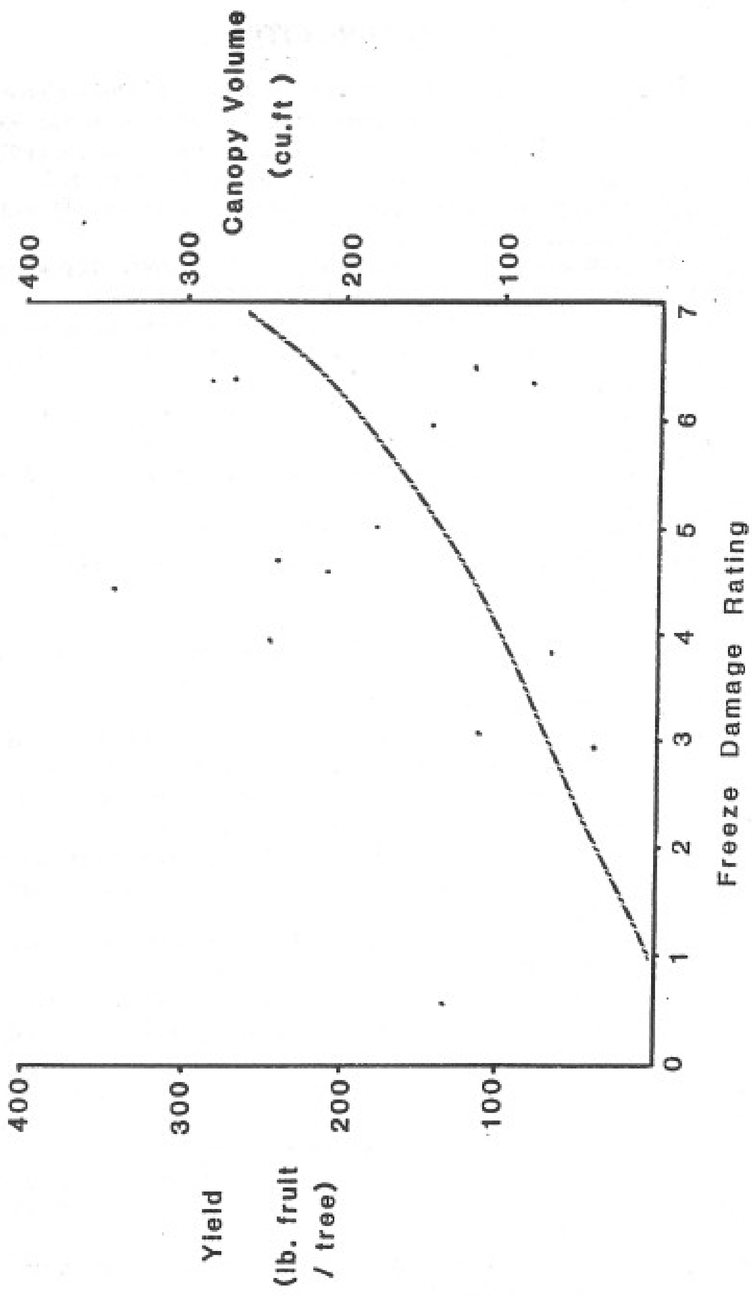

Fig. 2. Regression of 'Star Ruby' grapefruit yield on freeze damage rating: 1 = Dead to 7 = no trunk damage, scaffolds have no more than 10% dead wood. R = .33, standard error of estimate = ± 15 lbs. Freeze occurred in December, 1983, yields were from 1987 - 88 season.

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Bud-Forcing Method Affects Bud Break and Scion Growth of Citrus Grown In Containers

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Additional Index Words: *Citrus paradisi, C. aurantium*, graftage, budding, propagation, nursery.

ABSTRACT

Bud break and scion growth of 'Rio Red' grapefruit (*C. paradisi* Macf.) on Sour orange (*C. aurantium* L.) seedling rootstocks were compared using bending, topping, lopping, and notching methods of bud forcing. The effect of leaves on the rootstock below the bud was also studied. Bending-and-tying with seedling leaves remaining below the bud resulted in longer scion shoots and greater percentage of buds forced than when seedling leaves below the bud were removed. Bending also resulted in scion shoots with a greater number of leaves and leaves with greater surface area than topping or lopping. The presence of leaves below the bud did not affect the mean number of leaves or mean leaf areas on scion shoots. Generally, scion shoot length but not the percentage of bud break was increased on seedlings with leaves below the bud. Four weeks after unwrapping and forcing was found to be a satisfactory time to evaluate scion bud growth. Bending and tying provided the best combination of percentage buds forced and scion shoot length.

Citrus trees normally consist of two components, a rootstock and a scion. Graftage of citrus did not become a commercial practice until the late 19th century (8) when it was learned that grafted trees come into bearing earlier, maintain cultivars true-to-type, produce superior trees and, by utilizing resistant rootstocks, have less incidence of soil-borne diseases. Virtually all citrus is now propagated by budding, generally by T-budding (4,6,7).

Eliminating apical dominance in the rootstock seedling to induce the inserted bud to grow is a standard nursery practice usually accomplished by one of three common methods: bending, lopping, or topping (5). In bending, the seedling top is bent over and tied to its base to force growth of the inserted bud at the bend. Lopping is accomplished by cutting partly through the seedling stem 3 to 5 cm above the bud and breaking the top over while still being attached. Topping removes the entire portion of the seedling just above the bud. A fourth method commonly used by field nurseries in Texas is notching. This involves making two parallel notches 3 to 5 mm apart through the cambium of the rootstock above the bud to be forced and removing a small portion of bark. These methods have been described in detail elsewhere (2,3,4).

While topping and lopping are widely used in the tropics (5), in Texas, notching is the common method of forcing buds in field nurseries which currently produce more than

50% of the citrus nursery trees. Following the 1983 freeze, increasing numbers of trees were produced in containers with 40% being reported in the 1985 tree inventory survey (1). Because nursery managers in Texas have observed that methods used in field-grown trees (notching for example) are not as successful with greenhouse-grown container trees, topping is more commonly used in greenhouses and under shade cloth.

There are few published research reports comparing bud-forcing methods and evaluating scion growth and development after initial bud break. This study compared four bud-forcing methods using container-propagated citrus and evaluated the scion growth and development that results.

MATERIALS AND METHODS

Sour orange (*C. aurantium* L.) seedlings grown in 10.2 cm diam x 38.1 cm (4.0 x 15.0 inch) deep, 6 mil black polyethylene bag nursery containers filled with a commercial soilless medium (Sunshine Mix #1 Fison, Vancouver, B.C., Canada) were budded at a height of 15 cm (6.0 inch) with 'Rio Red' grapefruit (*C. paradisi* Macf.) using the inverted-T method. Prior to propagation, the leaves below the bud insertion point were removed from 400 seedlings. On another 400 seedlings only those leaves at the position of bud insertion were removed. The buds were wrapped with clear polyethylene tape and unwrapped 14 days later. Bud break was induced by either bending, lopping, topping, or notching. Each forcing method was employed on 200 seedlings, 100 with basal leaves removed and 100 with basal leaves intact. Treatments were randomly arranged in the center of a shadehouse covered with polypropylene 30% lath weave.

At 2,4, and 6 weeks after forcing was initiated, bud break and shoot length were recorded. The number of leaves per shoot and leaf areas were measured using a LI-COR Model 3000 portable area meter 4 weeks after bud forcing.

Nutrition was supplied by Osmocote 17-7-12, 12-14 month feed at the rate of 12 g per nursery container at the time seedlings were transplanted from Speedling trays to polyethylene bags, 4 months before budding. All seedlings were vigorously growing when budded and scion growth from forced buds was strong and healthy. Plants were irrigated by overhead sprayers.

The experimental design was a 2 (basal vs nonbasal leaves) x 4 (forcing methods) factorial with measurements taken at three independent times following bud unwrapping. Statistical comparisons of means between measurement times were not made.

RESULTS AND DISCUSSION

Most of the buds had forced and the initial growth flush had extended during the 4 weeks from unwrapping and forcing (Table 1). Growth continued at a slower rate between 4 and 6 weeks. However, the differences in shoot length after 4 weeks were still apparent at 6 weeks.

At 2 weeks after forcing the plants with seedling leaves remaining below the bud, bending, topping, and lopping resulted in the greatest number of buds forced (93%, 98%, and 99% respectively). When seedling leaves below the bud were removed at the time of budding, topping forced 99% of the buds, lopping forced 91% of buds, and bending forced only 80% of scion buds. After 4 weeks from bud forcing the number of buds forced by bending (97%) on seedlings with basal leaves was similar to topping (98%) and lopping (99%). Between 4 and 6 weeks 1% or fewer additional buds were forced in all treatments, except notching without basal leaves, which

Table 1. Percentage of scion buds forced and shoot length 2, 4, and 6 weeks after using four forcing methods on seedlings with or without leaves below the bud union[z].

Treatment	2 weeks		4 weeks		6 weeks	
	Forced buds (%)	Length (cm)	Forced buds (%)	Length (cm)	Forced buds (%)	Length (cm)
With leaves						
Bending	93	2.1	97	19.2	98	19.9
Lopping	99	3.4	99	11.0	100	11.8
Topping	98	4.2	98	8.4	98	8.7
Notching	27	2.4	31	17.0	31	17.7
Without leaves						
Bending	80	2.4	84	16.9	85	18.2
Lopping	91	2.9	95	7.6	97	8.6
Topping	99	3.8	100	5.9	100	7.1
Notching	31	2.6	35	18.0	40	19.1
LSD 0.05	9.0	0.4	9.0	1.3	8.0	1.3

[z] Values are means of 100 budded seedlings.

increased 5%. Four weeks after bud unwrapping was a satisfactory time to evaluate bud break.

Shoot length at 2 weeks was greatest when seedlings were topped, both for seedlings with (4.2 cm) and without basal leaves (3.8 cm) remaining below the bud. At 4 weeks, shoot length of scions from bending was approximately twice that from topping or lopping for both scions with and without seedling basal leaves. Scion shoot length from notching was similar to bending. Between the 4th and 6th week after bud forcing the scion shoots from all bud-forcing methods grew approximately one additional centimeter. It appeared that 4 weeks after bud forcing was also a satisfactory time to evaluate the shoot length of scions.

The best combination of treatments evaluated at 4 weeks after bud forcing appears to be bending with seedling basal leaves which forced 97% of the scion buds with a mean shoot length of 19.2 cm as compared to 98% and 99% bud force and 8.4 cm and 11.0 cm shoot growth of topped and lopped seedlings, respectively. Bending with basal leaves (97% and 19.2 cm) was better than bending without basal leaves (84% and 16.9% cm). Notching resulted in growth similar to bending with 17.0 and 18.0 cm with and without basal leaves, respectively, but only 31% and 35% of buds forced.

Seedling leaves below the bud union did not significantly increase the mean number of scion leaves per shoot or the mean area of these leaves (Table 2). Bud-forcing method significantly affected the number of scion leaves and leaf area. Bud forcing by bending

Table 2. Mean number of leaves per scion shoot and mean areas per leaf at 4 weeks after bud forcing from seedlings with and without basal leaves below the bud and by forcing method.

Treatment	Number of leaves	Leaf area (cm^2)
Stock leaf effect		
With leaves	12.3	29.6
Without leaves	12.6	27.7
LSD 0.05	ns	ns
Forcing method		
Bending	14.2	35.2
Lopping	11.3	24.1
Topping	11.5	16.5
Notching	12.9	38.8
LDS 0.05	1.8	4.3

produced more leaves and larger leaves on the scion than did lopping or topping. Although notching was not significantly different than bending (Table 1), notching forced fewer buds as compared to bending. Bending resulted in about three more leaves per scion shoot than lopping or topping. Surface area of scion leaves from bending was approximately 30% and 50% greater than by lopping or topping, respectively.

Under the conditions of this experiment, bending with seedling leaves remaining below the bud provided the best combination of percentage buds forced and scion shoot length. A greater number of leaves per shoot developed as a result of the additional shoot length and leaf size was larger as evidenced by leaf area measurements. Additionally, certain advantages have been observed by nursery managers when using bending to force buds. Rebudding is facilitated in comparison to lopped and topped seedlings which requires regrowth of the seedling top before rebudding. Many topped seedlings that do not force immediately are lost dur to water logging of the roots in the container if these plants are not moved and given a separate watering schedule from the active growing plants.

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Evaluation of Avermectin B_1 and Hexythiazox for Spider Mite Control on Texas Citrus

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ABSTRACT

Avermectin B_1 (0.0125 and 0.025 lb ai/acre) tank mixed with either petroleum oil (1 gal/acre) or Leaf Act 80 (2 oz/acre), and hexythiazox (0.625 to 0.250 lb/acre) were compared to fenbutatin-oxide (0.05 lb to 0.75 lb ai/acre) for efficacy against Texas citrus mite (TCM), *Eutetranychus banksi* (McG) and citrus red mite (RdM), *Panonychus citri* (McG), in orchard spray trials, 1985-1987. In 1985, both avermectin B_1 and oil and all hexythiazox treatments gave excellent knockdown and suppression of RdM comparable to fenbutatin oxide. After a midseason respray, avermectin B_1 + oil gave a significantly better knockdown of TCM than hexythiazox. Avermectin B_1 + Leaf Act 80 was the least effective treatment against both RdM and TCM. In 1986, all avermectin B_1 and hexythiazox treatments provided TCM knockdown and suppression comparable to fenbutatin oxide. Avermectin B_1 tank mixed with either oil or Citrufilm were equally effective in controlling TCM. The 1987 test was inconclusive due to low mite numbers in test plots.

Avermectin B_1 (Agri-Mek, Merck Sharp and Dohme Research Laboratories, Three Bridges, NJ) is a streptomycete-derived macrocyclic lactone that has demonstrated toxic activity against a broad spectrum of invertebrate pests. Avermectin B_1 at rates of .00625 to 0.025 lb ai/acre has consistently given more than 60 days control of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) on citrus fruit (3,5,6,8). However, it has been less effective in controlling spider mites (Tetranychidae) which feed predominately on citrus foliage (2,7,9).

We tested avermectin B_1 tank mixed with narrow range petroleum oil (NR 440) or various spray adjuvants to attempt to improve control efficiency against the spider mite species--Texas citrus mite (TCM), *Eutetranychus banksi* (McG.), and citrus red mite (RdM), *Panonychus citri* (McG.). In these orchard spray tests avermectin B_1 was compared to hexythiazox (Savey or DPX-Y5893, E.I. DuPont de Nemours and Co. Wilmington, DE) another promising experimental acaricide that has demonstrated selective control of spider mite species on several fruit crops, including citrus (4,7). This paper summarizes data from tests conducted over three seasons, 1985 to 1987.

MATERIALS AND METHODS

Chemical Formulations. Acaricides--Avermectin B_1 [a mixture of avermectins containing $\geq$ 80% avermectin B_{1a} (5-O-demethyl avermectin A_{1a}) and $\leq$ 20% avermectin B_{1b} (5-O-demethyl-25-de (1-methylpropyl)-25-(1-methylethyl) avermectin A_{1a})], a 0.15 lb ai Emusifible Concentrate. Hexythiazox [trans-5-(4-Chlorophenyl)-N-cyclohexyl-4-methyl-2-oxothiazolidine-3-carboxamide], a 50% ai Wettable Powder. Fenbutatin oxide (Vendex, E.I. DuPont De Nemours and Co., Wilmington, DE) Hexakis (2-methyl-2-phenylpropyl)-distannoxane, a 4 lb ai liquid.

Narrow range petroleum oil--with emulsifier and unsulfonated residue rating of 92% minimum; A.P.I. gravity at 60°F 34.8 minimum; 50% distillation point at 10mm Hg reduced pressure 440°F and 10 - 90% range of 80°F maximum.

Spray adjuvants--Leaf Act 80, nonionic (Pure Gro Co., Los Angeles, CA) Alkylphenoxy polyethoxyethanol and isopropanol, an 80% ai liquid. Citrufilm, nonionic (Helena Chemical Co., Memphis, TN) containing paraffin base oil, polyol fatty acid esters and polyethoxylated polyol fatty acid esters, a 99% ai liquid.

The rates of acaricides and tank mix additives tested are given in the tables (Results Section).

Test Design, Spray Application and Mite Count. In 1985, avermectin B_1 tank mixed with NR 440 oil and/or Leaf Act 80 was compared to hexythiazox and Vendex for efficacy against both RdM and TCM. Treatments were randomly assigned to 3-tree plots and replicated three times in a 22-year-old 'Marrs Early' orange orchard on 15 ft × 20 ft spacing. Treatments were applied initially on 1 April and reapplied 23 July 1985. In 1986 and 1987, avermectin B_1 was tank mixed with either NR 440 oil or Citrufilm spray adjuvant and again compared to hexythiazox and Vendex for efficacy against TCM. Treatments were randomly assigned to 6-tree plots and replicated four times in the same orchard as used in 1985. Treatment sprays were applied on 7 April 1986 and 28 May 1987, with no reapplications made in either of these tests.

All spray treatments were applied by commercial 1229 FTM Air Blast Sprayer (FMC Corp. Agricultural Machinery Division, Jonesboro, AR) with speed at 1 mph, and nozzling and pressure adjusted to apply a spray volume of 250 gal/acre.

Pre- and post-spray mite counts were made on leaves randomly collected from treatment trees. Trees were sampled up to arm's length within the canopy and in a zone from knee level to arm's length above the head. At each sampling date, 24 leaves per treatment replicate were processed through a mite brushing machine in the laboratory. All motile stages of TCM and RdM were collected and counted on detergent-coated glass discs using a binocular microscope at 15X.

Data were subjected to analysis of variance and means separated by Duncan's Multiple Range Test. Counts are reported as average number of TCM or RdM per leaf.

RESULTS

In 1985, the avermectin B_1 + NR 440 oil tank mix and both treatment rates of hexythiazox gave excellent initial knockdown and residual suppression of RdM comparable to that by Vendex (Table1). Following the midseason reapplication of test materials, significantly better TCM knockdown was obtained with the avermectin B_1 + NR 440 oil than with hexythiazox (Table 2). Avermectin B_1 tank mixed with Leaf Act 80 spray adjuvant was the least effective treatment against both RdM & TCM.

In 1986, all avermectin B_1 and hexythiazox treatments provided TCM suppression comparable to that by Vendex (Table 3). Avermectin B_1 tank mixed with either NR 440 oil or Citrufilm were equally effective in controlling TCM. The test conducted in 1986 was repeated in 1987; however, TCM populations failed to develop in the test orchard and additional efficacy data was therefore not obtained.

No tank mix incompatibility or phytotoxic effect on sprayed trees was observed with any of these test materials.

Table 1. Counts of citrus red mite (RdM) on leaves from orange trees sprayed with experimental acaricides, Weslaco, TX 1985.

			Mean No. RdM/leaf								
			Days Posttreatment:								
			Spray 1 April						Spray 23 July		
Treatment	lb. (ai) /acre	Pre-spray	+14	+30	+45	+60	+74	+110	+24	+53	+65
Avermectin B_1	0.025	27.6a[z]	3.2b	32.2a	4.1a	0.3a	0.1a	19.2a	4.7c	0.1b	0.1a
+ Leaf Act 80	2.0 oz										
Avermectin B_1	0.025	29.7a	0.6c	1.6b	0.2c	0.1a	0.0a	8.9c	2.0cd	0.1b	0.0a
+ NR 440 oil	1.0 gal										
Avermectin B_1	0.025	29.2a	0.8c	0.9b	0.3c	0.1a	0.0a	8.7c	1.1d	0.1b	0.0a
+ Leaf Act 80	2.0 oz										
+ NR 440 oil	1.0 gal										
Hexythiazox	0.062	31.1a	0.2c	0.7b	0.0c	0.0a	0.0a	6.0c	8.9b	0.0b	0.0a
Hexythiazox	0.125	32.2a	0.4c	0.2b	0.0c	0.0a	0.0a	6.7c	3.7cd	0.0b	0.0a
Vendex	0.50	29.4a	0.0c	0.2b	0.0c	0.0a	0.0a	2.4d	0.5d	0.0b	0.0a
Untreated		29.4a	10.3a	34.9a	0.9b	0.2a	0.1a	14.7b	16.4a	0.5a	0.2a

[z]Means within a column followed by the same letter are not significantly different (P = 0.05) by Duncan's Multiple Range Test.

DISCUSSION AND CONCLUSION

These data show that the experimental acaricides, hexythiazox and avermectin B_1, have potential for controlling both Texas citrus mite and citrus red mite in Lower Rio Grande Valley citrus orchards. Hexythiazox applied alone in orchard sprays was effective against both foliar-feeding mite species, while avermectin B_1 tank mixed with a low volume of either narrow range 440 petroleum oil (1 gal/acre) or Citrufilm spray adjuvant (1 gal/acre) was most effective against both mites.

Hexythiazox is a contact acaricide with novel ovicidal, larvicidal and residual ovicide activity. It has shown little activity against adult mite forms and species in the family, Eriophyidae, which includes the citrus rust mite (1). Conversely, avermectin B_1 has given excellent residual control of the citrus rust mite, particularly on the fruit (5,6). Fractionation studies (Data courtesy of Merck Sharp and Dohme Research Laboratories) have shown that avermectin B_1 partitions into the oil glands on the fruit peel surface and into petroleum oil additives. Partitioning reduces oxidateive photolysis of avermectin B_1 and extends its mite control effectiveness. The wax on citrus leaf surfaces likely precludes avermectin B_1 movement into underlying oil glands and may explain its poorer performance against citrus foliar-feeding mites.

Both hexythiazox and avermectin B_1 appear to have potential for inclusion in an Integrated Pest Management Program for Texas citrus. Hexythiazox was not toxic to beneficial insects such as *Stethorus* spp and predacious mites such as *Amblyseius fallacis* (Garman) (Hislop et.a.l. 1978) and *Metaseiulus occidentales* (Nesbitt) (1). Avermectin B_1 did not cause mortality of the beneficial parasitic wasp, *Leptomastix dactylopii* (Howard), nor the predatory insect species, *Diomus flavifrons* (Blackburn) and *Sympherobius barberi* (Banks) (Author's unpublished data). All of the latter species are important natural enemies of the citrus mealybug, *Planococcus citri* (Risso), a major Texas citrus pest.

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Table 2. Counts of Texas citrus mite (TCM) on leaves from orange trees sprayed with experimental acaricides, Weslaco, TX 1985.

		Mean No. TCM/Leaf									
		Days Posttreatment:									
			Spray 1 April						Spray 23 July		
Treatment	lb.(ai) /acre	Pre-spray	+14	+30	+45	+60	+90	+110	+24	+53	+65
Avermectin B_1	0.025	0.1a[z]	0.9a	2.7a	0.1a	0.0b	6.5a	84.3a	11.4c	3.9b	0.2a
+ Leaf Act 80	2.0 oz										
Avermectin B_1	0.025	0.0a	0.0a	0.1c	0.0a	0.0b	0.1c	27.8b	3.3d	1.0c	0.0b
+ NR 440 Oil	1.0 gal										
Avermectin B_1	0.025	0.0a	0.0a	0.0c	0.0a	0.0b	0.0c	17.1bc	3.4d	0.6c	0.0b
+ Leaf Act 80	2.0 oz										
+ NR 440 Oil	1.0 gal										
Hexythiazox	0.062	0.7a	0.0a	0.1c	0.0a	0.0b	0.1c	20.4b	26.0b	0.2c	0.1ab
Hexythiazox	0.125	0.0a	0.0a	0.1c	0.0a	0.0b	0.0c	9.9c	13.1c	0.0c	0.1ab
Vendex	0.50	0.8a	0.0a	0.1c	0.0a	0.0b	0.6c	17.3bc	5.2cd	0.5c	0.1ab
Untreated	-	0.4a	0.0a	1.4b	0.1a	0.2a	3.8b	21.0b	67.6a	7.1a	0.2a

[z]Means within a column followed by the same letter are not significantly different (P = 0.05) by Duncan's Multiple Range Test.

Table 3. Counts of Texas citrus mite (TCM) on leaves from orange trees sprayed 7 April 1986 with experimental acaricides, Weslaco, TX.

Treatment	lb (ai) /acre	Mean No. TCM/Leaf — Days Posttreatment: Pre-spray	+7	+21	+35	+60
Avermectin B_1	0.0125	35.1a[z]	5.4bc	1.4b	0.3b	0.3b
+ NR 440 Oil	1.0 gal					
Avermectin B_1	0.025	30.3a	6.8b	1.4b	0.0b	0.0b
+ NR 440 Oil	1.0 gal					
Avermectin B_1	0.0125	29.1a	2.1bc	1.0b	0.2b	0.0b
+ Citrufilm	1.0 gal					
Hexythiazox	0.125	32.4a	2.5bc	0.8b	0.3b	0.0b
Hexythiazox	0.250	26.1a	2.0bc	0.4b	0.4b	0.1b
Vendex	0.750	29.2a	0.1c	0.2b	0.0b	0.0b
Untreated	-	29.4a	46.3a	39.9a	11.5a	2.6a

[z]Means within a column followed by the same letter are not significantly different (P=0.05) by Duncan's Multiple Range Test.

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First Year Responses of Grapefruit Trees to Semi-Selective Pruning

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Additional Index Words: *Citrus paradisi*, peel blemishes, yield

ABSTRACT

The canopies of 15 year-old grapefruit trees (*Citrus paradisi* Macf. cv Ruby Red) spaced 6 × 6.6 m in east-west rows were pruned as follows: 1) sector -- wedge-shaped sectors were removed from opposite sides, 2) slab -- a hedging-type cut removed segments from opposite sides, 3) top -- the upper third was removed down to 3.5 m and 4) bottom -- the lower 1.5 m was removed. Sectors and slabs were pruned from both the E-W and N-S sides making 6 treatments plus a control. The weight of prunings removed, yields, and some fruit quality factors were determined. There were no differences in the total weight of prunings among treatments though slab prunings had the highest ratio of leave to wood. Fruit yields, size, grade or peel blemishes in the first post-pruning crop were unaffected by pruning.

Citrus is not generally pruned except prior to transplanting or to remove dead, diseased or damaged branches (6,7). Recent cultural innovations might favor reshaping citrus tree canopies even though the skill requirement and cost of labor prohibit the kind of extensive, selective pruning practiced in deciduous orchards (9). Even in those countries where citrus is traditional pruned by hand increased labor costs have stimulated interest in machine pruning (4,12). Yields in the year following pruning are usually reduced, but the inconsistency of this response, supports the need for more detailed pruning research on grapefruit (3,5,7). This study reports on the response of mature Texas grapefruit trees to several semi-selective pruning systems giving special emphasis to the first post-pruning crop.

PROCEDURE

The pruned trees were 15 year-old grapefruit trees (*Citrus paradisi* Macf. cv Ruby Red) spaced 6 × 6.6m in the southmost row of a 4 ha orchard at Texas A&I Citrus Center, Weslaco, TX., 28° 12′ N. latitude, 98° W longitude. The rows ran east-west. Tree canopies' were approximately 6m diameter and 5m high and ranged from good to fair condition primarily due to their differential recovery from severe freeze injury 6 years earlier. Overall, the trees were typical candidates for skeletonization or rejuvenation pruning (7).

The pruning treatments were: 1) sector - wedge-shaped sections were removed from opposite sides of the canopy; 2) slab - vertical, hedging-type cuts were made on opposite sides of the canopy; 3) top - the upper part of the canopy was removed

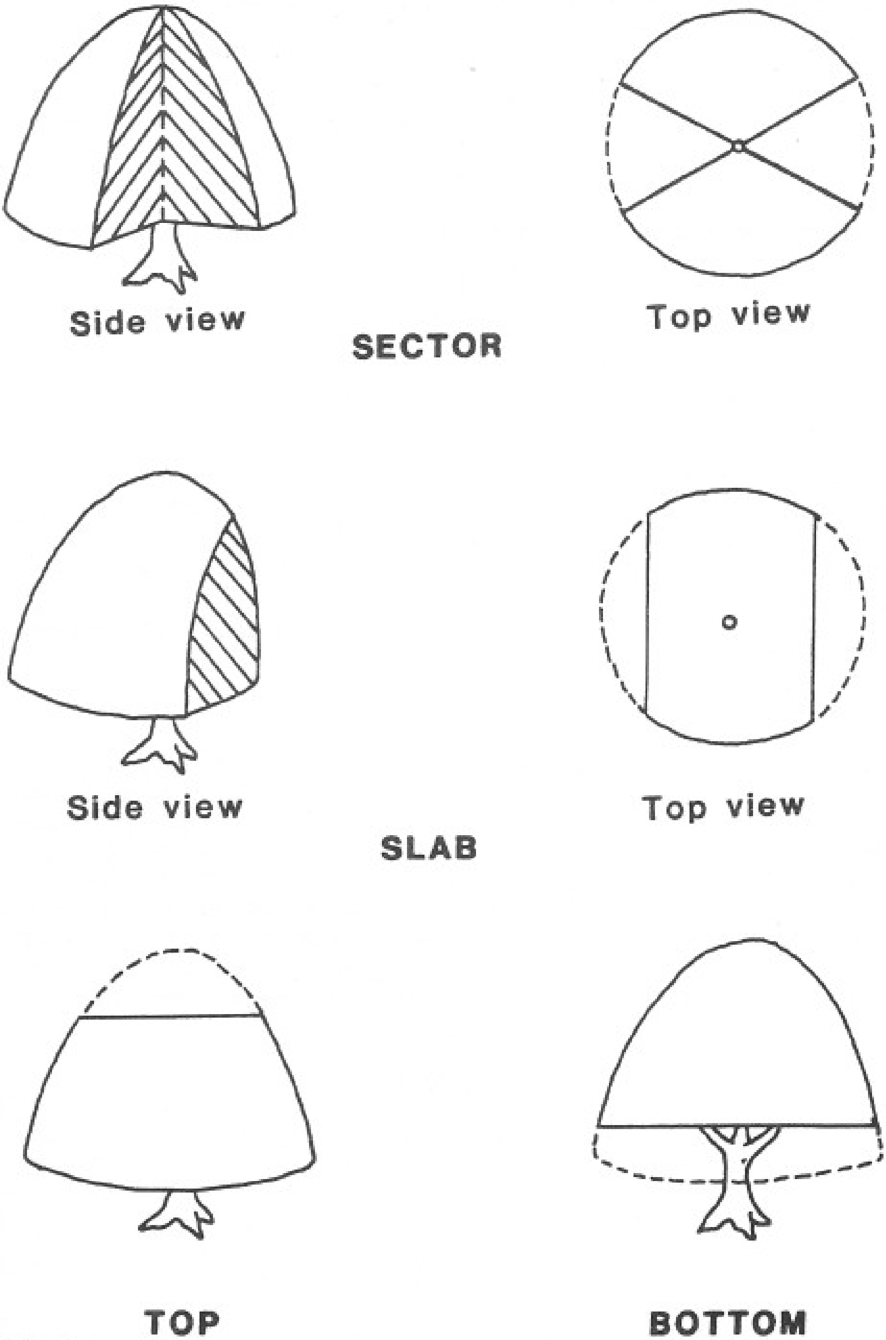

Fig. 1. Diagrams of the semi-selective pruning treatments used on 15 year-old Texas grapefruit trees. In the sector and slab treatments the pruned areas were oriented both parallel (E-W) and perpendicular (N-S) to the row.

down to 3.5m from the ground and 4) bottom - the lower 1.5m of canopy was removed (Fig. 1). Sector and slab cuts were oriented in both north-south and east-west directions making the pruned surface either parallel or perpendicular to the row. All treatments removed about a third of the canopy volume and were replicated 4 times. Trees were pruned in late February with manual power saws and lopping shears.

To compare the amount of plant material removed for each treatment, total fresh weight of the prunings from each tree was obtained and the weights of the leaves and wood determined. Leaves were stripped from a representative of ¼ to ⅓ of the total prunings. From this sample the ratio of leaves to wood were calculated and the total amount of leaves and wood removed. The following January, fruit from each tree was harvested, counted, weighed and the external quality evaluated. The specific causes for downgrading to a No. 2 or cull fruit were: windscar, a brownish, irregular blemish caused by a leaf or twig scraping the peel of young fruit; abrasion, physical injury to mature or nearly mature peel by thorn or branch; rust mite and melanose damage, and sheepnosed or misshapen fruit (1,12). The study originally planned for 3 years was involuntarily terminated when the trees were removed in order to relocate an orchard road. Standard statistical analyses and mean separations were used as appropriate (8).

RESULTS AND DISCUSSIONS

While there were not differences in the total fresh weight of the prunings between treatments, significantly more wood was removed by sector pruning and leaves by slab pruning (Table 1). Leaves accounted for 50% of the fresh weight of the slab prunings which gave a leaves/wood ratio of 1.0 compared to .35 for the other treatments. The prunings from the bottom had more dead, dry branches and fewer leaves than those from the top although their leaves/wood ratios were similar.

Highly variable yields among trees precluded detection of significant differences in yield and fruit weight (Table 2). The negative regression weight of leaves removed on yield reported elsewhere (3,4) while evident here, was not significant, $r = -21$. Fruit size tends to be larger as the proportion of bottom-inside fruit increases but is smaller as the total number of fruit per tree increases (3). In these trees no such correlations were found which suggests that pruning disturbs these relationships in the first crop after pruning.

None of the pruning treatments affected the percentage of No. 1 grade fruit (Table 2). Similar results have been reported on lemons and oranges in Italy (10). Pruning the top and sides of the canopy often results in more No. 1 fruit because the proportion of bottom-inside fruit is increased. This response, however, may be deferred until the second or third year after pruning (3,4,5). Pruning treatments plus windscreens and KNO_3 sprays reduced windscarring in lemons (2), but none of the pruning treatments in this study significantly affected the incidence of windscar, abrasions, rust mite, melanose and sheepnosedor misshapen fruit (Table 3). There were large differences in the percentage of fruit affected by these defects, bu the variability within treatments was too great to detect any trends.

CONCLUSIONS

While a second or third year's data would undoubtedly have made a more complete and valuable study, these first year results are not without application. Despite significant

Table 1. Fresh weight of leaves, wood and the leaves wood, ratio of prunings from 6 pruning treatments of 15 year-old grapefruit trees in Texas.

Pruning Treatment[z]	Mean weight of prunings (Kg/tree)[y]			Leaves/wood Ratio
	Wood	Leaves	Total	
Sector, N/S	40bc	14b	54a	.35a
Sector, E/W	42c	16bc	57a	.36a
Slab, N/S	20a	19c	39a	.95b
Slab, E/W	22a	23c	45a	1.04b
Top	37bc	14b	51a	.38a
Bottom	30ab	10a	40a	.33a

[z]See Fig. 1 for description.
[y]Means in columns separated by Duncan's New MRT, P=0.05.

Table 2. Yield, and mean fruit weight, percent No. 1 grade from 6 pruning treatments of 15 year-old grapefruit trees in Texas.

Pruning Treatments[z]	Yield[y] (kg/tree)	Mean Fruit[y] Weight (Gm)	% No. 1 Grade Fruit
Sector, N/S	157	290	44
Sector, E/W	188	281	40
Slab, N/S	169	318	44
Slab, E/W	158	300	41
Top	171	327	43
Bottom	219	281	46
Control (unpruned)	224	318	35
Significance[y]	N.S.	N.S.	N.S.

[z]See Fig. 1 for description.
[y]Means tested by Duncan's new MRT, p=.05

differences in the ratio of leaves/wood removed, total prunings for all treatments were quite similar. Additional replication would probably have shown the yield reductions for slab, section and top pruning to be significant. The bottom or "skirt" pruning, as practiced for snail control in California, however, appeared to have little affect on yield or fruit quality (11). The generally poor condition of these trees may have tempered and/or increased the variability of their responses to pruning as compared to more healthy, vigorous trees. However, these results may well be applicable to rejuvenation-pruned trees which are pruned because they are declining in vigor and production. It seems fair to conclude that even major pruning of wood and leaves on citrus does not automatically mean drastic changes in the yield and quality of the following crop.

Table 3. Fruit blemishes associated with 6 pruning treatments of 15 year-old Texas grapefruit trees.

	% Fruit downgraded[y]			
Pruning Treatments[z]	Windscar	Abrasions	Rust mite + melanose	sheepnosed and misshapen
Sector, N/S	7	5	14	4
Sector, E/W	13	10	9	7
Slab, N/S	8	6	14	7
Slab, E/W	15	12	9	3
Top	11	7	11	2
Bottom	7	7	11	5
Control (Unpruned)	7	12	16	4
Significance[y]	N.S.	N.S	N.S.	N.S.

[z] See Fig. 1 for description.
[y] Means tested by Duncan's New MRT, p = .05

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Flavanone Content of Whole Grapefruit and Juice as Influenced by Fruit Development

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ABSTRACT

Flavanone compositional studies or grapefruit were conducted in order to establish to what extent the leaves of citrus influence the nature of flavanone components accumulated in the fruit; and to determine if the nonbitter naringenin-7-rutinoside accumulates at the expense of the bitter naringen as fruit develop and mature. Analyses were made of fruit developing normally on a grapefruit tree on sour orange rootstock; of grapefruit grafted on seedling foster-mother trees after partial development; and of grapefruit grown from blossoms produced on leafless budwood on a seedling sour orange foster-mother tree. The results indicated that the genetic makeup of young developing grapefruit and not that of the leaves is the overriding factor in determining the nature of the flavanones accumulated in the fruit. With increasing maturity, some minor expression of the flavanone glycosidic type characteristic of the bearing tree may be seen in the juice. A relative constancy of flavanone aglycones and glycosides is maintained in grapefruit from the ovary stage to market maturity; indicating that no conversion from bitter to nonbitter flavanones is occurring.

Kesterson and Hendrickson (8), Maier (10), and Albach et al. (1) established that grapefruit accumulates the majority of its principle flavanone components, naringin and naringenin-7-rutinoside, during the early stages of fruit development, and that little synthesis and accumulation occur beyond that time.

Fisher (4) demonstrated that young grapefruit leaves are capable of producing naringin from phenylalanine and concluded that the biosynthesis of naringin occurs mainly in young, rapidly metabolizing grapefruit leaves. Maier and Hasgawa (11) demonstrated a direct relationship between L-phenyl-alanine ammonia-lyase activity and the rate of naringenin glycoside accumulation in developing grapefruit. Recently Lewinsohn et al. (9) has shown that grapefruit cell cultures are capable of specifically 0-glucosylating exogenous flavanone aglycones, although it is believed that chalcone gylcosylation occurs prior to its conversion to the flavanone. They observe that little is known about the biosynthetic pathways of the flavanone glycosides in *Citrus*.

From his studies of citrus fruit grafted to foster-mother trees, Gardner (5) concluded that with the exception of carbohydrates the fruit is a self-contained biosynthetic entity that produced compounds peculiar to its variety, regardless of the variety of foliage that supports the fruit growth and maturation. Gardner's work was confined to determining quantitative differences in fruit size, and soluble-solids and acid content of the juice.

Purcell and Stephens (13) demonstrated earlier, by means of reciprocal grafts of immature red- and white-fleshed grapefruit, that the chemical difference leading to the accumulation of larger amounts of pigment in colored varieties lies within the fruits.

Although the naringin content of whole citrus fruit increases and decreases slightly during growth and maturation (Albach and Redman, unpublished data), no evidence for a mechanism for turnover or degradation of naringin is available. Horowitz and Gentili (7), however, speculated that conversion of the bitter naringin (naringenin-7-neohesperidoside) to its nonbitter analog, naringenin-7-rutinoside may occur.

The purpose of the present research is to investigate the influence of the leaves of citrus on the nature of flavanone components accumulated in the fruit and to determine if naringenin-7-rutinoside accumulates at the expense of naringin as fruit develop and mature.

MATERIALS AND METHODS

Plant Material. In June 1968, 'Redblush' grapefruit of approximately 3cm diameter were grafted onto potted trees of five different citrus taxa: *Poncirus trifoliata* (L.) Raf., *Citrus aurantium* L., *C. aurantifolia* (Christm.) Swing., *C. macrophylla* Hood, and Troyer citrange (*P. trifoliata* × *C. sinensis*). The grafting technique was developed by Erickson (3) and Olson (12). The trees were kept on a bench in the open until the following January when the fruits were harvested (30 fruit on each of the five taxa of foster-mother trees). These fruits were juiced by a mechanical hand extractor and 40 ml portions of the juice were analyzed as described under isolation, fractionation, and quantitation of flavanoid components.

In January 1969, budwood of 'Redblush' grapefruit was grafted onto a mature sour orange tree (*C. aurantium*) growing in the grove of Rio Farms, Inc., Monte Alto, Texas. During the 1969 season leaves developed on the budwood. At the time of blossoming in March 1970, all leaves were removed from the grapefruit budwood and two fruits were set from grapefruit blossoms which were present. These fruits were allowed to develop on the sour orange foster-mother tree until harvested on April 22 and May 19, 1970. On these same dates, young sour orange fruit were harvested from the same tree and young grapefruit growing on a nearby mature grapefruit tree on sour orange rootstock were also harvested. These fruits were analyzed as described under isolation, fractionation, and quantitation of flavanoid components.

In March of 1967, 30 ovaries from citrus blossoms in the process of undergoing anthesis were collected from a mature 'Redblush' grapefruit tree on sour orange rootstock. In November 1966 and June 1967, mature and immature fruit respectively were harvested from the same tree. The ovaries and fruit were analyzed as described below.

Isolation, fractionation, and quantitation of flavanoid compoents. The individual fruits or ovaries were cut into sections and blended at high speed in either a Virtis Homogenizer[1] or Waring Blender with 4 ml of 1:1 methanol-isopropanol mixture per g of fruit. The juice samples were blended in the same manner. Blending was accomplished at the highest available speed until the slurry appeared homogeneous. The slurry was then filtered through a scintered glass Buchner funnel with vacuum.

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[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

After filtration of the methanol-isopropanol-water slurry the filter cake was rinsed twice with 1 ml anhydrous methanol per g of fruit. The methanolic solutions were combined and concentrated in a rotary-film evaporator at 40 °C to approximately a single proportional volume. The concentrated solution was successively extracted with hexane to remove lipoidal material.

The filter cake remaining after the methanol rinses was washed with two successive proportional volumes of a 1:1 (v/v) mixture of acetone and hexane. The acetone-hexane was then extracted five times with 25 ml portions of water and the aqueous-acetone phases combined.

The pulp residue was then air-dried and packed into a straight pass Soxhlet extractor. The pulp was extracted for 12 hr with refluxing anhydrous methanol.

The original concentrated aqueous extract, the aqueous-acetone extract, and methanolic Soxhlet extracts were combined and concentrated in a rotary-film evaporator to a small volume of syrup. The syrup was dissolved (sometimes with difficulty) in a methanol-water (4:1, v/v) mixture and brought to volume in a volumetric flask (50, 250, 500 ml capacity, depending on the size of fruit). After standing for about 1 week at 20 °C, a small amount of pectin precipitated.

A 5-ml aliquot of the extract was then chromatographed on a column of polyvinyl-pyrrolidone resin (Polyclar AT, General Aniline and Film Corp., Grasselli, New Jersey) essentially as described by Hagen et al. (6) with the following modifications: the weight of resin employed was increased to 20 g and the diameter of the column was increased to 30 mm. The respective solvent volumes employed for elution and the volumes of the collected fractions were increased by a factor of 2.3 to compensate for the greater weight of resin and larger column diameter.

Five eluate fractions were evaporated to dryness in the rotary-film evaporator. Fraction 1 was dissolved in water-methanol (2:1, v/v), and fractions 2 to 5 were dissolved in methanol. All five fractions were made to volume in 10-ml volumetric flasks.

The remaining thin-layer chromatography of fraction components and quantitation of the flavanones by fluorometry follows the procedure described by Hagen el al. (6); the only exceptions being the use of the Westinghouse FS415 lamp in the fluorometer in place of the General Electric G4T4/1 lamp, and the use of a Baird Atomic A-3 interference filter (325 nm) in place of the composite Corning 7-54 and Wratten No. 34-A filters. The standard deviation for all determinations ranged from 1.2% for naringin to 2.5% for naringenin rutinoside and poncirin. The standard deviation of the values for the more minor flavanones are about 10%.

RESULTS AND DISCUSSION

The data in Table 1 allow a comparison of the amount of naringenin neohesperidosides and rutinosides found in the juice of grapefruit grown on five different taxa of foster-mother trees.

Although the vast majority of flavanones were already present in the grapefruit at the time the fruit was removed from the parent tree for grafting (Albach et al. 1), there may be some indication in the grapefruit juice of the flavanone types characteristic of the foster-mother tree. Albach and Redman (2) have demonstrated that flavanone distribution of different citrus species can be quite distinctive. In the present work juice from grapefruit grafted onto *P. trifoliata* or *C. aurantium*, both of which produce principally neohesperidosides, had higher ratios of naringenin neohesperidosides to naringenin

Table 1. Naringenin glycoside content of grapefruit juice from fruit grafted onto foster-mother trees of related taxa.

Foster-mother tree	mg per 100 ml of juice Naringenin -7-neohesperidoside	Naringenin -7-rutinoside	Neo./Rut. Ratio
P. trifoliata	43.6 mg	10.6 mg	4.13
C. aurantium	59.9	13.0	4.62
C. aurantifolia	36.2	9.6	3.75
C. macrophylla	23.2	9.6	2.77
Troyer citrange	40.6	13.4	3.04

rutinosides than did juice from grapefruit grafted onto *C. aurantifolia* or *C. macrophylla*, which produced only rutinosides. Troyer citrange is a hybrid and produced both neohesperidosides and rutinosides.

The absolute values of flavanone concentration in the juice are of little significance in terms of flavanone synthesis, since the concentration is also a function of both fruit size and juice yield.

In Table 2 appears the flavanone compositional data for 5- and 8-week-old grapefruit, borne either on the conventional grapefruit scion and leafless sour orange rootstock or on leafless grapefruit budwood on a mature seedling sour orange foster-mother tree. For comparison, the flavanone composition of 5- and 8-week-old sour orange fruit are also given.

Although the grapefruit on the sour orange foster-mother tree developed from a blossom to over 31 g size during the period when most flavanones are synthesized and accumulated, its flavanone composition closely approximated that of grapefruit grown on the commercial grapefruit tree. The ratio of neohesperidosides to rutinosides, and aglycone distribution were nearly the same for fruit drawing photosynthate from sour orange leaves as for fruit drawing them from grapefruit leaves. There was no tendency, as in seedling sour orange fruit, toward an increased accumulation of hesperetin compounds with a higher ratio of neohesperidosides to rutinoasides.

The data in Table 3 illustrate the relative flavanone contents of grapefruit from ovary stage to market maturity. No significant changes in relative composition were observed. This relative constancy of flavanone aglycones and glycosides during development and maturation suggests that little, if any, interconversion occurs.

CONCLUSIONS

The nature of the flavanone accumulated in young, developing grapefruit is determined by the genetic makeup of the fruit and is independent of any influence from photosynthate supplying leaves. As a corollary to this, if any enzymes or precursors for flavanone synthesis are supplied to the developing fruit from the leaves, they must be undifferentiated as to aglycone or glycosidic type. During intermediate and final stages of fruit maturation, some minor deviations of flavanone composition from that of the

Table 2. Flavanone composition of 5- and 8-week-old whole citrus fruit.

	Fruit/Tree Combination					
	Grapefruit/ Grapefruit scion		Grapefruit/ Sour orange Foster-mother		Sour orange/ Sour orange	
Harvested April 22, 1970 (5 weeks old)	mg/fruit	Ratio	mg/fruit	Ratio	mg/fruit	Ratio
naringenin neohesperidoside	173.4 mg	7.78	233.5 mg	7.66	59.4 mg	7.52
naringenin rutinoside	22.3		30.5		7.9	
hesperetin neohesperidoside	4.2	1.3	6.4	2.1	176.7	5.16
hesperetin rutinoside	3.3		3.1		34.2	
isosakuranetin neohesperidoside	7.1	3.1	7.9	2.9	3.4	1.8
isosakuranetin rutinoside	2.3		2.7		1.9	
Fruit wt.	3.08 g		4.18 g		2.81 g	
Harvested May 11, 1970 (8 weeks old)						
naringenin neohesperidoside	836.1 mg	9.42	791.8 mg	7.97	287.9 mg	9.56
naringenin rutinoside	88.8		99.3		30.1	
hesperetin neohesperidoside	37.5	2.14	39.1	2.05	396.0	5.64
hesperetin rutinoside	17.5		19.1		70.2	
isosakuranetin neohesperidoside	45.9	4.8	49.8	4.05	14.2	2.7
isosakuranetin rutinoside	9.5		12.3		5.3	
Fruit wt.	31.07 g		31.42 g		20.58 g	

original fruit prior to grafting may reflect the flavanone synthesizing capacity of the bearing tree. Constancy of the flavanone aglycone and glycosidic content of fruit, from ovary to maturity, suggests that little if any interconversion occurs.

Table 3. Relative flavanone content of grapefruit at different stages of development.

	Mar. '67 Ovaries	June '67 Whole Fruit	Nov. '67 Whole Fruit
Naringenin neohesperidoside	75.8%	77.7%	75.3%
Naringenin rutinoside	13.9	12.9	17.6
Hesperetin neohesperidoside	6.5	1.8	1.8
Hesperetin rutinoside	Tr	1.7	1.7
Isosakuranetin neohesperidoside	2.3	4.8	2.8
Isosakuranetin rutinoside	1.5	1.1	0.8
	100.0	100.0	100.0

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Survey of Citrus Producers in the Rio Grande Valley: Results and Analysis

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ABSTRACT

A survey of citrus producers in the Lower Rio Grande Valley (LRGV) of Texas was conducted in the fall of 1987 to ascertain current chemical pest control practices in young and mature citrus orchards. The survey results may be used as an information base for answering questions relating to pesticide use practices in the LRGV and for identifying needs and opportunities for research in crop protection. Also, using the weighted average cost per acre of pest control by pest category, the relative economic magnitude of pest control costs in citrus in the LRGV were determined.

It is important for researchers and producers to be aware of current production practices in specific commodity areas. There has been no compilation of information relating to chemical pest control practices in citrus in the Lower Rio Grande Valley (LRGV) of Texas in the recent past. A survey of citrus producers was conducted in the fall of 1987, in an effort to determine current chemical pest control practices in the region. This information is useful for producers in determining how their individual production practices are similar to or differ from regional averages. Researchers can use the information to identify pest management areas which require further investigation in the area of crop protection and management. The results of the survey are not to be interpreted as recommendations for use of chemicals in pest control. Rather, the results are a record of actual use as reported by respondents. Any areas of improper use of chemicals in pest control may be identified and should be targeted by researchers, extension personnel, and pest management consultants as areas which require further dissemination of the correct information.

METHODOLOGY

Description of the Study Area

The LRGV is located in the southernmost tip of Texas and consists of the 4 counties of Cameron, Hidalgo, Starr, and Willacy. The area is bounded by the Gulf of Mexico to the east, the Rio Grande River on the south, and essentially native brush to the north and west. The total land area is approximately 2.714 million acres. Approximately 973,000 acres were in cropland and nearly 1 million acres in pasture and rangeland. Citrus acreage was approximately 30,000 acres as of 1987. The LRGV is characterized by a sub-tropical climate receiving 17 to 26 inches of rainfall per year. Freezes occur periodically, but the climate is generally suitable for citrus production.

Survey Approach

The data used in this study were collected through a mail survey of citrus owners and managers throughout the LRGV. Names and addresses were provided by the Texas A&I Citrus Center. All out-of-state addresses were excluded as were any institutions, businesses, or individuals which were not citrus owners and managers. No distinction was made between owner-operator management and custom citrus management provided by orchard management firms. Also, no distinction was made regarding size of orchard owned or managed.

Only 27 (12%) usable responses were returned by 214 citrus owners and managers surveyed (Table 1). This is a relatively low response rate; however, the responses represented 9812 acres, approximately 30% of the total current acreage of citrus in the LRGV. Some 69.1% (6,809 acres of the total acres represented were mature orchards (4 years and older) and 30.1% (2,963 acres) were young orchards (1-3 years). This ratio of mature to young orchards is similar to that reported in the 1987 Texas Citrus Tree Inventory (TASS). Thus, the survey results were considered to be representative of current tree age mix in the LRGV and adequately reflect pest control practices.

Table 1. Production practices survey - 1987 - general information.

	No.	Acres	Percent
Total survey sent -	214		
Total usable responses -	27		1.20
Total acres represented -		9,812	30.5
Total acres mature orchard -		6,809	69.0
Total acres young orchard -		2,963	30.1

Each questionnaire was 5 pages long and most of the questions required short answers or answers which were to be chosen from a prepared list. There was an opportunity for the respondent to specify an alternative response in most cases, if desired.

The survey was designed to cover all areas of chemical pest control. Pest control categories were defined as follows:

I. Diseases
   A. Phytophthora foot rot
   B. Melanose and greasy spot

II. Insects and mites
    A. All foliage, limb, twig and fruit insect and mite pests
    B. Ants
III. Weeds
    A. Weeds controlled with pre-emergence herbicides
    B. Weeds controlled with post-emergence herbicides

Separate responses were solicited for young orchards and mature orchards for each category of pests. Pest complexes may differ slightly between grapefruit and oranges, but pest control strategies (especially for young orchards) are generally similar regardless of species. Therefore, no differentiation was made in responses with respect to species of citrus.

Variables for each response were recorded as follows:

1. Number of acres sprayed
2. Pesticide used
3. Number of times pesticide applied

The variable "**acres sprayed one or more times**" was calculated for each pest category and pesticide used. Multiple applications were recorded where the same pesticide was used more than once. The variable "**total acres sprayed**" was calculated by multiplying the number of times the pesticide was applied by the **acres sprayed one or more times** for that application. This **total acres sprayed** for a particular pesticide was used as the divisor to calculate the percent of acres sprayed with that pesticide. The average number of applications a particular pest category was calculated by dividing the **total acres sprayed** by **acres sprayed one or more times**. For example, consider the situation where pesticide A was reported to be used to control insect pests on 2,000 acres of mature citrus using 2 applications, and pesticide B was applied to be used to control insect pests on 1,000 acres of mature citrus using 1 application. The **acres sprayed one or more times** equals 3,000 and **total acres sprayed** equals 5,000. Percent of acres sprayed one or more times equals 44% (3,000/6,809), pesticide A would account for 80% (4,000/5,000) and pesticide B would account for 20% (1,000/5,000) of total acres sprayed, respectively.

All treatments were considered to be applied on a complete coverage basis except for post-emergence weed control and ant control. Post-emergence herbicide applications are sometimes referred to as "spot treatment". This implies that each acre in an orchard is only partially sprayed, so a 20% weed infestation level throughout the orchard was assumed in this study. Thus, if 1.0 acre was reported as receiving a post-emergent application, only 0.2 acres were assumed to be actually covered with the herbicide, unless otherwise noted as 100% coverage. The number of acres sprayed on a complete coverage basis was added to the assumed number of acres receiving complete coverage. This total was then used as the divisor to calculate the percent of acreage sprayed with a particular post-emergence herbicide. "Spot treatment" was also assumed for ant control. No effort was made to determine "actual complete coverage" for ant control practices. The number of acres to which ant control treatments were applied was recorded. It has been suggested that approximately 1% of the actual area receives complete coverage for ant control. Only one pesticide was reported in use for ant control. Therefore, the only descriptive statistics calculated refer to the number of applications per acre (e.g. for mature trees, percent of acres receiving 1 application, percent receiving 2 applications, etc.)

Trade names for pesticides were used throughout the survey and this analysis

Table 2. Trade, common and chemical names for pesticides.

Trade name	Common name	Chemical name	Primary manufacturer
Insecticides			
Acaraben	Chlorobenzilate	Ethyl 4,4'-dichlorobenzilate	Ciba-Geigy Corp.Ag.Div.
Kelthane	Dicofol	4,4 Dichloro-alpha-trichloromethylbenzhydrol	Rohm & Haas Co.
Lorsban (spray)	Chlorpyrifos	O,O-Diethy O-(3,5,6-trichloro-2pyridyl) phosphorothioate	Dow Chemical
Supracide	Methidathion	O,O,dimethyl phosphorodithioate, S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one)	Ciba-Geigy Corp.Ag.Div.
Temik	Aldicarb	2-methyl-2-(methylthio) propionaldehyde-O-(methylcarbamoyl) oxime	Rhone-Poulenc Ag. Co.
Vendex	Fenbutatin-oxide	Hexakis (2-methyl-2 phenylpropyl)-distannoxane	E.I. duPont de Nemours
Herbicides			
Evik	Ametryn	2-(ethylamino)-4-isopropylamino-6-methylthio -s-triazine	Ciba-Geigy Corp.Ag.Div.
Gramoxone	Paraquat	1,1'-Dimethyl-4,4'-bipyridinium ion	ICI Americas
Hyvar X	Bromacil	5-Bromo-3-sec-butyl-6-methyluracil	E.I. duPont de Nemours
Karmex	Diuron	3-(3,4-Dichlorophenyl)-1,1-dimethylurea	E.I. duPont de Nemours
Krovar I	40% bromacil 40% diuron	see bromacil & diuron above	E.I. duPont de Nemours
Krovar II	27% diuron 53% bromacil	see bromacil & diuron above	E.I. duPont de Nemours
MSMA	MSMA	Monosodium methanearsonate	Drexel Chem. Co.
Princep	Simazine	2-chloro-4,6-bis(ethylamino)-s-triazine	Ciba-Geigy Corp.Ag.Co.
Prowl	Pendimethalin	N-(1-ethylpropyl)-3,4-dimethyl-2,6--dinitrobenzenamine	American Cyanamid Co.
Roundup	Glyphosate	isopropylamine salt of N-(phosphonomethyl) glycine	Monsanto Agric.Co.
Solicam	Norflurazon	4-chloro-5-(methylamino)-2-α,α,α,-trifluoro-m-tolyl)-3(2H)-pyridazinone	Sandoz Crop Protection
Surflan	Oryzalin	3,5-Dinitro-N_4,N_4-dipropylsulfanilamide	Elanco Prod. Co.
Treflan	Trifluralin	α,α,α,-Trifluro-2,6-dinitro-N,N-dipropyl-p-toluidine	Elanco Prod. Co.
Fungicides			
Aliette	Phosethylal	Aluminum tris(-O-ethyl spphosphonate)	Rhone-Poulenc Ag.Co.
Kocide	Copper hydroxide	Cupric hyrdroxide	Griffin Corp.
Ridomil	Metalaxyl	N-(2,6-dimethylphenyl)-N-(Methoxyacetyl) Alanine methyl ester	Ciba-Geigy Corp.Ag.Div.
Several	Tri-basic copper sulfate	tri-basic copper sulfate	Several

because different pesticides are more commonly identified by trade names by producers and researchers alike.[1]. A complete list of common names, chemical names, and manufacturers are given in Table 2.

The percentage of acres sprayed with a particular pesticide was used to calculate a weighted average cost for each pest control category (except ant control) using 1988 prices for each pesticide. Total costs for each category then were calculated by multiplying the weighted average cost of an application (over all responses) by the average number of applications for that pest category. Only pesticide material costs were calculated; no application costs were considered. Costs for all materials were obtained from local input suppliers. All chemical rates per acre used in all cost calculations are given in Table 3. A summary of weighted average pesticide costs per acre (excluding ant control) is presented in Table 4.

[1]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the Texas A&I University Citrus Center and does not imply recommendation to the exclusion of other products that may also be suitable.

Table 3. Pesticide rates used in cost analysis.

Pesticide	Mature trees (material/acre)	Young trees (material/acre)
Insecticide		
Acaraben	6 pts	3 pts
Citrus oil	7 gal	3.5 gal
Kelthane	4 pts	2 pts
Lorsban (spray)	4 pts	2 pts
Supracide	6 pts	3 pts
Temik	33 lbs	16.5 lbs
Vendex	1.5 pts	.75 pts
Herbicide (pre-emerge)		
Hyvar X	3 qts	2 qts
Karmex	4 lbs	2 lbs
Krovar I	4 lbs	3 lbs
Krovar II	4 lbs	3 lbs
Princep	4 lbs	2 lbs
Prowl	na	3 qts
Solicam	4 lbs	4 lbs
Surflan	4 qts	4 qts
Treflan	2 qts	2 qts
Herbicides (post-emerge)		
Evik	3 lbs	3 lbs
Gramoxone	1 qt	1 qt
Hyvar X	1 lb	1 lb
Karmex	1 lb	1 lb
Krovar I	3 lbs	3 lbs
Krovar II	2 lbs	2 lbs
MSMA	2 qts	2 qts
Roundup[z]	1 gal	1 gal
Fungicides		
Aliette[y]	na	5 lbs
Kocide	6 lbs	3 lbs
Ridomil[x]	.33 lbs	1 gal
Tri-basic copper sulfate	10 lb	5 lb

z/ Amount of material in 100 gal of water. This rate refers to concentration of solution rather than amount of material applied per acre.

y/ 5 lbs 80WP in 100 gal water, sufficient for 380 2-year-old trees.

x/ 0.33 lbs per acre for mature trees; 1 gal in 15 gal water, sufficient for 605 2-year-old trees.

RESULTS

Phytophthora Foot Rot Control

There were 718 acres of young orchards sprayed for foot rot representing 24% of total acres in young orchards (Table 5). Aliette was the most commonly used fungicide (48%) followed by Ridomil (38%) and Kocide (14%). Only 0.6% of mature orchards were sprayed for foot rot, indicating that foot rot is not considered a serious problem on older citrus trees.

Table 4. Weighted average pesticide costs per acre.

Pest control category	Cost/Acre ($)	
	Young Trees	Mature Trees
A. Phytophthora foot rot	40.77	-
B. Melanose and Greasy Spot	6.97	17.11
C. Insects and Mites		
Without Temik	53.59	99.16
With Temik	76.30	112.62
D. Pre-Emergence Weeds	76.54	98.58
E. Post-Emergence Weeds	7.34	8.13
Total Costs		
With Temik	$207.91	$236.44
Without Temik	185.20	222.98

A tree density of 145 trees/acre and rates sufficient for 2 year old trees were assumed. On young trees, Ridomil and Kocide were reported as being applied 1 time/year and Aliette 1 and 4 times/year. The label recommendations for Ridomil are a minimum of 2 applications/year and for Aliette a minimum of 3 applications/year. The weighted average cost of a fungicide application for young trees was $40.77 per acre. The mature trees were sprayed with 0.33 gal/acre for a $54.78/acre cost for 1 application.

Melanose and Greasy Spot Control

Only 8% (262 acres) of young orchards in the survey were reported as being sprayed for melanose and greasy spot. Melanose is not a major problem on young citrus trees. Young trees and mature trees were both sprayed approximately 1.2 times with Kocide, but 40% (2,745 acres) of mature trees in the survey were reported to be sprayed annually. Kocide (101 or 606) was the most common used fingicide for young and mature trees (Table 6). The average cost of treatment at recommended rates for young and mature trees was $6.96/acre and $17.11/acre, respectively.

Insect and Mite Control

Mature Orchards. Insecticides and miticides were a major crop protection input in mature orchards. The survey results indicated that 77% of the acreage was sprayed an average of 4.8 times. Kelthane was the most commonly used material (26%) followed closely by Lorsban (19%) and Vendex (15%) (Table 7). Citrus oil was applied in combination with other insecticides and acaricides on 12% of the acreage sprayed. Temik was applied on 12% of the survey acres in 1 application per year. Because Temik was known to be applied only one time per year, insecticide and miticide weighted average costs were calculated with and without Temik to more accurately represent the true average cost of insect and mite control. The average cost per acre for insect and mite control (excluding Temik applications) was $99.16/acre. The average insect and mite control cost for all materials was $112.62/acre.

Table 5. Chemical treatment for phytophthora foot rot control.

	Acres	Percent
Young Orchards		
Total acres sprayed	718	24
Ridomil (1 appl/yr)	273	38
Aliette (1 appl/yr)	198	23
Aliette (4 appl/yr)	172	25
Copper (1 appl/yr)	100	14
Mature Orchards		
Total acres sprayed	40	.6
Ridomil (1 appl/yr)	23	.345
Ridomil (2 appl/yr)	17	.255

Table 6. Chemical treatment for melanose and greasy spot control.

	Acres	Percent
Young Orchards		
Acres treated		
1 or more times	262	8
Total acres treated	362	12.2
Kocide 606	172	47.5
Kocide 101	161	44.4
Tri-basic copper sulfate	29	8.1
Mature Orchards		
Acres treated		
1 or more times	2745	40
Total acres treated	3365	49
Kocide 101	1847	55
Kocide 606	1381	41
Other[z]	137	4

[z]Other fungicides reported included tri-basic copper sulfate and Benlate.

Table 7. Chemical treatment for insect and mite control.

	Acres	Percent
Young Orchards		
Acres treated		
1 or more times	2053.5	69
Total acres treated	5603.5	
Kelthane	2048	37
Lorsban	1536	27
Temik	866.5	15
Supracide	578	10
Vendex	440	8
Oil	100	2
Acaraben	35	1
Mature Orchards		
Acres treated		
1 or more times	5253	77
Total acres treated	25558	
Kelthane	6597	26
Lorsban	4887	19
Vendex	3823	15
Temik	3118	12
Oil	2974	12
Acaraben	1723	7
Supracide	1896	7
Others	510	2

Young Orchards. Insect and mite control inputs were slightly less in young orchards. Applications were reported on 69% of the young tree acreage an average of 2.7 times. The most commonly used materials were Kelthane, Lorsban, and Temik used on 37%, 27%, and 15% of the acreage, respectively (Table 7). Supracide was reported being used on 10% of the acres sprayed. The average cost per acre for insect and mite control (excluding Temik) was $53.59/acre. The average cost per acre for all materials (including Temik) was $76.30.

Ant Control

Insecticides were applied for ant control on 1853 acres (62.5%) of young orchards an average of 4 times per year (Table 8). This compares with ant control applications on 3303 acres (48%) of mature orchards applied an average of 3.5 times per year.

Table 8. Chemical treatment for ant control[z].

Young Orchards		
	Acres	Percent
Acres treated		
1 or more times	1853	62.5
Total acres treated	7437	
Lorsban (2 appl)	7272	97.8
Lorsban (3 appl)	165	2.2
Mature Orchards		
Acres treated		
1 or more times	3303	48
Total acres treated	11535	
Lorsban (3 appl)	8568	74.92
Lorsban (10 appl)	2000	17.00
Lorsban (4 appl)	960	8.00
Lorsban (1 appl)	7	.08

[z]Treatments for ant control are assumed to be made on a spot treatment basis. The number of acres treated does not apply on a complete coverage basis; it has been estimated that ant control coverage is in the range of 0.5 to 2% of acres actually covered.

Lorsban was used exclusively for ant control. About 97.8% of young trees received Lorsban at least 2 times, with a maximum of 3 times per year reported. On mature orchards, the number of applications to mature trees ranged from 1 to 10 times per year with approximately 75% of the acres receiving Lorsban applications at least 3 times. No costs were calculated because of the difficulty in determining a rate per acre for Lorsban treatments.

Pre-emergence Weed Control

Mature Orchards. Pre-emergence herbicide applications were reported for 98.2% of the mature orchard acreage with an average number of applications of 3.5 times per year (Table 9). The most commonly used herbicide was Princep, applied on 38.3% of reported acres. Krovar I was applied to 21% of the acres and Solicam, Karmex, and Krovar II were applied on 12.2%, 11.2%, and 10.5% of the acreage, respectively. The weighted average cost per acre for pre-emergence herbicide materials on mature orchards was $98.58/acre.

Young Orchards. Herbicides for pre-emergence weed control were applied on 98.7% of reported acres in young orchards with an average number of applications of 3.6 times per acre (Table 9). Again, Princep was the most commonly used chemical (42.1%) followed by Krovar I (17.5%), and Prowl (13.2%). Prowl use, however, was recorded from one survey response only. The weighted average cost per acre of pre-emergence herbicides applied at recommended rates on young orchards was $76.54/acre.

Table 9. Chemical treatment for pre-emergence weed control.

	Acres	Percent
Young Orchards		
Acres sprayed		
1 or more times	2,923	98.7
Total acres sprayed	10,593	
Princep	4,456	42.1
Krovar I	1,852	17.5
Prowl	1,400	13.2
Surflan	837	7.9
Solicam	810	7.6
Krovar II	617	5.8
Karmex	556	5.3
Treflan	30	.3
Hyvar X	30	.3
Others	4	.04
Mature Orchards		
Acres sprayed		
1 or more times	6,685	98.2
Total acres sprayed	23,193	
Princep	8,823	38
Korvar I	4,878	21.0
Solicam	2,833	12.2
Karmex	2,591	11
Krovar II	2,441	10.5
Hyvar X	877	3.8
Surflan	616	2.7
Treflan	32	.1
Others	9	.04

Post-emergence Weed Control

Mature Orchards. Some 86.2% of acres of mature orchards reported were actually 100% covered with post-emergence materials with an average of 1.03 treatments per acre covered (Table 10). Roundup was the most commonly used material (33.8%). MSMA and Gramoxone were the only 2 chemicals reported to be applied on a 100% coverage basis and these were applied on 21.9% and 20.2% of the mature orchard acreage, respectively. All other materials were reported to be used in spot treatment where we assumed a 20% coverage basis. Evik and Krovar I were applied on 8.2% and 7.4% of the acreage, respectively. The weighted average cost per acre of post-emergence herbicides applied at recommended rates on mature orchards was $8.13/acre.

Young Orchards. While 93% of the acreage in young orchards were reported as receiving some post-emergence herbicide materials, only 5% received complete coverage (Table 11). Roundup, the most commonly used material, was applied on 83.6% of acres reported. Gramoxone was the only post-emergence material reported in use on a 100% coverage basis. Evik was applied to 6.1% of young orchard acres; all other post-emergence materials were used on 1.0% or less of reported acreage. The weighted average cost per acre of post-emergence herbicides applied at recommended rates on young orchards was $7.34 per acre.

Table 10. Chemical treatment for post-emergence weed control.

Mature Orchards			
	Acres		Percent
Acres sprayed	5,704		83.8
Acres actually covered	5,870		86.2
Total acres sprayed[z]	20,530	× .2 =	4106
Acreage 100% covered			1764
Acres actually sprayed			5870

Material	20% Coverage	100% Coverage	Percent
Roundup	1,985.9		33.8
MSMA	547.8	739	21.9
Krovar I	434.4		7.4
Evik	402.1		8.2
Princep	249.1		4.2
Karmex	201.1		3.4
Gramoxone	164.0	1,025	20.2
Hvyar X	36.8		.6
Solicam	5.0		.09
	4,106.1	1,764	39.8

[z]Assume 20% infestation level and concurrently 20% coverage. Thus, for 1 acre in orchard sprayed, 0.2 acres were actually covered with post-emergence material, unless otherwise noted as 100% coverage.

Table 11. Chemical treatment for post-emergence weed control.

Young Orchards				
		Acres		Percent
Acres sprayed		2,757		93.0
Total Acres Sprayed[z]		7,621.5	× 0.2 =	1,524
Acreage 100% covered				75
Acres actually sprayed				1,599
Material	20% Coverage	100% Coverage		Percent
Roundup	1,334			83.6
Evik	97			6.1
Gramoxone	68	75		5.0
MSMA	15			1.0
Hvyar X	4			.3
Princep	4			.3
	1,524	75		100.0

[z]Assume 20% infestation level and concurrently 20% coverage. Thus, for 1 acre in orchard sprayed, 0.2 acres were actually covered with post-emergence material, unless otherwise noted as 100% coverage.

CONCLUSIONS

These results are representative of the pesticide use practices in the LRGV at the current time. It must be stressed that the information solicited from the respondents is not to be interpreted as a record of correct or even legal use of chemicals in citrus production. We merely asked for a record of actual use. If a pesticide as reported was improperly used for a certain pest or category of use, then one purpose of the survey was served, specifically to document the improper use of chemical pest control. Researchers, extension personnel, and pest control consultants should review their efforts to disseminate the correct information needed by growers to ensure proper use.

From an examination of the number of applications and average cost of pest control, the pest categories causing use of the most pesticides appear to be insect, mite, and weed pests. The rates and costs of materials used could vary depending on location and individual circumstances. The per acre weighted average cost of pesticide materials is representative of the average cost of pesticide use in the LRGV, it may or may not be representative of any individual pest control situation. For the individual, a more relevant comparison of pesticide use by category to LRGV averages may be made in terms of percent of the total. For example, the average material cost per acre for insect control ($112.62) is approximately 47 percent of the total pesticide use ($236.44) on mature trees (from Table 3). By comparing this figure (47%) to a similar calculation for an individual orchard, one can determine whether individual pesticide use for this category is above or below the average for the LRGV. A comparison of cost of pest control between pest categories does give an indication of the particular areas where real or perceived pest problems exist.

LITERATURE CITED

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Experimental Transmission of Citrus Tristeza Virus by a Texas Population of *Aphis citricola* from Marrs Orange

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ABSTRACT

The efficiency of a Texas population of *Aphis citricola* Van Der Goot and a Texas and Florida population of *A. gossypii* Glover to transmit a Texas isolate of citrus tristeza virus (CTV) from "Marrs" sweet orange (*Citrus sinensis* L.) to Mexican lime (*C. aurantifolia* Swing) was determined. Florida and Texas populations of *A. gossypii* did not transmit CTV when 12 to 24 aphids were allowed to feed for 24 hrs on CTV-infected Marrs orange plants before transfer to Mexican lime acquisition plants. Feeding by 23 to 47 aphids of a Texas population of *A. citricola* on CTV-infected Marrs orange before transfer to Mexican lime resulted in 73 percent transmission efficiency as 11 of 15 acquisition plants became infected with CTV. Natural spread of CTV by indigenous populations of *A. citricola* in the Lower Rio Grande Valley of Texas could occur if the virus became established in commercial orchards.

Citrus tristeza virus, the most destructive virus disease of citrus, has killed or rendered unproductive approximately 40 million trees on sour orange rootstock in Brazil, Argentina, Spain, California, and Florida in the past 50 years (2,4,5). The widespread use of sour orange rootstock in these areas has been abandoned because of the presence of CTV. In the United States, CTV incidence and spread is currently quarantined to the Los Angeles Basin by an extensive survey and regulatory program. In Florida, however, CTV is ubiquitous and a CTV quick decline epidemic is causing extensive tree losses on sour orange rootstock (5). CTV is primarily spread by distribution of infected plant material and the 3 aphid species, *A. citricola* (green citrus aphid), *A. gossypii* (melon aphid), and *Toxoptera citricidus* (Kirk.) (brown citrus aphid) (1,4,9). The green citrus and melon aphids are endemic to citrus producing regions in the United States.

The Texas citrus industry in the Lower Rio Grande Valley (LRGV) is vulnerable to CTV because over 95 percent of citrus planting are on sour orange rootstock (6,12). Surveys for CTV in the 1950's and 1980's detected low incidences of the virus in backyards and commercial orchards (6,8). Natural spread, however, was limited or not detected and there have been no economic losses to CTV in Texas.

Natural spread of CTV in Texas has not occurred in spite of the presence of CTV, aphid vectors, and susceptible hosts plants. Inability of Texas aphid populations to transmit CTV has been suggested as the limiting factor to CTV spread in Texas. No transmission of CTV occurred in 706 transmission studies with Texas populations of *A. gossypii* and *A. citricola* (7). Several factors, however, may affect CTV spread in Texas. In the LRGV the transmissibility of resident CTV strains is unknown and grapefruit, a less preferred host by aphids compared to oranges, comprises two-thirds of the commercial acreage. Also, aphids are minor pests of citrus, high ambient temperatures from May to October may reduce virus titer in donor plants, and frequent tree killing freezes may reduce or eliminate infected plants.

The objective of this research was to examine the transmission of CTV by a Texas population of *A. gossypii* and *A. citricola*. A Florida population of *A. gossypii*, efficient at CTV transmission of CTV isolates from Florida, was included because the transmissibility of the Texas CTV isolate used in this study was unknown.

MATERIALS AND METHODS

An isolate of CTV maintained on Mexican lime (*Citrus aurantifolia* L.) at the Texas A&I University Citrus Center was used in transmission studies. Isolate 111-F originated from an infected Barth navel planted in the variety block planting at the Texas A&I University South Research Farm (6). The isolate was considered a mild CTV strain because it produced mild stem pitting, vein clearing, and leaf cupping on Mexican lime indicator plants.

Bark chips or leaf strips from CTV-infected Mexican limes were grafted onto Marrs orange plants on sour orange rootstock to be used as donor plants. Plants were maintained in the greenhouse through 2 growth flushes and determined to be infected with CTV by the enzyme-linked immunosorbent assay (ELISA) (3). Plants were pruned to force growth of young, tender shoots for aphid feeding.

Aphis gossypii and *A. citricola* populations were collected from squash (*Cucumis* spp.) at the Citrus center and Marrs oranges at the Texas A&M Hoblitzelle Research Farm, respectively. The Florida population of *A. gossypii*, previously demonstrated to be an efficient vector of CTV isolates in Florida, was supplied by the USDA Horticultural Research Lab., Orlando, FL. Aphids were maintained in an insectary on kenaf (*Hibiscus cannabinus* L.) and cotton (*Gossypium hirsutum* L.) grown at 25 C under flourescent lights with a 14/10 hr diurnal photoperiod. Apterous aphids were transferred to Marrs orange donor plants and allowed to feed for 24 hrs to acquire the virus. Twelve to twenty four viruliferous *A. gossypii* and 23 to 47 viruliferous *A. citricola* were transferred to caged 8-week-old Mexican lime acquisition plants and allowed to feed for 24 hrs (13). Plants were sprayed with malathion to kill aphids and maintained on a greenhouse bench for 3 months before rating visually for symptoms of CTV infection and assaying with ELISA. There were 15 replicate Mexican lime acquisition plants for *A. citricola* and *A. gossypii* (Texas population) and 14 replicate plants for *A. gossypii* (Florida population).

RESULTS AND DISCUSSION

The Texas population of *A. citricola* was highly efficient at transmitting the Texas CTV isolate used in this study (Table 1). Eleven of 15 Mexican lime acquisition plants tested positive for CTV infection based on mean O.D. 405 readings of 1.930 from ELISA. Mean O.D. 405 readings for buffer controls, uninfected Mexican lime controls, and the positive CTV 111-F virus control were 0.070, 0.262, and 1.924, respectively. One of the 11 Mexican lime plants was symptomatic for CTV infection based on vein clearing in the leaves.

Table 1. Transmission efficiency and ELISA O.D. 405 readings of a Texas mild strain Citrus tristeza virus isolate by a Texas population of *Aphis citricola* and Texas and Florida populations of *A. gossypii.*

Aphid population	Mexican lime Acquisition plants total reps	Mexican lime Acquisition plants CTV positive	Mean O.D. 405 reading	Transmission efficiency (%)a
Texas *A. citricola*	15	11	1.930[b]	73%
Texas *A. gossypii*	15	0	0.166	0%
Florida *A. gossypii*	9[c]	0	0.176	0%
Controls for ELISA				
Positive CTV 111-F	-	-	1.924	-
uninfected Mexican Lime	-	-	0.262	-
buffer	-	-	0.070	-

[a]Transmission efficiency = number CTV positive acquisition plants/number replicate acquisition plants.

[b]Mean O.D. 405 readings of 11 CTV positive Mexican lime acquisition plants.

[c]Five Mexican lime acquisition plants died.

Neither the Texas nor the Florida population of *A. gossypii* transmitted the Texas CTV isolate under these experimental conditions. Transmission efficiency of CTV is affected by aphid species and biotypes, virus strain, citrus species and cultivar, and environmental factors (9, 10, 11). The low number of viruliferous aphids transferred to Mexican lime acquisition plants could have affected CTV transmission by *A. gossypii*. Both populations of *A. gossypii* also may not transmit this particular Texas CTV isolate. Further studies should be conducted to test the transmission efficiency of several indigenous populations of *A. gossypii* and *A. citricola* on Texas CTV isolates and CTV isolates maintained in the CTV repository in Beltsville, MD.

CTV transmission studies conducted in the 1950's indicated that Texas aphid species were unable or highly inefficient at transmitting CTV (7). Many of these studies were conducted with Meyer lemon or grapefruit as the donor or acquisition plant. Aphid species feeding on citrus are known to prefer orange over grapefruit or lemons (11) and grapefruit is a poor donor host for CTV (10). During our field collections for the Texas population of *A. citricola* and *A. gossypii, A. citricola* was found feeding only on Marrs orange even through 'Rio Red' grapefruit trees of the same age and stage of growth flush were in adjacent blocks. The *A. gossypii* population was collected from squash because feeding populations were not found on citrus.

Our data indicate that the indigenous population of *A. citricola* was efficient at transmitting CTV. Thus the potential for natural spread of CTV in Texas may not be limited by low transmission efficiency of CTV in resident aphid populations. The absence of observed natural spread with resultant economic loss in Texas citrus to CTV is probably related to the extremely low incidence of CTV in the Lower Rio

Grande Valley citrus plantings (6) plus the high proportion of grapefruit plantings. CTV, however, can be vectored readily from orange to grapefruit as is occurring in the current CTV epidemic in Florida (5). Current regulatory efforts to prevent the introduction of CTV in budwood or containerized plants should be maintained and upgraded to ensure that the Texas citrus industry remains protected from this devastating virus disease. Additionally, due to the severe freeze in 1983 and resulting intensive replanting efforts, a systematic survey of new plantings for CTV infection is recommended.

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Mature Ash Trees Affect the Growth of Adjacent Young Grapefruit Trees

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Additional Index Words: *Citrus paradisi, Fraxinus Berlandieriana,* allelopathy, interplant competition

ABSTRACT

The first row of a newly planted orchard of 'Rio Red' grapefruit trees, *Citrus paradisi* MacF., was planted 37 feet from and parallel to a row of mature Mexican or Rio Grande ash trees, *Fraxinus Berlandieriana* A. DC. By the second year the ash trees had not only noticeably reduced the grapefruit trees' growth but had induced precocius bloom and fruit set. This effect continued into the third year. When compared to the second row of trees, 25 feet away, the trees in the first row averaged less than a seventh of the canopy size but had over 4 times the number of fruit per unit canopy volume.

Being part owner-manager of a young citrus orchard provides many opportunities to observe the growth and responses of the trees to their culture and environment. One such observation was the profound influence that a row of irregularly spaced mature Rio Grande ash trees had on the growth of a nearby row of 'Rio Red' grapefruit trees. The row of grapefruit trees, all on sour orange rootstock, were planted about 37 feet from the row of ashes. The grapefruit trees were planted 14 feet apart with row spacings of 25 feet. Figure 1 shows the distances between the 10 ash trees and their orientation with respect to the grapefruit trees. The ash trees ranged from 25-35 feet high with approximate canopy sizes as shown in Fig. 1.

The grapefruit trees were irrigated immediately after planting in late January, 1986, and received 3 more irrigations thereafter, the last being in mid-October. From that time, natural rainfall was sufficient to maintain vigorous growth in the orchard without supplemental irrigation. In the spring of 1987 a quarter pound, and 1988, a half pound, of nitrogen as urea was applied to each tree by hand. Weeds were controlled by both mechanical and/or chemical means.

The reduced growth of the trees in the first row compared to those in the rest of the orchard, already noticed by the fall of 1986, continued into 1987 (Fig. 2). Furthermore, those trees opposite the areas where the ash trees were concentrated bloomed in March, 1987, and set an estimated 6 to 8 fruit per tree compared to no fruit on all other trees. As the influence of the ash trees became increasingly pronounced in 1988, we decided to measure the canopies and count the fruit on the trees in the first row and compare these values with those of the trees in the second row which were typical of the rest of

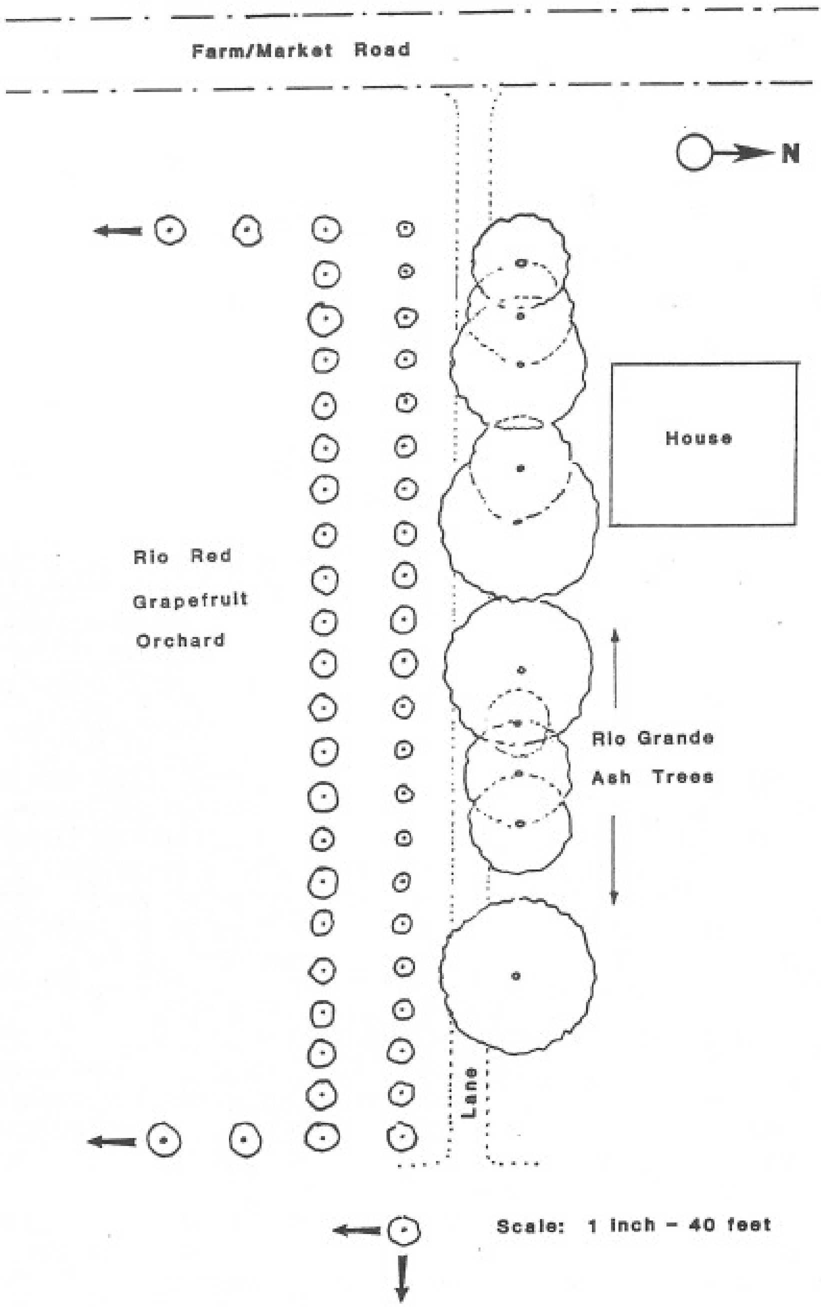

Fig. 1. Sketch of the position of Rio Grande ash trees their canopy size and orientation relative to a young 'Rio Red' grapefruit orchard. The grapefruit trees were planted in January, 1986, and the sketch was made in September, 1988.

the 'Rio Reds' in the orchard. Canopy volumes were calculated from tree diameters (d) and heights (h) using the formula for half a prolate spheroid i.e. $V = .524\ Hd^z$. The results, tested by a simple statistical test are shown below:

Row	Canopy Volume (ft^3)		Fruit / ft^3 Canopy	
	Mean	C.V.[z]	Mean	C.V.[z]
1	4.6	100%	3.1	97%
2	27.4	20%	.7	44%
	***[y]		***[y]	

[z] coefficient of variation (std deviation/mean × 100) is a measure of the variation among trees within each row.
[y] significance level of 0.1% or 1 chance in 1,000 there is no difference between rows.

Fig. 2. Photo taken from east end of Rows 1 and 2 of the 'Rio Red' grapefruit. The line of ash trees is on the right. Note the larger size of the trees in Row 2 (left) and the middle of Row 1 opposite the gap in the line of ashes.

The extreme variation among the trees in Row 1 is principally due to the 3 large trees at the east end of the row and the 3 near the middle which are opposite the gap between the 5th and 6th trees in the line of ashes. From this observation and the fact that the ashes did not shade the citrus trees, we suspect that it is the roots of the ash trees, extending some 12 to 15 feet beyond the canopy drip line, that are affecting the grapefruit trees.

Articles on windbreak plantings, which might be comparable to the line of ash trees, indicate that windbreak trees normally will compete with the citrus for nutrients and moisture (Platt, 1966; Turrell, 1973). The recommended practice is to prune the roots down 3 to 4 feet deep at a distance of 12 feet or more from the windbreak to reduce competition. Craighead (1967) claims that roots of windbreaks in the Great Plains generally occupy and compete only in an area as wide as the height of the windbreak. However, the soil layer at which the major root distribution of the competing trees vs. those of the crop occurs may be important. In this case, for example, the young 'Rio Red' tree roots may have to grow in the soil layer above the ash roots rather than in or through the same layer. Studies of root density and distribution suggest citrus trees of the same age and condition which are given good care do not suffer much from intertree root competition except at extremely high densities (Boswell, et al., 1975; Castle, 1980 and Cahoon and Stolzy, 1966). Information on root distribution and competition between citrus and other species, however, is lacking.

Although the effect of the ash trees on the young grapefruit might be a simple matter of competition for water and nutrients, the interesting possibility of an allelopathic reaction cannot be ruled out. Another species of ash, *F. excelsior*, whose roots were intermingled with oak reduced both mineral uptake and protein biosynthesis by the oak roots via a chemical compound exuded from the ash roots (Rice, 1984). While competition is most likely responsible the possibility still exists that our native ash produces a compound which reduces citrus growth and induces early bearing.

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Biological Control of Agricultural Pests: Concepts Every Producer Should Understand

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ABSTRACT

Biological control involves the utilization of insect parasites, predators and pathogens in an attempt to maintain pest organisms at subeconomic densities. Despite this relatively straightforward objective, many of the essential concepts of biological control are poorly understood by entomologists, producers and other practitioners of integrated pest management. An overview of the three principal strategies of biological control is presented, with emphasis on the processes by which effective natural enemies suppress and regulate (rather than control) pest populations, general characteristics of effective natural enemies, and the advantages, limitations and prospects of biological control on horticultural crops in southern Texas.

Biological control has been broadly defined to include a wide range of noninsecticidal pest control tactics (1), although the classical definition is generally restricted to "the action of parasites, predators and pathogens in maintaining another organism's population density at a lower average than would occur in their absence" (11). Biological control represents a fundamental component of the integrated pest management (IPM) programs developed for agricultural systems in the Lower Rio Grande Valley (LRGV) of Texas, and has produced an overall success rate superior to that of most other pest management strategies (12, 13, 34). Nevertheless, producers and other IPM practitioners frequently reveal limited knowledge regarding certain key concepts of biological control, particularly the meaning of natural enemy effectiveness, biological characteristics of effective natural enemies, and the means by which effective natural enemies regulate, rather than control, pest population densities. An understanding of such concepts is vital to fully appreciate the rationale, advantages and limitations of the three principal strategies of biological control.

PEST POPULATION REGULATION BY EFFECTIVE NATURAL ENEMIES

Natural enemies. Three broad categories of natural enemies may be employed singly or collectively in biological control programs. Insect **parasites,** often referred to as **parasitoids**, are particularly commonplace among the wasps (Hymenoptera) and flies (Diptera), but also include representatives in other insect groups. Parasites deposit eggs or egg clusters on, near or within a host individual, and develop either externally (ectoparasites) or internally (endoparasites). Parasite development almost invariably results in death of the host organism, an effect which differs fundamentally from that of true parasites, e.g., intestinal worms of mammals, which may weaken but rarely kill hosts. **Predators** include representatives from most animal groups and differ from insect parasites in two important respects: 1) immature predators are generally free-living and must search for suitable prey, whereas searching is generally a function of the adult female parasite alone, and 2) immature predators generally require consumption of several to many prey organisms during development, whereas immature parasites generally require but a single host individual. **Pathogens** include a wide range of disease-producing microorganisms which infect hosts through ingestion (bacteria, viruses) or penetration of the integument (fungi), and are commonly considered to include toxins produced by such organisms which have been developed into commercial formulations, e.g., Dipel^R (endotoxin of *Bacillus thuringensis* Berliner).

Pest population regulation. Although sometimes used synonomously, the terms control and regulation refer to distinct processes which produce fundamentally different effects. **Control** implies a suppressive factor which tends to destroy a constant percentage of a target population irrespective of population densities. For example, application of a broad-spectrum insecticide at a given rate may be expected to suppress a pest infestation ca. 90% regardless of whether the pest occurs at densities of 1,000 or 1 million per acre. Control may provide rapid and substantial suppression, although the effect tends to be extremely short-term in nature and is commonly followed by a rapid resurgence in pest densities (Fig. 1A).

Regulation, in contrast, is defined as "the actions of repressive environmental factors, collectively or singly, which intensify as the population density increases and relax as this density falls" (28). Although the theoretical basis of population regulation is highly mathematical (28,29,30,31,43), the effects are relatively straightforward (Fig. 1B). As pest densities increase, the increasing availability of food sources and/or reproductive sites allows a similar increase in densities of the regulator, i.e., associated natural enemy. It should be noted that natural enemy increases tend to be delayed somewhat with respect to that of the host or prey, since such increases result from reproduction and necessarily require a certain time interval for development of immature stages. Natural enemy increases are accompanied by a progressive increase in percentage mortality of the pest caused by parasitism or predation, a trend which tends to suppress pest densities before a certain characteristic upper level of abundance is attained. Conversely, decreasing pest densities are accompanied by a similar decline in natural enemy densities, due to the effects of starvation, dispersal and other factors, which results in a progressive decrease in percentage mortality of the pest caused by parasitism or predation. The latter trend allows pest densities to increase before some characteristic lower level of abundance has been attained, and effectively prevents extinction of the host or prey population.

Thus, the mechanisms and effects of regulation are fundamentally different from those of controls. Control involves 'density-independent' suppression which tends to remain relatively constant irrespective of densities, is relatively short-term in nature, and commonly contributes to wide fluctuations in densities of the target population (Fig. 1A). Regulation involves 'density-dependent' suppression characterized by cyclic intensification and relaxation as pest densities increase and decrease, respectively. The effect of regulation is to maintain populations of both pest and natural enemy

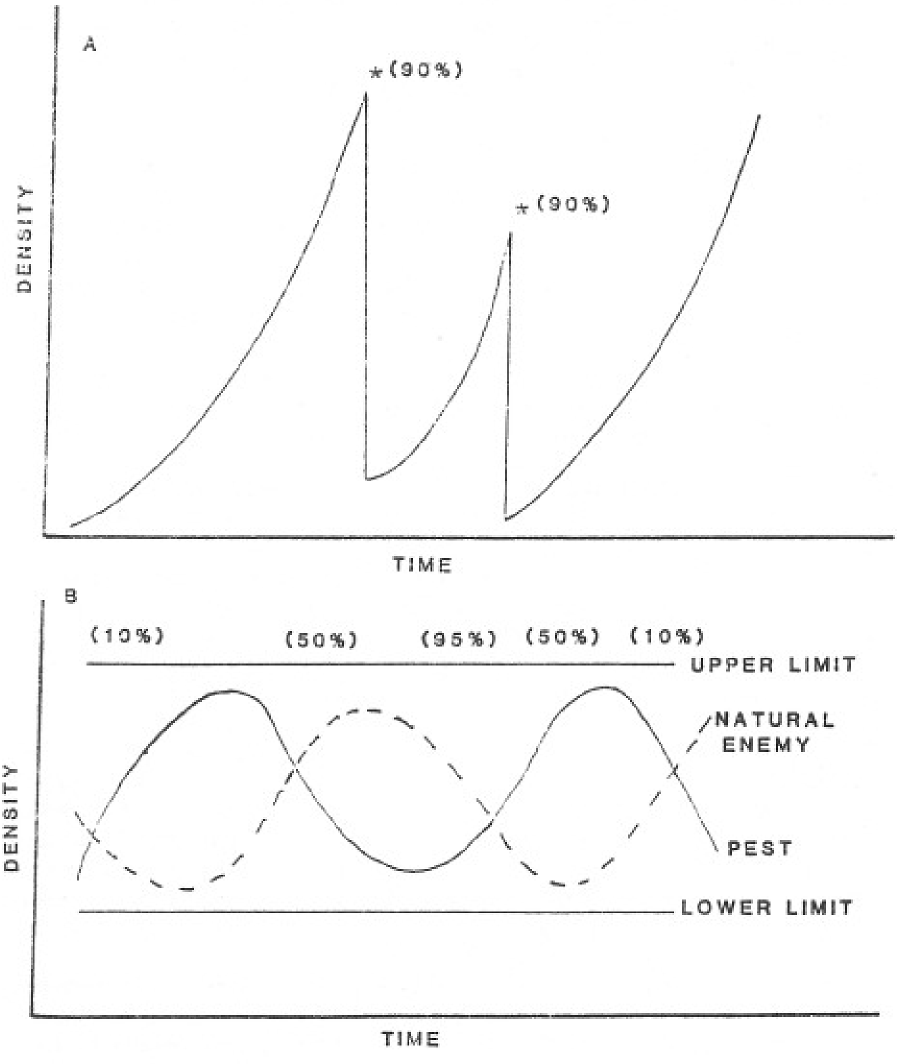

Fig. 1. Control vs. regulation of pest densities. Control by insecticidal treatment (*) tends to destroy a constant percentage of the target population regardless of densities (in parentheses). Such an effect is short-term in nature and commonly contributes to wide fluctuations in densities of the target population (A). Regulation by natural enemies is characterized by variable mortality rates (in parentheses) which are strongly influenced by densities of the target population (B). Mortality caused by regulators tends to intensify as pest densities increase, and to relax as pest densities decrease, a trend which serves to maintain both populations within characteristic upper and lower limits of abundance for extended periods (B).

within characteristic upper and lower limits for indefinite periods (Fig. 1B).

Characteristics of effective natural enemies. From an economic perspective, **effectiveness** implies the capability of one or more natural enemy species to regulate pest population densities at subeconomic levels within a given crop environment. Although a diverse array of natural enemy species have been utilized in biological control programs, those which have been particularly effective appear to share certain biological traits (17,30,31). In general, the most effective natural enemies appear to be characterized by: 1) considerable adaptability to the varying physical conditions of the environment, 2) a relatively high degree of host or prey specificity, 3) a high rate of population increase relative to the host or prey, which confers a capability to rapidly suppress host or prey densities, 4) a high searching capacity (i.e., ability to locate hosts or prey when scarce), which confers a capability to regulate host or prey populations at low densities, 5) other biological traits, e.g., spatial and temporal synchrony with the host or prey population and ability to survive host-free periods, if such exist, which collectively permit the natural enemy to maintain 6) a strong density-dependent relationship with the host or prey population. Several types have been documented by Huffaker, et. al. (30).

A comparison of two parasites. An example involving a hypothetical pest species and an associated parasite complex may help clarify several somewhat confusing aspects regarding natural enemy impact and effectiveness. Abiotic elements, i.e., weather and other factors not directly related to natural enemy activities, generally destroy an average of 75% of eggs deposited by the pest, 15% of the several larval stages, and less than 1% of individuals surviving to the pupal stage, which collectively sums to ca. 90% generation mortality. The pest is attacked by two parasites: 1) an egg parasite characterized by a wide host range, and 2) a pupal parasite which is specific to the given pest species. The egg parasite normally occurs at undetectable levels when the host is relatively rare, i.e., early-season, but increases rapidly and inflicts an average 50% egg parasitism when the host has increased to relatively high densities, i.e., mid-season. The pupal parasite generally inflicts ca. 45% parasitism of host pupae during early-season and ca. 90% parasitism during the mid-season period. It should be noted that since only 10% of the pest individuals normally survive to the pupal stage during both periods, pupal parasitism actually accounts for only a small percentage of total pest mortality during the early-season (10% surviving to pupal stage × 45% pupal parasitism / 100 = 4.5% total mortality) and mid-season periods (10% × 90% / 100 = 9.0%).

Although producers commonly consider the egg parasite to be the more effective of the two natural enemy species, egg parasitism would have essentially no control impact during the early- or mid-season periods. The parasite is largely absent from the habitat during early-season due to an inability to effectively locate rare hosts (i.e., a low searching capacity) which results in a propensity of the parasite to switch to more abundant alternate hosts occurring in other habitats. Although seemingly impressively, the 50% egg parasitism inflicted during mid-season is largely inconsequential, since most of the pest eggs parasitized would have died at any rate from abiotic factors. In contrast, the pupal parasite would have substantial impact during both periods. Total pest mortality resulting from pupal parasitism during early- and mid-season (4.5% and 9.0%, respectively), while seemingly insignificant, effectively eliminates 30% and 90%, respectively, of those pupae which would have otherwise produced adults. Moreover, mortality inflicted by the two parasite species has a distinctly different impact on host reproductive potential: assuming a 50:50 sex ratio of the host and an average egg complement of 100 eggs per female, an average group (cohort) of 100 host eggs exposed to the egg parasite alone during mid-season would be expected to increase 500% in the next generation (i.e., 5 emerged females × 100 eggs/female = 500 eggs), whereas a similar cohort exposed to the pupal parasite alone would decrease 50% (i.e., 0.5 emerged females × 100 eggs/female = 50 eggs). The important point is that the magnitude of host or prey mortality caused by a given natural enemy species may be extremely misleading as an indicator of effectiveness: factors such as host or prey stage attacked, and the impact of such mortality on host or prey reproduction, largely determine natural enemy effectiveness.

Several other aspects of the hypothetical host-parasite interaction deserve comment. The pupal parasite, which was highly effective against the host in the first habitat, proved to be largely ineffective against the same pest species in another crop system. Such a situation might reflect any of several possible factors: 1) temperature-humidity gradients and other environmental conditions in the second habitat may be favorable to the host but detrimental to the parasite, 2) the parasite may not be attracted to the second habitat, i.e., a lack of spatial synchrony with the host, and 3) host individuals developing in the second habitat might be unsuitable for parasite development, or the parasite may be in an unsuitable physiological condition, both of which indicate lack of reproductive synchrony of the parasite with respect to the host. A notorious example of the latter phenomenon involves the collection and sale of adult convergent ladybird beetles, *Hippodamia convergens* Guerin-Meneville, collected from winter aggregations in California for sale to producers and home gardeners. Although these insects are voracious predators of aphids and other pests, adults are collected in a diapausing (nonreproductive) state and tend to disperse immediately (without feeding) when released, unless preconditioned by special diets (13). Finally, the parasite may exert a similar degree of host suppression in both habitats: however, the economic (treatment) threshold established for the pest on the second crop occurs at a level below which the parasite is capable of consistently maintaining the host, and hence the parasite is considered ineffective. Thus, natural enemy effectiveness is a function of biological characteristics of both the host and natural enemy species, the environment in which the interaction occurs, and is fundamentally influenced by crop economics.

STRATEGIES OF BIOLOGICAL CONTROL

The objective of applied biological control is the utilization of effective natural enemies to regulate pest densities at subeconomic levels (12). Three principal strategies are commonly employed in such efforts.

Classical biological control. A majority of our major agricultural pest problems have resulted from the accidental (and sometimes deliberate) introduction of exotic plant or animal species into a new region, generally without its complement of regulating natural enemies. In an absence of effective regulators, such species commonly increase and subsequently stabilize at levels which consistently exceed economic injury thresholds. Notorious examples of such exotic pests which have become established in the LRGV include the boll weevil, *Anthonomus grandis* Boheman, and pink bollworm, *Pectinophora gossypiella* (Saunders) on cotton, and the California red scale, *Aonidiella aurantii* (Maskell), citrus red mite, *Panonychus citri* (McGregor), and citrus blackfly, *Aleurocanthus woglumi* Ashby, on citrus.

Classical biological control involves the introduction and establishment of effective natural enemies associated with such exotic (and sometimes native) pest species in an attempt to permanently reduce average pest densities, ideally to subeconomic levels,

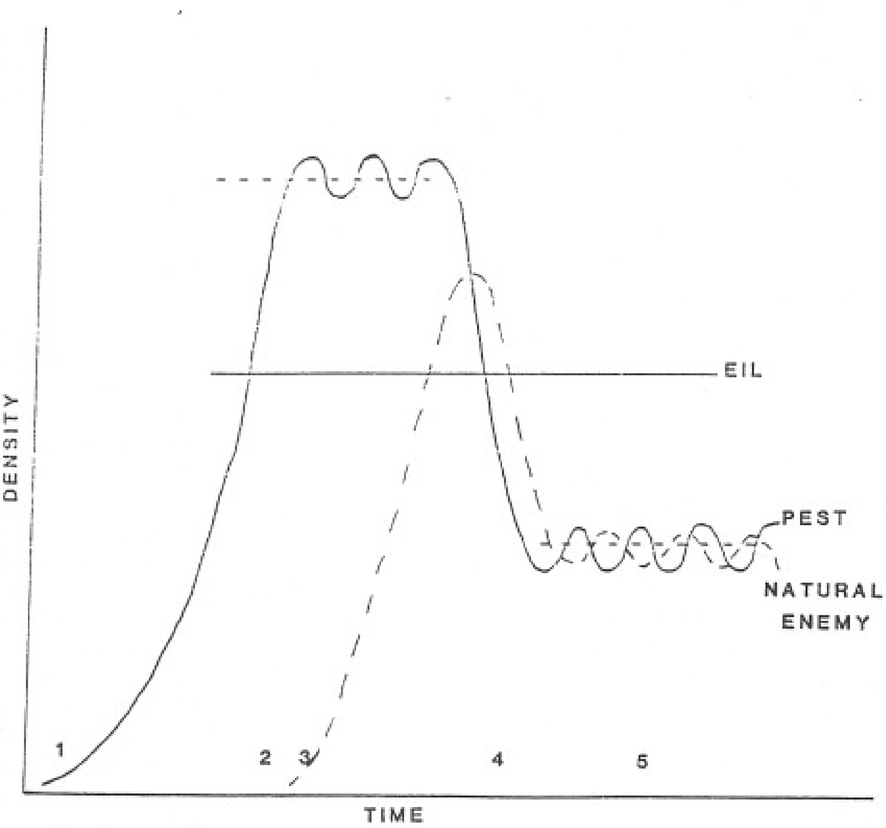

Fig. 2. Objectives of classical biological control. Exotic pest species invades a new environment without complement of regulating natural enemies (1). Pest densities increase and eventually stabilize at an average level of abundance which exceeds the economic injury level (EIL) for the crop attacked (2). Exotic natural enemy introduced into the target region (3) becomes established and provides an initial suppression of pest population densities (4). Pest and natural enemy populations eventually attain a new equilibrium at an average level of abundance below the economic (treatment) threshold (ET) for the particular crop (5).

through density-dependent regulation (Fig. 2). The initial phase of a classical biological control program involves foreign exploration for effective natural enemies. Such efforts are commonly initiated in the aboriginal home of the pest, i.e., the region in which the pest species and associated natural enemies evolved (if known), but may require additional efforts in other regions in order to obtain natural enemy strains climatically adapted to the target region. The remaining sequence of phases include: 1) strict quarantine procedures to ensure that imported natural enemies are not potentially detrimental (19); 2) mass propagation (18,36); 3) field release and colonization of natural enemies in the target region, and 4) long-term evaluation of natural enemy impact

(14,15,16). Due to the substantial expense and effort involved, classical biological control projects are generally conducted by state, Federal or international agricultural agencies in an attempt to achieve biological control of exotic (and sometimes native) pest species over wide geographic regions.

Classical biological control has traditionally received major emphasis in the LRGV region. Programs which have reduced the need for insecticidal treatment substantially or entirely include the biological control of 1) Rhodesgrass mealybug, *Antonina graminis* (Maskell), on Rhodesgrass by the parasite *Neodusmetia sangwani* (Rao) (5,6,9,39); 2) Florida red scale, *Chrysomphalus aonidum* (Linnaeus), on citrus by the parasite *Aphytis holoxanthus* DeBach (4); 3) purple scale, *Lepidosaphes beckii* (Newman), on citrus by the parasite *Aphytis lepidosaphes* Compere (3); 4) brown soft scale, *Coccus hesperidum* Linnaeus, on citrus by a complex of parasites, including *Microterys flavus* (Howard) and *Coccophagus lycimnia* (Walker) (23,24,25); 5) citrus mealybug, *Planococcus citri* (Risso), on citrus by a natural enemy complex, including the parasites *Leptomastix dactylopii* Howard and *Anagyrus* sp. near *sawadai* Ishii (35); and 6) citrus blackfly, *Aleurocanthus woglumi* Ashby, on citrus by the parasites *Amitus hesperidum* Silvestri, *Encarsia* (= *Prospaltella*) *clypealis* and *E. opulenta* Silvestri (24,40,41,42) (Fig. 3). A serious disruption of citrus blackfly, which has occurred during the past several years from undetermined causes, has recently become a major concern to the LRGV citrus industry (see following discussion). A summary of other citrus pests which have not been direct targets of classical biological control, but appear to be under substantial to complete biological control, has been presented in a recent review (10).

Natural enemy conservation. Certain events or practices which seriously disrupt populations of efficient natural enemy regulators are commonly associated with 'secondary' pest outbreaks (Fig. 4). Injudicious use of chemical insecticides has accounted for the bulk of the documented examples of such disruptions in the LRGV region: e.g., frequent outbreaks of tobacco budworm, *Heliothis virescens* (Fabricius), on cotton resulting from application of organophosphate insecticides directed against key pests such as boll weevil; a general outbreak of brown soft scale on citrus caused by insecticide drift (methyl parathion) from cotton (25,26,27); and destructive outbreaks of citrus mealybug on citrus which accompanied widespread application of organophosphate insecticides to citrus (7). Until evidence to the contrary is obtained, insecticidal disruption should be considered a prime suspect in the recent resurgence of citrus blackfly. Thus, a major emphasis of current IPM research has been directed to development of nondisruptive, or minimally-disruptive, insecticidal control strategies (8). However, a significant effort has also been expended in development of strategies designed to minimize detrimental effects of ants, dust and other factors (10), and to increase natural enemy effectiveness through provision of supplementary food sources (22). Natural enemy conservation thus represents a preventative rather than remedial strategy, and is primarily the responsibility of the individual producer.

Natural enemy augmentation. Two related strategies have been developed to enhance natural enemy effectiveness through periodic release. Mass (innundative) releases are designed to achieve rapid short-term suppression of pest infestations, primarily as a result of mortality caused by the released natural enemies (Fig. 5A). Examples include mass release of *Trichogramma* spp. and *Chrysoperla* (= *Chrysopa*) spp. for control of Lepidopterous pests in field crops (38). Innoculative releases, involving substantially lower numbers of released insects, are

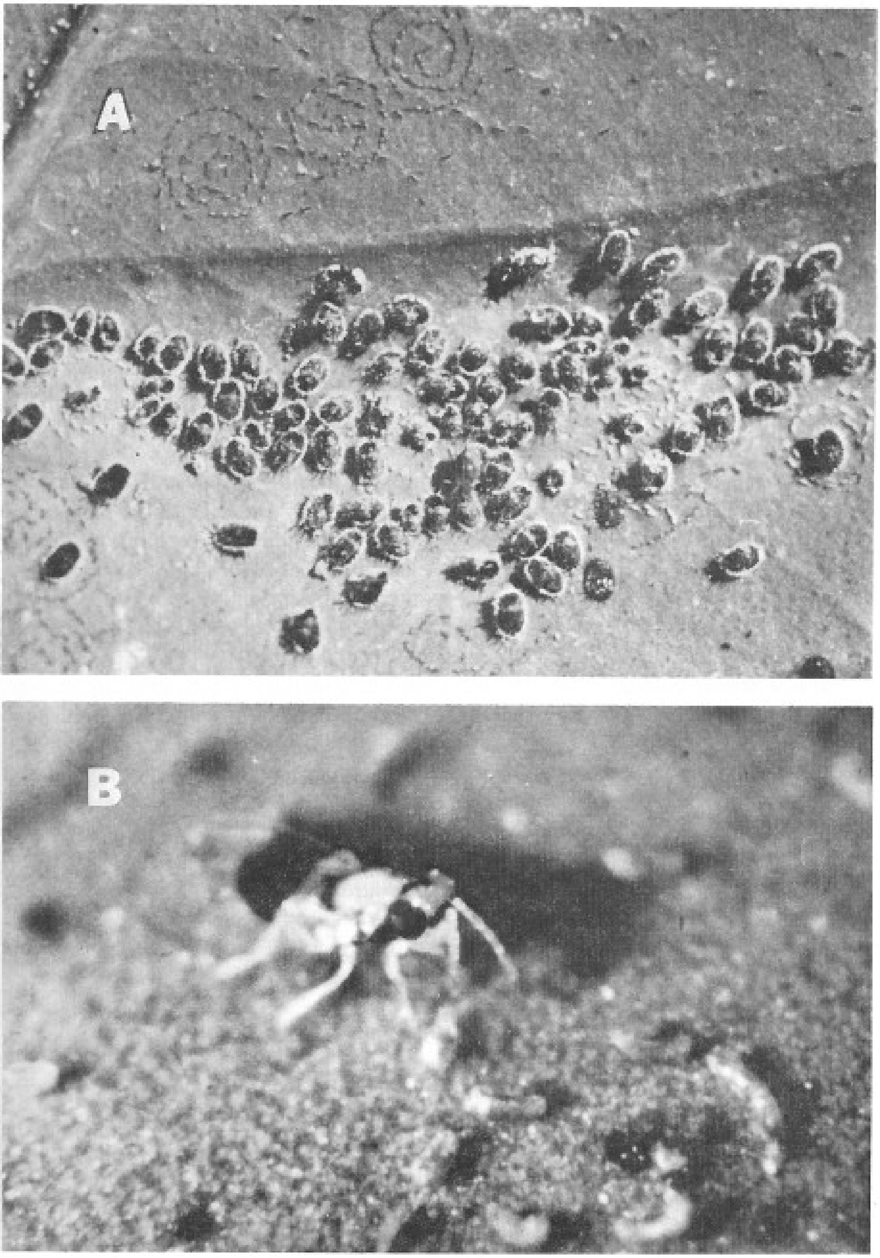

Fig. 3. Immature stages of citrus blackfly, *Aleurocanthus woglumi*, on the lower leaf surface of citrus (A) and the parasite *Encarsia opulenta* (B).

designed to achieve long-term biological control through cumulative mortality caused primarily by progeny of released natural enemies (Fig. 5B). Examples are numerous and include most of the classical biological control programs.

An innovative augmentation strategy was instrumental in the success of the Rhodesgrass mealybug project in southern Texas (39). One of the principal logistical difficulties in achieving biological control of the pest involved the brief adult lifespan (ca. 24 hrs) and brachypterous (functionally wingless) condition of the female parasite *Neodusmetia sangwani*. Distribution of infested grass stems by aircraft greatly facilitated dispersal of the parasite throughout a 60,000 sq. mi. region in which control was required (39). A somewhat similar approach was used in Mexico, in which ca. 300 million parasites were artifically distributed to all regions of that country during 1950-1953 to expedite biological control of citrus blackfly (20).

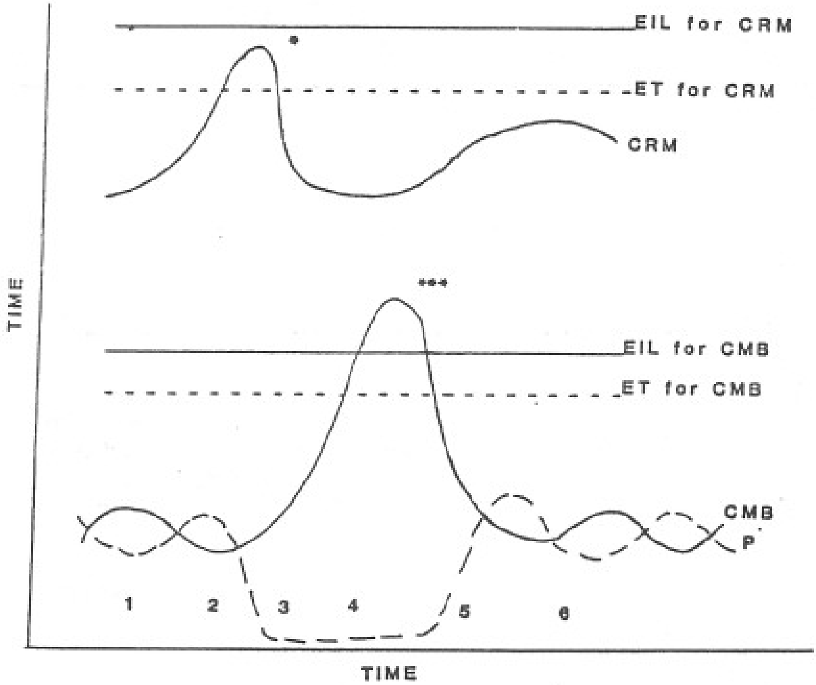

Fig. 4. Anatomy of a secondary pest disruption. Citrus mealybug (CMB) and associated parasites (P) in stable interaction at average densities below economic threshold (ET) for grapefruit (1). Densities of citrus rust mite (CRM) increase to economic threshold and require insecticidal treatment (*) to prevent increases to the economic injury level (EIL) (2). Application of broad-spectrum pesticide (*) reduces densities of citrus rust mite, but also decimates parasites of citrus mealybug (3). Densities of citrus mealybug increase to economic threshold and require insecticidal treatment (*), which further disrupts parasite population and may allow mealybugs to increase to the economic injury level (4). Curtailment of insecticidal treatment allows the parasite population to recover and suppress mealybug densities (5) to a level below the economic threshold (6).

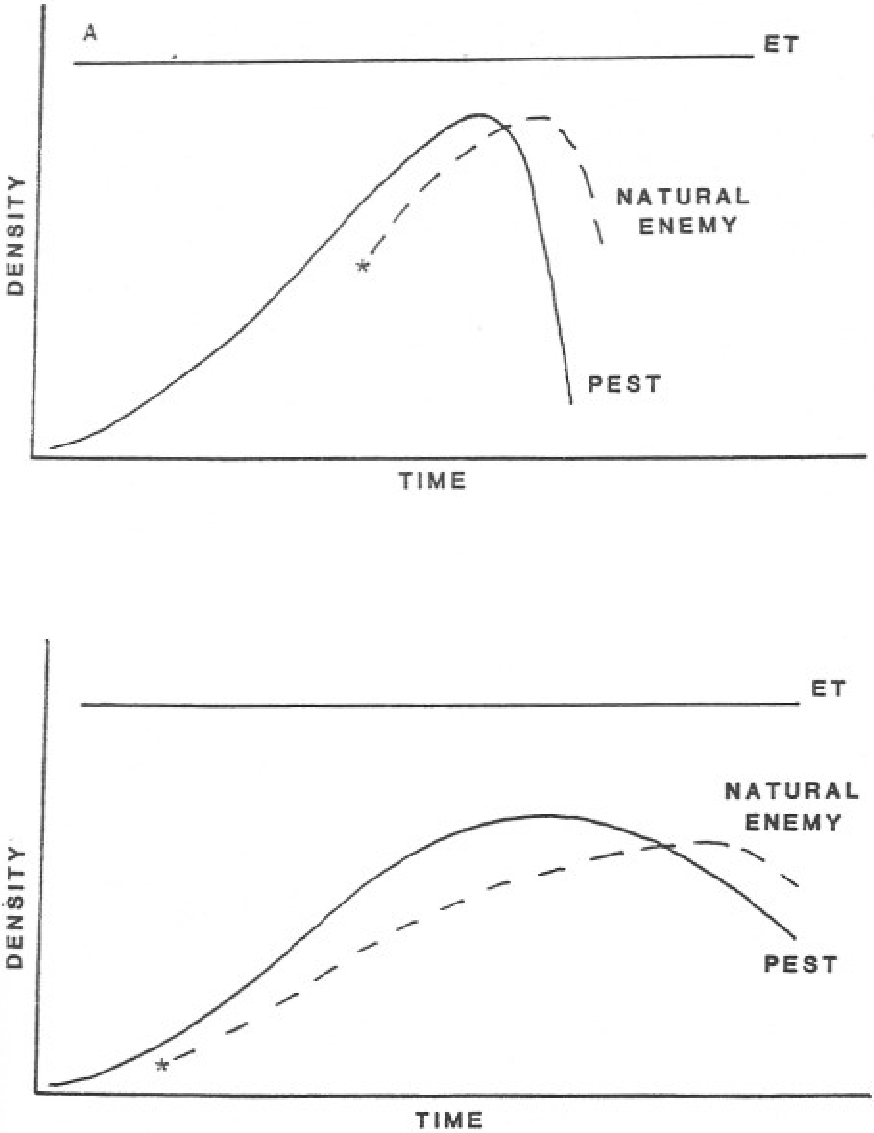

Fig. 5. Objectives of natural enemy augmentation. Mass (innundative) release designed to rapidly suppress pest densities primarily through mortality caused by released insects (A). Innoculative release involving substantially fewer natural enemies designed to provide long-term biological control primarily through cumulative mortality caused by progeny of released insects (B).

ADVANTAGES, LIMITATIONS AND PROSPECTS OF BIOLOGICAL CONTROL

Advantages. The numerous advantages of biological control were summarized in a major review (13). Effective natural enemies generally exhibit a high degree of host or prey specificity and thus pose little or no biological hazard to nontarget organisms, including humans. In contrast to a high incidence of pesticide resistance which has evolved among numerous pest species, biological control has rarely, if ever, been seriously disrupted by evolution of resistance to natural enemies. A given pest species may evolve adaptations detrimental to associated natural enemies, although such processes generally occur over evolutionary time and are commonly associated with counteradaptations by the natural enemy species. Moreover, density-dependent regulation by natural enemies tends to provide relatively long-term, and often permanent, control of a given target pest. Of the classical biological programs directed against 223 insect pest species prior to 1974, partial to complete success was documented for 120 species and the need for insecticidal treatment was eliminated for 42 species (13). Finally, the biological control method is generally cost-efficient. Classical biological control projects conducted against insect pests in California prior to 1974 produced an estimated net return of ca. 30 to 1, and resulted in an estimated savings of ca. $200 million to California producers (13). Indeed, naturally-occurring biological control agents, and exotic counterparts established through classical biological control efforts, essentially cost the producer nothing, with the exception of practices (i.e., IPM strategies) designed to prevent disruption of such systems.

Limitations. Despite such inherent advantages, biological control may also be subject to certain limitations which should be clearly recognized by producers and other IPM practitioners. Not all pest species within a given complex are attacked by effective natural enemies: in particular, exotic pest species may be entirely devoid of natural enemies, while others (both exotic and native) may be attacked by inherently ineffective natural enemies which may not be rendered effective by either conservation or augmentation. Moreover, natural enemies tend to be considerably more susceptible to pesticides than many foliage-feeding pests, which possess enzyme systems (microsomal oxidases) designed to metabolize natural plant toxins, but which also effectively detoxify petroleum-based insecticides. Thus, insecticidal treatment directed against certain key pests may severely reduce the impact of certain natural enemies which are normally effective against certain other pests in the same or different crop environments (Fig. 4). Natural enemy augmentation represents one means by which to compensate for such disruptions, although the feasibility of such a strategy is predicted on a reliable source of effective natural enemies in sufficient quantities when needed. A partial list of commercial insectaries has been compiled in a recent review (37). Of particular significance, each of the three biological control strategies involves a time element: natural enemy increases tend to lag behind the host or prey (Fig. 1), and hence do not generally provide the immediate suppression provided by chemical insecticides.

Prospects. Biological control was firmly established as a scientific discipline following the spectacular suppression of cottony-cushion scale, *Icerya purchasi* Maskell, on California citrus by the imported vedalia beetle, *Rodolia cardinalis* (Mulsant), ca. 1888-1889 (13). During the past century, classical biological control has produced an impressive overall record (13,2), and the incorporation of related biological control strategies (i.e., natural enemy conservation and augmentation) into IPM programs for various production systems has become a major priority. The significance of biological control may be expected to increase substantially in the future due to: 1) the increasing costs of insecticidal treatment, 2) an increasing incidence of pesticide resistance, 3) mounting public concern regarding pesticidal contamination of the environment, and 4) increasingly stringent regulation of pesticide usage.

Classical biological control, which has resulted in several major successes in the LRGV region, will continue to be of major importance in attempts to locate effective natural enemies of key pests, e.g., citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), and Texas citrus mite, *Eutetranychus banksi* (McGregor), and importation of natural enemies known to be effective against certain pests in other regions, e.g., *Aphytis melinus* DeBach against California red scale. Natural enemy conservation is currently a principal objective in the majority of the IPM programs developed by the U.S. Department of Agriculture (Agricultural Research Service and Animal and Plant Health Inspection Service), Texas Agricultural Experiment Station and Cooperative Extension Service, and Texas A&I University Citrus Center. Natural enemy augmentation, which has traditionally received less emphasis in the LRGV region than the other biological control strategies, would appear to be highly feasible for control of certain pests, particularly those associated with nursery, greenhouse and garden crops. Augmentation strategies developed for pests known to occur in the LRGV region have been developed and widely adopted in Europe, e.g., releases of *Phytoseiulus persimilis* Athias-Henriot against two-spotted mite, *Tetranychus urticae* Koch, and *Encarsia formosa* Gahan against greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (32,33). An additionaly potential for augmentation involves the 'compensatory release' concept, e.g., augmentation of *Microterys flavus* to suppress secondary outbreaks of brown soft scale (23). Moreover, an augmentation approach involving artificial distribution of parasites similar to that employed against citrus blackfly in Mexico (20) will almost certainly be necessary to expedite rapid suppression of the current outbreak in Texas. However, augmentation will probably receive limited emphasis until commercial or industry-operated insectaries similar to that of the Fillmore Citrus Protective District in California (21) are established.

The current outbreak of citrus blackfly and other secondary pests on LRGV citrus should reemphasize the significance of natural enemies as regulators of agricultural pests. Among the most significant endeavors to ensure that this interest does not become transient will be education regarding the essential processes and effects of biological control, which this review has attempted to clarify.

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ON THE COVER

A serious disruption of citrus blackfly, *Aleurocanthus woglumi*, has recently occurred on Valley citrus. To understand the possible causes and solutions, see "Biological control of agricultural pests: Concepts every producer should understand" in this issue.

Photo courtesy of Texas A&I University Citrus Center