JOURNAL

OF THE

RIO GRANDE VALLEY HORTICULTURAL SOCIETY

Volume 14, 1960

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JOURNAL
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Published By
RIO GRANDE VALLEY HORTICULTURAL SOCIETY
Box 107, Weslaco, Texas

Editor, Edward O. Olson

Associate Editor, Bailey Sleeth

Aims and Objectives of the Society

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

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

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

The Society has sponsored 14 annual Institutes, where outstanding speakers from all parts of the country present new developments in the field of horticulture. Panel discussions, social get-togethers and a barbecue round up the all-day program.

Talks given at the Institute and reports of Valley research are published in the Journal of the Society, which provides a continuing record of horticultural progress in the Valley.

Anyone interest in horticulture can become a member of the Society. The annual fee is $4.00, which includes the Journal. Applications for membership, and annual dues should be sent to the Secretary-Treasurer, Rio Grande Valley Horticultural Society, Box 107, Weslaco, Texas.

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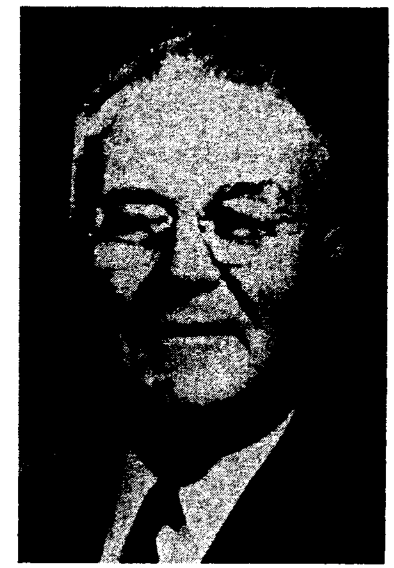

ORVAL STITES
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The Arthur T. Potts Award

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

Arthur T. Potts	(1955)
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E. M. Goodwin	(1957)
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Dr. G. H. Godfrey	(1959)
Dr. W. C. Cooper	(1960)

Dr. W. C. (Bill) Cooper

Dr. William C. Cooper
Recipient of the Arthur T. Potts Award
January 26, 1960

Dr. William C. Cooper, recently of Weslaco, received the Arthur T. Potts Award for 1959 at the fourteenth annual Valley Horticultural Institute in Weslaco on January 26.

Dr. Cooper was an inspiration. He showed what things could be accomplished by energetic research on problems of the industry. He encouraged others and often smoothed the way for their research.

He fostered the climate favoring research by encouragement of the Rio Grande Valley Horticultural Society, the Texas Avocado Society, and by support of organizations and groups interested in solving local horticultural problems.

As for his accomplishments, he was able to build up the U.S.D.A. staff at the Weslaco horticultural station and obtain modern facilities for U.S.D.A. personnel concerned with crops research.

He did research pertinent to industry problems. His articles on cold-hardiness, salt-tolerance, flower-induction, and control of chlorosis laid a foundation for new research since they clarified or solved old problems.

In addition to his work as a researcher, Dr. Cooper was active in community activities such as church, Little League, Rotary and the Weslaco band parent organization.

A native of Salisbury, Maryland, Dr. Cooper graduated from high school there in 1925 and received his Bachelor of Science degree in horticulture four years later from the University of Maryland. His master's in plant physiology he received from California Tech in 1936 and his doctor's degree in plant physiology from the same school in 1938. His doctor's thesis was on hormones and root formation.

His professional experience began as junior pomologist for the U. S. Bureau of Plant Industry at Pasadena and Pomona, California in 1929. He did research on transportation, storage and handling of citrus fruit.

He was associate plant physiologist at the U. S. Subtropical Fruit Experiment Station at Orlando, Florida from 1938 to 1942 and again in 1945. There he did research on rooting cuttings of subtropicals, the role of auxin in growth of citrus, induced flowering of pineapples and citrus and cold hardiness of citrus and citrus rootstocks.

He was horticulturist for the Office of Foreign Agricultural Relations in Mayagues, Puerto Rico, and Tingo Maria, Peru, in 1943 and 1944 doing research on cinchona, derris and cube.

Dr. Cooper became plant physiologist with the Bureau of Plant Industry in Weslaco in 1946 and served until July, 1959 when he was promoted to plant physiologist in charge of the U.S.D.A. Horticultural Station at Orlando which automatically places him in charge of U.S.D.A. citrus production research carried on in Orlando, Weslaco and Indio, California.

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Head, Dept. of Horticulture, Texas A&M College

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Tasks Ahead In South Texas Agriculture[1]

R. D. LEWIS
Director, Texas Agricultural Experiment Station

The masons, carpenters, electricians, and mechanics have come to this location and left us with a fine and challenging structure. Concrete, steel, bricks, electrical and mechanical equipment do not, however, give South Texas, this Valley, and this Station an operating facility. Into this building there now goes a group of devoted scientists and educators who are eager and ready to give vitality to the structure—to use it well in solving problems and spreading knowledge of their solutions.

These scientists in company with their fine co-workers in the federal and other state laboratories at this location and at others in the Valley will have no shortage of problems. In this Valley there now exists the most diverse and complex agriculture in this State. Over 50 vegetable, fruit, field and special crops are now grown here. Production activities and hazards occupy the full year; there are no seasonal let-ups or vacations.

There is time today only to indicate certain major tasks and objectives before all of us—researchers, educators, producers, suppliers, processors and distributors. Together we should periodically forecast with vision and imagination, tempered with objectivity, the major problems which agriculture, related industries, and consumers of agricultural products will likely face in the years ahead. Insofar as we do this, will today's research determine tomorrow's progress.

Without apology or prejudice for the order of listing, I now present the following short statements of major problems or tasks:

1. The first is to improve further the communication of the results of research. This requires cooperative action by many groups, including those who desire or need the information.

2. More and more the great body of consumers will determine the type of agriculture—so a second major task is to study and analyze consumer preferences, market needs and potentials, as the basis for adjustments in production, processing, and distribution.

3. A third major objective is to develop locally applicable principles and practices for the use and management of the basic physical resources of soil and water—for both irrigated and dry lands. Here we must give more attention to preventative measures rather than wait for situations to arise for which cures must be developed. Two illustrations of this on Valley soils involve drainage and salinity.

[1] Remarks at dedication of a new laboratory and office building, Texas Agricultural Experiment Station Substation 15, Weslaco, on October 5, 1959.

4. The fourth big task, involving scientists of several kinds and wide training is to identify, maintain, improve and protect the quality and nutritive values of the products of the agriculture of South Texas, so as to reduce marketing risks and insure greater consumer acceptance.

5. This next task again involves stronger emphasis on preventative measures. It is to increase the knowledge of diseases, insects, nematodes; weeds and other pests and hazards, and to develop practical methods of prevention and control in plants and animals.

6. Continually before us is the sixth task of locating and developing further methods, equipment, and procedures for cutting relative costs of production, processing and distribution of the products of agriculture.

7. Through application of new techniques of evaluating the consequences of operational decisions—a technique now known as linear programming—the results of research may aid in analyzing the comparative advantages and disadvantages of alternative types of farm and ranch organizations and operational procedures.

8. More research and education may well be directed toward providing factual information and analyses as the basis for development of state and national policies and programs related to agriculture.

9. A task that should challenge every one of us is to develop ways and means of attracting and retaining capable men and women as researchers, educators, suppliers, handlers, and operators in all phases of agriculture and its related industries.

10. The tenth and last task, I cite from among many that could be discussed at length, is for all of us to recognize and to act positively with regard to today's greatest single need in agriculture. It is for *understanding*—understanding among those directly engaged in farming and ranching; understanding by those who provide services and materials to the farms and ranches; understanding by those who transport, process and distribute the plant and animal products coming from farms and ranches; and above all, understanding among the great majority of our people who live in towns and cities and who are the principal consumers of the products of our agricultural industries.

I trust you will pardon me for mentioning that in dedicating this new facility and the workers who are to be privileged to be headquartered therein, that we must remember that year by year we shall face the serious and perplexing problem of having adequate funds for making possible successful and concentrated attacks on these tasks which we have mentioned. Complacency by local people in this respect would jeopardize the future.

This Valley now has one of the outstanding research centers of the State in which scientists and educators from State and Federal agencies will work together. Currently there are more than 60 research projects in which these resident workers, and co-workers from the Main Station and other field units, are cooperating.

From the Staff of the Texas Agricultural Experiment Station I bring to you sincere appreciation for this new laboratory and office building. Our thanks go to the citizens of Texas, their Legislature, and the Board of Directors of the Texas A. & M. College System.

A New Center for Agricultural Research And Education in South Texas[1]

R. E. Patterson
Vice Chancellor for Agriculture
The Texas A. and M. College System

This is a very special occasion for all of us in the Texas A. and M. College System who work in agriculture. It marks the end of a long period of impatient waiting. It is the moment in which many of our hopes have become realities. I am grateful to have an opportunity to take part in the dedication of this outstanding agricultural facility.

I am sure I speak for all of our agricultural staff in expressing a genuine appreciation to you, to the Board of Directors of the Texas A. and M. College System, and to all other citizens of Texas for having made possible the construction of these facilities. They are designed to give us every opportunity to improve our three-fold effort of research, education and extension for the betterment of agriculture in Texas.

Stones, mortar and steel cannot, alone, broaden the horizons of knowledge or contribute significantly to the education of our people. Only men of great skill and devotion can contribute to these goals. Still, you and I both recognize the fact that even the best of men work better and accomplish more with the proper tools in the right surroundings.

The cause to which this structure is dedicated can be stated simply as the improvement of Texas agriculture, with particular emphasis on the phases of agriculture most important to this immediate area. The work through which these contributions will be made will be in three fields, through research, extension and education. Each of these is simply a separate strand of a single cord.

When the Weslaco Substation was established, thirty-six years ago, its sole purpose was to conduct research to seek solutions to problems hampering the agriculture of South Texas. Throughout its early years it was practically a one-man operation. During this time the Rio Grande Valley was developing into one of the most intensified production areas in the Nation.

The great agricultural revolution which started during World War II and is still under way has made it necessary to apply every scientific and technological development known to increase the efficiency of production and reduce the unit cost. With the encouragement and backing of far-sighted agricultural and civic leaders of the Valley, we have con-

[1] Remarks at dedication of a new laboratory and office building, Texas Agricultural Experiment Station Substation 15, Weslaco, on October 5, 1959.

stantly expanded and intensified our research programs to meet this need.

You are familiar with many of the contributions which have been made to the improvement of agriculture in your areas through research at this substation. The development of improved strains of tomatoes is a well-known example. The research workers have combined disease resistance, product quality and increased yield to produce valuable commercial strains suited to this area. Further improvements are needed and will be made. The recent dramatic progress made in lettuce research has produced a new strain that promises to appreciably increase the income of Texas agriculture from this crop.

Research aimed at conservation, improvement and wise use of soil and water resources has paid rich dividends in this region. Progress has been made in developing soil management practices which maintains and even improves productivity. Investigations of quantity and frequency of irrigations have shown the way to greater efficiency in water use. This is of great importance in time of drouth but even in periods of adequate water supply they point the way to preventing loss from high water tables due to excessive irrigation.

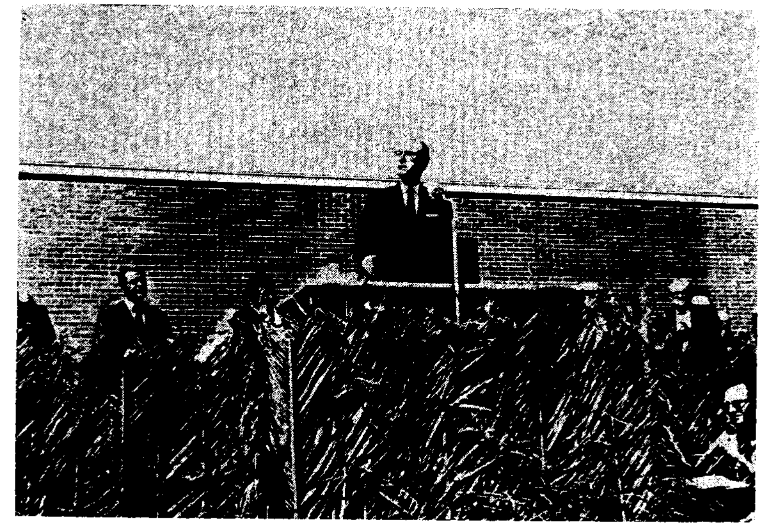
There are many concrete examples of rich returns to the agriculture of this area from research at this location. We are proud of the fact that every dollar spent on research here has been returned many times over to the citizens of Texas. But what has been accomplished in the past is minor, compared with what can and must be done in the future. The problems of soil, water and plant relationships are numerous and very complex. Their full solution will require the application of the keenest minds, well-trained in the sciences, using ever-improving research techniques and tools.

Much of our progress to date has been based on principles developed from basic research many years ago. We must strengthen the basic research aspects of our work to supply the ideas and raw materials for future applied research. The use of radioisotopes to study nutrition and growth of cotton, vegetables and citrus trees offers good leads to the solution of many practical problems in these crops. Plant improvement is possible through the changing of genes by atomic irradiation. Nuclear energy may one day be used economically to desalinate sea water for agricultural and industrial uses. We must do more work in the fundamental biology and nutrition of insects, if we are to effectively control these pests within the limits of economic practicality.

The applications of the electronic computer to the analysis of agricultural research data are opening new paths for exploration which a few years ago would have seemed beyond our reach.

We are living in one of the most exciting periods in history. New developments are coming at an ever-increasing rate. Practices which are believed impossible today will be commonplace a few years hence.

But, research alone will not solve the problems of agriculture. A



Dr. M. T. Harrington, Chancellor of the Texas A and M College System, was a featured speaker at the dedication ceremony.

scientific discovery is of real use only after it has been put to use.

The second phase of our work, therefore, is extension—carrying the results of research to the people who can put these results to practical and profitable use. These two phases of our work are so inseparable that neither would long exist without the other. The Weslaco substation serves also as headquarters for District 12 of the Agricultural Extension Service. This building provides office space for the extension district agents and subject-matter specialists.

It is both appropriate and practical that these extension workers should be housed in close proximity to our state and federal researchers. This provides an opportunity for free and immediate exchanges of information. Problems are brought directly from the field to the research laboratory by extension workers; research results are carried back to the field through the same channels. Careful consideration is being given to even closer ties between the researcher and extension worker.

There is an ever-increasing need for more highly trained people in the various subject-matter areas. It appears desirable that extension specialists should have some research responsibilities and researchers should do some extension work. I am convinced that both research and extension would benefit from such an arrangement—and, what is more important—the agriculture of this area would benefit.

Extension, which joined research at this substation in 1947, is now an integral part of its effort. The newest phase of our service, of which you will see more evidence in the years immediately ahead, is education.

The facilities being dedicated here today will be used to an ever-increasing degree to meet the training requirements of men and women for research, extension and educational duties in the Rio Grande Valley and all of Texas. It will provide the opportunity for internship, graduate and post-graduate training under the guidance of outstanding research and extension leaders. Agriculture today is a highly competitive, highly technical business in which the economic hazards are great. Only the competent and aggressive can expect to survive and prosper in this field. It is inevitable that agriculture in the future will require an even higher degree of competence, a more thorough specialized training and a broader background of basic understanding of the sciences and the humanities than it requires today.

Research and extension attempt to solve the problems of today and anticipate the needs of the future. In education lies our future. The quality of tomorrow's agriculture is being determined now, in the agricultural classrooms and scientific laboratories of today.

In its three-fold functions of research, extension and education, this modern substation today represents an instrument for the genuine betterment of agriculture in your area. But it could not have reached its present state of development without your interest and support. The contributions which have been made to its development by the farm and industrial leaders of this area have been great in the past and we believe will be even greater in the future.

It would be a sad omission if acknowledgement were not made of the excellent cooperation we have received from the staff of the U. S. Department of Agriculture, housed in that other fine new building across the street, and from the Texas A. and I. Citrus Training Center, diagonally across the road. Working together in a common cause, we have all accomplished far more than any of us could have accomplished separately.

To these agencies—and to you—we pledge our continued cooperation and our very best efforts toward the common goal—a greater and more prosperous Texas agriculture.

CITRUS SECTION

Current Practices and Problems in the California Citrus Industry[1]

R. G. PLATT
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There have been a number of changes in California citrus in the past fifteen years—changes in the location of commercial citrus, new practices tried and adopted, and new problems which the industry has had to meet.

To perhaps give you a better picture of the areas in the state where citrus is grown, let's briefly go over these locations.

Southern California has been the principal citrus-growing area in the state since the industry began. This area includes a wide variety of climates from coastal through intermediate and interior valleys to the low desert valleys. With this wide range of climates, all commercial varieties are grown in the area best suited for their production.

Considerable citrus has also long been grown in the San Joaquin Valley of central California. Here the Washington Navel orange has been the principal variety.

Another area, in the Sacramento Valley of northern California, has also been a small but important Navel-orange-producing area. This area, incidentally, is on the same latitude as Baltimore.

Immediately following World War II, citrus acreage in California was 330,000 acres of all varieties. By 1956 the total acreage had dropped to 230,000 acres.

What happened?

Too many people heeded the words of Horace Greeley and "Went west, young man, went west"! Citrus groves, as we say, were "budded to bungalows." What were once orchards became housing tracts, industrial areas, schools, parks and Disneylands. With the increase in population more super highways were needed to carry the people to and fro, and it seemed that every freeway, each mile taking twenty-six acres, was routed through the best citrus land in the area.

While urbanization has accounted for by far the major portion of the acreage loss, there have also been losses due to the virus tristeza or "quick decline." First discovered in California in 1939, there was a considerable loss of trees in the early 40's, and it is estimated that 400.000 trees had been killed by the disease by 1956. An outbreak or flare-up

[1] Talk given at the Annual Horticultural Institute, Weslaco, on January 26, 1960.

this past year has seriously affected another estimated 100,000 trees so that the problem is still with us. There are still many acres on sour orange rootstock but with strict quarantines regulating the movement of citrus within the state it is hoped we can keep it out of these clean areas. So far the quarantine seems to be working.

With the population pressures on the older established areas, new citrus plantings are now being made in the outlying interior valleys and desert valleys of southern California and in the San Joaquin Valley of central California. Even with continued loss of acreage due to subdivisions there has been a net increase since 1956. Today citrus acreage in California is approximately 238,000 acres.

The trend of variety selection during the past few years has been to Navel and Valencia oranges, some grapefruit and a small amount of mandarins. With lemon acreage close to an all-time high, including several thousand acres of non-bearing trees, new planting of lemons has been low.

As I'm sure you realize, our citrus in California is dependent on water for irrigation. Without it, we don't grow citrus. Water development and expansion of irrigation districts has played an important part in our ability to expand citrus into new areas. The Metropolitan Aqueduct has brought Colorado River water to southern California. The All American and Coachella Canals have brought Colorado River water to the Imperial and Coachella Valleys. In central California the Friant-Kern Canal has made available water from the Sierras to the lower east side of the San Joaquin Valley.

Methods of irrigation include all types, depending on location and water quality. Irrigation by furrows is the most common method. Basin flooding is used to some extent, primarily in the desert valleys. Where water quality is good—so that there is no salt accumulation or injury on the foliage—sprinkler irrigation is increasing in use. In problem soils where water penetration is slow, low-volume sprinklers are providing moisture control not possible with furrows.

As an aid to irrigation, tensiometers are becoming more widespread in their use by growers. If properly placed, serviced and read, these instruments have given the answer to some perplexing irrigation problems.

In the selection and use of scion varieties, nucellar lines of most of the commercial citrus varieties are now being widely used. The increased tree vigor, production and reduced incidence of virus diseases make them outstanding in their performance over many old-lines.

We are, at present, in somewhat of a dilemma over planting distances. The trend is definitely toward closer planting with more trees per acre. Twenty to twenty-two feet is the most common spacing between rows. In the row trees are spaced from nine to eighteen feet. Certainly picking records show greater early production per acre for the close planted orchards. As they grow older there may be problems in crowd-

ing; however there are good examples of older closely planted orchards (12 feet by 24 feet) which have consistently out-produced orchards set at 24 feet by 24 feet. It is anticipated that tree size can be maintained with mechanical pruning equipment which brings us to the next item.

I know of few new orchard practices which have caught on as quickly as has mechanical pruning. Side walls of trees are pruned by hedgers, a vertical bank of circular saws mounted on a truck or trailer. Tops of trees are pruned by one of several mechanical topping machines. Lemon growers who prune annually were the first to adopt this mechanical method and it has reduced their pruning costs by 40 per cent. Mechanical pruning is now also used on oranges to reduce crowding, prevent shading out of the tree skirts, lower tree height to facilitate picking and for rejuvenation of old trees. Results have been outstanding. An interesting possibility is maintaining a tree at a six foot width to permit mechanical or semi-mechanical harvesting!

In rootstocks, the Troyer citrange and trifoliate orange are being widely used for Navel and Valencia oranges. The cold tolerance and high fruit quality imparted by these stocks make them desirable. For lemons, Citrus macrophylla looks very good in its ability to better absorb the necessary micronutrients and partially exclude some of the toxic ones.

We are well under way with a budwood certification program in California. Domestic selections, new hybrids and foreign introductions are being indexed and screened for virus freedom. We are overdue on such a program, but are anticipating a real improvement in nursery stock offered for commercial planting in the near future.

These are some of our problems and practices today. What of the future?

With our dependence on water for irrigation, its development and distribution is all-important for citrus expansion. The "California Water Plan," now being considered, will bring water from northern California to central and southern California. When completed, it is estimated that one million acres of new land will have high quality water. Of this, several hundred thousand acres would be suitable for citrus.

Will it be planted to citrus? This will depend on economics. The soil and climate is suitable.

We're optimistic and confident of our citrus future in California.

The Importance of Research to the Citrus Industry[1]

M. W. Parker, *Director, Crops Research Division,*
Agricultural Research Service, U. S. Department of Agriculture

It is a real privilege to speak to you on the subject of the importance of research. As nurserymen, you both deserve credit and bear responsibility for the health and prosperity of the citrus industry. Citrus orchards genetically are no better than the mother trees from which they were propagated. I am sure it the desire of every good nurseryman to produce the best nursery stock possible. It is our business, through research, to discover and pass on to you means and methods which will help you to do this.

Let us reflect for a moment on what constitutes research. *Research* has been defined as critical exhaustive experimentation having as its aim the substantiation or revision of accepted conclusions in the light of newly discovered facts. Research in most fields and the application of its results have made most everyone aware of what can be accomplished through careful investigations. The progress of research is in general limited by such factors as the availability of appropriately trained manpower, necessary equipment, and time. Research is relatively costly. It is inherently speculative in nature no matter how carefully and intensively it is planned and conducted. Often a long time elapses before tangible progress is made. Research is an investment which pays dividends in fundamental and applied facts which are useful in enabling industries to produce better products at lower costs.

The citrus industry of the United States has a farm-gate value of over $400,000,000 and a consumer value of over one billion dollars. It supports not only growers, but labor and manufacture of equipment for production, harvesting, processing, warehousing, transport and merchandising. It also supports management, the advertising necessary to apprise the public of the value of citrus in the human diet, private and tax supported research, and other miscellaneous costs.

How has this great industry developed? Much of the credit is due to enterprising earlyday growers who took the knowledge they had available, added their own judgment and resources, and went to work. In the early days, culture was simpler than it is now. Demand was good, in fact oranges were mostly luxury and holiday fruits. Only the best lands were used for groves, pest control was simple, labor was plentiful and cheap. The chief problems were transport and distribution to get fruit into the consumer's hands in good condition.

Times have changed. Citrus has now assumed a stable place in the American diet. Along with the great increase in production, new problems have arisen. Most of the good land suitable to citrus has already been planted making it necessary that any future expansion be on reclaimed land or on second class new land or by replanting old groves with better producing stocks. Costs all along the line have gone up. Pest control has become more complex and expensive. Competition and processing have created a demand for fruit of higher quality, ripening over a longer period. All of these problems have added up to the necessity for more efficient production at a lower cost.

[1] Talk given at the Florida Citrus Nurseryman's Institute, Winter Haven, Florida, September 24, 1959.

HOW HAS RESEARCH HELPED THE CITRUS INDUSTRY

It is difficult to assess on a dollar basis the value of research accomplishments to the citrus industry. The rapid advances in recent years in Florida citrus culture were made because advantages have been taken by nurserymen and growers of improvements in our basic knowledge of the nutrition of the tree, of the chemistry and specificity of fungicides and pesticides and other improvements in basic knowledge related to the control of the environment of the tree. For example, during the past 30 years there has been a revolution in the mineral nutrition of citrus in Florida. First came the demonstration of need in addition to N-P-K of the so-called minor elements of zinc, magnesium, and copper. The absences of these elements served to limit production and quality even though other factors were sufficient.

Following these findings growers became fertilizer conscious and this attitude, along with prosperity, resulted in overdoing fertilization. New research findings during the last 10 years contributing to more efficient fertilizer practices include: (1) desirability of lowering application rates of phosphorus and potassium and in most cases increasing nitrogen; (2) identification of copper toxicity and the removal of copper from the fertilization program of established groves; (3) the finding of boron deficiency and adding this constituent to the fertilizer program; (4) the successful use of iron chelates to supply iron requirements to iron deficient trees. These changes in practice have materially increased the quality of citrus and reduced the present day production cost per box.

RESEARCH ON VIRUS DISEASES

A second major field of advancement resulting from research is the demonstration of the near universal occurrence of viruses in commercial citrus grove trees which reduce their overall growth and vigor. This is augmented by the development of means of finding virus-free or producing virus-free clones of these varieties. These findings help to explain the exciting vigor and increased production and apparent increased cold-hardiness of nucellar clonal lines of citrus as compared with parental material. It is extremely fortunate that most virus diseases affecting citrus in the United States, with the exception of Tristeza, do not appear to spread under natural grove conditions and do not pass through either true sexual or nucellar asexual seeds. As a result virus-free clones of varieties can be developed merely by growing seedlings if that variety produces nucellar seeds. In the same manner true hybrids produced in breeding programs can be obtained free of virus. The complex and difficult part of this research problem is to develop tests and procedures which are sure to indicate the presence of or freedom from viruses.

The Florida citrus virus-free budwood program carried on by the Florida Plant Board is a good example of turning basic research results into practical use. In this program, the Plant Board has undertaken the job of locating, testing and registering varietal budwood sources free of viruses making these available to the nurserymen for use in propagating virus-free nursery stock. They have also set up a registry system which will serve to indicate to the grower that certain standards have been met and have taken on the job of educating the growers of the need of such standards. As of this date, nurserymen may, with assurance, obtain budwood free of both psorosis and xyloporosis. It is expected that in the near future, budwood not only free of all virus diseases will be available but also from progeny-tested, superior-performing-variety clones. The research information which has made possible the Florida citrus budwood program was developed by combined efforts of Federal and State and Plant Board agencies with the help of growers and nurserymen and some phases are the result of cooperative efforts.

NEED FOR BASIC RESEARCH IN INHERITANCE OF CHARACTERS IN CITRUS

Considering the extent and value of the citrus industry in this country, very little effort has been made during the last 20-year period to improve our knowledge of the inheritance and genetic makeup of citrus in contrast to the research effort expended on improvements in basic knowledge related to control of the environment of the tree. It seems likely now that the greatest opportunity for further large advances in the production of citrus, whether it be for increased quality, greater yield, resistance to disease, salinity or greater cold-hardiness, lies in the improvement of the genetic constitution of the trees—both for the varieties used as scions and those used as rootstocks.

In some of the important crops such as wheat, corn, cotton, onions, and strawberries, extensive basic studies of the inheritance of various characters have been conducted during the past 50 years, with the result that breeders of these crops now have an excellent theoretical basis for practical breeding. These studies have resulted in the development of many new varieties of fruits and vegetables commonly found on the dinner table today that did not exist 10 years ago. In contrast, we find that all of our citrus varieties that are grown extensively on a commercial scale have originated as chance seedlings or bud mutations. Only a few specialty varieties such as the tangelos originated as a result of breeding work.

There are several reasons why little basic research in inheritance of various characters has been done with citrus. In the first place, few

workers have been engaged in citrus breeding. Also, it has seemed that investigation of the inheritance of characters in citrus was extraordinarily difficult because most citrus is slow in coming into bearing. In some of the best varieties the pollen or the ovules or both are sterile, and some varieties produce only asexual (nucellar) seedlings, and in many others most of the seedlings are nucellar and these are difficult to distinguish from the hybrids. While it is true that the conditions in citrus are not as favorable for studies of inheritance of characters as in many of the annual crops, it is far from the hopeless task it was thought to be only a few years ago. Now we can tell by a simple dissection of a sample of the seeds produced by a variety or a new hybrid seedling that has just come into bearing, with considerable accuracy, whether, if used as a seed parent, it will produce only hybrids or only nucellars or a mixture of the two. In the last case, we can determine about what proportion of the seedlings will be hybrids. This simple method of determining whether a prospective seed parent will produce all asexual seedlings, part asexual seedlings, or all sexual seedlings will be of tremendous value to the breeder for future work with citrus and will make it possible by a judicious selection of seed parents to carry out reliable studies of inheritance in citrus.

BREEDING FOR SCION VARIETY IMPROVEMENT

For a number of years the USDA Citrus Advisory Committee has urged the USDA to expand its work in the general area of citrus breeding and variety improvement as funds would permit. This is being done. Basic exploratory work to determine what parents are likely to produce fruits of certain specialized types has been started or is planned; as for example, early seedless oranges with good juice color and high solids, late high-quality grapefruit with few seeds, a series of attractive, high-quality, loose-skinned tangerine types, both early- and late-maturing high-quality round oranges suitable for processing. When crosses are found that produce fruits of the types desired, additional crosses will be made to obtain large numbers so as to greatly increase the chances of obtaining highly superior fruits of the desired type.

The recent work at Orlando, Florida, and at Indio, California, has greatly improved our knowledge of the breeding characteristics of a large number of varieties that have been used as parents in crosses designed to produce new fruit varieties or new rootstock varieties. Some of the best of these, and especially those that exhibit outstanding traits that would be useful in further hybridizing, are being tested for combining ability. Some seedlings which are of no value for commercial production but have certain characters such as large fruit size, high solids, brilliant color, seedlessness or a combination of several desirable characters developed to an outstanding degree are being tested for transmission of these special traits. That such material can be very useful is illustrated by the results of a cross between Umatilla tangor (which is large, attractive and nearly seedless but of poor quality) and Honey tangerine (which is small, poorly colored and seedy but of high quality). This cross produced an unusually high proportion of good progeny.

BREEDING IS ALSO NEEDED FOR IMPROVEMENT OF ROOTSTOCKS

Research has shown that all the currently known and used rootstocks have one or more faults and that there is need for new and better ones. The species and varieties have been fairly well tested for rootstocks. Species hybrids such as some of the citranges (trifoliate orange x sweet orange), backcrosses—citrangors (citrange x sweet orange) and trigeneric hybrids—citrangequats (citrange x kumquat) produced by Swingle and Webber in the early 1900's have shown promise as rootstocks. The Troyer citrange (navel x trifoliate orange) is particularly promising and is being widely used in California. Rootstocks will have to be tailored for the different types of soil, for different varieties and climates.

COLD HARDINESS RESEARCH

Breeding also appears to be the most promising approach for increasing cold hardiness. The breeding work begun in Florida over 60 years ago by W. T. Swingle and H. J. Webber of the U. S. Department of Agriculture had as its primary objective the production of cold hardy types. They used the trifoliate orange which is deciduous and known to stand temperatures down to 0° F. in crosses but most of the resulting hybrid seedlings while more cold hardy than sweet orange had shortcomings of other natures. These hybrids are still available and should be valuable for backcrossing to get rid of undesirable characters.

COMPATIBILITY

Future research on all tree crops produced on rootstocks must give more attention to the problem of compatibility. Webster defines compatible as being "capable of coexisting in harmony" while incompatible is "incapable of being put or used together because of physiological effects."

It is well known that in certain genera there are similar species which when used as rootstock or as scions develop more or less incompatibility between them. Furthermore, cases are known in which even complete incompatibility exists between the rootstock and scion variety of the same species. For example, in pure Chinese chestnut the rootstocks of any progeny tested so far are, with time, completely incompatible with scions of the Carr variety. In some instances, complete incompatibility has been shown to be due to the presence of a virus in the scion. A classic example is that of Spy 227 in apple. Root rot is a limiting disease of avocado in many areas of the world. All the commercial varieties used for rootstocks are susceptible. A large number of closely related species with fruits resembling commercial types were determined resistant or immune, yet commercial varieties are entirely incompatible with all of them and will grow only on the root rot susceptible sorts which are of the same species as the commercial avocado.

On the other hand, a kind of incompatibility between rootstock and

scion is commonly employed in modern horticultural practice; for example, to dwarf the scion growth and to increase fruiting or to modify the composition of the fruit produced as is true in apples and citrus, respectively.

These effects are of a physiological or biochemical nature, and although clonal varieties have been extensively propagated for centuries, very little is known as to the basic causes of the varying forms and degrees of incompatibility between rootstock and scion. The basic fundamental facts as regards the chemical, physiological, and morphological changes brought about between rootstock and scion must be made known through research before the practice can have the greatest application in horticulture.

RESEARCH NEEDS TEAM APPROACH

Research has shown that the factors controlling production are interrelated and interdependent. Breeding alone could fail if it were not guided by basic results developed in the other sciences. The breeder needs the plant pathologist to determine etiology of the pathogenic disorders to be overcome and to develop methods for screening resistance in hybrid seedlings. The breeder, to determine whether progenies are truly cold hardy, needs to know whether cold hardiness is a function of dormancy or some other physiological function; therefore, is dependent upon the physiologist to determine these basic facts. New promising hybrids, whether for scion varieties or for rootstocks, must be widely tested and evaluated under commercial growing conditions; therefore, the breeder needs to cooperate with growers.

INDUSTRY COOPERATION AND ASSISTANCE

Research agencies must work in close cooperation with industry and welcome the opportunity in order to know their problems and to be of maximum assistance. Industry advises the research agencies directly or through organizations which represent them such as members of Congress, representatives of farm organizations, agricultural trade organizations and others. In addition, industry is represented through the research and marketing advisory committees which meet each year to review the farm research program and make suggestions.

Industry's interest in and support of citrus research is forcefully illustrated by its recent action in the formation of the Florida Citrus Research Foundation, an organization having one purpose, that of aiding research. Through this Foundation, a 500-acre site has been purchased. Use of this land will be assigned to the U. S. Department of Agriculture and the Florida State Plant Board for the citrus breeding and research work and for the virus-free budwood program. Availability of suitable land will enable the programs to go forward to develop better citrus fruits for the future.

Citrus Trees from Nucellar Seedlings

GUY W. ADRIANCE
Texas Agricultural Experiment Station, College Station

In the seed of some citrus species, hybrids and relatives, polyembryony (multiple embryos) exists (Webber 1900). These extra embryos are produced in two ways: (1) commonly from cells of the seed parent, which is true nucellar embryony; and (2) occasionally by the production of two or more gametic (sexual) embryos, evidently from one fertilized egg (Frost, 1943). While the latter condition is not frequently encountered, Frost (1926) found ten such cases among 1200 hybrids produced at the California Citrus Experiment Station. Similar cases also have been recorded by Traub and Robinson (1937). Nucellar embryos are not produced unless fertilization occurs; but the nucellar embryos begin to develop ahead of the hybrid and usually crowd it out.

True nucellar embryos develop asexually by ordinary division of the nucleus cells and no male cells contribute to their formation. Nucellar seedlings, therefore, not only inherit from the seed parent alone, but are actually identical with it in genetic constitution, except for possible differences due to bud variation.

Frost, *et. al.* (1957) outlined several reasons why nucellar seedling lines may differ from the old-line seed-parent tree. These include (1) juvenile characters, such as thorniness; (2) differences due to the elimination of viruses; and (3) genetic variations which may arise.

Frost, *et. al.* (1957) gave detailed records of three entirely different strains that were obtained in a group of nucellar seedlings from one parent tree of the Owari strain of Satsuma. Twenty-two trees budded from these seedling trees were planted in the orchard ;and ten years later a second lot was budded from the first budded trees. Of the three strains that continued to be different, Strain A was superior to Strains B and C and also to the old-line trees, in overall horticultural promise. It had fairly regular heavy crops and relatively early coloring, with higher soluble solids than the old line. Fruit shape was different from the old line in the two better Strains A and B and the tree-branching habit was also different from the old line. These studies covered a period from 1915 to 1957, with one nucellar seedling generation and two successive generations of trees budded from the original nucellars.

In 1952, companion articles by Frost, and by Cameron and Soost, described in detail (1) the behavior in the nursery of budlings of young citrus nucellar-seedling lines and parental old lines; and (2) the later behavior of these same trees after 15 more years in the orchard, from the standpoint of size, yield and fruit characters.

Young new-line nucellars nearly always showed the juvenile char-

acteristics, principally thorniness and excessive vigor, and these characteristics disappeared first in the upper part of each tree. For this reason, budwood from each parent tree was taken from two locations, one in the upper part of the tree, and the other in the lower part, within 1½ meters of the ground. Frost, reporting on 2-year-old trees stated that of 82 old-line budlings, 65 carried fruit, 33 from high budwood and 32 from low budwood; in contrast, of the 85 young-line budlings, only 9 carried fruit and 7 of these were from high budwood. There was a decided difference in trunk diameter, in favor of the young-line trees. These same trees also showed more thorniness, with trees propagated from low budwood being much more thorny by comparison. Thus, at 3 years of age, the budlings from new-line nucellars were bigger and thornier but less productive.

This same lot of trees was later studied by Cameron and Soost (1952) with yield and fruit data being taken over a 2- to 4-year period beginning when the trees were 18 years old. Trunk cross-section-area measurements were also taken, and with one exception, the young-line trees were from 33 per cent to 108 per cent larger than those of the old line. Top volume, though not measured, was visibly larger in every comparison.

With one exception, the young-line trees showed yield increases ranging from 33 per cent to 102 per cent. Fruit shape, individual fruit size, and juice percentage and composition were similar. Thorniness, which was so apparent in the 3-year-old young-line trees, was slight. Some other characters observed in the young trees of the young line such as thick rind and coarse pulp texture had not entirely disappeared.

In tests observed to date, there has been evidence that the virus diseases, such as tristeza and psorosis, are not transmitted through the nucellar seedlings; this is one explanation for the vigor of the young-line trees. However, nucellar seedlings are also physiologically different from their old-line parents.

With particular reference to the problem in Texas, Cooper and Olson (1958) reported on the performance in nursery and orchard of several nucellar seedling clones. They observed the vegetative invigoration, the tendency to thorniness and the lack of early fruit production that have been reported by previous investigators. The fruit that was produced, however, was similar in shape, size and quality to fruit on old-line trees of the same varieties. A recent planting to evaluate nucellar seedlings of many varieties was also described by them. In view of the limited time of observation, they were unable to make an accurate determination of the commercial value of the nucellar clones.

A careful program of testing and evaluation of nucellar seedlings is highly important. The principle of using budwood only from trees of known satisfactory performance is still good. Budwood-source trees should be true-to-type and heavy producers of high-quality fruit.

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Effects of X-rays and Thermal Neutrons on Citrus Propagating Material[1]

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"Bud sports," or somatic mutations, have played an important part in the improvement and growth of the citrus industry in the Lower Rio Grande Valley. Twenty years ago it was recognized that our early grapefruit varieties had been superseded by varieties that had originated through bud sports (Friend, 1941). The extensive plantings of Ruby or Redblush type grapefruit and the popularity of the Marrs Early orange, both relatively recent Texas discoveries, confirm the potential of chance mutations. It is likely that more of these favorable mutations or sports in our commercial citrus varieties will be found.

The use of ionizing radiations to induce mutations has presented a new approach to systematic breeding in clone propagated species where every selected new genotype, chromosomal aberration, or gene mutation can be reproduced by vegetative means and tested separately (Gustafson, 1951). In the breeding of citrus, with its high degree of genetic heterozygosity and the long time interval between sexual generations, radiation may be of considerable value. Frost (1946) writes that the genetic constitution of ordinary citrus varieties should be very favorable to the production of somatic variations through the use of radiation.

Bishop (1954, 1957), working with X-rays and thermal neutrons on apple scions produced giant sized fruits, frequent sectorial chimeras in skin color, and branches on which developed apples of a very desirable dark red color. Granhall (1953) also reported color changes in apples after treatment with X-rays. Hough and Weaver (1958) found radiation-induced mutations in peaches affecting the firmness and texture of the fruit. Both earlier and later maturing types were produced. Haskins and Moore (1935) reported citrus seedlings grown from irradiated seed showed various morphological abnormalities including leaf development ranging from partially bifoliate to trifoliate.

In the light of recent progress in mutation breeding with other vegetative propagated crops a program was established at the Citrus Center of Texas College of Arts and Industries whereby citrus seed and scions would be subjected to ionizing radiation in an effort to induce

[1] Acknowledgement is made to Dr. Seymour Shapiro, Brookhaven National Laboratory for conducting the irradiation of material.

somatic mutations thus permitting critical observations of many mutants, or bud sports, growing in a concentrated planting. This paper is a report on some of the preliminary results of the first prefruiting year of the project showing essentially the lethal ranges of the treatments.

MATERIALS AND METHODS

From three varieties of grapefruit (Webb Red Blush, Foster Pink, and Hudson's Foster Pink) and three varieties of oranges (Washington Navel, Jaffa, and Valencia) approximately 32,000 seed were gathered and sent to the Brookhaven National Laboratory for treatment with X-rays and thermal neutrons. Scions of Nucellar Webb Redblush grapefruit with approximately 2300 buds were also sent for treatment with X-rays.

Because there was little information on the response of citrus propagating material to radiation the first treatments covered a broad range. The seed were divided into lots. Some received X-ray doses of 5,000 roentgens, 10,000 r., 15,000 r., 20,000 r., 30,000 r., and 40,000 r. Others were placed in the thermal column of the nuclear reactor and exposed to thermal neutrons. Exposure times were 3, 6, 9 11/60, 12, 15, 20, and 35 hours. One lot of each variety was left untreated as a control. The scions received X-ray doses of 0, 2,000 r., 4,000 r., 6,000 r., 8,000 r., and 10,000 r.

The seed were planted in protective frames in the college nursery and the buds placed on Cleopatra mandarin rootstocks with three buds on each rootstock.

RESULTS

Due to the cost of growing trees from seed it may be desirable to use higher radiation doses to increase the frequency of mutations. However, as the doses are increased their lethal effects also increase until a point is reached where none survive. The L. D. 50 (lethal dose for 50 per cent) has been suggested as an efficient level for treatment. This would permit high radiation doses and yet allow recovery of a sufficient number of trees.

Seventy days after the seed were planted the seedlings were counted. A long storage period for Washington Navel and Jaffa seed was credited with poor germination of all lots and these varieties are not considered here.

As seen in Figure 1 the L. D. 50 for X-ray treated lots of all varieties falls between 5,000 r. and 10,000 r. Approximately 1300 seedlings grew from the X-ray treated seed.

Between 12 and 15 hours exposure to thermal neutrons was lethal for more than 50 per cent of the seed of Webb Redblush, Foster Pink, and Hudson's Foster Pink (Figure 2). Valencia fell below 50 per cent viability with six hours exposure. Approximately 4600 seedlings grew

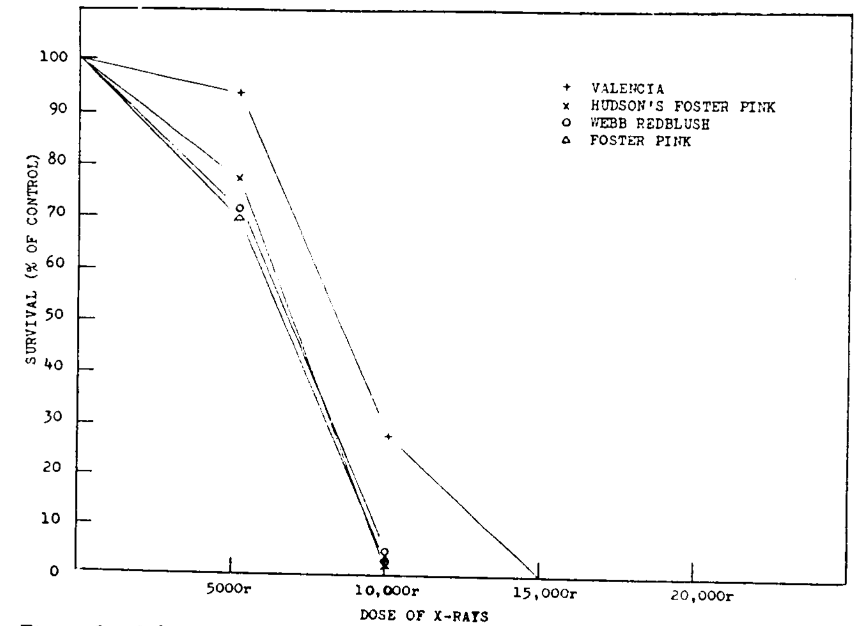

Figure 1. Relation of survival of citrus seed to dose of X-rays.

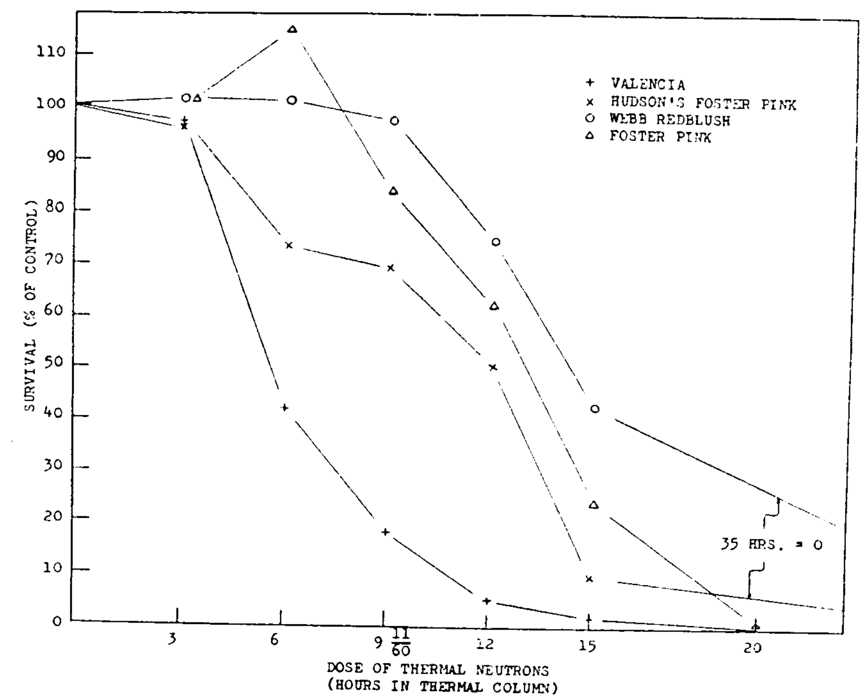

Figure 2. Relation of survival of citrus seed to dose of thermal neutrons.

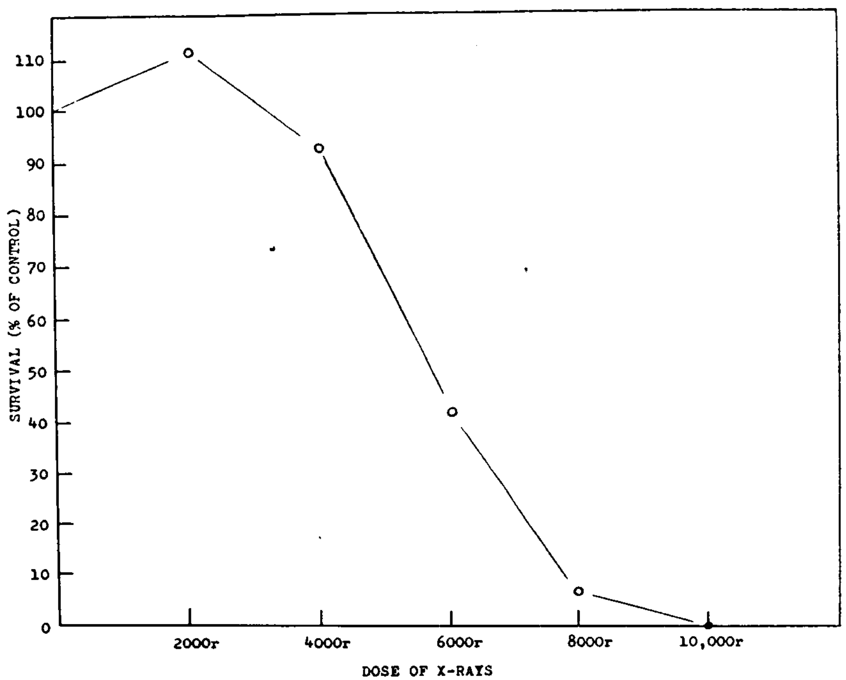

Figure 3. Relation of survival of Nucellar Webb Redblush propagating buds to dose of X-rays.

from lots treated with thermal neutrons. Reasons for survival percentages being higher than controls in lots of Webb Redblush and Foster Pink exposed to thermal neutrons for three and six hours have not been determined.

Less than 50 per cent of the nucellar Webb Redblush buds grew after receiving 6,000 r. of X-rays (Figure 3). Subsequent trees that did live were considerably smaller and grew much slower than those receiving lower doses. This difference in size was not noticed between controls and treatments up to 4,000 r. There are 853 treated buds now growing in the nursery.

Thorough evaluation of the mutagenic effects of these radiations and their horticultural value must await flowering and fruiting of the trees. Some morphological abnormalities of interest have developed such as faint leaf variegations, thickened leaves (indicating polyploidy), and distorted leaves including absence of petioles. One Webb Redblush seedling has grown with all leaves trifoliate.

SUMMARY

Citrus seed and scions were subjected to a range of doses of X-rays and thermal neutrons.

The L. D. 50 (lethal dose for 50 per cent) for seed treated with X-rays was between 5,000 r. and 10,000 r. for all varieties. The L. D. 50 for seed exposed to thermal neutrons was between 3 and 6 hours for Valencia orange and between 12 and 15 hours for Webb Redblush, Foster Pink, and Hudson's Foster Pink grapefruit.

Less than 50 per cent of the Nucellar Webb Redblush buds grew after receiving an X-ray dose of 6,000 r.

Some morphological abnormalities have been observed in the first year's growth.

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Xyloporosis (Cachexia or Fovea) Disease of Murcott Honey "Orange" in Texas

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A disease of Murcott honey "orange," recently was described in Florida and was named "fovea." The disease is due to a virus infection; similarity of fovea to xyloporosis (cachexia) of Orlando tangelo strongly suggests that they have the same cause (Knorr and Price, 1959). The objective of the present note is to indicate that fovea symptoms occurred in Texas on a nucellar Murcott honey orange tree bud-inoculated with a known source of xyloporosis (cachexia) virus; they did not occur in uninoculated control trees.

METHODS

In January 1952, nursery-size virus-free citrus trees, mostly nucellars, of several varieties on Cleopatra mandarin rootstock were available for inoculation studies. One or more trees of each variety were inoculated by budding from a single old-line red grapefruit tree known to be carrying xyloporosis (cachexia) and exocortis viruses. One or more nursery-size trees of each variety were used as uninoculated controls.

In November 1953, the control trees were set out in a variety collection at 25- x 15-foot spacing; at the same time, the bud-inoculated trees were set out in a nearby field at 14- x 5-foot spacing.

The trees were inspected from time to time for the gum-staining and pit-peg symptoms of xyloporosis (cachexia) and for the bark-shelling symptoms of exocortis (Rangpur lime disease).

RESULTS

Inoculations with virus-carrying buds from a single red grapefruit tree caused the bark-shelling symptoms of exocortis in nucellar mandarin-lime trees and gum-staining and pit-peg symptoms of xyloporosis (cachexia) in nucellar sweet lime, mandarin, tangelo, tangor and Murcott trees (Table 1).

Seven years after inoculation, no symptoms of virus-caused disease was evident on the tops of the following varieties: calamondin, Duncan grapefruit, Siam, Ichang, and Koa Phuang pummelos, mandarin 10630; Hamlin, Parson Brown, Ruvel, and Louisiana Sweet orange; Rustic and Uvalde citranges, Sacaton citrumelo, and citremon. Similarly, none of the uninoculated trees—including the sweet lime, mandarins, tangelo, tangor, and Murcott—were affected after 82 months.

DISCUSSION AND SUMMARY

Knorr and Price (1959) noted that the peg-like outgrowths in the bark and the corresponding pits in the wood in fovea-affected Murcott trees resembled closely the pegs and pits that occur in the trunks of Orlando tangelo trees affected by xyloporosis. They found fovea in Murcott branches growing on trees which were top-worked 4-6 years previously on Ruby Red grapefruit trees on rough lemon rootstock. In Texas inoculation with xyloporosis virus by budding from old-line infected red grapefruit caused the symptoms identical with those described for fovea in 33 months on Murcott. Trees of 5 other citrus varieties, known to be sensitive to xyloporosis (cachexia), also developed xyloporosis (cachexia) symptoms after bud-inoculation with the same source of xyloporosis virus.

Xyloporosis (cachexia) disease occurred on 15 mandarin and mandarin-hybrid varieties in Florida (Childs, 1951) and 25 similar varieties in Texas (Olson, 1954). The symptoms, method of transmission, and probable cause of fovea fit the concept that the Murcott honey "orange" is another addition to the list of mandarin-hybrids sensitive to xyloporosis (cachexia).

Table 1. Virus diseases evident in tops of different varieties after bud-inoculation with buds from a single red grapefruit tree, known to be carrying xyloporosis and exocortis viruses.

Variety of seedling top:	*Virus disease symptoms evident in bud-inoculated top after indicated time*	
	Kind	*Months*
Columbian sweet lime	Xyloporosis	27
Dancy mandarin	Xyloporosis (cachexia)	62
Kusaie mandarin-lime	Exocortis (Rangpur lime disease	49
Kara tangor	Xyloporosis (cachexia)	82
King mandarin	Xyloporosis (cachexia)	82
Minneola tangelo	Xyloporosis (cachexia)	33
Murcott honey "orange"	Xyloporosis (cachexia or fovea)	33
Rangpur mandarin-lime	Exocortis (Rangpur lime disease)	49

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Evaluation of Rootstocks for Valencia Orange Trees Following Inoculation Under Screenhouse Conditions with a Severe Strain Of Tristeza Virus

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Different strains of the causal virus of tristeza were inadvertently brought into Texas with a few citrus varieties between 1923 and 1942. The tristeza virus strains in these varieties were studied and the results reported (Olson, 1955, 1956, 1958; Sleeth, 1956). The present article is concerned with the growth of Valencia orange trees on 16 different rootstocks following inoculation with the most severe tristeza virus strain encountered in Texas. The tests were carried out in a screenhouse to avoid the hazard of insect spread of the virus.

METHODS AND MATERIALS

Healthy nucellar Valencia trees on 16 rootstocks (Table 1) were transplanted on October 3, 1957, to the soil inside a screenhouse. Four trees of each scion-rootstock combination were set out at a 6- by 3-foot spacing. On January 30, 1958, each tree was bud-inoculated with a single bud from a Cleopatra mandarin seedling infected with a severe strain of tristeza virus. This strain was originally obtained from a Sueoka satsuma introduction from Japan. This virus source was apparently free of psorosis, xyloporosis and exocortis viruses. The inoculated trees were observed until September 13, 1959, when the experiment was terminated.

RESULTS

After bud-inoculation with a severe strain of tristeza, Valencia orange trees on 8 different sour orange rootstocks were severely dwarfed, flowered prematurely, and showed varying degrees of chlorosis (Table 1). Trees on Australian "sour" orange rootstock did not respond like those on other sour orange rootstocks; the Australian "sour" orange is apparently a hybrid as indicated by the fact that its seedlings generally show several trifoliate leaves when small. The trees on Natsu dai dai sour orange were variable in their response; those on Natsu Mikan rootstock made relatively uniform growth. The best growth was made by trees on Rangpur lime, followed by those on Troyer citrange and Cleopatra mandarin, and then by those on Morton citrange and Ponkan mandarin rootstocks.

Twenty months after inoculation, 2 of 4 trees on Morton citrange rootstock showed stem pitting on the rootstock; this symptom was similar to or identical with that reported from California (Bitters 1953).

Table 1. Response of young nucellar Valencia trees on 16 different rootstocks to bud-inoculation by a severe strain of tristeza virus.[a]

Rootstock Variety	*No. Showing Tristeza chlorosis 10 months after inoculation*	*No. Flowering 14 months after inoculation*	*Tree growth sq. mm of trunk at 4" 20 months after inoculation*	*Estimated rating of rootstock in relation to tristeza virus only*
1. Rangpur lime	0	0	1310	suitable[b]
2. Troyer citrange	0	0	857	suitable[b]
3. Cleopatra mandarin	0	0	843	suitable[b]
4. Morton citrange	0	0	767	suitable[b]
5. Ponkan mandarin	0	0	749	suitable[b]
6. Australian "sour" orange	0	0	658	deserve further testing
7. Natsu Mikan	0	0	632	deserve further testing
8. Natsu dai dai	2	0	629	not suitable
9. Seville sour orange	3	4	513	not suitable
10. Oklawaha sour orange	3	4	511	not suitable
11. Texas sour orange	4	4	480	not suitable
12. Sour orange #2	3	4	443	not suitable
13. Bittersweet sour orange	4	4	441	not suitable
14. Albers sour orange	4	4	375	not suitable
15. Bergardier sour orange	4	3	370	not suitable
16. Sauvage sour orange	1	2	366	not suitable

[a] Four trees of each combination tested under screenhouse conditions. Varieties are listed according to growth response and suitability as rootstocks in presence of tristeza virus.

[b] Buds must be free of xyloporosis and exocortis viruses if these rootstocks are used.

DISCUSSION

The results obtained in this test in Texas are in general agreement with those of field trials reported in other areas. In Brazil (Grant et al., 1949) and California (Bitters, 1959), sweet orange trees on many mandarin and citrange rootstocks were relatively tolerant to tristeza while those trees on sour orange rootstocks died. The Natsu Mikan rootstock was distinctly nontolerant to the severe strain of tristeza in Brazil; the Australian "sour" orange rootstock was not tested there.

At present sour orange is the rootstock used in the Lower Rio Grande Valley of Texas. It will probably continue to be. The trees on sour orange have considerable tolerance to cold, foot rot, and high-lime soils, and such trees produce high-quality fruit. Tristeza-tolerant rootstocks which might be used as a replacement for sour orange also have weaknesses. Compared to trees on sour orange rootstock, trees on Rangpur lime rootstock have greater tolerance to saline water and soil but have less tolerance to high-lime soils; the same is true of the Cleopatra mandarin and the Ponkan mandarin. Trees on Troyer and Morton citrange rootstocks are more sensitive to chloride toxicity. Still other rootstocks produce fruit of poor internal quality. At present in Texas, the hazards of using new rootstocks are greater than the hazard of tristeza.

However, in the event of an epidemic of severe tristeza, standard sour orange selections now in Texas would be unsuitable for rootstocks and a tristeza-tolerant rootstock would be needed. For this reason, knowledge of orchard performance and tristeza virus reactions of other rootstocks is still important to the Texas citrus industry. Tests on the orchard performance of virus-free trees on the rootstocks listed in Table 1 are under way, along with other studies utilizing nucellar grapefruit tops.

SUMMARY

Twenty months after bud-inoculation with a severe strain of tristeza virus, young nucellar Valencia orange trees on 8 different sour orange rootstocks were severely dwarfed, had flowered prematurely, and were chlorotic. Trees on Australian "sour" orange rootstock, a probable hybrid, did not; nor did those on Troyer and Morton citranges, Cleopatra and Ponkan mandarins, Natsu dai dai, Natsu Mikan and Rangpur lime rootstock. The best growth was made by trees on Rangpur lime rootstock. Morton citrange rootstocks sometimes showed a stem-pitting symptom.

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Chemical Spray Trials for the Control Of Mites on Citrus

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The recent success of zineb in Florida (Johnson, et al., 1957) in providing longer, more effective control of citrus rust mites has gained wide acceptance. Since one of the advantages of this material for rust mite control has been its extended life as compared to sulfur, there has been interest in improving still further the control of mites on citrus. The present article reports on trials during 1958 and 1959 with zineb and a number of other chemicals for mite control on citrus.

METHODS AND MATERIALS

All materials tested were applied as sprays to citrus trees in the field. Sprays were applied with a conventional John Bean hydraulic sprayer, at 400-600 psi, either with hand guns or an air-blast attachment.

Mites were counted in all instances by the following technique: A sample of mature leaves, usually 10 per tree, was taken from around the periphery of four or more centrally-located trees in each test plot, the leaves combined with a single sample and taken at once to the laboratory for processing. The mites were brushed from the leaves onto counting plates with a Henderson-McBurnie mite-brushing machine, and the mites counted at 15X under a binocular microscope.

RESULTS AND DISCUSSION

Experiment I. In 1958, a 5-acre block of 10-year-old trees consisting of alternating rows of grapefruit and oranges near Harlingen, Texas, was used in a test of several miticides.

Four rows of trees were sprayed on March 14 with one pound Parzate, 65% W.P., one pound Tedion, 50% W.P., and two pounds CuO, 34%, all in 100 gallons of water. At the same time, 13 rows were sprayed with 10 pounds wettable sulfur and two pounds CuO, 35%. All sprays were applied with multiple-nozzle broom-type spray guns at 400-450 psi. The foliage was wet until the point of runoff.

Two months later, May 16, mite counts were begun. The rust mite population had reached sizeable numbers on the sulfur-sprayed foliage. On April 22, the grower began dust applications in the 13 rows which had received the sulfur spray. In the four rows adjoining the Parzate plot, Ethion 4% dust was applied; the next four rows received sulfur dust; the next three rows Trithion 2% dust and the last two rows sulfur dust. All dusts were applied with a truck-mounted Niagara duster at the rate of 50 pounds per acre. The Parzate-Tedion plot received no treatment.

Mites were counted June 5 and at seven-day intervals for the remainder of the test and the results are presented in Table 1.

By mid-July, the scale population had become damaging and rust mites were numerous in the entire block. On July 18, the grower applied an oil-Parzate spray to all trees. Subsequent mite counts are not included here.

Rust mites were controlled satisfactorily from mid-March until mid-July (a period of four months) where Parzate was used. The Tedion used with the Parzate still appeared to be controlling spider mites after four months, when it became necessary to apply materials for other pests.

Sulfur dust appeared to be satisfactory for rust mite control for approximately six weeks.

Ethion dust or Trithion dust did not control rust mites notably better than sulfur and in view of their higher cost would be poor substitutes for sulfur.

No instances of adverse plant reactions were observed.

Experiment II. A block of 7-year-old red-grapefruit trees at Texas A&I College, Weslaco, was divided into plots six or more rows wide and at least 18 trees long. Treatments were applied with a John Bean hydraulic sprayer equipped with an Aircrop attachment operating at 500 psi. Plot I was sprayed 4/2/59 and Plots II, III and IV sprayed 4/3/59, using approximately 7 gal. of spray per tree.

The following materials were applied in 100 gallons of spray:

Plot I –	Zineb[1]	65% W.P.	1#
	CuO	53%	1#
	Tedion[2]	25%	.6#
Plot II –	Maneb[3]	70% W.P.	1#
	CuO	53% W.P.	1#
	Tedion	25% W.P.	.6#
Plot III –	Kepone[4]	50% W.P.	1#
	CuO	53% W.P.	1#
	Tedion	25% W.P.	.6#
Plot IV –	Wettable Sulfur		10#
	CuO	53%	1#
	Tedion	25%	.6#

1 Supplied by the DuPont Company
2 Supplied by Niagara Chemical Company
3 Supplied by Rohm & Haas Company
4 Supplied by General Chemical Company

Table 1. Mite control by four different dust and spray treatments, 1958, Harlingen.

	Rust Mites Per 10 Leaves on Indicated Dates							
Date	*5/16*	*6/5*	*6/12*	*6/20*	*6/26*	*7/3*	*7/11*	*7/17*
Treatment								
I. Parzate-Tedion	1	0	6	0	19	142	21	31
II. Ethion 4% dust	°	0	4	1	32	158	76	75
III. Sulfur spray	40°	1	2	0	75	114	54	75
IV. Trithion 2% dust	°	1	7	1	50	174	68	80

°Sprays, sulfur and Parzate-Tedion applied March 14

Sulfur – 10 lbs. wettable plus 1 lb. Cu in 100 gal. water, to plots 2, 3, and 4

Parzate-Tedion – 1 lb. Parzate, 1 lb. Tedion 25%, 1 lb. Cu in 100 gal. water, to plot 1

Dusts applied at 50 lbs. per acre, May 22: (Parzate-Tedion plot not dusted)

Ethion 4% dust, plot 2

Sulfur dust, plot 3

Trithion dust, plot 4

Mite counts in the test plots were begun on April 17. Samples were taken from the test plots by removing 10 mature leaves evenly spaced around the perimeter of 4 randomly selected trees within each plot. The leaves were returned to the laboratory and brushed onto counting plates and the mites counted under a binocular dissecting microscope at 15X. Numbers of mites are converted to average number of mites per 10 leaves. Counts were continued until July 18, when high numbers of rust mites in several plots required re-treatment and the test was terminated.

Wettable sulfur provided the least efficient rust mite control and for the shortest period of time (Table 2). Zineb and maneb were similar in effectiveness. Kepone appeared to be the most effective material, showing a slight margin of control over zineb and maneb. The numbers of Texas citrus mites are not noted because when found, they were usually present only in trace numbers.

However, the number of predatory mites in the Kepone plot was notably higher than in any of the other treatments. The average number of predaceous mites per leaf for the 95-day period was: sulfur .1, zineb .2, maneb 0, kepone 1.3. It is evident that Tedion in the initial spray did not eliminate the predaceous species.

Experiment III. In the Spring of 1959 a test* was performed to determine if the effectiveness of zineb for the control of rust mites could be improved by the addition of spray-oil to the spray mixture.

A block of 6-year-old red grapefruit trees at A&I College was divided into six plots, each plot being four rows wide and five trees deep. The treatments were applied in such a way that no adjacent plots received identical treatments.

Table 2. Mite control by 4 different spray materials.

	Number rust mites per 10 leaves (A&I College plots) in indicated plots on indicated dates			
Date	*Sulfur*	*Zineb*	*Kepone*	*Maneb*
4-17-59	6	1	0	3
5- 1-59	0	1	6	0
5-15-59	5	2	1	2
5-29-59	8	0	0	2
6-13-59	9	2	0	4
6-26-59	128	20	4	20
7- 7-59	736	109	19	79
7-18-59	790	105	49	....

*In cooperation with the California Spray Chemical Corp.

Test materials were applied by single-nozzle spray-guns from a John Bean hydraulic sprayer at 400-500 psi, on April 3 and 4, 1959. The trees were sprayed from the outside, directing the stream through the foliage into the inside of the trees wherever possible, and the foliage was soaked to the point of runoff.

Following are the materials and dosages used on the basis of 100 gallons of spray material:

Plot I	.8% Volck Soluble oil 1# 65% zineb (W.P.) 1# 53% Cu
Plot II	.8% Niagara Emulso 90 oil 1# 65% zineb (W.P.) 1# 53% Cu
Plot III	1# 65% zineb (W.P.) 1# 53% Cu
Plot IV	1# 65% zineb (W.P.) 1# 53% Cu
Plot V	.8% Niagara Emulso 90 oil 1# 65% zineb (W.P.) 1# 53% Cu
Plot VI	.2% Ortho Volck Soluble oil 1# 65% zineb (W.P.) 1# 53% Cu

On April 13, mite counts in all plots were begun by removing 10 mature leaves from the periphery of 4 trees located in the center of each plot and processing and counting as described earlier. Counts were continued until July 9, when retreatment of all plots was scheduled.

The addition of oil to the original zineb spray apparently improved slightly the control of rust mites where .8% oil was used (Table 3).

Table 3. Mite control by oil-zineb sprays in 1959.

	Rust mites per 10 leaves, oil-zineb test, in indicated plots on indicated dates					
Date	*Plot I*	*Plot II*	*Plot III*	*Plot IV*	*Plot V*	*Plot VI*
4-13-59	4	2	1	0	2	0
4-27-59	1	0	0	1	4	0
5-13-59	0	0	1	0	1	0
5-27-59	0	0	1	0	3	0
6-10-59	1	1	1	0	3	0
6-24-59	2	4	0	7	10	6
7- 9-59	9	24	94	57	25	71

However, the lower oil dosage, (.2%) did not appear to improve control to any extent as compared to where zineb alone was used.

The numbers of spider mites remained very low or nil and were not important during the test.

Scale counts performed July 13 on all plots were made to determine the effects of the early oil application on the scale population. The counts given as live scale per 100 fruit examined were as follows: Plot I 56, Plot II 356, Plot III 328, Plot IV 303, Plot V 234, Plot VI 609. The average number of scale in the plots which received oil, as compared to those which did not, show that the early use of oil gives only slight advantage, if any.

Experiment IV. During 1959, a test was conducted for Texas Citrus mite control with several materials which have not been used on citrus in the Rio Grande Valley, and one, (Chlorobenzilate) which has been tested previously in this area (Dean, 1959). The other materials tested were: Ortho Mitox (California-Spray Corp.), Genite (General Chemical Co.), and Glyodin (Union Carbide Corp.). All four materials are considered to be useful for spider mite control and are of interest because of their selective nature. None of the four are noted for their high potency or broad spectrum of killing action.

The treatments were applied to 12-year-old orange trees in plots four rows wide and six trees deep.

The dosages employed were as follows:

Plot I	Mitox 40% W.P.	1#/100 gal.
Plot II	Chlorobenzilate 25% W.P.	1#/100 gal.
Plot III	Glyodin 34% E.C.	1 qt./100 gal.
Plot IV	Genite 50% E.C.	.75 qt./100 gal.

Sprays were applied with single nozzle hand guns from a John Bean hydraulic sprayer at 400-500 psi, wetting the foliage thoroughly until the point of runoff. All treatments were applied on July 3, 1959.

A count of spider mites in each plot and the untreated check area

Table 4. Effects of 4 spray materials on the Texas citrus mite.

	Texas citrus mites per leaf in indicated plots on indicated dates				
Date	*Plot I*	*Plot II*	*Plot III*	*Plot IV*	*Check*
7-3 (Pre-spray)	7.1	21	5	28.8	5
7-10	1.6	4.3	2.2	6.8	3.5
7-21	1.1	4.0	1.6	7.3	1.5
7-29	1.3	3.7	1.6	7.7	1.5
8-8	.9	11.7	1.6	17.6	4.5
8-17	4.9	23.6	5.4	30.0	1.5

was made immediately preceding spraying and at approximately 10-day intervals thereafter, by removing 10 mature leaves from each of four trees in the center of each plot and processing and counting as described under METHODS.

Mitox and Glyodin were nearly equal in controlling spider mites under the conditions of this test, and show promise for further testing (Table 4). Chlorobenzilate, which is said to be effective against rust mites also, did not show outstanding control. Genite was the least effective material tested and gave poor control. Six weeks after treatment, the numbers of spider mites were very high where chlorobenzilate and genite had been applied, suggesting that complications may result where these two materials are used.

SUMMARY AND CONCLUSIONS

The use of zineb as a spray was found to be notably superior to sulfur for the control of citrus rust mites. Kepone and maneb also showed considerable promise. Tedion did not appear to eliminate certain beneficial mites when used for Texas citrus mite control.

An .8% spray-oil in combination with zineb gave slightly longer kill of rust mites than zineb alone.

Ortho Mitox and Crag Glyodin, applied as sprays for Texas citrus mite control gave satisfactory control. Chlorobenzilate and Genite provided poor control of this mite.

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Introduction of Beneficial Insects for the Control Of Citrus Scale Insects and Mites[1]

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The biological control of scale insects and mites of citrus in the Lower Rio Grande Valley of Texas has been a factor of economic importance during the past 23 years. However, chemical control of the citrus rust mite, *Phyllocopruta oleivora* (Ashmead), has been necessary. Several species of parasites and predators were made available to this station during the past 8 years to improve the biological control of various citrus pests.

The various parasites herein under consideration are taken up in order of pest species on which they were introduced. Recovery of certain species cannot be reported due to lack of time for adequate study or failure of the species to become established. However, the policy of of this station has been to introduce all available beneficial insects whether or not time permitted the sampling for recovery and establishment or the rearing of the species in the laboratory for distribution.

Aphytis lepidosaphes Compere.—The first introduction proved to be the most important introduced species. This external parasite of purple scale, *Lepidosaphes beckii* (Newman), was introduced from Riverside, California in July 1952. The original introduction into the United States was made in 1948 from South China, according to Smith and Flanders (1950). Evaluation studies of this parasite in the Lower Rio Grande Valley area will be reported by Dean (1960). This parasite has been found in almost every grove where purple scale has been sampled even though the original releases were made in only three groves as follows: Substation No. 15, south and west of Weslaco and 2 miles east of Mercedes. This parasite has maintained itself in low purple scale populations which is a characteristic of a successful parasite. Purple scale may now be considered as a minor pest of citrus in this area.

Aphytis maculicornis (Masi).—This parasite was introduced into the U. S. from Iraq to combat the olive scale, *Parlatoria oleae* (Colvée) in California (Compere, 1955). Colonies were sent to Weslaco in March and April 1956 from Albany, California as a possible parasite of chaff scale, *Parlatoria pergandii* Comst. Releases of approximately 1,000 parasites each were made on March 29, 1956, in a grove just east of Mercedes and a grove at Hoblitzelle Ranch north of Mercedes. On April 13, releases of approximately 1,000 each were made at Substation No. 15 and at Delta Lake and Farm Highway 88. No recovery of the parasite has been made.

Aphytis diaspidis Howard.—This parasite was originally imported in 1952 from Asmara Eritrea, Africa into California according to Compere (1955). A small colony was received October 23, 1953 from laboratory stock at Riverside. Two apparently healthy females were released at Substation No. 15 around chaff scale. No recovery has been attempted due to the difficulty of distinguishing the various *Aphytis* spp. which attack chaff scale.

Prospaltella perniciosa Tower.—The strain which attacks California red scale, *Aonidiella aurantii* (Maskell), was introduced from Formosa. Colonies were received from Riverside, California on September 4, 1953. About 500 parasites were released in an orange grove at Hoblitzelle Ranch north of Mercedes. A colony was received on May 28, 1956 and released in the Langford orange grove at Mile 2½ West and Highway 83 east of Weslaco. Some evidence of an internal parasite on California red scale has been found in these two groves, but live parasites were not in the few samples that were examined. California red scale, though increasing somewhat in these groves, was considered in very low population numbers.

Comperiella bifasciata Howard.—A colony of this California red scale strain, originally from South China, was received from Riverside on September 4, 1953 and released at Hoblitzelle Ranch north of Mercedes in grapefruit trees. These parasites were in much poorer condition than *P. perniciosa.* The scale insect was present in very small numbers. Very little evidence of internal parasite attack of California red scale was found within the year following release.

Prospaltella aurantii (Howard).—Florida red scale, *Chrysomphalus aonidum* (Linnaeus), was reduced to such small numbers following the 1951 freeze that it was very difficult to find under field conditions for some years. In 1955, this scale insect appeared in 2 particular groves which showed no evidence of control by parasites. It seemed advisable to reintroduce *P. aurantii* before the scale insect had an opportunity to develop to the heavy infestation levels that were prevalent before the freeze. A colony of approximately 180 adults was received from Lake Alfred, Florida and released on October 2, 1955 in the Baker-Potts Grove west of Harlingen. Another colony was released the same day at Substation No. 15. Recoveries were made from young female scales the following month and the parasite is now generally distributed throughout the Rio Grande Valley area. Although this parasite has been found quite prevalent in certain groves, it has appeared to be somewhat inconsistent in numbers in various levels of Florida red scale.

Pseudhomalopoda prima Girault.—This parasite occurred commonly around Florida red scale infestations just prior to the 1951 freeze. The parasite was found on an elaeagnus shrub in October and November,

[1] Thanks are due to the Department of Biological Control in California; the Citrus Experiment Station, Lake Alfred, Florida; an dthe Insect Identification and Parasite Introduction Research Branch, Entomology Research Division, U. S. Department of Agriculture for making parasites and predators available for introduction.

1951, possibly attacking *Melanaspis elaeagni* McKenzie. The reintroduction of this parasite seemed advisable because it was not found attacking Florida red scale on citrus. Three shipments were received during September 1955 from Lake Alfred, Florida and released in the Baker-Potts Grove west of Harlingen and in a grove at Substation No. 15. Immature stages were found one month following release. Samples of the scale during 1959 showed wide distribution of the parasite in the Valley area.

Aphytis lingnanensis Compere.—By 1958, it was apparent that the 2 previously-mentioned parasites were not reliable controlling agents of Florida red scale in this area. The need for additional beneficial insects for the control of this scale insect seemed very necessary since the scale continued to increase in numbers. The Florida red scale strain of *A. lingnanensis* was obtained from Tel-Aviv, Israel through a cooperative effort with the Insect Identification and Parasite Introduction Research Branch of U. S. Department of Agriculture. The parasite originated from Southern China. The Parasite Receiving Station at Moorestown, New Jersey screened the parasite through quarantine and shipped only adults. *A. lingnanensis* proved so successful against Florida red scale in Israel that the scale insect is almost unknown in a major part of the citrus area, according to a letter from David J. Nadel, Entomologist-in-charge, Biological Control Laboratory, Tel-Aviv, Israel. Local releases of adult parasites were made as shown in table 1.

Recoveries were made in August and December 1959 in the Substation No. 15 and Holland groves. The parasite was much more numerous in the orange trees at the Holland grove than in the grapefruit trees at Substation No. 15.

Metaphycus luteolus Timberlake.—Soft (brown scale, *Coccus hesperidum L.*, has been a minor insect pest in this area due primarily to the activity of beneficial insects. However, at times this scale insect has

Table 1. Releases of *Aphytis lingnanensis* (Florida red scale strain) during 1959.

Location	*Date*	*Number*
Holland Grove, Mission	6-22	50
	6-30	103
W. H. Friend Grove, Weslaco	6-19	24
Substation No. 15, Weslaco	6-24	112
	6-28	55
	6-29	72
	7-13	35
Boca Chica Grove, Brownsville	7-1	33
Baker-Potts Grove, Harlingen	6-26	186
Miller Grove, East of Mercedes	6-30	60
	Total	730

increased to damaging numbers in a few groves. Parasite material was made available through the Department of Biological Control, Citrus Experiment Station, Riverside, California. *M. luteolus,* the dominant parasite of soft (brown) scale in California, caused near elimination of the scale according to Bartlett (1953). Flanders (1942) reported this parasite may have accidentally been introduced into California. Colonies of the parasite were released during 1954 as follows: (1) Hoblitzelle Ranch north of Mercedes on January 28, (2) 0.3 miles west of Sugar Road on Farm Road 495 on January 29, (3) 3½ miles North Shary Road, Mission, Texas on March 3, (4) 2.7 miles North Victoria Road on March 27 and (5) 2.3 miles north of Highway 83 on Highway 800 on March 29. Hitherto checks have proved negative.

Metaphycus angustifrons Compere.—This parasite was introduced into California from Eritrea, Africa. A colony was released around soft (brown) scale in a grove 3½ miles North Shary Road on March 26, 1954. Another colony was released in a grove at 2.3 miles North Bass Boulevard on March 21, 1954. The parasite was recovered in the latter grove during September 1954 as reported by Dean (1955).

Coccophagus eleaphilus Silv.—This internal parasite, originally from Eritrea, Africa, was sent from Riverside_ California during March 1954. A colony was released around soft (brown) scale in a grove at 3½ miles North Shary Road on March 26. About 75 parasites were released in a grove at Tower Road and Farm Road 495 on March 27. Another colony was released in a grove at 2.3 miles North Bass Boulevard on March 29. No recovery of the parasite has been made to date.

Microwesia coccidivora (Ashm.).—Although a *Microwesia* sp. has been reported from this area by Dean (1955), this diaspid scale-feeding beetle was introduced in September 1953 and released in a grove at Hoblitzelle Ranch north of Mercedes. No recovery samples were made.

Cybocephalus sp.—This Diaspid scale-feeding beetle (Chinese form) was introduced from Riverside, California in September 1953 at the Hoblitzelle Ranch grove north of Mercedes. No recovery has been made to date.

Lindorus lophanthae Blaisdell.—This diaspid scale-feeding beetle was sent to Moorestown, New Jersey from South Africa, but may have originated from Australia. On September 1, 1959, 155 adults were received by airmail and released in a grove at Substation No. 15. Florida red scale was the predominant pest in the grove along with some California red scale, mealy bugs, white flies and cottony cushion scale. On October 2, 1959, 28 beetles were released at Hoblitzelle Ranch north of Mercedes. Soft (brown) scale was common at the release site while chaff, Glover and California red scales were also present. No recovery records have been taken.

Brumus suturalis (F.).—This beetle was sent to Weslaco from Orlando, Florida where it was being reared on aphids in the laboratory. The beetle was imported from Pakistan. Selhime (1956) reported this

Table 2. Releases of introduced spider-mite-feeding beetles during 1956.

Location	Date	*Stethorus guatemalensis*	*Stethorus utilus*	*Stethorus picipes*
0.9 North Hutto Road	5-10		25	
	6-13	4		91
Monte Alto	5-12		25	
	6-13	86		86
1.6 miles North Taylor Road	5-10		75	
	6-13	96		83
Substation No. 15	5-11		4	
	6-29	11		
0.8 mile North Bass Boulevard	6-27	189		
	6-29			194
South of Highway 83 on Mile 3 West	6-13	2		11
	6-27	179		
	6-29			117
Mile 13¾ North on Highway 88	6-27	185		
Hoblitzelle Ranch North of Mercedes	6-13	86		99
2 Miles North of Edinburg	6-29			295
I Road and Farm Road 495	6-29	256		
Sugar Road and Farm Road 495	6-29	158		
McColl Road and Farm Road 495	6-29	127		
Goodwin Grove	6-29	519		
Simmond Grove North of Goodwins	6-29	182		
3 miles North of Edinburg	6-29			295

beneficial insect to feed in the laboratory on mites, white fly, aphids, mealy bugs and some scale insects. On April 24, 1956, 18 individuals were released at Hoblitzelle Ranch north of Mercedes. Two pair were released at 1.6 miles North Taylor Road on May 10 and on May 12, two pair were released at Substation No. 15. Recovery has not been successful.

Mite-feeding beetles.—One of the principal predators of the Texas citrus spider mite, *Eutetranychus banksi* McG., has been *Stethorus atomus* Casey. The beetle has offered considerable help in the biological control of this mite during the winter. However, the beetle has not been found to increase in sufficient numbers to control the heaviest populations of this mite during the May-July period until after a depression of the peak mite population occurs. Although *Stethorus punctum* Lec. has also been found on citrus, additional predators of mites were considered highly desirable if lower mite populations were to be main-

tained. Several mite predators became available from other citrus areas. *Stethorus utilus* Horn (a predator of six-spotted mite, *Eotetranychus semaculatus* Riley, and citrus red mite, *Panonychus citri* (McG.) in Florida, as reported by Muma (1955) was received from Lake Alfred, Florida during May 1956. A native species from California, *Stethorus picipes* Casey (citrus red mite its primary food source according to De Bach, *et al*, 1950), was received from Riverside, California. An introduced species from Guatemala, *Stethorus guatemalensis* Hall and Fleschner, was received from Riverside. Releases are shown in table 2. Collections during 1957 and 1958 showed a ratio of two *atomus* to one *utilus* in selected groves. No recoveries have been made of *picipes* or *guatemalensis*.

SUMMARY

Some 17 different species of beneficial insects have been introduced into the Lower Rio Grande Valley area during the past 8 years as possible predators on various citrus pests. The importance of purple scale has been greatly reduced due to a parasite, *Aphytis lepidosaphes*, imported from China via California. An external parasite of Florida red scale, *Aphytis lingnanensis*, has shown indications of establishment and possible importance in the biological control of this scale insect. Several species have established while others have not been recovered.

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The Use of Tensiometers as an Aid in the Irrigation of Citrus Groves

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Simple procedures are needed for determining the frequency, rates and amounts of water that should be applied to citrus groves. Some growers use changes in the color of the foliage or other growth characteristics of the plants as a guide in determining when to irrigate. However, apparent visual plant growth changes are dependent upon variable factors, such as time of day, climate, available soil moisture and even the individual's evaluation. Condition or appearance of the citrus foliage is not a very reliable criterion to employ for efficient water use. For this reason the most effective methods used to determine when to irrigate crops are based upon determining or estimating the available moisture in the soil.

Soil moisture can be determined by sampling the soil with a probe and weighing the soil samples before and after drying at 110° C. for 24 hours. However, this is a time-consuming method and requires that farmers have special equipment, such as soil sampler, oven and a balance and the available time and labor for taking the samples. Another simpler, but less accurate, method of estimating soil moisture is by feeling the soil (Thurmond, 1957). Bloodworth (1959) has listed and discussed various soil-moisture-indicating instruments and methods.

A rapid, easy and relatively inexpensive method or guide to determine when to irrigate citrus would be of considerable benefit to citrus growers in the Lower Rio Grande Valley. The only moisture-measuring device that has such possibilities is the tensiometer. Tensiometers may be of the vacuum gauge or mercury column type. The vacuum gauge type tensiometer is the one best suited for use by citrus growers. It is simple to install and easy to read.

Tensiometers consist of a porous cup in contact with the soil and a water-filled connecting tube from the cup to an above-ground indicator. The water in the closed tube moves through the porous cup at the bottom of the tube and comes to equilibrium with the soil moisture. As the soil dries, water is pulled or moved out of the tube through the porous cup and a vacuum is created in the upper part of the closed tube which is indicated on the gauge. The wetter the soil the lower the gauge reading; the drier the soil the higher the gauge reading. Tensiometers are more sensitive in indicating the higher soil moisture ranges and less sensitive in indicating lower soil moisture ranges. The tensiometer is a good indicator of available moisture in coarse-textured soils (sands) and medium-textured soils (loams). It is especially effective in measuring the available soil moisture in sandy soils. Most of the citrus in the Lower Rio Grande Valley is grown on coarse or medium-textured soils in which tensiometers may be used to give a good estimate of available soil moisture.

PROCEDURE

The objectives of the investigation were: (1) to determine the feasibility of using tensiometers to indicate when to irrigate, (2) to determine irrigation water distribution, (3) to determine the primary zone of water use by citrus and (4) to determine the best depth for placing tensiometers in citrus orchards.

In July, 1959, four sets of tensiometers were placed at depth of 8, 16, 24 and 36 inches in a 4-year-old grapefruit orchard located at Substation No. 15, near Weslaco in Willacy loam soil. The 4 tensiometers at each location were placed beneath the outer branches in the root zone of 4 representative trees distributed through the grove. The tensiometers were usually read every day, except Sundays, between 8:00 and 9:00 A.M. The orchard was in sod, with broad permanent borders between the tree rows with trees 28 feet apart.

RESULTS AND DISCUSSION

The data obtained from July, 1959, through December, 1959, are indicated in Figure 1.

A rough classification of the available soil moisture at different tensiometer readings are listed in Table 1. Tensiometer readings of 60-85 do not mean that all the available moisture has been removed from the soil. Readings of 60 and 85 correspond to tensions of 0.6 and 0.85 atmosphere. Soils at the wilting point have tensions of approximately 15 atmospheres. However, it does indicate that the soil water supply is not as readily available to plants. Photographs of tensiometers and their locations with respect to the trees are indicated in Figures 2A, 2B and 2C.

Table 1. Relative supply of soil moisture at different tensiometer readings.

Tensiometer Readings	*Soil Moisture*
0 - 10	Saturated soil
10 - 30	Good supply of available moisture
30 - 60	Approximate time to irrigate*
70 - 85	Low supply of available moisture

*Readings of 50-60 at a soil depth of 24 inches indicate that it is time to irrigate the citrus orchard.

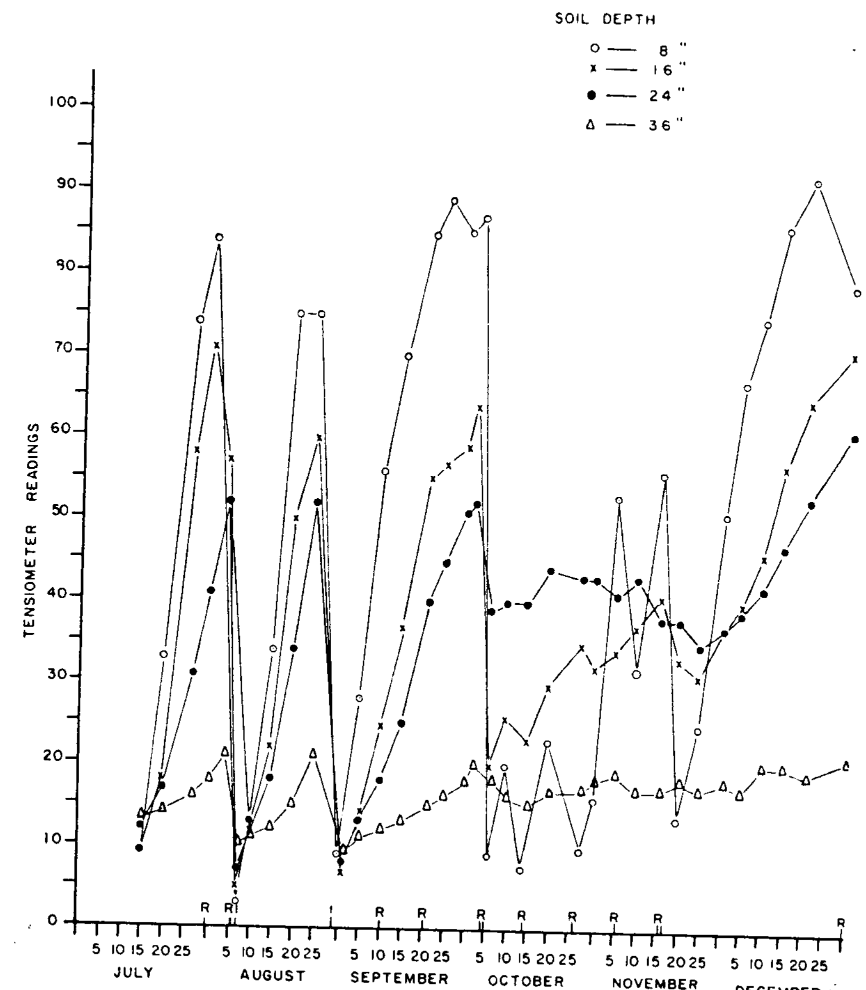

Figure 1. Tensiometer data obtained from citrus groves at Substation No. 15, Weslaco, from July through December, 1959, at depths of 8, 16, 24 and 36 inches. Irrigations are shown as "I" and rains as "R".

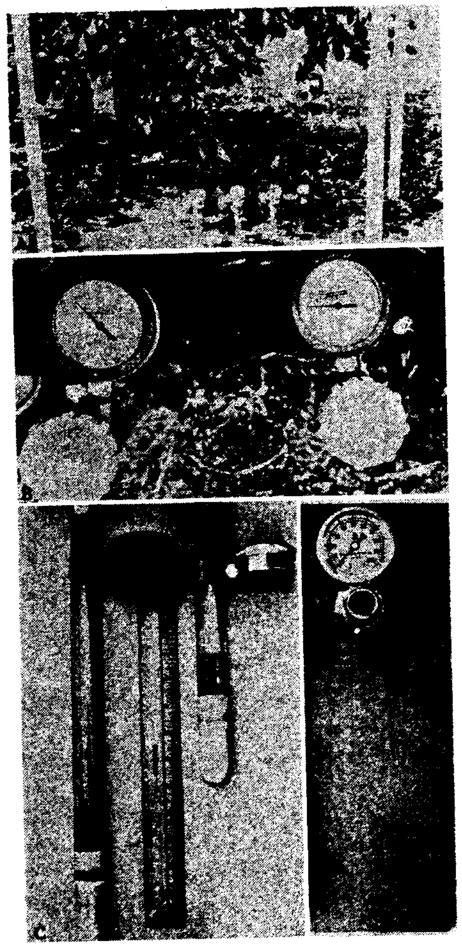

Figure 2A. Photograph of location of tensiometers with respect to citrus trees.

Figure 2B. Photograph of tensiometer gauge readings when the soil still had a good supply of available moisture.

Figure 2C. Photograph of two small tensiometers (6 and 12 inches in length), of gauge and type of screw cap for water-filled tube.

Dates of rains of 0.15 inch or greater are indicated as "R" in Figure 1. The orchard was irrigated on August 6 and August 29. These dates are indicated by "I" in Figure 1.

Figure 1 indicates that the citrus trees used soil moisture at soil depths of 8, 16 and 24 inches. High tensiometer readings at these depths indicate that the soil moisture was partially used during the period of July through December. The low tensiometer readings at 36 inches indicate that soil at this depth was wet at all times from July through December and that moisture utilization from this soil depth was small. If only a limited number of tensiometers are available, it would be best to place the tensiometer at a soil depth of 24 inches. Readings of 50 to 60 and even 70 at a depth of 24 inches would indicate that the upper 2 feet of soil is even drier, and it is time to irrigate. The grower's exact irrigation schedule would depend on his water supply. Hilgeman and Howland (1955) at Arizona recommended irrigation of citrus on Mesa loam soil when tensiometers placed at 30 inches had readings of 50 to 60.

According to soil tensiometer readings, July and August were months of high moisture demand in 1959. The irrigations in August were sufficient to replenish the soil moisture supply in the depleted zone.

Tensiometer readings at a depth of 24 inches also indicate the effectiveness of rains. A 3-inch rain in October 4 saturated the soil at 8 and 16 inches, but not at 24 inches. Rains in October and November coupled with apparent lower water demand by citrus supplied the apparent needs of the citrus trees. This is indicated by little or no change in the tensiometer readings at 24 inches in October and November. The tensiometer readings at 24 inches in late December indicated that the soil moisture supply was getting low. The grove was irrigated in early January, 1960.

The best placement of the tensiometers may be influenced by the age of the grove and the type of soil management practiced. However, results do indicate that tensiometers placed at 24 inches would probably serve as a good guide for determining when to irrigate. If the tensiometers are properly placed in the orchard, the tensiometer readings could be used as a guide as to when sufficient water was applied to the grove.

Tensiometers placed at 24 inches would require only limited attention. The tensiometers could be read and refilled with water about once a week.

These are preliminary observations. It probably would be desirable to observe growth changes in the citrus trees and fruit and try to correlate these changes with soil tensiometer readings. The irrigation schedules followed during the course of this investigation were considered satisfactory for citrus growth and production.

SUMMARY

Preliminary investigations indicate that the tensiometers placed at 24 inches may serve as an important guide for the purpose of determining

when to irrigate citrus. Tensiometer readings of 50 to 70 at a depth of 24 inches would indicate that the upper 2 feet of soil is even drier, and it is time to irrigate. It also gave an indication of the effectiveness of irrigations or rains in replenishing the water that had been removed from the soil. Young citrus trees seem to use most of their water from the first 2 feet of soil.

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Changes in Citrus-Leaf Temperatures During Freezing

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Ice formation in living plant cells has led to many investigations of the changes in plant-tissue temperatures during freezing. Luyet and Gehenio (1937), Walter and Weismann (1935), and Zacharowa (1926) reported a characteristic rise in temperature during freezing in tissues of onion, rye seedlings, and potato tubers. Before this rise, the tissue temperature dropped below the freezing point. The minimum temperature before the rise was called the "undercooling point." The rate of temperature change during freezing varied considerably.

The purpose of this paper is to present data on changes in leaf temperatures during freezing of plants of several citrus species.

MATERIALS AND METHODS

Temperature changes in leaf tissues during freezing were recorded with a Rubicon potentiometer and thermocouples. The leaf used for temperature measurement was folded over a thermocouple and clamped tight with a paperclip. Recordings were obtained in milli-volt units which were subsequently converted to degrees Fahrenheit (° F.). Plant materials to be frozen were placed in a walk-in freezer, set at 33° F., and the temperature was lowered to 20°-21° F. at a rate of about 15° F./hour. Recordings were taken every minute until the leaves were frozen and their temperatures had equilibrated with the air of the freezing chamber. Materials used were 2-year-old budded trees of nucellar Red Blush grapefruit on Cleopatra mandarin rootstock, and 6-month-old seedlings of sour orange, rough lemon, Rangpur mandarin-lime, Duncan grapefruit, and Troyer citrange. Following the freezing period, the plants were removed to a 75° F. glasshouse for observations on the extent of damage. Data reported are typical of results obtained from several different trials using similar plant material.

RESULTS AND DISCUSSION

In a typical freezing curve (Figure 1A) of a nucellar Red Blush leaf, the rise in temperature 55 minutes after initiation of the trial indicated that freezing had begun. At that time water-soaking became apparent in the leaf; as the leaf temperature increased, the water-soaking became more general. The true freezing temperature occurred at 25.1° F., at which point the leaf was completely water-soaked. This freezing point represented an increase in the leaf temperature of 3.1° F. from the "undercooling" temperature of 22.0° F. The temperature of the leaf subse-

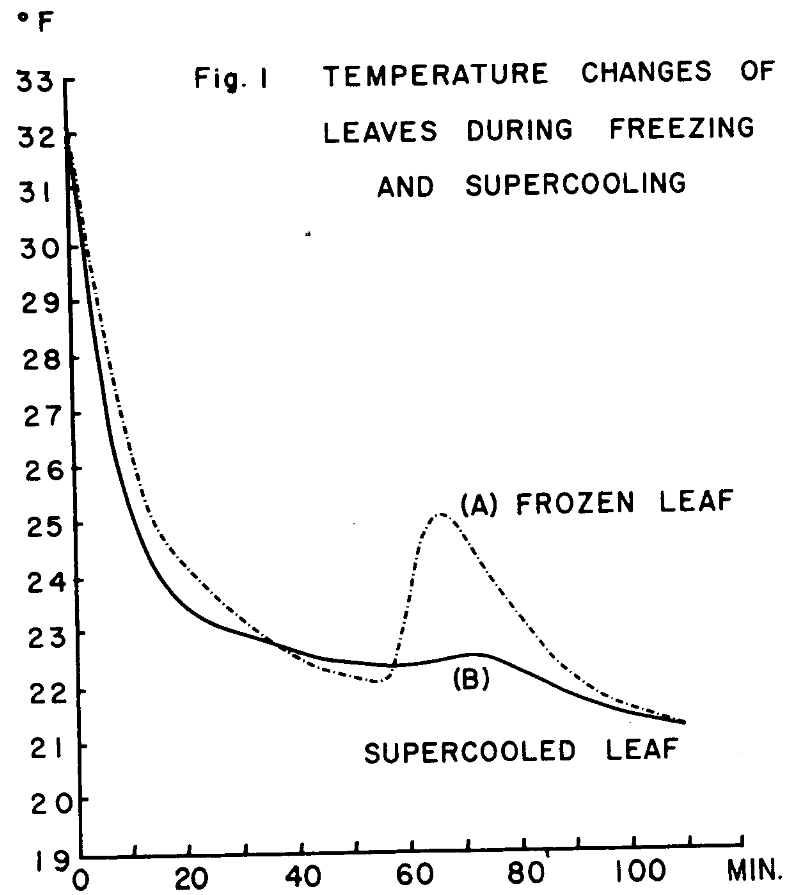


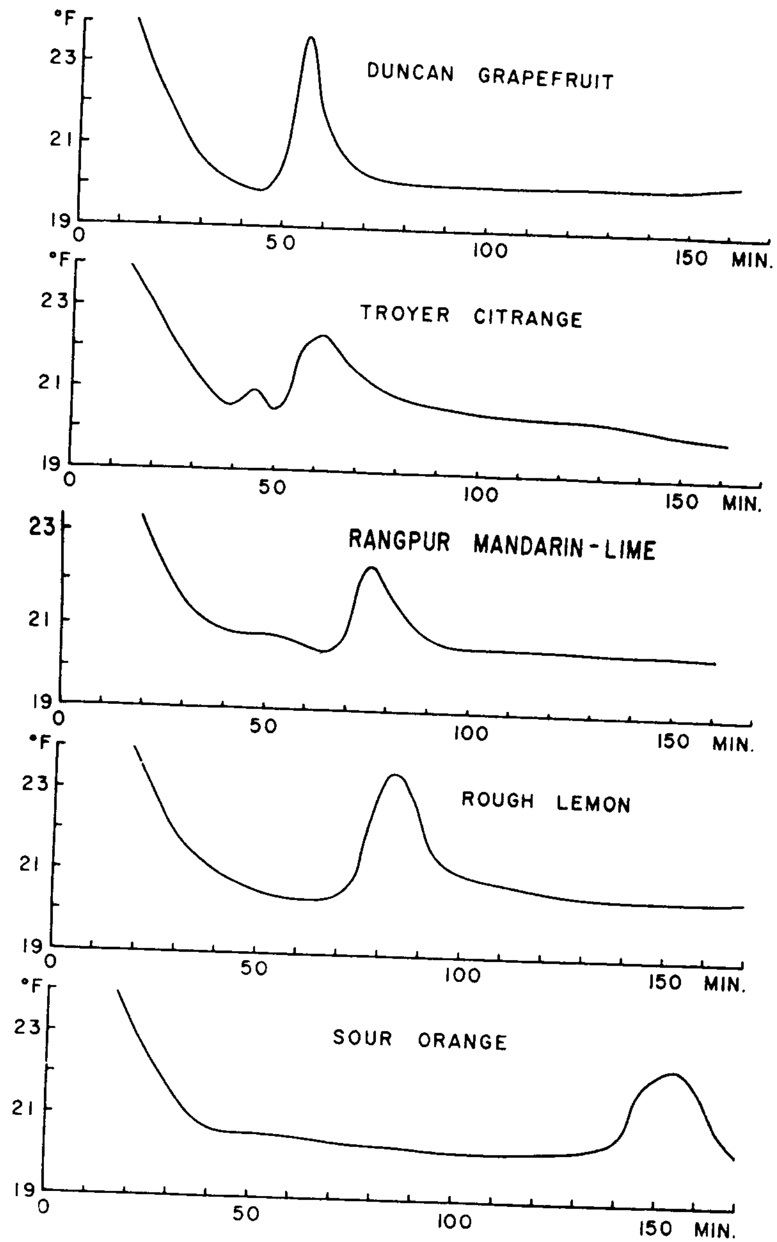
Fig. I TEMPERATURE CHANGES OF LEAVES DURING FREEZING AND SUPERCOOLING

quently decreased indicating that most of the solute within the leaf was frozen and that no further heat of crystallization was being released.

Curve B (Figure 1) summarizes the temperature changes in a similar leaf from a plant which did not freeze. In contrast to the temperature increase recorded in curve A, no temperature increase was noted in curve B. Rather, a gradual decrease in temperature occurred. Leaves on this plant did not exhibit water-soaking throughout the freezing period and remained undamaged. This plant exhibited what is commonly referred to as "supercooling."

A second experiment was initiated to study the freezing-curve characteristics of several common citrus species. Seedlings of Duncan grapefruit, rough lemon, sour orange, Rangpur mandarin-lime, and Troyer citrange were grown under similar conditions for 6 months in one-gallon

Fig. 2 LEAF TEMPERATURE CHANGES OF SEEDLINGS OF FIVE CITRUS SPECIES DURING FREEZING



pots. On December 12, the plants were frozen under identical circumstances and leaf-temperature changes on each plant were recorded. Freezing was initiated first in grapefruit seedlings, followed by Troyer citrange, Rangpur mandarin-lime, rough lemon, and sour orange seedlings (Figure 2). This order corresponded fairly closely with the degree of dormancy of the species; grapefruit was the most active and sour orange the most dormant. Cooper, et al. (1955, 1960), Chandler (1950), and Wilder (1948) have indicated that freeze injury is less in dormant citrus trees than in actively growing ones. Freeze damage on the grapefruit, rough lemon, and Rangpur mandarin-lime seedlings was severe; the leaves and 50% of the woody branches were injured. Only the leaves of Troyer citrange and sour orange seedlings were injured.

The freezing curve patterns for all the species tested were similar in shape. Variability in the height of the curves may be related to variability in the per cent moisture in the leaves—more moisture resulting in more heat evolved on freezing. Grapefruit showed the greatest increase in leaf temperature, followed by rough lemon, Troyer citrange, Rangpur mandarin-lime, and sour orange. The per cent moisture contents of the leaves were 78, 69, 68, 65, and 66, respectively.

SUMMARY

Changes in leaf temperatures during freezing of nucellar Red Blush grapefruit budded on Cleopatra mandarin rootstock and seedlings of Duncan grapefruit, Rangpur mandarin-lime, rough lemon, Troyer citrange, and sour orange were recorded. A characteristic rise in the leaf temperature, apparent as freezing was initiated, was followed by a reduction in temperature after the leaf was fully frozen. Freezing-curve patterns for the six species tested were similar in shape. Variability in the height of the freezing curve attained was noted between species.

The growth status of the plants influenced the length of time required to initiate freezing. Plants of actively-growing species were frozen more quickly and with greater injury than plants of dormant species.

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Effect of Rootstock-Scion Combination and Dormancy on Cold Hardiness of Citrus[1]

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Rootstock-scion combinations differentially influence the cold hardiness of citrus. In Florida, Valencia orange scions on *Poncirus trifoliata* (trifoliate-orange), sour orange, and Savage citrange rootstock were more cold-tolerant than those on Rangpur mandarin-lime and rough lemon rootstocks(Gardner and Horanic, 1958). In California, satsuma scions on trifoliate-orange, tangerine, citrange, and sour orange stocks were more cold hardy than those budded on grapefruit and rough lemon stocks (Webber, 1948). In Texas, Red Blush grapefruit scions on sour orange rootstock were more cold hardy than those on Rangpur mandarin-lime or rough lemon rootstock. (Cooper, 1952).

It is common knowledge that citrus species vary considerably in cold hardiness. Webber (1948) listed the following species according to their increasing cold hardiness: citron, lime, lemon, grapefruit, sweet orange, sour orange, mandarin orange, kumquat, and trifoliate-orange. The relative differences in cold hardiness of these species have been suggested to be related to dormancy. To what degree dormancy is involved has not been ascertained.

Cooper et al. (1955) and Cooper (1960), in studies with Red Blush grapefruit, found that actively growing trees were often injured at 27° F.; comparable injury to dormant trees occurred at temperatures of 23° F. or lower.

The purpose of this study is to summarize the effects of several rootstock-scion combinations and dormancy on the cold hardiness of citrus.

MATERIALS AND METHODS

The plant materials used were growing in two field trials in Monte Alto, Texas. All trees were also planted in two rows at 5' x 5' spacing on Feb. 17, 1958. In the first, 3-year-old nucellar Red Blush trees were growing on sour orange, Troyer citrange, *Citrus macrophylla*, Rangpur mandarin-lime, *Citrus moi*, Sunki mandarin, and Columbian sweet lime rootstocks.

[1] The work was a cooperative project of the Agricultural Research Service, U. S. Department of Agriculture, the Texas Agricultural Experiment Station, and Rio Farms, Inc., Monte Alto, Texas.

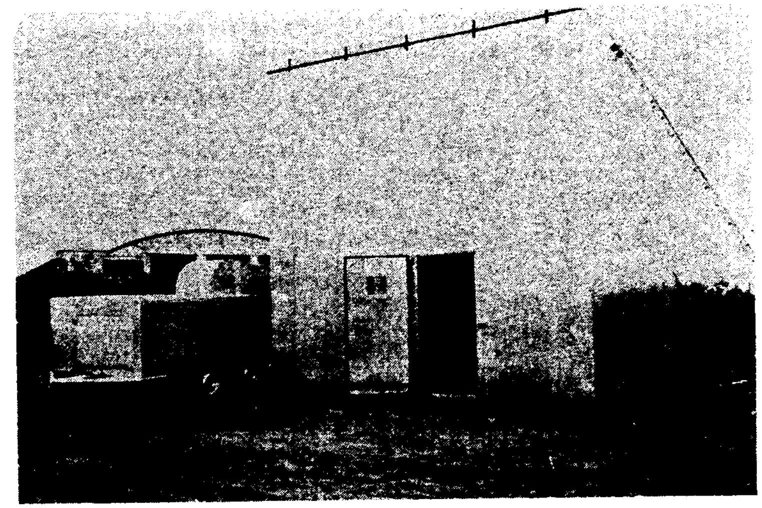

Figure 1. Portable tree freezer used in freeze trials. Trailer at side of freeze chamber houses refrigeration equipment.

In the second field trial, 3-year-old nucellar Red Blush grapefruit, Mexican lime, and satsuma mandarin trees were growing on trifoliate-orange, Savage citrange, sour orange, Cleopatra mandarin, and Mexican lime rootstocks. Nucellar Valencia orange trees on Cleopatra mandarin and Rangpur mandarin-lime rootstocks were also included. Buds for all trees were taken from previously determined virus-free nucellar parent materials except for satsuma mandarin. Satsuma buds were taken from a satsuma seedling which had not been indexed for viruses.

Beginning October 26, 1959, the growth status of all trees in both field trials was recorded every 2 weeks until all trees had ceased growth and the leaves had hardened.

On December 9, 1959, freeze trials were initiated. The freezing trials were conducted with an 18' x 18' x 18' portable tree freezer equipped with 7½ tons of refrigeration capacity (Figure 1). Freeze trials were conducted at night, and 6 trees were frozen during each freeze period. A temperature of 22.8° F. was maintained for 4 hours; variation at the center of the chamber 6' above ground level ranged from 21.9° F. to 23.2° F. Temperature variations in other parts of the chamber at the 3' and 6' levels were similar to that at the center of the chamber. The length of time required to cool the freeze chamber to 22.8° F. varied from 2 to 6 hours, depending on the air temperature outside the chamber and the warmth of the day preceding the freeze trial.

Data recorded on all trees included the ease of peeling of twig bark the day before freezing, per cent leaf defoliation, bark splitting, and twig damage 2 weeks after freezing.

RESULTS

The first field trial included nucellar Red Blush grapefruit trees on 7 different rootstocks (Table 1). Elongation of new shoots of the fall flush ceased on some trees October 15, and continued on others as late as November 23. A period of 2 or 3 weeks after cessation of elongation was required for the stems, buds, and leaves of these shoots to mature and harden. All growth on these shoots had not ceased at this time as there was still some cambial activity as indicated by park peeling. However, in the present study trees with terminal shoots mature and hardened are considered dormant in that the buds are mature and are not elongated. All the trees in this experiment had become dormant by December 9, when freeze tests were initiated.

Table 1. Effect of rootstock and dormancy on freeze damage on nucellar Red Blush grapefruit trees exposed to 22.8° F. for 4 hours between December 9 and December 16, 1959.

Dormancy of trees on indicated rootstock	*No. of trees*	*Bark-peeling index on day of freeze test*[a]	*Damage 2 Weeks After Freezing* Percent leaf defoliation	*Bark splitting*[b]	*Twig damage*[b]
Trees dormant by October 26:					
Troyer citrange	3	1.0	55	0.0	0.3
Citrus moi	1	2.0	40	1.0	1.0
Rangpur mandarin-lime	2	0.5	55	0.0	1.0
Sour orange	3	0.7	30	0.0	0.0
Columbian sweet lime	1	1.0	20	0.0	0.0
Sunki mandarin	2	1.0	45	0.0	0.0
Average		1.0	41	0.2	0.4
Trees dormant by November 23:					
Citrus moi	2	0.5	33	1.3	0.7
Rangpur mandarin-lime	2	1.0	85	1.5	1.0
Citrus macrophylla	2	1.0	88	2.0	1.0
Sour orange	1	1.0	100	0.0	1.0
Average		0.9	76	1.2	0.9
Trees actively growing on November 23:					
Citrus macrophylla	2	2.0	81	1.0	1.0
Columbian sweet lime	1	2.0	75	2.0	1.0
Average		2.0	78	1.5	1.0

[a] 0 = bark does not peel; 1 = bark barely peels; 2 = bark peels easily; 3 = bark peels easily and is moist.

[b] 0 = none; 1 = slight; 2 = moderate; 3 = severe.

The previous growth history of the trees strongly influenced the degree of cold injury (Table 1). Trees that had been dormant for the longest period showed much less damage than those that had been dormant for shorter periods. Generally, sour orange, Troyer citrange, and Sunki mandarin rootstocks induced slightly earlier dormancy than did the other stocks. *Citrus macrophylla* tended to induce late active growth, while Rangpur mandarin-lime and *C. moi* were intermediate between *C. macrophylla* and sour orange. Columbian sweet lime as a stock was variable.

The second field trial included satsuma mandarin, Red Blush grapefruit, and Mexican lime trees on trifoliate-orange, Savage citrange, sour orange, Cleopatra mandarin, and Mexican lime rootstocks. Valencia orange trees on Cleopatra mandarin and Rangpur mandarin-lime rootstocks were also employed. The trees, except Mexican lime, had become dormant one full month before the freezing tests were initiated on December 30. The Mexican lime trees, however, were actively growing during the freezing tests. Freeze damage closely paralleled the growth status of the four scions tested (Table 2). The satsuma trees incurred only slight leaf damage, whereas the Red Blush grapefruit and the Valencia orange trees showed slight twig injury and moderate leaf injury. The Mexican lime trees were most severely injured; all leaves and small twigs and branches up to ½" diameter were killed (Figure 2).

Rootstocks had little or no effect on the cold hardiness of satsuma or Mexican lime trees. Mexican lime rootstock slightly lessened the cold hardiness of the satsuma trees.

Rootstocks affected the cold hardiness of Red Blush grapefruit and Valencia orange trees. Red Blush trees on sour orange rootstocks were most cold hardy and sustained least freeze damage; those on Cleopatra mandarin, Savage citrange, and trifoliate orange were less cold hardy than those on sour orange. Red Blush trees on Mexican lime rootstock were the least cold hardy. Differences in cold hardiness due to rootstocks were apparent in Valencia orange trees; those on Rangpur mandarin-lime rootstock were more cold hardy than those on Cleopatra mandarin rootstock.

DISCUSSION

Results from these and other freeze tests have indicated that the cold hardiness of citrus is closely associated with dormancy. The effects of top and rootstock on dormancy in these studies reflected interactions with environmental conditions. In Table 3 are listed the average weekly maximum and minimum air and soil temperatures for November and December 1959, and January 1960. No significant change in the average weekly temperature maximum was apparent from November 1 to December 7. During this period the daily temperature minimum was generally 55° F. or lower which induced bud dormancy of Red Blush, Valencia orange, and satsuma mandarin scions.

The rootstock effect observed in the first field trial, frozen December 9-16, may have been due to the interaction of rootstock and soil temperatures. A change in average soil temperature maximum from 81° F. to 70° F. was apparent from November 1 to December 7; the soil temperature minimum changed from 69° F. to 61° F. during the same period.

Table 2. Effect of rootstock on cold hardiness of 3-year-old satsuma mandarin, Red Blush grapefruit, Mexican lime, and Valencia orange trees exposed to 22.8° F. for 4 hours between December 30 and February 1.

Tops on indicated rootstock	No. of trees	Bark-peeling index on day of freeze test[a]	Damage 2 Weeks After Freezing: Percent leaf defoliation	Bark splitting[b]	Twig damage[b]
Satsuma mandarin:					
Trifoliate-orange	1	0.0	1	0.0	0.0
Savage citrange	3	0.0	1	0.0	0.0
Sour orange	4	0.3	5	0.0	0.0
Cleopatra mandarin	4	0.0	1	0.0	0.0
Mexican lime	4	0.0	50	0.0	0.4
Average		0.1	12	0.0	0.1
Red Blush grapefruit:					
Trifoliate-orange	2	0.5	70	0.0	0.5
Savage citrange	4	1.0	62	0.1	0.5
Sour orange	4	0.2	39	0.1	0.1
Cleopatra mandarin	4	1.2	49	0.1	0.6
Mexican lime	4	0.2	98	0.6	0.5
Average		0.6	64	0.2	0.4
Mexican lime:					
Trifoliate-orange	----	----	----	----	----
Savage citrange	3	2.7	100	0.0	3.0
Sour orange	4	2.2	100	0.0	3.0
Cleopatra mandarin	3	1.3	100	0.0	3.0
Mexican lime	----	----	----	----	----
Average		2.1	100	0.0	3.0
Valencia orange:					
Cleopatra mandarin	4	0.7	80	0.1	1.2
Rangpur mandarin-lime	4	1.2	44	0.2	0.2
Average		0.9	62	0.1	0.7

[a] 0 = bark does not peel; 1 = bark barely peels; 2 = bark peels easily; 3 = bark peels easily and is moist.

[b] 0 = none; 1 = slight; 2 = moderate; 3 = severe.

Figure 2. Freeze damage incurred by satsuma mandarin, Red Blush grapefruit, and Mexican lime tops on Cleopatra mandarin rootstock from exposure to 22.8°F. for 4 hours.

Table 3. The average weekly maximum and minimum air and soil temperatures for November and December 1959 and January 1960, at Monte Alto, Texas.

Date		Air (°F.) Max.	Air (°F.) Min.	Soil (°F.)[1] Max.	Soil (°F.)[1] Min.
Nov.	1- 7	79	58	81	69
	8-14	76	54	----	----
	15-21	65	43	68	59
	22-30	73	45	73	61
Dec.	1- 7	76	51	70	61
	8-14	79	57	70	67
	15-21	70	42	71	61
	22-31	73	54	71	64
Jan.	1- 7	67	50	64	60
	8-14	78	63	74	69
	15-21	61	41	----	----
	22-31	67	48	----	----

[1] Soil temperature at 6" level.

Significant rootstock and top effects on cold hardiness were noted in the second field trial. The satsuma mandarin trees became dormant early in the winter and remained completely dormant throughout the freezing trials. These tops were the most cold hardy. Red Blush grapefruit and Valencia orange trees, which cease growth at temperatures of about 50° F. and 55° F., respectively (Cooper and Peynado, 1959), were less cold hardy than the satsuma mandarin trees. These varieties of trees, though with dormant buds, were not in an entirely non-growth condition as indicated by slight cambial activity in the twigs. Also, the Mexican lime trees, least cold hardy of the four scions, were showing considerable shoot elongation. The differences in cold hardiness of the four scions can be partially accounted for by dormancy; it is not clear, however, whether dormancy is the only major factor involved, since these scions were in different stages of dormancy. Genetically inherited differences in cold hardiness other than that induced by dormancy may also be involved in the results obtained in these studies.

In these tests rootstocks did not affect the cold tolerance of completely dormant scions (satsuma mandarin) or actively growing scions (Mexican lime). Where dormancy was not complete (Red Blush grapefruit and Valencia orange) rootstock effects were apparent. The stock effect on cold hardiness of Red Blush grapefruit and Valencia orange trees may have resulted from an interaction of stock and soil temperature changes on the growth status of the trees. Increases in the average maximum and minimum air and soil temperatures were noted from January 8-14.

The behavior of these scions and stocks under artificial freezing conditions are in general agreement with their reported behavior in California, Florida, and Texas under natural freezing conditions. However, trifoliate-orange which has induced cold hardiness to satsuma mandarin and Valencia orange trees in California and Florida failed to induce cold hardiness in satsuma mandarin and Red Blush grapefruit trees in these studies. The difference in the cold hardiness of the trifoliate-orange rootstocks in the different areas may lie in differences in soil temperature of the areas, it being generally warmer in Texas than in California or Florida (Cooper and Peynado, 1959).

The large portable freezer used in these studies lends itself well to evaluating the cold hardiness of citrus grown under field conditions.

SUMMARY

Three-year-old trees of four citrus species on several rootstocks were exposed to 22.8° F. for 4 hours during the winter of 1959-60. Significant effects of rootstocks, scions, and dormancy on cold hardiness were noted. Nucellar Red Blush trees which had ceased growth and were dormant by October 26 were more cold hardy than those actively growing as late as December 1. Generally, Red Blush trees on sour orange, Sunki mandarin, and Troyer citrange rootstocks had ceased growth by October 26. Red Blush trees on *C. macrophylla* rootstock were actively growing up to December 1; trees on Rangpur mandarin-lime, *C. moi*, and Columbian sweet lime were variable.

The varieties of citrus tops tested varied considerably in their cold hardiness. The satsuma mandarin was cold hardy while the Mexican lime was cold sensitive; Red Blush grapefruit and Valencia orange as scions were intermediate in cold hardiness. Rootstocks had essentially no effect on the cold hardiness of the satsuma mandarin and the Mexican lime, but did influence cold hardiness of Red Blush grapefruit and Valencia orange trees.

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Quality of Red Grapefruit on Old-Line Grapefruit Varieties on Xyloporosis- and Exocortis-Tolerant Rootstocks[1]

W. C. Cooper[2] and Bruce J. Lime[3]

The present paper is one of a series dealing with the influence of rootstocks on grapefruit grown in the Rio Grande Valley of Texas. This paper deals with rootstock effects on fruit quality; the effects of rootstock on cold hardiness, tolerance to xyloporosis and exocortis viruses, and growth and yield have been investigated (Cooper, 1952; Cooper and Shull, 1953; Cooper et al, 1956, 1957).

The most important factor influencing growth and yield of the tree was found to be the tolerance of the rootstock to xyloporosis and exocortis viruses. Three groups of rootstocks were recognized: those sensitive to xyloporosis virus, those sensitive to exocortis virus, and those insensitive to the viruses. In the presence of these viruses, all virus-sensitive rootstocks proved unsatisfactory for commercial use in Texas. Experiments are now in progress to determine the orchard performance of virus-free nucellar Red Blush grapefruit on many of these virus-sensitive rootstocks. These nucellar-line plantings, however, have not borne fruit, and until their productiveness is known, they are not recommended for commercial planting. In the meantime, attention is focused on the performance of xyloporosis- and exocortis-tolerant rootstocks with virus-infected old-line red grapefruit tops. Some of these have been found unsuitable for commercial use because of lack of salt, boron, and cold tolerance. Others when budded to red grapefruit produced very little fruit. Among those tolerant rootstocks that have produced good yields of fruit as comparable with the sour orange were the Cleopatra and Ponkan mandarins, calashu (calamondin X satsuma), rough lemon, citrumelo 4475, Highgrove citremon, Uvalde and Savage citranges, Red Blush grapefruit, Sampson tangelo, Precoce de Valence sweet orange, and bergaldin.

Much evidence of the direct effect of rootstocks on the various factors that make up fruit quality is available from California (Sinclair and Bartholomew, 1944), Florida (Harding and Fisher, 1945; Cook et al, 1952), and South Africa (Marloth, 1959). The purpose of the present paper is to present further data on fruit quality of red grapefruit grown on rootstocks tolerant to xyloporosis and exocortis in the Rio Grande Valley, Texas. The performance of some of these in any commercial areas has not been reported previously.

[1] These investigations are a part of the cooperative Citrus Rootstock investigations conducted by the CRD, ARS, U. S. Department of Agriculture and the Texas Agricultural Experiment Station, Rio Farms, Inc., Monte Alto, Texas. The writers acknowledge the assistance of Norman Maxwell, E. O. Olson, F. P. Griffith, Ascension Peynado, and Thomas Stephens.

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METHODS AND MATERIALS

Red grapefruit samples collected in 1956-57, 1957-58, and 1958-59 in a rootstock orchard owned by Rio Farms at Monte Alto were analyzed. In this orchard trees grown on 87 kinds of rootstock were planted in 1950 in 4 replicates of 3-tree blocks, making 12 trees on each rootstock. Fruit samples for analyses were collected at 4 intervals during each of the 3 seasons from trees on the following 6 rootstocks: sour orange, Cleopatra mandarin, rough lemon, Red Blush grapefruit, citrumelo 4475, and Uvalde citrange. Fruit samples were collected on December 3 in each of the 3 years from trees on the following additional rootstocks: Ponkan mandarin, calashu (calamondin X satsuma), Highgrove citremon, Precoce de Valence sweet orange, bergaldin, Savage citrange, and Sampson tangelo. Red Blush grapefruit from a rootstock orchard at the Texas Agricultural Experiment Station (TAES) at Weslaco were also analyzed. In this orchard the trees, grown on 34 kinds of rootstocks, were planted in 1947, replicated in the same manner as those in the Rio Farms orchard described above. Fruit samples for analyses were collected at the same 4 sampling dates during the same 3 years as in the Rio Farms orchard. The TAES trees sampled were on the following rootstocks: sour orange, Cleopatra mandarin, and rough lemon.

The soil in the TAES orchard was Hidalgo fine sandy loam, was slightly calcareous, and had a pH of 7.7. The soil of the Rio Farms orchard was Brennen fine sandy loam, was non-calcareous, and had a pH of 7.0. The TAES orchard was flood irrigated and was cultivated 6 times a year with weed covers growing between cultivations. The Rio Farms orchard was sprinkler-irrigated and was kept under Bermuda sod until January 1958, when it was cultivated 6 times a year. Weed covers were growing between cultivations at both places.

The sampling dates covered a period when the fruit was barely acceptable for consumer consumption until the middle of March when the fruit was generally very ripe and the red color of the flesh had faded, as follows: October 20, December 9, January 28, and March 15.

Two samples consisting of 30 grapefruit each were picked from each of the 4 replicates of each rootstock indicated. Fruit analyses were made in the U. S. Fruit and Vegetable Products Laboratory in Weslaco, Texas. The analyses included weight and diameter of the fruit, color of rind, and thinness of rind of fruits in one set of samples from each replicate. The juice was extracted, and volume of juice, total solids, and total acids were determined. Sections were removed from the other set of samples and used for taste test and analysis for red color.

The external color of the rind was determined by procedures described by Harding and Fisher (1945). Each fruit was visually compared with the 9 color plates and the closest match noted. The average color for each sample was obtained by assigning a numerical value to each color and averaging these values.

The procedures for juice extraction and determining volume of juice, total acids and solids were similar to those described by Harding and Fisher (1945).

The color of the edible portion was determined by a method described by Lime et al (1956). Four sections were carefully removed with a sharp knife from each half of the 30 fruits, care being taken to exclude all seeds and rag. The combined sections were blended for 5 minutes at high speed in a 1-gallon Waring blender. The blended sample was deaerated in a vacuum dessicator under vacuum and agitation until foaming ceased. Reflectance measurements were obtained of the sample, using a special cell, with standard plate LRI, on a Gardner Automatic Color Difference Meter. The cell was fabricated by gluing a 1-mm. thick glass plate to the bottom of a plastic cylinder approximately 8.9 cm. in diameter and 10.2 cm. in height. The ratio of the "a" and "b" readings (a/b) were used as the numerical color index. The "a" readings represent color changes from green to red, while the "b" readings represent color changes from blue to yellow. Lime et al (1956) reported that this ratio provides a reliable index of color change.

The procedures for evaluating flavor were similar to those described by Harding and Fisher (1945). Sections of flesh acquired at the same time and in the same manner as the sections for the blended color analysis described above were tasted by a panel of staff members acting as taste judges. Six to 10 taste judges appraised and scored each lot of fruit according to the following arbitrary standards:

	Score
Too tart for consumer approval	60-69
Pleasantly tart, minimum stage of acceptability for consumer	70-79
Pleasantly tart to sweet	80-100

The average taste score for each sample was ascertained by averaging the 6 to 10 taste scores of the taste panel.

RESULTS

Although there are some striking differences in the effects of the various rootstocks on physical characteristics and chemical constituents of the fruit, a relatively uniform rate of change occurred during the ripening period of fruit on trees on the 6 rootstocks grown in the Rio Farms orchard. Data on seasonal trends are presented for only fruit on trees on sour orange, Cleopatra mandarin, and rough lemon rootstocks (Tables 1, 2, and 3). The weight and size of the fruit increased steadily

Table 1. Seasonal changes in physical characteristics and chemical constituents of Shary Red grapefruit on sour orange rootstock grown in the Rio Farms orchard over a 3-year period.

Year and date	Wt. of fruit	Diam. of fruit	Rind thin-ness	Rind[a] color score	Extracted juice: Volume	Extracted juice: Soluble solids	Extracted juice: Acid	Extracted juice: Solids/acid ratio	Color ratio (a/b) of blended juice	Flavor[b] of fruit score
	gm.	cm.	mm.		ml/100 gms fruit	%	%			
1956-57:										
Oct. 22	310	3.5	5.5	4.5	43.1	10.3	1.29	8.0	.968	68
Dec. 9	361	3.7	5.5	7.0	42.7	10.4	1.23	8.5	.645	81
Jan. 28	410	3.9	5.8	7.3	44.6	10.2	1.11	9.2	.415	85
Mar. 17	472	4.0	5.8	7.0	44.7	10.0	0.95	10.5	.276	92
Mean	388	3.8	5.7	6.5	43.8	10.2	1.15	9.1	.576	82
1957-58:										
Oct. 22	428	3.9	5.7	4.4	37.4	10.3	1.37	7.5	1.298	74
Dec. 9	504	4.0	5.5	7.4	42.2	10.1	1.24	8.2	.804	81
Jan. 28	556	4.2	5.6	7.9	45.7	10.4	1.12	9.3	.558	90
Mar. 17	632	4.5	6.1	7.6	46.4	9.9	1.02	9.6	.438	89
Mean	530	4.2	5.7	6.8	42.9	10.2	1.19	8.7	.775	83
1958-59:										
Oct. 22	408	3.9	5.2	3.2	39.5	9.2	1.38	6.6	1.320	62
Dec. 9	490	4.1	5.1	5.5	46.6	8.9	1.16	7.7	.820	74
Jan. 28	551	4.3	5.4	6.4	48.3	9.0	1.12	8.0	.729	89
Mar. 17	576	4.3	5.4	6.5	49.7	9.0	1.01	9.0	.489	94
Mean	506	4.2	5.3	5.4	46.0	9.0	1.17	7.8	.840	80
1956-59 Mean	475	4.1	5.6	6.2	44.2	9.8	1.17	8.5	.730	82

from October to March in all 3 years except for the trees on rough lemon rootstock from January to March in 1958-59.

The rind tended to become thicker from October to January and to level off from then on, but there were exceptions in all samples. Yellowness of rind generally increased from October to March, but the principal change occurred from October to December, when generally green fruit became predominantly yellow fruit. The volume of juice per 100 grams of fruit increased with the season and was highest during March. Rough lemon was generally an exception in that frequently the highest volume of juice occurred during January. The seasonal trend in soluble solids varied from year to year for any one rootstock. In some years soluble solids remained more or less constant from October to January and then decreased slightly. In other years there was a small but steady decrease in soluble solids from October to March. In all years total acids were highest in October and decreased steadily through March. Consequently,

[a] Each fruit was visually compared with nine color plates and the closest match noted. Score 1 is dark green, 3 medium green, 5 light green, 7 yellow, and 9 orange-yellow.

[b] Flavor of fruit score 60-69 is too tart for consumer approval, 70-79 is pleasantly tart, 80-100 pleasantly tart to sweet.

Table 2. Seasonal changes in physical characteristics and chemical constituents of Shary Red grapefruit on Cleopatra mandarin rootstock grown in the Rio Farms orchard over a 3-year period.

Year and date	Wt. of fruit	Diam. of fruit	Rind thin-ness	Rind[a] color score	Extracted juice: Volume	Extracted juice: Soluble solids	Extracted juice: Acid	Solids/acid ratio	Color ratio (a/b) of blended juice	Flavor[b] of fruit score
	gm.	cm.	mm.		ml/100 gms fruit	%	%			
1956-57:										
Oct. 22	326	3.5	5.5	4.3	43.8	9.7	1.16	8.4	1.167	66
Dec. 9	364	3.7	5.0	7.3	43.3	9.8	1.12	8.8	.817	81
Jan. 28	415	3.9	5.8	7.3	45.8	9.9	1.00	9.9	.537	86
Mar. 17	443	3.9	5.0	7.3	48.0	9.7	.90	10.7	.393	87
Mean	387	3.8	5.3	6.6	45.2	9.8	1.05	9.5	.729	80
1957-58:										
Oct. 22	364	3.6	5.7	4.1	37.6	9.9	1.88	7.2	1.349	74
Dec. 9	436	3.8	5.4	6.8	42.8	9.8	1.19	8.3	.889	80
Jan. 28	465	4.0	5.5	7.7	46.9	10.3	1.12	9.2	.613	88
Mar. 17	530	4.2	5.9	7.5	47.9	9.8	.99	9.8	.507	89
Mean	449	3.9	5.6	6.5	43.8	10.0	1.17	8.6	.840	83
1958-59:										
Oct. 22	362	3.7	4.9	2.9	40.8	9.0	1.30	6.9	1.334	65
Dec. 9	438	3.9	4.8	5.0	48.2	8.8	1.12	7.8	.867	75
Jan. 28	474	4.0	5.2	6.7	49.5	9.0	1.09	8.3	.724	87
Mar. 17	523	4.1	5.2	6.8	51.8	8.9	.97	9.2	.551	94
Mean	449	3.9	5.0	5.4	47.6	8.9	1.12	8.1	.869	80
1956-59										
Mean	428	3.9	5.3	6.2	45.5	9.6	1.11	8.7	.813	81

from October until March the soluble solids/acids ratio showed a steady increase, due primarily to decrease in acids. The red color of juice decreased sharply and steadily from October until March. Although in October there were large differences in the amount of red color in the juice of fruit grown on the 3 rootstocks, there was no rootstock effect on the rate of fading of the fruit's red color. Differences in flavor were influenced by rootstocks, but the seasonal trend of increased sweetness and decreased tartness was similar for all the rootstocks.

[a] Each fruit was visually compared with nine color plates and the closest match noted. Score 1 is dark green, 3 medium green, 5 light green, 7 yellow, and 9 orange-yellow.

[b] Flavor of fruit score 60-69 is too tart for consumer approval, 70-79 is pleasantly tart, 80-100 pleasantly tart to sweet.

Table 3. Seasonal changes in physical characteristics and chemical constituents of Shary Red grapefruit on rough lemon rootstock grown in the Rio Farms orchard over a 3-year period.

Year and date	Wt. of fruit	Diam. of fruit	Rind thin-ness	Rind[a] color score	Extracted juice: Volume	Extracted juice: Soluble solids	Extracted juice: Acid	Solids/acid ratio	Color ratio (a/b) of blended juice	Flavor[b] of fruit score
	gm.	cm.	mm.		ml/100 gms fruit	%	%			
1956-57:										
Oct. 22	332	3.6	5.9	4.3	43.9	9.1	1.13	8.1	1.171	63
Dec. 9	351	3.7	5.3	6.3	42.9	9.2	1.09	8.5	.796	80
Jan. 28	421	3.9	6.0	6.8	45.7	9.2	.96	9.7	.587	85
Mar. 17	466	4.0	5.5	7.3	44.4	8.8	.81	10.9	.413	84
Mean	393	3.8	5.7	6.2	44.2	9.1	1.00	9.3	.742	78
1957-58:										
Oct. 22	422	3.8	5.9	4.4	37.6	9.3	1.25	7.4	1.519	75
Dec. 9	526	4.1	5.9	7.0	41.9	9.0	1.07	8.4	1.013	79
Jan. 28	589	4.4	6.1	7.7	46.9	9.0	.97	9.3	.715	88
Mar. 17	689	4.5	6.6	7.3	47.0	8.2	.83	9.4	.589	87
Mean	557	4.2	6.1	6.6	43.4	8.9	1.03	8.6	.959	82
1958-59:										
Oct. 22	490	4.1	6.0	3.2	39.0	8.1	1.24	6.5	1.464	62
Dec. 9	595	4.4	6.3	5.0	44.4	7.9	1.10	7.1	.950	72
Jan. 28	698	4.5	5.9	6.3	47.7	7.6	1.04	7.3	.833	85
Mar. 17	696	4.5	6.3	6.7	46.6	7.4	.91	8.4	.634	88
Mean	620	4.4	6.1	5.3	44.4	7.8	1.07	7.3	.970	77
1956-59										
Mean	523	4.1	6.0	6.0	44.0	8.6	1.03	8.4	.890	79

There was an annual decrease in solids/acid ratio common to all rootstocks. For the Texas industry as a whole, the 1958-59 season was very poor as far as grapefruit quality was concerned; grapefruit generally showed very low solids. It is not believed that the increased age of the trees would account for the decrease in fruit quality, as just the opposite is expected from young trees such as these.

The effect of the orchard location on the quality of the grapefruit is clearly demonstrated in Table 4, which summarizes the comparative

[a] Each fruit was visually compared with nine color plates and the closest match noted. Score 1 is dark green, 3 medium green, 5 light green, 7 yellow, and 9 orange-yellow.

[b] Flavor of fruit score 60-69 is too tart for consumer approval, 70-79 is pleasantly tart, 80-100 pleasantly tart to sweet.

Table 4. Effect of rootstock-orchard location on the physical characteristics and chemical constituents of grapefruit[a].

Rootstock and location	Wt. of fruit	Diam. of fruit	Rind thinness	Rind[b] color score	Extracted juice: Volume	Extracted juice: Soluble solids	Extracted juice: Acid	Solids/acid ratio	Color ratio (a/b) of blended juice	Flavor[c] of fruit score
	gm.	cm.	mm.		ml/100 gms fruit	%	%			
Sour orange:										
Rio Farms	475	4.1	5.6	6.2	44.2	9.8	1.17	8.5	.730	82
TAES	428	3.8	5.6	5.7	45.4	10.3	1.28	8.2	.624	79
Cleopatra mandarin:										
Rio Farms	428	3.9	5.3	6.2	45.5	9.6	1.11	8.7	.813	81
TAES	380	3.7	5.4	5.4	46.2	10.1	1.30	7.9	.700	78
Rough lemon:										
Rio Farms	523	4.1	6.0	6.0	44.0	8.6	1.03	8.4	.890	79
TAES	443	3.9	5.7	5.6	45.9	8.9	1.09	8.4	.624	79

analysis of fruit samples from the two orchards for the 3-year period. Although in the Rio Farms orchard the strain of red grapefruit used was Shary Red and that in the TAES orchard was Red Blush, the differences in the composition of the fruit grown at these two locations are believed to be caused principally by differences in soil and cultural practices rather than by inherent differences in the two strains because Krezdorn and Maxwell (1959) found that red grapefruit of these two strains grown at the same location (TAES) on the same rootstock were almost identical in composition. The mean temperatures and rainfall at the two locations do not reveal any real differences in climate. The distance between the two locations is 20 miles.

In general the fruit from the Rio Farms orchard was heavier, larger and yellower in rind color and contained slightly less juice per 100 grams of fruit than that from the TAES orchard. Juice in the fruit from the Rio Farms orchard was less acid, sweeter, and redder than that from the TAES orchard. These differences between orchards were similar for fruit grown on all 3 rootstocks.

[a] The value recorded for each rootstock location is the mean value for 4 samplings for each of the 3 years (1956-57, 1957-58, 1958-59). The variety of grapefruit in the Rio Farms orchard was Shary Red, while that in the TAES orchard was Red Blush.

[b] Each fruit was visually compared with nine color plates and the closest match noted. Score 1 is dark green, 3 medium green, 5 light green, 7 yellow, and 9 orange-yellow.

[c] Flavor of fruit score 60-69 is too tart for consumer approval, 70-79 is pleasantly tart, 80-100 is pleasantly tart to sweet.

Excluding other factors there are some striking differences in fruit composition caused by the direct effect of rootstocks, as illustrated in Table 5. The fruit grown on sour orange rootstock ranked generally high

Table 5. The effect of rootstock on the physical characteristics and chemical constituents of Shary Red grapefruit grown in the Rio Farms orchard over a 3-year period[a].

Rootstock and year	Wt. of fruit	Diam. of fruit	Rind thinness	Rind[b] color score	Extracted juice: Volume	Extracted juice: Soluble solids	Extracted juice: Acid	Solids/acid ratio	Color ratio (a/b) of blended juice	Flavor[c] of fruit score
	gm.	cm.	mm.		ml/100 gms fruit	%	%			
Sour orange:										
1956-57	388	3.8	5.7	6.5	43.8	10.2	1.15	9.1	.576	82
1957-58	530	4.2	5.7	6.8	42.9	10.2	1.19	8.7	.775	83
1958-59	506	4.2	5.3	5.4	46.0	9.0	1.17	7.8	.840	80
Mean	475	4.1	5.6	6.2	44.2	9.8	1.17	8.5	.730	82
Cleopatra mandarin:										
1956-57	387	3.8	5.3	6.6	45.2	9.8	1.05	9.5	.729	80
1957-58	449	3.9	5.6	6.5	43.8	10.0	1.17	8.6	.840	83
1958-59	449	3.9	5.0	5.4	47.6	8.9	1.12	8.1	.869	80
Mean	428	3.9	5.3	6.2	45.5	9.6	1.11	8.7	.813	81
Rough lemon:										
1956-57	393	3.8	5.7	6.2	44.2	9.1	1.00	9.3	.743	78
1957-58	557	4.2	6.1	6.6	43.4	8.9	1.03	8.6	.959	82
1958-59	620	4.4	6.1	5.3	44.4	7.8	1.07	7.3	.970	77
Mean	523	4.1	6.0	6.0	44.0	8.6	1.03	8.4	.890	79
Red Blush grapefruit:										
1956-57	376	3.7	5.5	6.3	44.3	10.3	1.18	8.9	.645	80
1957-58	488	4.1	6.5	6.6	42.9	10.1	1.27	8.1	.773	82
1958-59	493	4.1	5.6	5.3	46.7	8.9	1.22	7.4	.744	78
Mean	452	4.0	5.7	6.1	44.6	9.8	1.22	8.1	.731	80
Citrumelo 4475:										
1956-57	377	3.7	5.0	5.8	46.1	10.2	1.05	9.9	.672	83
1957-58	504	4.1	5.6	6.6	43.5	10.2	1.15	9.0	.829	84
1958-59	470	4.0	5.3	5.1	46.9	9.0	1.19	7.7	.772	80
Mean	450	3.9	5.3	5.8	45.5	9.8	1.13	8.9	.758	82
Uvalde citrange:										
1956-57	443	3.9	5.4	6.0	43.7	9.7	1.01	9.8	.717	82
1957-58	484	4.0	5.2	6.2	42.1	10.0	1.14	8.8	.788	87
1958-59	497	4.0	5.1	5.0	46.2	8.6	1.14	7.7	.837	77
Mean	475	4.0	5.2	5.7	44.0	9.4	1.10	8.8	.781	82

[a] The values given for each year are the mean for samples taken on October 22, December 9, January 28, and March 17.

[b] Each fruit was visually compared with nine color plates and the closest match noted. Score 1 is dark green, 3 medium green, 5 light green, 7 yellow, and 9 orange-yellow.

[c] Flavor of fruit score 60-69 is too tart for consumer approval, 70-79 is pleasantly tart, 80-100 is pleasantly tart to sweet.

in weight, diameter, yellowness of rind, solids, and flavor, but low in volume of juice per given weight of fruit and in red color of the juice. Fruit on Cleopatra mandarin rootstock rated generally high in thinness of rind, volume of juice per 100 grams of fruit, and red color of juice and generally low in regard to weight and diameter of the fruit. Fruit on rough lemon rated generally high in weight, diameter, and red color of juice and generally low on rind thinness, volume of juice per 100 grams of fruit, acid content of juice, soluble solids of juice, and flavor of fruit. Fruit on Red Blush grapefruit rootstock rated generally high in acid content and solids content and generally low in solids/acid ratio and red color of juice. Fruit on citrumelo 4475 rated generally high in rind thinness, solids, solids/acid ratio, and flavor and generally low in weight of fruit and red color of juice. Fruit on Uvalde citrange was more or less average in all respects. No rootstock rated high in all categories. If one were primarily interested in large red-fleshed fruit with fruit quality only a minor consideration, he would select rough lemon rootstock. If one were primarily interested in fruit of a high acids and solids content, with little regard to red color, he would select sour orange and Red Blush grapefruit rootstocks.

Determinations on the quality of grapefruit on 7 additional virus-tolerant rootstocks—Ponkan mandarin, Highgrove citremon, Precoce de Valence sweet orange, bergaldin, Savage citrange, calashu and Sampson tangelo—were made in early December of 1956, 1957, and 1958. Since these determinations were made at only one time of year, comparisons with the other six rootstocks were made with the December sampling only. These data, not given in this paper, show that the weight and diameter of the fruit, yellowness of rind, and volume of juice per 100 grams and per cent acid and solids of the juice do not vary greatly from that of fruit on sour orange rootstock. The rind on fruit grown on Sampson tangelo rootstock was slightly thinner than that grown on sour orange, and the rind on fruit grown on Precoce de Valence sweet orange was slightly thicker than that on sour orange, while the rind thickness of fruit grown on other rootstocks was similar to sour orange. Red color of the juice and flavor were not determined on fruit grown on these 7 additional rootstocks.

DISCUSSION

The results of the present investigation substantiate the earlier finding of other workers that rootstock influences fruit composition and that juice of grapefruit on rough lemon usually has a low concentration of acids and soluble solids. The larger size and increased redness of fruit on rough lemon rootstock to some extent increases the consumer acceptability, but occasional fruit in samples collected in March showed drying of sections and off-flavors not observed in the fruit on trees on other rootstocks.

Although some differences occurred in acids, soluble solids, and other characteristics of the fruit, for all practical purposes the fruit on Cleopatra mandarin, Red Blush grapefruit, citrumelo 4475, and Uvalde

citrange had quality equal to that of fruit on sour orange. Sinclair and Bartholomew (1944) indicate that fruit on Morton and Savage citrange rootstocks has a higher concentration of soluble solids than that on sour orange. In the present investigations fruit grown on the Uvalde citrange did not show any higher concentrations of acids or soluble solids than that on fruit on sour orange. Likewise, fruit grown on Savage citrange harvested in December gave no indication of greater soluble solids than for sour orange. Thus, the Texas results indicate that as far as fruit qualities other than red color of juice are concerned, any of the 12 xyloporosis- and exocortis-tolerant rootstocks used, with the exception of rough lemon, produced fruit of quality more or less equal to that of fruit grown on sour orange. Grant et al (1949) considered that the Cleopatra mandarin, Ponkan mandarin, citrumelo 4475, Savage citrange, and Sampson tangelo were tolerant to tristeza; the Precoce de Valence sweet orange was not tested. Should it ever become necessary to abandon the sour orange rootstock because of tristeza, at least one of the rootstocks listed could become a satisfactory substitute for the sour orange rootstock. However, the rootstock that replaces sour orange in Texas must also be productive, long-lived, and salt-, cold-, lime-, and foot-rot-tolerant.

These studies have demonstrated that rootstock affects the red color of grapefruit. Since the red color of Texas grapefruit is one of its main selling points, this aspect of fruit quality is of great importance to the Texas grapefruit grower. Unfortunately, the rootstock associated with the lowest acid and soluble solids content is also associated with the highest red color content. Fruit grown on sour orange rootstock, which is widely known for its high-quality fruit, has the poorest red color. Red color, however, is influenced by environment as well as by rootstock, the fruit grown on sour orange rootstock in the Rio Farms orchard being redder than that grown in the TAES orchard. It appears profitable to look into factors either cultural or associated with differences in soil to determine what can be done to improve the red color of high-solids fruit.

Many rootstocks in the experimental orchards were eliminated for consideration as commercial rootstocks because of their intolerance to xyloporosis and exocortis viruses. Some of these rootstocks may possibly influence the soluble solids content and the red color of the fruit as much as the virus-tolerant varieties included in this report, or even more. Tests are now underway using nucellar virus-free red grapefruit tops on these other rootstocks, but the trees are just beginning to come into bearing and are not suitable for fruit quality analysis.

SUMMARY

Although there are some striking differences in the effects of various rootstocks on the composition of fruit, a relatively uniform rate of change occurred in the fruit on all rootstocks during the ripening period. In some years soluble solids remained more or less constant from October to January and then decreased slightly, while in other years the soluble solids decreased at a slow rate from October to March. In all years total acids were highest in October and decreased steadily through March.

The red color of the juice decreased sharply and steadily with time from October until March for all rootstocks.

Regardless of season and orchard, fruit on rough lemon rootstock was heavier, larger, thicker in rind, lower in acids and soluble solids, and deeper in red color of juice than fruit grown on the other rootstocks. The soluble solids and acids contents of the juice were similar for all other rootstocks. Although some differences in various physical characteristics of the fruit on these rootstocks occurred, they were in general small; and for all practical purposes, the fruit of trees grown on Cleopatra mandarin, Red Blush grapefruit, citrumelo 4475, and Uvalde citrange rootstocks had quality equal to that of fruit on trees grown on sour orange and superior to that on rough lemon rootstock.

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Effects of Rootstocks on Physical Characteristics and Chemical Composition of Fruit of Six Citrus Varieties in Texas[1]

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The direct effect of rootstocks on chemical composition and physical characteristics of different kinds of citrus fruit has been reported in California (Hodgson and Eggers, 1938; Sinclair and Bartholomew, 1944) Florida (Harding and various associates, 1940, 1945, 1949, and 1959), South Africa (Marloth, 1949, 1956, 1959) and the Rio Grande Valley of Texas, where Cooper and Lime (1960) presented data on fruit quality of red grapefruit grown on certain exocortis- and xyloporosis-tolerant rootstocks.

The present paper deals with the influence of rootstock on the size, quality and grade of fruit, with special emphasis on Meyer lemon. The present paper includes data on six rootstocks not mentioned by Cooper and Lime (1960).

METHODS AND MATERIALS

The present investigations were limited to fruit samples taken during a single year from young (3-and-4-year-old) trees located in rootstock experimental orchards at Rio Farms, Inc., Monte Alto, Texas, and from Texas Agricultural Experiment Station, Substation 19, near Crystal City, Texas. The Meyer lemon and Marrs orange trees were located at Monte Alto; the Hamlin orange, navel orange, Clementine tangerine and Orlando tangelo trees were located near Crystal City. Except for the Clementine tangerine trees, which carried exocortis virus, the trees are free of the viruses causing psorosis, xyloporosis (cachexia), exocortis, and tristeza. Meyer lemons on Carrizo citrange rootstock showed a bud-union disorder similar to the incompatibility shown by Eureka lemon on Troyer citrange rootstock (Weathers et al., 1955). Marrs oranges and Meyer lemons were 3-and 4-year-old trees, respectively, while the Hamlin, navel orange, Clementine tangerine, and Orlando tangelo trees were 3-, 4-, 4- and 3-year-old, respectively. The rootstocks are listed in each of the 8 tables.

Fruit samples, each consisting of 30 fruit, were taken from each of 4 replicates from the Meyer lemon trees, August 10, September 10, October

[1] These investigations are part of the cooperative citrus rootstock investigations conducted by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station. Rio Farms, Inc., Monte Alto, Texas, also cooperates. The writers acknowledge the assistance of Art Shull and Gordon Buffington.

7, and November 12. Samples of 15 Marrs oranges, each from 2 replicates, were harvested December 3. Samples of 15 navel oranges and 25 Clementine tangerines, each from 3 replicates, were harvested November 19, and samples of 10 Hamlin oranges and 15 Orlando tangelos, each from 2 replicates, were harvested November 20.

Analyses included the determination of the weight and measurements of the rind thickness, rind color, and diameter of each fruit in a given set of samples from each replicate. Rind colors for lemons were determined by comparison of the fruit with the color plates for grapefruit published by Harding and Fisher (1945), and the rind colors for the orange, tangerine, and tangelo varieties were determined from the color plates for oranges published by Harding et al., (1940). The color of each fruit in a given sample was measured by assigning to each color a numerical value, the greater value indicating a higher degree of orange or yellow color, and then giving a numerical color value for each fruit. The obtained values were then averaged.

The juice was extracted and composited from all the fruit in each sample and volume of juice, weight of juice, soluble solids, and titratable acidity were determined. Total solids were determined with a hand refractometer. Titratable acidity was determined by titrating a 10 ml. sample of the extracted juice with 0.1 N NaOH to a pH of 8.1.

The data from studies of Meyer lemon, Clementine tangerine, and navel orange fruit were analyzed statistically by the multiple range and multiple F test described by Duncan (1955). The data from studies of

Table 1. Weight of fruit (grams) of six different citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	100	119	282	284	137	99
Sunshine tangelo	126	118	288	----	133	108
Rangpur lime	128	129	318	276	148	122
Columbian sweet lime	136	141	358	274	139	149
Sunki mandarin	123	121	292	269	----	108
Cleopatra mandarin	119	121	244	----	121	93
Non-budded Meyer lemon cutting	103	----	----	----	----	----
Morton citrange	----	138	----	259	105	----
Carrizo citrange	----	----	317	291	----	119
Rough lemon	----	----	----	293	118	----

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Columbian greater than Sunki, Cleopatra, Meyer lemon cutting, and sour; Rangpur, Sunshine, Sunki, and Cleopatra greater than Meyer lemon cutting and sour.
Navel orange tops: Columbian greater than all others; Carrizo and Rangpur greater than sour, Sunshine, Sunki, and Cleopatra; sour, Sunshine and Sunki greater than Cleopatra.
Clementine tangerine tops: Columbian greater than all others; Carrizo and Rangpur greater than Cleopatra and sour.

Hamlin and Marrs orange and Orlando tangelo fruit are presented but were not analyzed statistically because of lack of sufficient replications.

RESULTS

Fruit from trees on Columbian sweet lime, Rangpur mandarin-lime, and Carrizo citrange rootstocks were heavier; those on sour orange were intermediate, and fruit from trees on Cleopatra mandarin rootstock were consistently lighter (Table 1).

Table 2. Diameter of fruit (inches) of six citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	2.1	2.5	3.2	3.4	2.6	2.3
Sunshine tangelo	2.3	2.5	3.2	----	2.5	2.4
Rangpur lime	2.3	2.6	3.2	3.3	2.6	2.5
Columbian sweet lime	2.4	2.7	3.5	3.2	2.5	2.7
Sunki mandarin	2.3	2.5	3.3	3.3	----	2.4
Cleopatra mandarin	2.2	2.5	3.0	----	2.5	2.3
Non-budded Meyer lemon cutting	2.1	----	----	----	----	----
Morton citrange	----	2.6	----	3.2	2.3	----
Carrizo citrange	----	----	3.3	3.4	----	2.5
Rough lemon	----	----	----	3.4	2.4	----

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Meyer lemon cutting and sour less than all other stocks; Cleopatra mandarin, Rangpur lime, and Sunki less than Columbian.
Navel orange tops: Columbian larger than Rangpur, sour, Sunshine, and Cleopatra; Carrizo and Sunki larger than Cleopatra.
Clementine tangerine tops: Cleopatra and sour less than Carrizo and Rangpur; Sunki less than Rangpur; Columbian larger than all others.

Table 3. Volume of juice of fruit (cc of juice per kilogram of fruit) of six different citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	348	455	421	483	466	376
Sunshine tangelo	404	477	403	----	410	380
Rangpur lime	392	465	406	485	506	357
Columbian sweet lime	408	459	449	466	490	363
Sunki mandarin	395	449	408	482	----	414
Cleopatra mandarin	404	451	417	----	443	392
Non-budded Meyer lemon cutting	362	----	----	----	----	----
Morton citrange	----	465	----	464	427	----
Carrizo citrange	----	----	489	479	----	375
Rough lemon	----	----	----	461	422	----

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Sour and Meyer lemon cutting less than all others.

The diameter of fruit from trees on Columbian sweet lime rootstock was generally large and the diameter of fruit from trees on Cleopatra mandarin rootstock was generally small (Table 2).

No rootstock showed a distinct advantage in its effect on the juice content of all fruits. However, Meyer lemons grown on their own roots or on sour orange rootstock contained significantly less juice than on all other stocks tested (Table 3).

Fruit from trees on Rangpur lime, Morton and Carrizo citrange rootstocks had a high intensity of coloration in the rind and fruit from trees on Cleopatra mandarin rootstock generally had low intensity of coloration in the rind. Rind color was consistently poor for fruit of trees on sour orange, Sunki and Cleopatra mandarin, except for navel on sour and Meyer lemon on Sunki. Clementine tangerines had high color when grown on sweet lime rootstock (Table 4). However, many of the Clementine tangerines from trees on Columbian sweet lime rootstock showed a drying of the sections; this was not observed in the fruit from trees on other rootstocks.

The rind of fruit from trees on Columbian sweet lime and rough lemon rootstocks was thicker than those from trees on sour orange and Cleopatra mandarin rootstock (Table 5).

No rootstock produced a distinct difference in acid content of the fruit. However, fruit from trees on Sunshine tangelo and Sunki mandarin were high in acid and those on sour orange rootstock were low in acid (Table 6).

Fruit from trees on sour orange rootstock were consistently high in total solids and those on Columbian sweet lime were consistently low in total solids (Table 7). Sugar-acid ratios of fruit from trees on sour orange rootstock also were consistently high (Table 8). The only signifi-

Table 4. Rind color[1] of fruit of six different citrus varieties on different rootstocks.

Rootstock variety[2]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	2.5	5.6	8.2	5.6	8.4	8.6
Sunshine tangelo	3.0	5.4	7.9	----	7.4	10.0
Rangpur lime	2.9	5.8	7.3	5.6	8.7	10.5
Columbian sweet lime	2.9	5.7	6.1	5.7	7.0	11.2
Sunki mandarin	2.8	5.4	7.0	5.5	----	9.3
Cleopatra mandarin	2.5	5.6	6.5	----	6.7	8.4
Non-budded Meyer lemon cutting	2.4	----	----	----	----	----
Morton citrange	----	5.9	----	6.1	8.7	----
Carrizo citrange	----	----	7.6	5.5	----	10.8
Rough lemon	----	----	----	5.4	8.8	----

[1] For Meyer lemon, higher values indicate higher intensity of yellow coloration of the rind; for oranges, tangelos and tangerines, higher values indicate higher intensity of orange coloration in the rind.

[2] Significant differences caused by rootstocks:
Meyer lemon tops: Columbian greater than Cleopatra, sour, and Meyer lemon cutting; Rangpur and Sunshine greater than Meyer lemon cutting.
Clementine tangerine tops: Columbian greater than Cleopatra, sour and Sunki; Rangpur and Carrizo greater than Cleopatra and sour.

Table 5. Rind thickness (mm.) of fruit of six different citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	2.5	3.1	3.8	4.1	1.9	1.9
Sunshine tangelo	2.7	3.3	3.9	----	1.9	2.3
Rangpur lime	2.6	2.9	4.0	4.2	2.2	2.7
Columbian sweet lime	2.9	2.8	4.9	4.2	2.7	2.8
Sunki mandarin	2.7	3.1	4.3	4.1	----	2.3
Cleopatra mandarin	2.6	3.2	3.7	----	2.2	2.3
Non-budded Meyer lemon cutting	2.5	----	----	----	----	----
Morton citrange	----	3.2	----	4.0	2.3	----
Carrizo citrange	----	----	3.3	4.2	----	2.3
Rough lemon	----	----	----	4.5	2.5	----

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Columbian greater than Sunki, Rangpur, Cleopatra, sour and Meyer lemon cutting; Sunshine, Sunki and Rangpur greater than Meyer lemon cutting; Sunshine and Sunki greater than sour.
Clementine tangerine tops: Sour less than all others; Columbian and Rangpur greater than Carrizo, Sunki, Cleopatra, and Sunshine.

Table 6. Acidity (% acid as citric) of fruit of six citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	4.31	.75	.57	.50	1.58	.94
Sunshine tangelo	5.72	1.01	.61	----	1.52	.95
Rangpur lime	5.21	.84	.56	.47	1.46	.97
Columbian sweet lime	4.67	.81	.62	.50	1.54	.91
Sunki mandarin	5.70	1.12	.49	.49	----	.97
Cleopatra mandarin	5.51	.81	.63	----	1.60	.95
Non-budded Meyer lemon cutting	4.61	----	----	----	----	----
Morton citrange	----	.94	----	.45	2.03	----
Carrizo citrange	----	----	.56	.49	----	.87
Rough lemon	----	----	----	.46	1.68	----

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Columbian, Sunki, Cleopatra, Rangpur, and Sunshine greater than sour; Sunki, Cleopatra, Rangpur, and Sunshine greater than Columbian and Meyer lemon cutting; Sunki and Sunshine greater than Rangpur.

cant differences in sugar-acid ratios of the extracted juice of fruit from trees on different rootstocks occurred with the Meyer lemon.

DISCUSSION

The effect of rootstock on the physical characteristics and chemical composition of citrus fruit is well known. In this investigation fruit from trees on Columbian sweet lime rootstock possessed the most striking differences from fruit of trees on other rootstocks. Fruit from trees on

Table 7. Percentage soluble solids of fruit of six citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	8.8	10.8	10.8	10.0	11.6	12.8
Sunshine tangelo	8.6	11.0	10.3	....	11.3	12.0
Rangpur lime	8.3	10.4	10.3	9.4	10.6	12.0
Columbian sweet lime	8.1	10.0	10.1	9.0	10.7	11.1
Sunki mandarin	8.9	10.7	10.2	9.6	....	12.2
Cleopatra mandarin	8.8	10.2	10.5	....	11.7	11.4
Non-budded Meyer lemon cutting	8.3	....	....	....	....	....
Morton citrange	....	10.2	....	9.8	12.5	....
Carrizo citrange	....	....	9.2	9.4	....	12.1
Rough lemon	....	....	....	8.7	12.5	....

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Cleopatra, sour, and Sunki greater than Columbian, Rangpur, Meyer lemon cutting and Sunshine; Sunshine greater than Columbian, Rangpur, and Meyer lemon cuttings.
Clementine tangerine tops: Sour greater than all others; Rangpur, Sunki, Sunshine, and Carrizo greater than Columbian and Cleopatra.

Table 8. Sugar: acid ratios of fruit of six citrus varieties on different rootstocks.

Rootstock variety[1]	*Meyer lemon*	*Hamlin orange*	*Navel orange*	*Marrs orange*	*Orlando tangelo*	*Clementine tangerine*
Sour orange	2.1	14.4	19.3	19.9	7.4	13.6
Sunshine tangelo	1.5	10.9	17.1	....	7.4	12.7
Rangpur lime	1.6	12.5	18.5	20.1	7.2	12.3
Columbian sweet lime	1.8	12.3	16.7	18.3	7.0	12.2
Sunki mandarin	1.6	9.5	21.0	19.7	....	12.7
Cleopatra mandarin	1.6	14.7	16.6	....	7.4	12.1
Non-budded Meyer lemon cutting	1.8	....	....	....	....	....
Morton citrange	....	10.9	....	21.9	6.2	....
Carrizo citrange	....	....	16.5	19.3	....	13.9
Rough lemon	....	....	....	18.9	7.5	....

[1] Significant differences caused by rootstocks:
Meyer lemon tops: Sour greater than all other stocks; Meyer lemon cutting and Columbian greater than Sunshine, Sunki, Cleopatra, and Rangpur.

Columbian sweet lime rootstock were heavier, and larger; they had thicker rinds, lower total solids and generally lower total acids. Meyer lemons grown on Columbian sweet lime rootstock also contained the highest volume and weight of juice per kilogram of fruit. The disadvantage of low total solids and low acid may be less important with higher yields and higher juice content of the fruit.

With lemons grown for the fresh fruit market, yield and length of the life of the tree are most important considerations in choosing a rootstock. The fact that lemons with a minimum of 25% juice by volume are considered mature in California and Arizona regardless of color or size is indicative of the small importance attached by both consumers and growers to whether a lemon has a juice of high or low acid content or possesses good body. However, the yield of total acid in pounds of acid per acre is important in producing lemons for juice and certain byproducts, concentrates, etc.

In Texas commercial Meyer lemons are grown either on their own roots or on sour orange rootstock. While such trees had fruit with higher-than-average total solids content, the fruit of Meyer lemon trees on either their own roots or on sour orange were consistently below average in all other respects. Total solids and total solids-acid ratios are relatively unimportant in Meyer lemon production. The yield of juice is probably most important and Meyer lemon fruit from trees on their own roots or on sour orange rootstock were low in this respect.

Fruit of Marrs orange trees on rough lemon rootstock was large and had low juice content, thick rind, low acids and total solids, low total solids-acids ratio. Orlando tangelos from trees on rough lemon had low juice content and thicker rind; however, the other fruit characteristics were quite opposite to the expected in that Orlando tangelos were small, and total solids, acids and total solids-acid ratios were above average. The fruit were immature at the time of harvest and perhaps these characteristics would have changed later in the season.

The effect of rootstock upon the rind color of the various fruits was not consistent but very striking. Navel oranges from trees on sour orange rootstock had an outstanding bright orange color; Clementine tangerines from trees on Columbian sweet lime had a brilliant orange color; and Meyer lemons from trees on Sunshine tangelo rootstock had a bright yellow color.

Certain differences in fruit quality may be much more marked when the trees are young, although they still exist when the trees are in full bearing (Marloth, 1959). The data presented in this paper are for young trees first coming into bearing, and more data from mature trees will be necessary before recommendations and conclusions can be made concerning these rootstocks.

SUMMARY

Fruit samples were taken from Meyer lemon trees on different rootstocks during August, September, October, and November. Navel, Marrs, and Hamlin oranges, Clementine tangerines, and Orlando tangelo trees on different rootstocks were sampled on only one date.

The data are from young trees first coming into bearing. Fruit from trees on Columbian sweet lime rootstock possessed the most marked differences from other stocks. Characteristics of the fruit on Columbian sweet lime rootstock were large size, thick rind, low total solids, and low acid content. No distinct differences for the effect of any rootstock on the juice content of the fruit, acid content or sugar-acid ratios of the extracted juice of all the varieties tested were evident.

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Greening of Mature Grapefruit

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Greening or regreening of mature grapefruit has become a problem to many growers who otherwise grow clean russet-free fruit in the Lower Rio Grande Valley. The greening or green areas vary in intensity from light strippled green with a light yellowish background to dark green. Frequently the green areas are so pronounced in contrast with the light yellow color of the mature grapefruit as to seriously impair the external fruit quality. Eye appeal is greatly reduced and the consumer associates the appearance with green or unripe fruit. Greening has become more evident as measures to control rust mites and scale pests have increased in effectiveness within the past few years. In the past russeting and scale injury have tended to mask and obscure the greening condition. It has been observed to occur with equal frequency on white, pink and red grapefruit.

The sequence in which the greening or green areas develop on the external surface of the grapefruit is not definitely known. It is the opinion of some growers and shippers that the maturing grapefruit develops a normal light yellow rind color which is followed by a regreening of the rind. It is obvious that the greened areas become apparent by contrast with the light yellow rind color on the same fruit. It seems more reasonable to assume that the greened or regreened areas are areas that remain green while the rest of the rind is turning a normal light yellow color. This assumption implies the presence of some inhibiting substance or factor which preserves the green color or prevents the development of the yellow pigment in the affected areas.

PROBABLE CAUSE

Greening as observed occurs with greatest frequency on the outer or exposed surface of the fruit with little or no greening on the rind towards the center of the tree. The outside and exposed fruit is more subject to greening than the inside and shaded fruit. Usually the visible affected areas appear to be a uniform green color or mixture of green and light yellow to the eye. On examination of the green or greenish areas with a hand lens, 10x or higher magnification, numerous minute black spots are found to occur on the rind between the oil glands. These black spots are very small, usually less than 0.1 mm. in diameter. In severely greened areas the number of black spots may range from 10 to 30 per sq. mm. It is not unusual to find 40 or more black spots per sq. mm. in the darker green areas. There is an apparent correlation between the number of minute black spots in an area and the intensity of greening.

The minute black spots are apparently caused by a fungus like or similar to the fly speck fungus, *Leptothyrium pomi* (Mont. Fr.) Sacc., which has been reported as causing visible black spots on citrus (Fawcett 1936, and Knorr, et al 1957). The black spots of fly speck reported on citrus appear to be considerable larger than the minute black spots associated with greening. Shading favors development of fly speck on grapefruit and apparently adversely favors greening. Depth of penetration of the fungus into the rind appears to be slight. When infected rind tissue was held for several days in a moist chamber, the black spots sporulated. The spores were hyline or subhyline in color, single celled, oblong and 0.7-1.2 x 2.0-4.0 microns in size. It is not known when fruit infection occurs in the grove.

SPRAYING RESULTS

Assuming that the greening was caused by a fungus and that infection probably occurred during the summer or early fall, a small number of grapefruit trees were individually sprayed twice; July and August, with either zineb, maneb or thylate at the rate of 2 pounds per 100 gallons. Representative samples of fruit were picked in early February 1960 and examined carefully for lack of or for relative amount of greening. The fruit was practically free of russeting. Results are given in Table 1.

These preliminary results (Table 1) are considered satisfactory and indicative that effective control measures can be developed. All spray chemical treatments were effective in increasing the number of mature clean yellow fruit over the control by 2 to nearly 3 times. Zineb treated trees gave the largest yield of clean fruit, 42.8 per cent and the lowest amount of badly greened fruit, 19.1 per cent, compared to 14.8 and 57.1 per cent respectively for the control. The other two chemicals were intermediate in effectiveness. The results indicate that the greening of mature grapefruit can be reduced by spraying with an effective fungicide. It is also apparent that more information is needed on how and when infection occurs and the critical period in which control sprays should be applied.

Table 1. Effect of two summer sprays on greening of grapefruit.

Treatments[1]	*Fruits examined*	*Greened fruit classes and amounts*			
	Number	*None* *Percent*	*Slight* *Percent*	*Moderate* *Percent*	*Extensive* *Percent*
Control	338	14.8	16.3	11.8	57.1
Thylate	198	31.3	19.2	14.1	35.3
Maneb	190	34.7	17.9	16.3	31.0
Zineb	194	42.8	20.6	17.5	19.1

[1] The spray chemicals were applied in July and August at the recommended fungicidal dosage rate of 2 pounds per 100 gallons.

SUMMARY

A greening or regreening condition of mature grapefruit is described and effectiveness of preliminary control measures given. The greening is associated with minute black spots, about 0.1 mm. in diameter, that occur between the oil glands. The black spots, compact hyphal mats, were observed to sporulate, the single celled spores were about 1 x 2-4 microns in size. Zineb as a spray was more effective than two other fungicides in reducing greening.

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The Preservation of Pulp and Fortification of Late Season Poorly Colored Red Grapefruit Juice

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The increase in production of red grapefruit in the Lower Rio Grande Valley has focused attention on the problems involved in producing a canned single strength juice from the colored grapefruit. When the juice from red meated grapefruit is canned in the same manner as juice from white meated grapefruit it developes a "muddiness" or browning upon storage. Matlack (1935) reported the pigments in Foster and Marsh pink grapefruit as lycopene and carotene. Khan and MacKinney (1953) reported the same pigments in the Ruby Red grapefruit. These pigments are water insoluble and are found in the juice sacs or pulp of the fruit. Lime, Stephens and Griffiths (1956) studied the pigment content in relation to maturity and found a steady decline in the pigment content as the fruit matured. They also found close agreement with the pigment content and the reflected color notations. The naringin content (bitterness) was shown to decrease as the grapefruit matured, Lime, et al (1954). Data presented by Lime, et al (1958) showed that a high quality canned single strength pulp fortified juice product can be obtained throughout approximately the first two-thirds of the processing season by the careful adjustment of the pulp content of the product. It was pointed out that of the available 22 to 30% suspended solids of the fruit only about 9% could be used in early season packs because of the excessive bitterness. It was also noted that late in the season the bitterness level had decreased so that the pulp content could be increased but the color of the pulp had also decreased so that an acceptable juice from a color standpoint could not be obtained.

This paper discusses methods of recovering and storing the excess pulp from the processing of early season red grapefruit to be used to fortify the color and flavor of poorly colored late season red grapefruit juice products.

EXPERIMENTAL PROCEDURE

Three methods of separation of pulp from seeds and rag were tried on a laboratory scale. These methods were: A water flotation procedure suggested by Gray Singleton (1955), a screw type finisher with large screen openings, and a paddle-type finisher using brushes in place of the paddles. The raw materials used in these experiments were obtained from a plant using Food Machinery Extractors[2]. This type of juice extractor eliminates most of the rag but allows the small seeds and pulp to pass into the juice. A paddle-type finisher in the plant removes the seeds and about 50 to 70% of the pulp from the juice. This seedy pulp which is normally discarded was used as the raw material.

For the water flotation method of separating the seeds from the pulp a V-type tank, as described by Singleton, was fabricated. This tank was 3 feet wide, 3 feet deep and 6 feet long. A break up box was provided at one end where the pulp was mixed with air and water. Three perforated water pipes were mounted 18 inches apart across the top of the tank. This allowed small jets of water to agitate the pulp as it floated across the top of the tank. Three ½-inch gate valves were placed along the bottom of the tank. The flow of pulp and seeds were as follows: The pulp was introduced at the break-up box where it was mixed with three jets of water from a 1-inch water line. The water and pulp overflowed into the V-tank (which was full of water) where the pulp floated and the seeds sank. The pulp was carried across the top of the tank by the water jets from the three perforated pipes. The pulp overflowed at the end of the tank onto a screen. The seeds were removed from the system through the three ½-inch valves at the bottom of the tank.

The separation of the seeds and rag from the pulp was also accomplished by the use of a Chisholm Ryder Model C[2] screw type juice finisher. This machine was equipped with .040 inch screens and the pressure adjusted so that the seed and rag pomace was comparatively dry.

The pulp separation by use of a brush finisher was accomplished by the use of fiber brushes in place of the paddles on a Langsenkamp Indiana Junior Pulper[2]. This machine was equipped with .030 inch screens. The waste opening was set at a small 1 inch position to allow for the fullest separation of the pulp and juice from the seed and rag.

The pulp was stored at four temperatures: -10° F., 40° F., 68° F., and room temperature. The pulp for frozen storage was filled into No. 1 cans immediately after finishing and deaeration and stored at -10° F. The pulp intended for storage above freezing temperatures was deaerated, heated in a tubular heat exchanger to 190° F., filled into No. 1 cans, sealed, held for 1½ minutes and cooled by rolling the cans under a tap water spray. Pulp was obtained on December 12 and December 29, processed as described, and stored for 3 months. Reflected color measurements were determined on the pulp before and after storage, by the use of a Gardner Automatic Color Difference Meter[2]. The "a" and "b" readings were used to express the color values a/b as described by Lime, et al (1958). The "a" reading designates the amount of red color present and the "b" reading the amount of yellow color present—the higher the value the more intense the color. The "Rd" value indicates black-white reflectance. A completely absorbing specimen would have an "Rd" value of zero, and a perfect diffusing white would have a value of 100.

The results of the preliminary packs described above prompted a demonstration of the commercial feasibility of the collection and storage of early season excess red grapefruit pulp to be used to improve the

[1] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.
[2] It is not the policy of the Department to recommend the products of one company over those of any other engaged in the same business.

quality of late season poorly colored grapefruit juice. These experiments were run in the juice plant of the Texsun Citrus Corporation, using standard juice plant equipment wherever possible, including Food Machinery[2] extractors. Pulp was collected and processed as follows: While the plant was processing red grapefruit, excess or waste pulp was collected from the paddle finishers and passed through a Fitzpatrick Comminuting Mill[2] equipped with a .040 inch screen. Eighty ounces of grapefruit juice was added to each three gallons of pulp as it was being milled. This reduced the viscosity so the pulp was easily pumped into a holding tank after milling. Approximately 200 gallons of pulp were collected in the holding tank. The tank was equipped with an agitator that kept the pulp well mixed.

The pulp was fed into the plant deaerator with little difficulty. It was then heated in a tubular heat exchanger to 195° F., and filled into 46 ounce cans using the regular juice filler running at a slow speed. The cans were closed and cooled by rotating under tap water. The cooled cans were stored in the plant warehouse.

Two lots of red juice were pulp fortified using the stored pulp. Both lots of juice, March 5 and April 1, were prepared in the following manner: While the plant was processing juice from red grapefruit the juice flow from the finishers was adjusted so as to be equally divided into two holding tanks. When each tank contained approximately 400 gallons, the juice flow was diverted back into normal plant procedure. The juice from one tank was processed and sample cases were taken and marked "control." Thirty gallons of canned stored pulp was added to the other tank and the juice was processed through the same equipment as the control. Sample cases of the second lot were marked as pulp fortified juice. The per cent flavanones as naringin, as measured by the method of Davis (1947), degree Brix and the reflected color as determined by use of a Gardner Automatic Color Difference Meter[2] were noted on both lots of juice and the stored pulp.

Samples of the April 1 pack were taste-tested by a ten member taste panel, using the triangle method of determining the differences. Three juice samples were submitted to each panel member, two alike and one different. The panel member was asked to pick out the different sample and also to indicate a preference. The samples were served in dark amber glasses in subdued light so that no visual differences could be detected.

RESULTS AND DISCUSSION

Table 1 shows the results of efforts to separate the seed from pulp by the water flotation method. Complete separation was never accom-

Table 1. Water flotation separation of pulp and seeds.

Sample No.	*Wt. Before Treatment-lbs.*	*Wt. After Treatment-lbs.*	*Dry Wt. %*	*Naringin %*	*Seeds/10 g. After Treatment*
Control	----	----	12.5	0.098	13
1	14.5	14.3	4.8	0.038	5
2	16.5	18.5	4.6	0.031	3
3	12.5	13.5	5.0	0.035	3

plished. Although there was an advantageous decrease in the naringin content, the decrease in the dry weight would indicate a watery product.

Table 2 compares the pulp recovery by the use of the brush finisher and screw type finisher. The percentage by weight of pulp recovered by both finishers was about the same, but the pulp from the brush finisher contained a much higher per cent of suspended solids. Since the brush finisher produced a pulp so much higher in suspended solids, this finisher was used to obtain the pulp for the storage studies.

Little effect was noted on the color of pulp after three months' storage as shown in Table 3. Pasteurized pulp stored at room temperature

Table 2. Pulp recovery by the use of two types of finishers.

Date	*Total lbs.*	*Yield lbs.*	*Suspended Solids %*	*Recovered %*
		BRUSH FINISHER		
2-15-57	88	38½	48	44
2-6-57	37	18	88	49
1-25-57	120	56	72	47
1-16-57	52	21	88	40
12-29-56	53½	31	84	58
		C. R. SCREW TYPE FINISHER		
2-1-56	225	123	35	55
1-24-56	460	205	38	45
1-4-56	412	100	13	24
1-4-56	668	299	21	45

Table 3. Reflectance[1] readings of pulp stored three months.

Sample	*Storage Time Months*	*Rd*	*a*	*b*	*a/b*
12-12					
Raw	0	32.1	7.7	19.7	.390
Pasteurized	0	34.0	7.7	21.1	.365
Frozen Raw	3	32.1	7.0	20.3	.345
Frozen Past.	3	31.5	8.0	20.0	.400
40° F.	3	32.6	8.2	20.4	.402
68° F.	3	32.2	8.5	20.6	.413
Room	3	32.3	8.0	20.5	.390
12-29					
Raw	0	26.4	16.3	19.8	.823
Pasteurized	0	27.0	16.5	21.3	.775
Frozen Raw	3	26.5	16.1	19.8	.813
Frozen Past.	3	27.0	16.0	20.4	.784
40° F.	3	27.2	16.8	20.6	.816
68° F.	3	27.2	17.0	20.6	.825
Room	3	27.1	16.8	20.7	.812

[1] Reflectance readings were made with a Gardner Automatic Color Difference Meter using a Std. Plate LR 1.

Table 4. The effect of the addition of stored pulp on the qualities of late season poorly colored red grapefruit juice.

	Acid %	Brix °	Suspended Solids %	Naringin %	Color[1]
Original pulp	0.98	8.5-9.5	84-100	0.170	+ .929
Pulp after 3½ mo. storage	1.02	9.5	83	0.228	+1.083
March juice, control	1.15	9.0	8	0.091	− .110
March juice, pulp-fortified	1.18	9.2	10	0.098	+ .061
April juice, control	1.00	10.0	8.5	0.083	− .211
April juice, pulp-fortified	1.03	10.0	12.5	0.096	+ .031

[1] Color is expressed as a/b from the a and b readings of the Gardner Automatic Color Difference Meter. + readings are considered acceptable.

had as good a color as raw pulp at frozen storage. Lower than room temperature storage of pasteurized pulp showed no advantage.

The results of analysis of pulp and juice used in the commercial preparation of pulp and pulp fortified juice is listed in Table 4. The results indicate that storage had no adverse effect on the pulp. The addition of pulp increased the color notation of both commercial juice packs from an unacceptable minus value to an acceptable plus level. A corresponding increase is noted in the suspended solids and naringin values of the treated juices but none of the juices were considered excessively bitter. There was little effect on the acid and Brix values.

The results of the taste test performed on the April 1 pack indicated no significant difference of flavor between the control and pulp fortified juices on the .05 level. Of the ten member panel only four could correctly identify the odd sample. Two of the four preferred the control and the other two indicated a preference for the treated sample.

SUMMARY AND CONCLUSIONS

A highly colored red grapefruit pulp, free of seeds and rag, was recovered early in the season from waste products of juice plant finishing operations by use of a brush finisher. Pulp was kept for three months in frozen storage or at room temperature after pasteurization without adverse effects on quality. Excess pulp, from the processing of red grapefruit juice, was recovered, stored, and successfully used to improve the color of canned single strength colored grapefruit juice under normal processing plant conditions, which indicates the commercial applicability of the process.

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Effects of Heat Treatment and Storage Temperature On Shelf Life of Chilled Juices Made From Texas Citrus

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Prior to the freezes of 1949 and 1951 Texas produced approximately 28,000,000 boxes of citrus annually. A considerable proportion of this fruit was canned and sold as juice. During the war this juice found a ready market, but subsequent to 1945 a gradual slackening of demand for canned juice was evident. Demand and price were maintained because of the rapid increase in sales of the frozen orange concentrate. Although no concentrate was produced in Texas, diversion of Florida oranges into this product tended to maintain the price of all fresh oranges. Prices of grapefruit declined, however, and even after Texas production was eliminated Florida prices for grapefruit were sometimes below the cost of production. As Texas gets back into heavy production, a larger proportion of this production is expected to be utilized in processed products. Texas grown grapefruit should be particularly well suited for chilled juice production because of its attractive color, mild flavor, and high vitamin content.

Attempts to market chilled juice date back to the early 1930's, but the early attempts ended in failure due to the lack of knowledge of preparation, handling and distribution of this type of product (Hamrick, 1957). The present chilled juice industry had its beginning in the early 1950's, and in Florida this industry utilized 6,900,000 boxes of citrus fruit in the 1957-58 season (Lassiter and Capel, 1959).

Wenzel, et al (1955) observed that the stabilization of orange juice by heat treatment, prior to rapid cooling to 32° F. or lower after stabilization and refrigerated storage temperatures as close to 32° F. as possible during distribution to consumers throughout the country, was one of the chief factors that has made possible the large expansion in the production and distribution of chilled orange juice.

The series of experiments described in this paper was prompted by the desire of consumers for not only more but higher quality fruit and vegetable products ready to serve without any, or with only a minimum of preparation. Chilled single strength juice products were chosen for investigation because they meet this need and in addition lend themselves to "milk distribution" methods which may tend to encourage regular and increased consumption. Experiments were designed to investigate the effects of various pasteurization and storage temperatures upon the storage life of "chilled" grapefruit juice, orange juice, and grapefruit-orange juice blends of Texas fruit, and to investigate the effects of seasonal changes upon keeping quality of these juices.

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EXPERIMENTAL PROCEDURE

1957-58 Season: All packs during this season were processed from juice obtained from the blending tanks of a local citrus canning plant. The juice was processed as soon as possible after extraction. It was deaerated in a 20 gallon stainless steel vacuum tank under agitation but with no heat application. Unpasteurized control samples of the deaerated juice were withdrawn from each experimental lot of juice and placed at the storage temperatures listed. The remaining juice was passed through two tubular heat exchangers connected in series. The first was used to heat the juice to the desired temperature (7-10 sec.), using circulated hot water, and the second was used to cool the juice (15-20 sec.), using an agitated ice-salt water bath. The juice was cooled to 50° F. or lower and stored in sterile one-half gallon glass milk bottles at 40°, 68°, and 80° F.

The limitations of heat treatment were determined by flavor evaluation of portions of juice that had been heat treated at 160°, 165°, 170°, 175°, 180°, 185°, 190° and 195° F. Evaluations were made at the time of preparation and after 14 days storage at 40° F.

Taste tests were performed using a panel of five laboratory staff members. Samples were presented for tasting at a temperature of 45°-50° F., and panel members were asked to rate each sample from 0 to 10; 0 being obviously deteriorated, 5 acceptable, and 10 ideal (Culver and Cain, 1952). The mean flavor score was used. Samples with a flavor score of less than 2.0 were judged spoiled.

1958-59 Season: Procedures described above were expanded to include orange juice and orange-grapefruit juice blends in addition to grapefruit juice. Grapefruit juice for all packs and orange juice for the late season packs were obtained from a local citrus canning plant. For the orange juice used in the three early and three mid season packs, oranges which did not meet fresh fruit standards because of small sizes and blemishes were obtained from a local packing shed, reamed by an automatic reamer, the juice put through a paddle finisher, and then treated as the grapefruit juice. Blended samples were prepared from the raw deaerated orange and grapefruit juices in the following proportions:

Early season packs: 60% orange juice – 40% grapefruit juice
Mid season packs: 55% orange juice – 45% grapefruit juice
Late season packs: 50% orange juice – 50% grapefruit juice

These proportions were chosen so that more grapefruit juice could be used in preparing the blended samples as the acid content of the grapefruit juice decreased throughout the season. Using these proportions, the grapefruit juice content of any pack did not exceed the amount (50%) recommended in the present standards for blended grapefruit juice and orange juice (USDA, 1954). The juices were processed as soon as possible after extraction. They were deaerated in a 20 gallon vacuum tank under agitation, after being heated to 85°-90° F. by passing them through a tubular heat exchanger immersed in hot water. Control samples were withdrawn and divided into two portions, and portions of the remaining juice were pasteurized at 165°, 170°, 175°, and 180° F., respectively, by passing them through two tubular heat exchangers connected in series. The first was used to heat the juice to the desired temperature (7-10 sec.), using circulated hot water, and the second was used to cool the juice to 29°-34° F. (15-20 sec.), using recirculated brine. After pasteurization and cooling all samples were stored along with unpasteurized controls at the designated temperature in sterile one-half gallon glass milk bottles which had previously been chilled to 10° F. To provide a better basis for flavor evaluations, the remaining portions of each control sample (orange, grapefruit, and blended juices) of the three mid-season and three late season packs were frozen on the day of preparation and held at –5° F. until thawing on the date of testing.

Samples were tested after storage at 14,21 and 28 days at 32°, 40° and 50° F. The juice was analyzed for acid, Brix, cloud, flavanone content and suspended solids by standard procedures. Acid content was determined by titration to pH 8.2 (pH meter) with standard sodium hydroxide, and is reported as total titratable anhydrous citric acid. Brix was recorded as read from a Zeiss Abbe refractometer[2]. Cloud was read as per cent transmittance at 650 mu of the supernatent liquor after centrifuging for ten minutes at 1400 r.p.m. in a size 1 International centrifuge[2] (Loeffler, 1941). Suspended solids were read from the same centrifuge tubes. Flavanone content was determined by the Davis test (Davis, 1947), and was calculated as per cent naringin. Davis test values obtained from all three juices (orange, grapefruit, and blend) were all converted to per cent naringin, using a standard naringin curve. It is understood that hesperidin also gives a positive Davis test, but for comparison purposes, all Davis test values were converted to per cent naringin. Reflected color was calculated as the a/b ratio from reflectance readings obtained using the Gardner Automatic Color Difference Meter[2] (Lime, et al, 1956).

A panel of four laboratory staff members performed the taste tests, using the same numerical rate scale previously described. All samples of the mid and late season packs were compared at each tasting session for flavor scores with frozen control samples which were thawed just prior to testing, and were assigned a taste value of 8.0 (very good). Samples were presented for tasting at a temperature of 40°-45° F. The results are reported as the mean score. Samples that were deemed spoiled by the panel were dropped from future tests.

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[2] The mention of trade products does not imply endorsement over similar products not mentioned.

RESULTS

1957-58 Season: Table No. 1 lists the mean taste panel flavor score given to juice heat treated at various temperatures. The panel was asked to rate the juice on its freshness or "uncooked" qualities, with a value of 8.0 indicating no "cooked" flavor at all and lower flavor scores indicating more "cooked" flavor. Treatment temperatures of 165° F. to 185° F. show little adverse effect on flavor after 14 days storage at 40° F. Treatment temperatures of 190° F. and 195° F. had a low flavor score at the time of preparation and showed no improvement upon storage. Although treatment temperature of 160° F. had a relatively high flavor score initially, it showed a definite decrease upon storage. These three treatment temperatures were eliminated from the remaining studies.

Samples of the first packs were stored at 68° F. and 80° F. These samples were put up in an attempt to find some correlation between storage life at these temperatures and storage life at a lower temperature (40° F.). Results did not bear out this hope however, as samples stored at these higher temperatures went off flavor in 24 hours or less.

1958-59 Season: Tables 2, 3 and 4 show variations in composition between three early, two mid and three late season packs over the entire 1958-59 season, as exemplified by the juice sample heat treated at 175° and stored at 32° F. for 21 days. This particular sample was chosen because it showed the widest variation over the entire season. Control (unpasteurized) samples are not listed because it was found that there was no apparent difference in chemical composition between heat treated and untreated juices immediately after treatment.

Figure 1 shows the season's average of mean taste panel flavor scores given to orange juice, grapefruit juice and orange-grapefruit juice blend

Table 1. Effect of treatment temperature on flavor after 14 days storage at 40° F.

	Flavor scores after	
Treatment Temperature	*0 days storage*	*14 days storage at 40° F.*
160	5.8	2.3
165	4.8	5.8
170	5.3	5.0
175	3.8	4.5
180	4.8	6.8
185	5.3	5.8
190	3.8	3.8
195	2.5	1.8

Table 2. Composition of grapefruit juice heat treated at 175° F. before and after 21 days storage at 32° F.

Period of Season	Date	Flavor Score Days stored 0	21	% Citric Acid Days stored 0	21	° Brix Days stored 0	21	Cloud (% T.) Days stored 0	21	Reflected Color a/b Days stored 0	21
Early	11-12-58	4.5	4.6	1.40	1.37	9.0	8.7	21.0	24.0	–.184	–.180
	11-21-58	4.4	5.8	1.12	1.12	8.7	8.7	18.5	25.5	.000	–.065
	12-19-58	7.3	5.3	1.36	1.34	10.2	10.0	20.5	24.0	–.232	–.015
Middle	1-23-59	6.8	6.7	1.26	1.26	9.8	9.4	24.5	25.0	–.021	–.074
	2-25-59	7.0	7.3	1.04	1.07	8.3	8.3	25.0	28.5	–.106	–.078
Late	3- 9-59	7.8	7.0	1.08	1.08	9.1	9.1	19.0	21.0	–.262	–.318
	3-13-59	8.0	7.4	1.03	1.05	8.4	8.6	19.5	23.0	–.200	–.304
	4- 1-59	7.8	6.5	1.10	1.11	9.8	9.8	18.0	20.5	–.503	–.517

Table 3. Composition of orange juice heat treated at 175° F. before and after 21 days storage at 32° F.

Period of Season	Date	Flavor Score Days stored 0	21	% Citric Acid Days stored 0	21	° Brix Days stored 0	21	Cloud (% T.) Days stored 0	21	Reflected Color a/b Days stored 0	21
Early	11-12-58	4.2	4.8	0.49	0.44	8.0	8.2	17.0	16.5	–.263	–.249
	11-21-58	6.0	6.0	0.70	0.69	10.1	9.9	22.0	19.0	–.239	–.249
	12-19-58	8.0	7.7	0.72	0.70	11.0	11.1	15.0	17.5	–.230	–.211
Middle	1-23-59	7.8	7.5	0.80	0.79	12.0	12.0	13.0	14.0	+.133	+.095
	2-25-59	8.0	8.3	1.01	1.01	11.0	10.7	14.0	17.5	–.104	–.098
Late	3- 9-59	8.7	7.8	0.83	0.81	11.4	11.1	13.0	14.0	–.038	–.025
	3-13-59	8.3	7.8	0.75	0.75	10.2	10.0	14.0	14.0	–.019	–.030
	4- 1-59	8.2	7.3	0.76	0.76	11.6	11.4	9.5	10.5	–.019	0.000

Table 4. Composition of orange-grapefruit juice blend, heat treated at 175° F., before and after 21 days storage at 32° F.

Period of Season	Date	Flavor Score Days stored 0	21	% Citric Acid Days stored 0	21	° Brix Days stored 0	21	Cloud (% T.) Days stored 0	21	Reflected Color a/b Days stored 0	21
Early	11-12-58	5.8	5.2	0.88	0.87	8.6	8.4	17.5	19.0	–.199	–.207
	11-21-58	5.6	6.2	0.87	0.86	9.4	9.4	16.5	21.5	–.181	–.195
	12-19-58	7.8	6.7	0.97	0.97	10.7	10.7	17.0	20.0	–.237	–.193
Middle	1-23-59	7.8	7.2	1.02	1.01	10.9	10.8	17.0	17.0	+.071	+.056
	2-25-59	7.6	8.0	1.02	1.05	9.2	9.7	18.0	23.0	–.095	–.082
Late	3- 9-59	8.0	6.8	0.95	0.95	10.0	10.0	16.0	20.0	–.100	–.115
	3-13-59	8.0	8.0	0.89	0.90	9.4	9.0	16.0	19.0	–.088	–.106
	4- 1-59	7.8	6.5	0.96	0.93	10.5	10.7	13.5	15.0	–.115	–.112

Table 5. Flavor scores of mid season citrus juices.

Date and Time of Season	Sample	Past. Temp.	0 days	14 days 32°	14 days 40°	21 days 32°	21 days 40°	28 days 32°	28 days 40°
Mid Season 1-23-59	Grape-fruit	Control	7.0	6.4	6.5	7.0	4.6	5.6	Spoiled
		165°	6.8	7.4	6.8	6.5	5.6	5.8	4.8
		170°	7.0	7.4	7.3	6.2	5.6	5.6	4.8
		175°	6.8	7.4	7.0	6.7	6.2	6.2	3.2
		180°	6.6	7.2	8.0	6.7	6.4	6.4	4.0
	Blend	Control	6.4	7.4	7.2	7.3	5.0	6.0	Spoiled
		165°	7.2	7.4	7.5	7.2	7.0	7.2	5.4
		170°	8.0	8.2	7.7	7.0	6.8	7.8	6.0
		175°	7.8	8.8	8.3	7.2	6.6	7.8	6.4
		180°	6.6	8.0	7.7	6.8	7.0	7.8	6.6
	Orange	Control	7.8	8.2	6.7	7.0	5.4	6.4	Spoiled
		165°	7.6	7.0	7.7	6.3	6.2	7.4	Spoiled
		170°	7.8	8.0	8.0	7.5	7.0	7.0	6.2
		175°	7.8	8.4	7.7	7.5	6.4	7.6	6.6
		180°	7.6	8.2	7.7	7.2	6.4	7.4	7.4

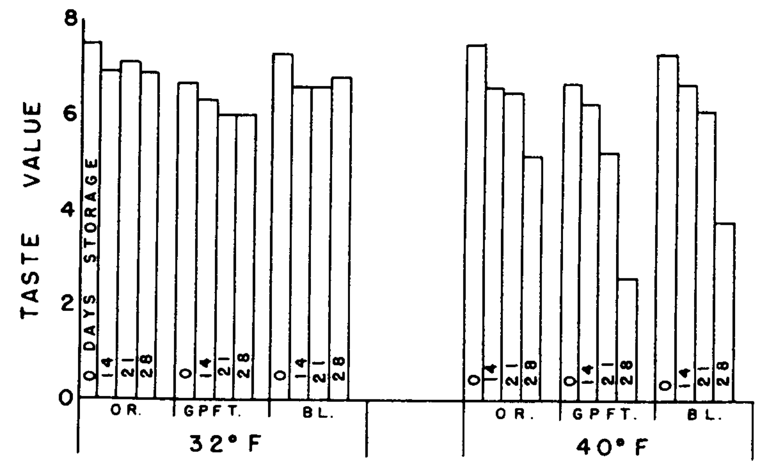

Figure 1. Flavor score (0, obviously deteriorated – 10, excellent) of orange, grapefruit, and orange-grapefruit blend juices as affected by length of storage at 32° and 40° F.

after heat treatment at 170° F. and storage for 0, 14, 21 and 28 days at 32° F. and 40° F. The panel was asked to judge the juice samples on the basis of fresh juice flavor.

Table 5 lists flavor scores from a mid season pack of grapefruit, orange, and blended juices. All samples were spoiled after 14 days storage at 50° F. All but two controls stored at 40° F. were spoiled after 28 days storage, and these two samples were below an acceptable level.

DISCUSSION

1957-58 Season: The data contained in Table 1 indicate that any temperature from 165° F. to 180° F. gives adequate stability to juices stored at 40° F. for 14 days.

The packs put up during this season were prepared to give basic data on keeping quality of grapefruit juice at various storage temperatures after heat treatment at given temperatures. This information was used in setting up packs during the 1958-59 season discussed below.

1958-59 Season: Tables 2, 3 and 4 show the chemical composition of 8 juice packs put up over the entire season. These tables show the changes in composition which appeared after 21 days storage at 32° F. in all packs over the entire season. Therefore, data from only one pack are included in the tabulation of flavor scores in Table 5. The marked and continuous increase in citric acid content of orange juice and blends between 11/12/58 and 2/25/59 shown in Tables 3 and 4 is apparently due to the changes from early to mid season varieties of oranges in late

November, and from mid season varieties to Valencia oranges in early February.

The values in Table 5 show that even after heat treatment of 180° F., samples of all three juices generally had a higher flavor quality when stored at 32° F. than when stored at 40° F. There does not appear to be any great degree of difference between samples heat treated at 165°, 170°, 175°, and 180° F. after 21 days storage at 32° F., but there is a definite difference in flavor between heat treated and non-treated samples, the heat treated samples having a much higher flavor quality. This difference between heat treated and non-treated samples is even more pronounced after 21 days storage at 40° F.

The data graphed in Figure 1 indicate that under the conditions studied while there is some deterioration of flavor upon storage at 32° F., there is a much greater and more rapid loss of palatibility after storage at 40° F. during a corresponding storage period.

From this information it appears that under optimum conditions, using sterile, prechilled glass bottles and storage temperatures controlled within plus or minus 1° F., these juices may be held no more than 21 days at 32° F. Lest these results be misinterpreted, several points should be stressed. First, in the experiments above, juices were stored in *glass bottles,* not in the conventional waxed paperboard cartons. Second, the times shown indicate the maximum holding time for an acceptable product. It is understood that placing even the freshly processed product in normal distribution channels would probably shorten this holding time appreciably. Third, and perhaps most important of all, is that these experiments were carried out under optimum conditions that in commercial practice would be difficult to attain. Therefore, in any commercial application, it would be imperative to exercise rigid control over storage temperature and other storage conditions. Fourth, even though the majority of packs over the 1958-59 season were acceptable after 28 days storage at 32° F. and 14 days storage at 40° F., it is *definitely not* recommended that juices be held longer than 21 days, and that they be held at a storage temperature of 32° F. *maximum,* due to the spoilage of some packs when these limits were exceeded. The average flavor scores after 28 days storage at 32° F. exceeded the average flavor scores after 14 days storage at 40° F. For these reasons, a storage temperature of 32° F. is recommended.

There were no significant changes in citric acid content, Brix values, cloud, flavanone content, or reflected color values of heat treated samples during the storage periods recommended. In general, it appears that seasonal changes have little or no effect on keeping quality of the juices tested. It also appears that, provided a minimum treatment of at least 165° F., is given the juice, variations in temperatures used in heat treatment do not affect storage life as much as changes in storage temperatures.

From these data four conclusions are evident: First, flavor quality goes down with time. Second, flavor quality goes down faster in juices

held at higher storage temperatures. Third, the effect of heat treatment within the limits studied is dependent on the storage temperature, heat treatment being highly effective in prolonging "shelf life" of juices stored at 40° F., while the advantage of heat treatment of juices stored at 32° F. is not as evident as at higher storage temperatures, since flavor deterioration is slower at 32° than at 40° F. Fourth, all of the foregoing conclusions apply equally to grapefruit, orange, and blended juices.

SUMMARY AND CONCLUSIONS

Early season, mid season and late season packs of Texas grapefruit juice, orange juice and grapefruit-orange juice blends have been prepared, processed and stored at 32°, 40°, and 50° F., and the keeping time and quality determined. The advantages of 32° F. storage, both in keeping time and flavor quality, have been repeatedly demonstrated. Grapefruit, orange, and grapefruit-orange blend juices can be stored up to 21 days at 32° F. after heat stabilization treatments of 165°-180° F. Storage at 40° F. reduces keeping time in some cases to less than 14 days, even though higher temperatures, 170°-180° F. are used for stabilization. When stored at 50° F., samples were spoiled in less than 14 days. In general, samples of all three juices had a higher flavor quality when stored at 32° F. than when stored at 40° F. Seasonal differences in the quality of the juice did not appear to greatly influence the length of time heat stabilized juice could be kept.

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Rapid Procedure for the Semi-Quantitative Measurement of External D and C Red No. 14 Dye in the Presence of Citrus Red No. 2 Dye on Oranges

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INTRODUCTION

This paper presents a rapid method of determining the amount of External D and C Red 14 dye (m-xylylazo-2-napthol) present as a contaminent in Citrus Red No. 2 dye (1-(2,5-dimethoxy-phenylazo)-2-napthol). An amendment to the Federal Food, Drug, and Cosmetic Act (1959) forbids the use of External D and C Red 14 dye to color oranges after May 1, 1959. In its place a new dye known as Citrus Red No. 2 is now being used. In changing from one dye to another the industry found that the treated fruit contained a mixture of the dyes. Although only the new Citrus Red No. 2 dye was being added to the coloring tanks there was enough residual External D and C Red 14 dye in inaccessible portions of the coloring equipment that the oranges were being colored by a mixture of the dyes. A rapid method of determining the amount of contamination was desired to indicate the extent of equipment cleaning necessary and the success of cleaning in eliminating the unwanted Red 14.

Ting (1955) reports a colorimetric method for the determination of the color added to oranges. He suggests the oranges be weighed, rolled in chloroform and the amount of coloring material determined by the absorption of the chloroform solution in a spectrophotometer.

It has been reported by Silk (1959) that oil-soluble colors can be separated by paper chromatography with acetone water mixtures after the paper has been impregnated with a small amount of soy bean oil. She also noted that Citrus Red No. 2 could be eluted from the paper chromatogram with a 40% acetone developer, while it took a 55% acetone solution to elute External D and C Red 14. Mark and McKeown (1959) used mineral oil instead of a vegetable oil to impregnate the paper. This information formed the basis for the analytical procedures reported in this paper.

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EXPERIMENTAL PROCEDURE

The analysis was divided into two parts. Colorimetry was used to determine the total amount of coloring material present and paper chromatography was used to separate the colors so that an estimate of the composition could be made.

Colorimetry: Chloroform solutions of Citrus Red No. 2 Dye and External D and C Red No. 14 were prepared by dissolving 25 mg. of dye in 100 ml. Mixtures of these solutions were used to obtain solutions containing 20% No. 14 - 80% No. 2, 10% No. 14 - 90% No. 2, and 100% No. 2. These three mixtures containing 250 ppm. total dye were diluted to contain 2 ppm., 3.5 ppm., and 5 ppm. Absorbance measurements were made on the diluted solutions using a Lumetron Colorimeter[2] with a 530 mu filter. A standard curve was prepared from the readings of the 10% No. 14 - 90% No. 2 solutions.

Paper Chromatography: Paper was prepared for chromatography by dipping 8x11 inch sheets of Whatman No. 1[2] filter paper in a 5% W/V light mineral oil-ether solution and allowing to dry. Solutions were prepared for a standard paper strip by mixing 250 ppm. chloroform solutions of No. 2 dye and No. 14 dye in the following proportions: 100% No. 2, 95% No. 2 - 5% No. 14, 90% No. 2 - 10% No. 14, 85% No. 2 - 15% No. 14, 80% No. 2 - 20% No. 14. The standard paper strip was prepared by spotting 10 lambda of the five mixtures of dyes 1 inch from the bottom of the prepared filter paper and developing with an ascending 50% acetone-water solution. Upon developing the No. 2 dye moved up the paper strip, leaving the No. 14 near the place of spotting.

Fruit analysis: Extracts from fruit samples were prepared by accurately weighing about 500 grams of oranges. The oranges were extracted with two 50 ml. portions of chloroform by placing the fruit and solvent in a tightly capped one-gallon glass jar and slowly rotating the jar on its side so that the fruit would rotate in the solvent. The extracts were diluted to 100 ml. and the absorption at 530 mu noted. A sample blank used to zero the colorimeter was obtained by extracting uncolored oranges in the same manner.

The total ppm. of the solution can be read from the previously prepared standard curve. The ppm. of dye on the sample can be calculated by dividing the ppm. of the solution by the weight of the fruit sample and multiplying by 100.

A portion of the extract for chromatographic analysis was taken so that after concentration 1 ml. would contain 250 ppm. This portion was evaporated to dryness and allowed to cool and taken up in 1 ml. of chloroform. Ten lambda of the concentrate was spotted and chromatographed as described for the standard chromatogram. Per cent contami-

[2] The mention of trade products does not imply endorsement over similar products not mentioned.

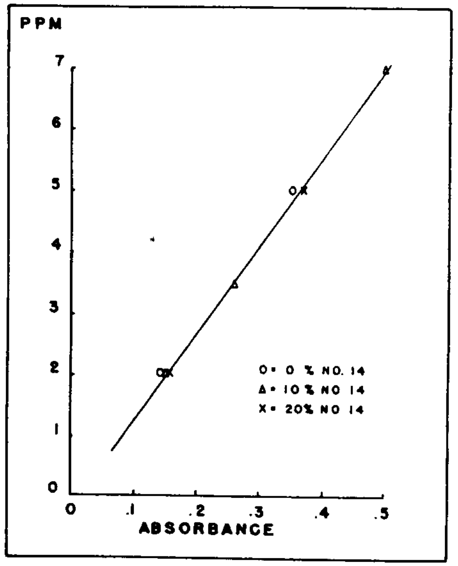

Figure 1. Standard curve of 10% External D and C Red 14 dye–90% Citrus No. 2 dye in chloroform.

Figure 2. Standard chromatogram showing 0, 5, 10, 15, and 20% External D and C Red 14 dye contamination.

nation was estimated by comparison of the No. 14 dye spot with the standard chromatogram.

Figure 1 shows the standard curve prepared from the 10% No. 14 - 90% No. 2 dye solution to be a straight line which approaches the zero point of the graph. It also indicates only a small error in the calculation of the total dye when the per cent of No. 14 is between 0 and 20.

Figure 2 is a photograph of a standard paper strip after development. It shows the clean separation of the two dyes. Although it is a black and white picture the difference in intensities of the colors of the lower spots (No. 14 dye) are clearly indicated.

The fruit analyzed contained approximately 1 ppm. total dye. This concentration gave absorbance readings around 0.3 when a 500 gram sample was extracted in 100 ml. of solution. This was well within the straight portion of the curve. It was necessary to prepare the sample blank because of the turbid nature of the solutions.

In the preparation of the standard chromatogram the Citrus Red No. 2 dye spot moved cleanly away from the No. 14 dye spots in 2 to 3 hours. The Citrus Red spot was reddish purple, whereas the smaller No. 14 spot was orange-red. The difference in intensities of the color of the various concentrations of No. 14 dye made it possible to visually distinguish a difference of 0, 5, 10, 15, and 20% concentrations. When known amounts of mixed dye solutions were added to chloroform extracts of uncolored oranges and these solutions evaporated, redissolved in chloroform and chromatographed as described in the experimental procedure, close correspondence of color intensities of the test spots with spots on the standard chromatogram were obtained. It was possible to closely match the intensity of spots from chromatographed fruit extracts with those on the standard, thus giving an indication of the amount of No. 14 dye present on the fruit.

SUMMARY

A rapid method of determining the amount of External D and C Red 14 dye (m-xylylazo-2-napthol) present as a contaminant in Citrus Red No. 2 dye (1-(2,5-dimethoxy-phenylazo)-2-napthol). The total dye concentrations are determined colorimetrically from chloroform extracts of oranges. The extent of contamination is determined by comparing a developed paper chromatogram to a previously prepared standard chromatogram. The amount of Red 14 dye present in Citrus Red No. 2 can be estimated to within 5%.

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Characteristics of *Poncirus Trifoliata* Selections

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Recently there has been renewed interest in Trifoliate orange, *Poncirus trifoliata,* as a rootstock for citrus (Bitters and Bachelor, 1952). This species has many characteristics which make it a desirable rootstock (Benton et al, 1950). It is tolerant to tristeza and resistant to brown rot gummosis; fruit characteristics and production are excellent; it is one of the most hardy rootstocks; it is resistant to the citrus nematode and is an excellent rootstock for replanting in old citrus orchards (Baines et al, 1957, 1960). The Trifoliata rootstock has certain limitations, however. Scion wood must be free of the exocortis virus; it does very poorly on calcareous and saline soils; and it is incompatible with Eureka lemon (Nauriyal et al, 1958).

The characteristic most frequently attributed to the Trifoliate orange rootstock is its dwarfing effect on tree size (Hodgson and Cameron, 1943). Reports from various parts of the world, however, indicate that not all trees on this stock are reduced in size (Benton et al, 1950; Davis, 1919). The authors have observed many large and productive Valencia, grapefruit, and Washington navel trees budded in Trifoliate orange rootstock. Immediately adjacent to the large and productive trees, however, one frequently observes trees exhibiting varying degrees of dwarfness. Many of these dwarf trees appear free of psorosis and exocortis viruses.

Several possible explanations have been advanced for the observed variation in size of trees grafted on Trifoliate orange rootstock. Clark Powell (1930) and Hearman (1943) suggested that variation in tree size may result from the use of Trifoliate strains, each genetically different and thus capable of imparting varying degrees of vigor to the grafted tree. Benton et al (1950) showed conclusively that variability in size of trees grafted on Trifoliate orange may be caused by the scaly butt (exocortis) virus. This virus affects Trifoliate orange tissue and manifests itself in decreased vigor and bark shelling. Fraser (1958) reported trees on Trifoliate orange may be stunted with no apparent symptoms of bark shelling. She suggested that these trees may be infected with a strain of scaly butt (exocortis) virus which diminishes vigor but does not induce bark shelling.

One objective of our work with *Poncirus trifoliata* is to gain information which may explain the nature of the variability in size of trees grafted on Trifoliate orange rootstocks. The present report concerns primarily the growth characteristics of seedlings from some 36 Trifoliate selections secured from sources described below.

PLANT MATERIAL

In 1945 one of the authors[1] surveyed the citrus producing areas of California and obtained cuttings of Trifoliate rootstock suckers from under dwarf, medium-sized, and large Valencia, grapefruit, and Washington navel trees (Table 1). The trees from which the cuttings were taken showed no symptoms of exocortis or psorosis viruses. The cuttings were rooted and planted in the field for production of seed.

The Citrus Experiment Station, Riverside, California, supplied seed of six selections employed in the present study. Trifoliate seeds were also secured from various parts of the United States and South America. These

Table 1. Description of trees from which Trifoliate selections were obtained.

Selection	Size of tree	Selection	Size of tree
Selections collected from under Valencia scions		*Selections collected from under Grapefruit scions*	
R 12-2	Large	K 8-5	Large
R 16-6	Large	K 43-3	Large
R 21-3	Large	K 5-5	Medium
R 22-2	Large	K 25-4	Medium
R 7-5	Medium	K 55-1	Medium
R 5-2	?	K Medium	Medium
Towne F	Large	K 60-2	Medium
Towne G	Large	K 28-3	Dwarf
Benecke	Large	K 15-3	?
Jacobsen	Dwarf	*Miscellaneous selections. Performance with scions unknown*	
English Large	Medium		
English Small	Very dwarf		
Selections collected from under Navel scions		Ronnse	?
		Argentina	Vig. sdlg.
		Yamaguchi	Vig. sdlg.
Christian	Large	Marks	?
Taylor	Medium	Benoit	?
Davis A	Medium	Simmons	?
Davis B	Medium	Texas	?
		Pomeroy	?
		Barnes	?
		Webber-Fawcett	?
		CES Diploid	Vig. sdlg.
		Frost Tetraploid	Vig. sdlg.
		Rubidoux[a]	?

[1] Dr. S. H. Cameron was assisted in this survey by Mr. Paul Moore, Laboratory Technician, and County Farm Advisors Harold Walberg and Karl Opitz.

[a] Twenty-five-year-old Valencia, Washington Navel and Marsh grapefruit trees grafted on Rubidoux trifoliate in the U.C.L.A. orchard were 20 to 30% smaller than trees grafted on sweet orange rootstock.

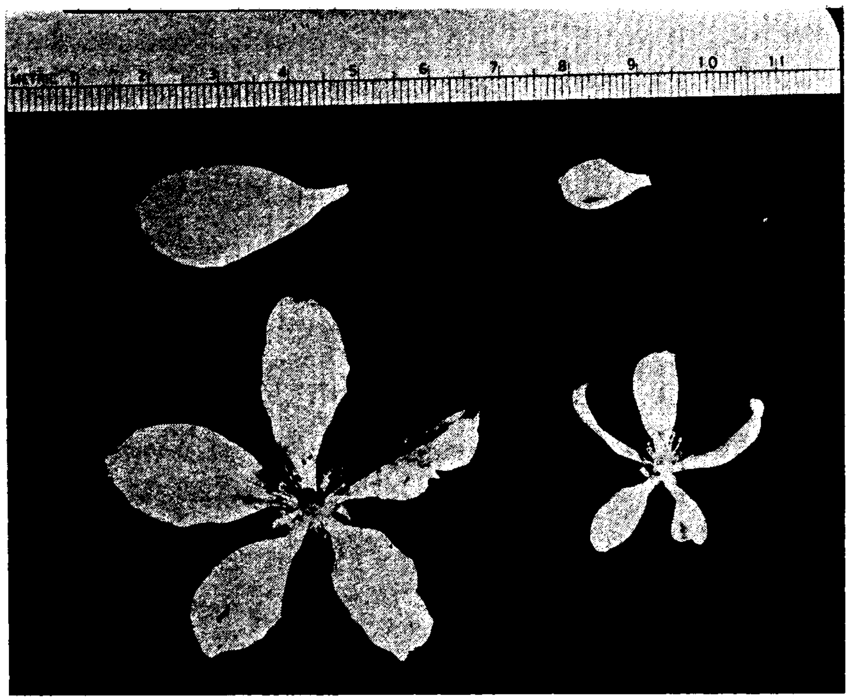

Figure 1. Trifoliate flowers from "large flowered" group (left) and "small flowered" group (right).

seeds were germinated in the glasshouse and the most vigorous seedlings planted in the field for seed production. The behavior of these selections as rootstocks is not yet known.

RESULTS AND DISCUSSION

Floral characteristics of parent Trifoliate selections. – When the rooted cuttings of the original Trifoliate selections attained bearing age it was observed that the floral characteristics provided a means whereby the Trifoliate selections could be divided into two distinct groups, Fig. 1.

The flowers of one group are 3.0 to 4.0 cm in diameter with the petals turned up giving a slightly cupped appearance. The petals are constricted at the base and rolled upward along the edges, thus giving them a narrow appearance. Trifoliate selections possessing flowers which exhibit these characteristics will be referred to as members of the "small flowered" group.

Flowers of the second group are 5.5 to 6.5 cm in diameter. The petals remain in a horizontal position and exhibit no tendency toward cupping. The petals are less constricted at the base and show little tendency to

roll upward along the edges. Trifoliate selections possessing flowers which exhibit these characteristics will be referred to as members of the "large flowered" group.

Table 2 lists the floral grouping for each Trifoliate selection examined.

In the UCLA orchard Trifoliate selections within the "small flowered" group have consistently matured their fruit about one month earlier than selections within the "large flowered" group. It is also observed that stem cuttings from selections within the "small flowered" group produce roots more readily than stem cuttings from plants in the "large flowered" group. Nauriyal et al (1958) reported the Eureka lemon-Trifoliate orange incompatibility was much more severe with members of the "large flowered" group than with members of the "small flowered" group.

Table 2. Average trunk diameter and top weight of two-year-old Trifoliate seedlings trained to a single trunk[a].

Selection	*Fresh weight of top[b] grams*	*Trunk diameter[c] cm*	*Flower size of parent cutting*	*Selection*	*Fresh weight of top[b] grams*	*Trunk diameter[c] cm*	*Flower size of parent cutting*
K 25-4	285	1.62	Large	English Large	150	1.23	Small
K 60-2	282	1.60	Large	Barnes[d]	139	1.08	?
K 5-5	282	1.57	Large	Taylor	131	.97	Small
D 8-5	279	1.57	Large	R 22-2	125	1.07	Small
K 55-1	278	1.48	Large	Ronnse	122	1.09	Small
R 5-2	276	1.51	Large	R 21-3	118	1.08	Small
Christian	275	1.54	Large	Texas[d]	109	1.04	Small
Pomeroy[d]	275	1.52	Large	Jacobsen	105	.97	Small
Towne F	259	1.57	Large	Rubidoux	104	1.08	Small
R 7-5	256	1.53	Large	Davis A	102	1.04	Small
R 12-2	249	1.72	Large	English Small	69	.94	Small
Benecke	238	1.46	Large	CES Diploid[d]	55	.85	Small
K 28-3	234	1.44	Large				
Towne G	219	1.43	Large				
Argentina	218	1.46	Large				
U.S.D.A.[d]	213	1.41	Large				
Yamaguchi	210	1.40	Large				
Average	255	1.52			111	1.06	
LSD 5%.	Fresh weight = 57 grams; Trunk diameter = 0.18 cm.						

[a] Seedlings suckered at frequent intervals to maintain single trunk to height of 15 inches.
[b] Top severed from roots at ground level and weighed. Weights made in spring prior to leafing out.
[c] Trunk diameter measured at budding height, 8 inches above ground level.
[d] Flower size from R. K. Soost, University of California, Riverside.

These distinguishing morphological and physiological characteristics firmly establish that genetically different strains exist within *Poncirus trifoliata*.

Growth characteristics of seedlings from parent Trifoliate selections. —Trifoliate seed employed in the present study were extracted in the fall from mature fruit, treated with Arasan (1% soln.) and stored two months in polyethylene bags at 40° F. Following the two-month storage, the seed were germinated in the glasshouse. By June (5 months from sowing seed) the seedlings had attained a height of 8 inches and were transplanted to nursery rows.

Standard nursery practices were employed throughout the 2-year period of the experiment. Suckers were removed from the lower trunk of the seedlings at frequent intervals to attain a single trunk to height of 15 inches.

Table 2 presents the average trunk diameter at budding height (8 inches) and the average fresh weight of tops of two-year-old plants. These data indicate that seedlings of the most vigorous selections possessed an average trunk diameter in excess of 1.60 cm and an average top weight in excess of 280 gr. Seedlings of the least vigorous selections possessed an average trunk diameter less than 1.00 cm and an average top weight less than 70 gr.

Comparing the vigor of the seedlings in this planting with the floral grouping (Table 2) it is apparent that seedlings of Trifoliate selections within the "large flowered" group are, without exception, more vigorous than seedlings of selections within the "small flowered" group.

Experiments have been initiated to establish if Trifoliate selections from the "large flowered" group, when used as rootstocks, impart greater vigor to the grafted tree than selections from the "small flowered" group. In our oldest experiment, five-year-old Frost nucellar Washington navel orange trees grafted on Christian Trifoliate ("large flowered") are approximately 20 per cent larger than trees grafted on Rubidoux Trifoliate ("small flowered").

Last year experiments were initiated to establish if inoculum of Trifoliate cuttings collected from under dwarf trees would diminish the vigor of Trifoliate seedlings grafted to nucellar scions. Growth data from this study is not yet available.

The relative vigor among the Trifoliate selections listed in Table 2 is based upon growth measurements obtained in the University orchard at Los Angeles, where relatively low summer temperatures prevail. Preliminary observations suggest the relative vigor among the selections may be different in areas where summer temperatures are higher.

During the first growing season it was noted that seedlings within the "small flowered" group required more frequent suckering than seedlings within the "large flowered" group. In view of this observation a second experiment was initiated in which the seedlings were not suckered. The purpose of this experiment was to ascertain if there was a difference in growth habit among the Trifoliate selections, and to compare the relative vigor among the selections when the seedlings were permitted to grow without removing suckers.

Table 3 presents the average fresh weight of tops after one growing season. These data indicate only slight difference in vigor among the Trifoliate selections when the seedlings were permitted to grow undisturbed. In the previous experiment in which the seedlings were continually suckered to maintain a single trunk, the average weight of seedlings within the "large flowered" group was twofold greater than seedlings within the "small flowered" group. Hence it would appear that certain nursery management practices may modify the relative vigor among the Trifoliate selections.

Figure 2 illustrates the growth habit of typical unsuckered seedlings from the "small flowered" and "large flowered" groups. Without excep-

Table 3. Average top weight of one-year-old unsuckered Trifoliate seedlings[a].

Seedlings of "large flowered" group		Seedlings of "small flowered" group	
Selection	*Fresh weight grams*	*Selection*	*Fresh weight grams*
Christian	26.0	Taylor	27.7
K 55-1	24.4	Jacobsen	26.9
K 25-4	22.7	Ronnse	26.7
R 12-2	26.5	Davis A	26.5
U.S.D.A.	20.5	R 21-3	26.2
Towne F	19.3	R 22-2	24.3
K 5-5	19.3	Davis B	23.5
Yamaguchi	19.3	Simmons	23.2
K 28-3	19.1	Barnes	23.0
K-Medium	18.6	English Small	21.5
Webber Fawcett	18.5	Rubidoux	19.9
Towne G	18.0	English Large	16.7
Benecke	17.9	CES Diploid	13.9
K 15-3	16.8		
K 8-5	16.8		
R 7-5	16.7		
Pomeroy	16.3		
R 5-2	16.3		
K 60-2	15.7		
Argentina	14.9		
Average	19.2		23.1
LSD 5% 5.2			

[a] Tops severed from roots at ground level and weighed. Weights taken in spring prior to leafing out.

Figure 2. Growth habit of unsuckered Trifoliate seedlings from "large flowered" group (left) and "small flowered" group (right).

tion, seedlings of the "small flowered" and "large flowered" groups. Without exception, seedlings of the "small flowered" group possessed a bushy habit of growth with multiple trunks, while seedlings of the "large flowered" group possessed an upright habit of growth with a single trunk.

This difference in growth habit is of practical significance to the nurseryman. Seedlings possessing the bushy-multiple trunk habit of growth require more frequent suckering to attain a single trunk suitable for budding. Seedlings possessing the upright-single trunk habit of growth are easier to handle and require little, if any, labor to attain a single trunk suitable for budding.

"Unknown" chlorosis of Trifoliate orange.—That Trifoliate seedlings are very susceptible to lime chlorosis is well established and will be discussed in the following section.

The chlorosis presently under discussion is illustrated in Figure 3 and is quite distinct from lime chlorosis. The symptoms develop on rapidly growing, succulent, leaf and stem tissues. Once developed, the symptoms tend to persist and may remain throughout the life of the tissue.

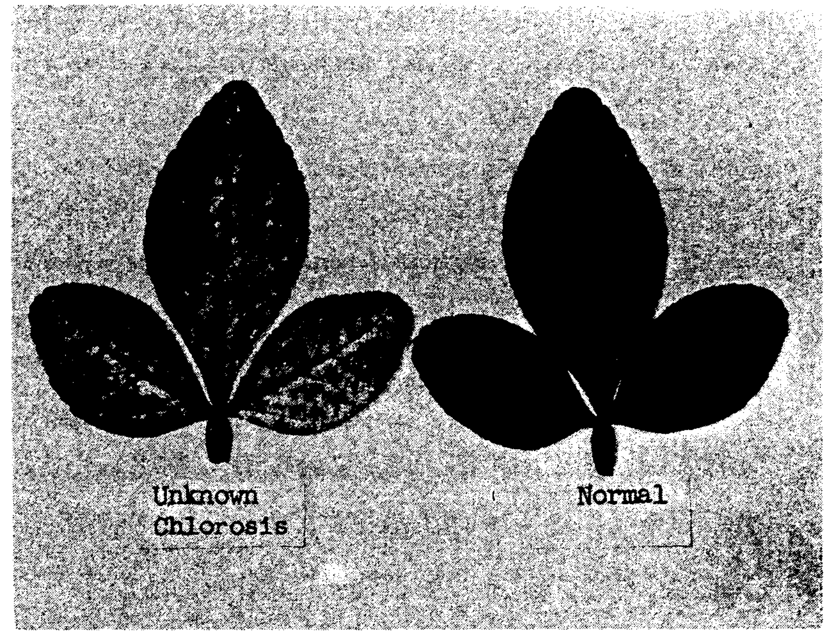

Figure 3. Normal Trifoliate orange leaf (right) and leaf showing symptoms of "unknown chlorosis" (left).

Affected leaves show irregular green spots surrounded by chlorotic tissue. The green spots vary in size and may be situated in interveinal tissue or directly on top of veinal tissue. Terminal growth is markedly diminished when the seedling develops this disorder.

Numerous experiments were undertaken to study this disorder. Results of these experiments indicate the disorder becomes apparent only when the seedlings are growing under environmental conditions which favor rapid succulent growth. Environmental factors favoring the development of the symptoms include: heavy nitrogen fertilization, high root temperature, 80 to 90° F., and high air temperature, 90 to 105° F.

Repeated experiments have demonstrated Trifoliate selections within the "large flowered" group are more susceptible to this disorder than selections within the "small flowered" group. As mentioned earlier, terminal growth of seedlings which develop symptoms of this disorder is markedly diminished. Hence, when seedlings are grown under environmental conditions conducive to the disorder, seedlings within the "small flowered" group frequently out-grow selections within the "large flowered" group. This is another illustration that certain nursery management practices may modify the relative vigor among the Trifoliate selections. The nature of this disorder is not established.

Susceptibility to lime chlorosis.—Uniform seedlings from each selection were transplanted from the germinating flat to 6-inch pots containing a mixture of 50% 20-mesh $CaCO_3$ and 50% clay loam. As a control, seedlings from each selection were transplanted to pots containing a mixture of 50% 20-mesh silica sand and 50% clay loam. These seedlings were maintained in the glasshouse throughout the one-year period of the experiment.

Immediately after transplanting to the 50% $CaCO_3$-50% soil mixture the new growth on seedlings from *each selection* developed severe symptoms of lime chlorosis. Very little new growth developed on these seedlings after the initial flush. When the experiment was terminated the control seedlings were luxuriantly green and over twice as large as the seedlings growing in the 50% $CaCO_3$-50% soil mixture.

These observations illustrate the growth of each selection tested was very markedly diminished when grown in soil containing lime. Hence it would appear that *not one of the 36 Trifoliate selections under study was resistant or tolerant to high lime soils.*

SUMMARY

This investigation was undertaken to gain information which may explain the nature of the variability in size of trees grafted on Trifoliate orange rootstocks. The present report describes the floral and seedling growth characteristics of 36 Trifoliate orange selections. The principal findings are summarized below:

(1) Floral characteristics indicated the Trifoliate selections could be divided into two distinct groups, a "small flowered" group and a "large flowered" group.

(2) Seedlings of selections within the "small flowered" group possessed a bushy habit of growth with multiple trunks; seedlings of selections within the "large flowered" group possessed an upright habit of growth with a single trunk.

(3) Seedlings of selections within the "large flowered" group were shown to be more susceptible to a condition described as "unknown chlorosis." Affected seedlings showed an unusual chlorosis pattern of the foliage and reduced terminal growth. Environmental factors favoring this disorder include heavy nitrogen fertilization, high soil temperatures, 80 to 90° F., and high air temperatures, 90 to 105° F.

(4) Very little difference in vigor among the Trifoliate selections was apparent when the seedlings were permitted to grow naturally. When the seedlings were continually suckered to maintain a single trunk suitable for propagation, however, the average weight of seedlings within the "large flowered" group was twofold greater than seedlings within the "small flowered" group.

(5) Five-year-old Washington navel orange trees grafted on Christian Trifoliate ("large flowered") were 20 per cent larger than trees

grafted on Rubidoux Trifoliate ("small flowered").

(6) Each of the 36 Trifoliate orange selections under study was shown to be very susceptible to lime-induced chlorosis.

(7) Insufficient data are available to determine if the variation in size of the original trees was due to genetic variability of the Trifoliate rootstock or to a virus carried by the scion.

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VEGETABLE SECTION

Control Studies of Curly-Top Virus Disease on Spinach in the Winter Garden Area of Texas

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The beet leafhopper, *Circulifer tenellus* (Baker), is the only known means by which curly-top virus is disseminated. Curly-top virus and its insect vector have been studied extensively in the sugar-beet-growing areas of the West. In the Winter Garden, Jones (1936) noted the first serious spinach losses due to the disease. Richardson (1957) found the leafhopper was present in this area the year around and did not arrive as a concentrated migration into the crop as in other parts of the West. Richardson and Raabe (1956) also studied transmission in the Winter Garden. None of these papers dealt with control methods.

It appears that curly-top virus is always present in the area and the disease can be seen on most susceptible hosts throughout the growing seasons. However serious losses of economic importance to crops are sporadic.

The purpose of this paper is to report the results secured from chemical control studies conducted during the 1958-59 growing season. The studies included tests on time of spray application, spraying interval, screening of spray and granular insecticides, and systemic insecticides.

MATERIAL AND METHODS

Experiments shown in Tables 1 and 2 consisted of plots arranged as randomized blocks having each treatment replicated 8 times. Each plot was 4 rows wide and 20 feet long. Experiments shown in Tables 3 and 4 were designed similarly except treatments were replicated 6 times. Treatments were applied to the first three rows leaving one guard row between plots. Seed treatment tests with systemic insecticides as shown in Tables 5 and 6 were replicated 6 times on one-row-plots 10 feet long. The small plots used were deemed necessary to minimize plant escape from virulent leafhopper feeding or, in other words, to detect the difference between plant escape and insect control with more accuracy.

Granules were weighed for each row and applied by hand. Sprays were applied by a compressed-air sprayer with one nozzle directly over the row. Thirty pounds of pressure per square inch delivered 5 gallons of liquid per acre. In the systemic seed treatment tests, granules and emulsions were applied in the seed furrow. In these monthly tests, one hundred hand-counted seeds were then put in the seed furrow and covered in each plot. The results secured are presented in Tables 5 and 6.

Dark green Bloomsdale spinach was used in all tests. Furrow irrigation was also used with the rows located on beds having 18-inch

centers. Seeds were planted on top of the beds to minimize leaching of the insecticides from one plot to another.

Treatments were evaluated by periodic counts at 15- to 20-day intervals of plants that definitely showed symptoms of curly-top virus disease. These plants were recorded and then removed from the plot. Counts were begun when the plants were 45 days old and continued for at least 6 inspections. Adjustment for stand was made in the monthly systemic tests.

Data were evaluated statistically to determine whether differences significant at the 5 per cent probability level existed by use of the F test. Duncan's New Multiple Range Test (Duncan, 1955) was then applied to evaluate differences between treatment means.

RESULTS

The test test was designed to investigate plant age in relation to susceptibility of the virus by spraying at various times and combinations to protect the plants from the beet leafhopper for certain periods of early plant growth. Results are shown in Table 1. It has been shown that melons are only susceptible when in the cotyledonary stage or 1-leaf stage (Hills, 1958). Seeds were planted on November 3 and spray treatments of 1¼ lb. active malathion per acre were begun on November 14. Analysis of the records taken showed that there were fewer diseased plants in the sprayed plots than in the untreated plots, but no significant differences appeared due to spray schedule and therefore plant age.

Data shown in Table 2 are from a test designed to compare three applications at three intervals and three toxicants. All plots were sprayed 11 days after planting to begin the spray interval schedules. All sprayed plots had less disease than the check. Treatments with Perthane at 7- and 21-day intervals and Sevin at 7-, 14- and 21-day intervals were more

Table 1. Effect of spraying 1¼ lb. active Malathion per acre at various times after seeding on the number of spinach plants showing curly-top virus symptoms.

Treatment Times	*Total number of plants with curly-top symptoms*
Nov. 14 (Cotyledonary)	25
Nov. 21	49
Nov. 28	36
Dec. 5	41
Nov. 14 and 21	32
Nov. 21 and 28	35
Nov. 14, 21 and 28	30
Nov. 14, 21, 28 and Dec. 5	28
Check	70

effective than Perthane on a 14-day schedule or Trithion in reducing curly-top diseased spinach plants.

Spinach in the test shown in Table 3 was seeded on November 7. The first spray was applied on November 19 when the plants were in the cotyledonary stage. A second spray was applied on December 1. Analyses showed all treatments were effective in reducing the number of diseased plants but no differences were apparent among the treatments. No phytotoxic symptoms occurred on the sprayed plants.

Table 2. Effect of three applications of three insecticides each at three different intervals in curly-top virus symptoms in spinach.

Material	*Intervals (days)*	*Pounds active/ acre/application*	*Total number of plants with curly-top symptoms*
Trithion	7	¾	35
Sevin	7	1	17
Perthane	7	1	10
Trithion	14	¾	24
Sevin	14	1	16
Perthane	14	1	21
Trithion	21	¾	37
Sevin	21	1	17
Perthane	21	1	13
Check			54

Table 3. Effect of two spray applications of various toxicants on curly-top symptoms in spinach.

Material	*Pounds active/ acre/application*	*Total number of plants with curly-top symptoms*
Methoxychlor	1½	10
Malathion	1¼	6
Diazinon	¾	16
Dibrom	¾	15
Thiodan	¾	10
Ethion	½	15
Foliafume*	1/5	16
DDT	1	14
Check		35

*57.2% oils, Cube extractives, Rotenone and Pyrethrins.

Table 4. Effect of granular formulations of several insecticides on curly-top virus symptoms in spinach.

Granular Material	*Pounds active/acre*	*Total number of plants with curly-top symptoms*
Malathion	1¼	13
Parathion	½	26
Toxaphene	2	22
Guthion	1	22
Korlan	1	21
Sevin	1	22
Thiodan	1	16
Check		45

Records obtained from one application of granular insecticides to plants in the cotyledonary stage on November 19, 12 days after planting are summarized in Table 4. All treatments reduced the incidence of obvious curly-top but there was no significant difference in the effectiveness of the various chemicals. No phytotoxicity resulted.

Data on the effects of systemic insecticides applied at planting time on plant stands are summarized in Table 5. Four tests in which seed were hand counted were planted in October, November, December, and January. Averages of these tests are shown. Emergence of plants were recorded 14 to 21 days after planting and final stand counts were taken 51 days later. Analysis of the results indicated that Thimet on carbon as a seed coating or as an emulsion in the furrow and American Cyanamid

Table 5. Effects of systemic insecticides as seed treatments on spinach seed emergence and final stand from four monthly experiments using counted seeds.

Material	*Lb. active per acre*	*Principal form*	*Average per 100 seeds per monthly test*	
			Emergence	*Final stand*
Thimet	¾	Granular	17.6	16.7
"	1½	"	14.1	**15.6**
"	¾	38D(carbon)	12.1	11.9
"	1½	Emulsion	9.1	**9.6**
#12880	¾	"	19.9	**17.6**
"	1½	"	17.7	16.0
#18706	¾	"	15.5	13.1
"	1½	"	14.8	12.3
Systox	¾	"	19.4	17.1
"	1½	"	17.9	18.5
Di-Syston	¾	Granular	19.2	18.5
"	1½	"	17.4	16.2
Check	----	----	22.4	22.1

Table 6. Effects of systemic insecticides as seed treatments on curly-top virus symptoms in spinach from four monthly tests using counted seeds.

Material	*Pounds active per acre*	*Principal form*	*Total percentage of diseased plants*
Thimet	¾	Granular	14.0
"	1½	"	15.6
"	¾	38D (carbon)	27.2
"	1½	Emulsion	24.0
#12880	¾	"	21.2
"	1½	"	16.8
#18706	¾	"	37.2
"	1½	"	37.2
Systox	¾	"	18.4
"	1½	"	22.8
Di-Syston	¾	Granular	19.6
"	1½	"	24.4
Check	----	---	36.8

#18706 significantly reduced the stand. Other chemicals showed no deleterious effects on the stand.

Economical control of curly-top disease by systemic insecticides is indicated by the records presented in Table 6. Other studies with systemic insecticides for beet leafhopper control have been conducted in the laboratory. There were no significant differences in reduction of curly-top plants due to the treatments used. However, some materials show promise. The disease appeared more prevalent in the October planting than any of the others.

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Gibberellin Foliar Spray on Fresh Market Carrots

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Carrots in the Winter Garden section suffered severe damage by Cercospora leaf spot and other blight diseases during the summer and fall of 1958. Weather conditions from August through November were most favorable for development of the disease and unfavorable for good plant growth. There were only 36 clear days during these 4 months, and the average soil temperature, 4 inches deep, ranged from 83° F. in August to 54° F. in November. The atmosphere generally was cool and moist. Carrots planted in August and September in most fields lost their foliage twice and developed slowly. A test to determine the effects of gibberellin on these diseased plants was conducted.

PROCEDURE

Emulsifiable Gibberellin as 0.5 per cent potassium gibberellate[1] was used in treatments of 5, 10, 20 and 50 parts per million. A Latin square design with six treatments was used. Two check plots were included in each replication, one untreated and one sprayed with water. Each plot was 20 feet long on a 36-inch row with plants in two bands on flat beds, and each was divided into two subplots so that two volumes of solution could be used. The solutions of the four treatments and water were applied at 4 and 16 gallons per acre on November 20 at 20 pounds per square-inch pressure and 4 miles per hour ground speed. Alternate rows were treated to allow for drifting spray. Wind movement was about 1 to 2 miles per hour when the treatments were applied.

The test was repeated in four fields of carrots of different ages on the same soil type. Planting dates for the respective fields were 1, August 21; 2, August 29; 3, September 14; and 4, October 10.

Measurements of top height were made 20 and 40 days after application, and field number 4 was measured 100 days after application. Field 1, 2 and 3 were harvested on February 16 and 17, and 4 was harvested March 24, 1959.

Harvest records were taken on field-graded carrots for cello pack from five feet in each subplot. Weights of marketable root were used for the comparison of yields. Yield differences between treatments and checks from field 2, August 29 planting, and field 4, October 10 planting, were too small to measure statistically. About December 1, temperatures were low enough to inhibit development of disease organisms, and the plants were able to grow normally. The younger plants did not lose their leaves.

[1] Samples under the trade name Gibrel were supplied by Merck & Company, Rahway, New Jersey.

RESULTS AND DISCUSSION

Measurable differences in yield were found in fields 1 and 3. In field 1, the carrots tops were in the poorest condition of all, with three or four new leaves per plant on November 20. Table 1 shows that in the oldest plants there were significant differences in yield between gibrel treatments and checks at 5, 10 and 20-ppm rates from the combined subplot weights. The greatest difference was at the 10-ppm rate. The highest rate produced little more than the checks.

Results from field 3 show that a significant difference was found between checks and the 10 and 20-ppm rates. The greatest increase came at the 20-ppm rate. Again the highest rate was the same as the checks.

Data for comparing top growth were obtained by taking the average plant height of three locations in each subplot. Measurements were taken from the ground surface to tips of leaves. No difference in leaf growth was found at any time in field 2. In field 4, the differences disappeared by the time the second reading was made and a third measurement, immediately before harvest, confirmed that all effects of the treatments were lost soon after application. Table 2 shows the amount of differences found in the three locations where significant increases occurred. The highest rate caused a highly significant increase in height wherever differences were found, but the weights of roots from these plots were about equal to the checks.

Table 1. Marketable carrots from gibrel treated plants.

	Pounds per acre	
Treatment	*Field 1*	*Field 3*
Check	12,502	21,018
Water	12,545	20,306
5 ppm	15,065	21,925
10 ppm	16,248	23,196
20 ppm	15,732	25,541
50 ppm	13,758	20,945
L.S.D. 5%	2,410	2,730
L.S.D. 1%	3,282	3,710

Table 2. Response of carrots to gibrel spray as shown by the amount of top growth 20 and 40 days after application.

	20 days			40 days		
	Field			Field		
Treatment	1	3	4	1	3	4
Check	129[1]	148	91	221	250	114
Water	130	158	95	226	247	98
5 ppm	160	161	111	249	273	107
10 ppm	167	180	112	255	282	112
20 ppm	159	191	149	262	288	111
50 ppm	188	190	150	279	305	122
L.S.D. 5%	18	23	11	20	21	N.S.
L.S.D. 1%	25	31	15	27	29	

[1] Measurements as millimeters high.

No difference was found between the two volumes of output for applying the spray.

Carrots in all fields outside the test areas were harvested. Tonnage was lower than in more favorable seasons. Under similar conditions, a farmer may expect to obtain 2 to 2½ tons increase per acre by applying gibrel in the proper amounts at the proper time. A rate of application for best results seems to be between 10 and 20 ppm.

SUMMARY

Carrots in the Texas Winter Garden area were damaged severely by Cercospora leaf spot and other blight diseases during the 1958-59 growing season. A test was designed to find the effects of 0.5 per cent potassium giberrellate on plants of four ages.

Application of 10 parts per million gibrel in water on the oldest and most damaged plants gave a highly significant yield increase. On the third group, 20 ppm caused a highly significant increase. An application rate between these two seems to be indicated to give best results under conditions of this test.

This test indicates that, under extremely adverse growing conditions, a gibrel spray will have some beneficial effect on fresh market carrots. Tonnage probably will be 25 to 30 per cent less than in favorable growing conditions.

Use of gibrel spray for revitalizing blighted carrots is not recommended at this time, because there are so many unknown factors about timing, rates of application and plant condition. Use of the spray would be almost a salvage operation in fields like those in which these plots were located.

Evaluation of Insecticides, Gallonage and Pressure For Corn Earworm Control

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The corn earworm, *Heliothis zea* (Boddie), is a major factor limiting the production of sweet corn in the Lower Rio Grande Valley. Although effective chemical control measures are available, commercial growers maintain that the number of insecticide sprays required to produce worm-free corn is too costly. Corn earworm control tests in the spring of 1959 were designed (1) to evaluate insecticides and (2) to study the effect of variations in pressure used to deliver spray material and in the rate of gallonage applied per acre for corn earworm control.

MATERIALS AND METHODS

Experimental plots located in a field of Calumet sweet corn consisted of one row, 30 ft. long, replicated four times in a randomized complete block. Dusts were applied with a hand duster at a rate of 20 lbs. per acre. Spray applications were made by treating both sides of each plot row with a 3-gallon compression sprayer.

Nine insecticides were included in the screening test. Three applications of each spray material were made at 3-day intervals beginning on May 7. The Sevin* (1-napthyl-N-methyl carbamate) dust plots received treatments at 2-day intervals. All sprays included mineral oil at the rate of 1.5 gallons per acre with the exception of the Dylox* (0,0,dimethyl 2,2,2-trichloro-1-hydroxethyl phosphonate) spray. Insecticides were applied at 65 lbs. pressure p.s.i. at 20 gallons of water per acre. Earworm damage was recorded from 15 ears per plot on May 21 and expressed as the percentage of worm-free ears.

The effects of pressure and water gallonage were evaluated in a second test with DDT (.75 lbs/A). Five, 10, 20, 30 and 40 gallons of water per acre each was tested at 30 and 60 lbs. pressure p.s.i. In addition, 1.5 gallons of mineral oil per acre was compared in 10 and 40 gallons of water. Three applications were made at 3-day intervals on May 14, 17 and 20. Fifteen ears per plot were examined on May 28 for earworm damage.

RESULTS AND DISCUSSION

The number of effective toxicants for corn earworm control was limited (table 1). DDT (2 lbs/A), Sevin dust, and Sevin spray at 1.5 and 1.0 lbs. per acre gave good control. Dibrom* (0,0-dimethyl-0-(1,2-dibromo-2,2-dichloroethyl)phosphate) and Guthion* (0,0-dimethyl S-(4-oxo-3H-1,2,3-benzotriazine-3-methyl)phosphorodithioate) were superior to most of the remaining materials. Toxaphene, Dylox, Trithion* (S(p-chlorophenylthio)methyl 0, 0-diethylphosphorodithioate), Delnav* (2,3-p-dioxanedithiol S,S-bis(0,0-diethyl phosphorodithioate)) and ethion did not produce economical control.

*Registered Trademark

The addition of mineral oil to DDT for use in corn earworm control was more important than the variations in gallonage and in pressure of application in the second test (table 2). A greater degree of control resulted as the rate of water gallonage increased, with a linear relationship existing between the volumes of 10 and 40 gallons per acre. Pressure did not exert an effect on the DDT efficiency. The addition of mineral oil (1.5 gal/A) to DDT provided the most significant effect by greatly increasing earworm control based on the limited gallonages used in this particular test.

DDT (2 lbs/A) with oil (1.5 gal/A) is still the most economical control measure for the corn earworm. Three applications applied at 3-day intervals appear to be sufficient for economic control provided that applications are started at the proper time. The first spray should be applied when approximately 10 per cent of the corn has silked. Sevin at 1.0 lb. per acre is equally effective as DDT, but the former is not as economical as the latter at this time.

Table 1. Corn earworm control with organic insecticides. Weslaco, Texas, 1959

Treatment			*Percent*
Toxicant	*Lbs./A*	*Formulation*	*Undamaged Ears*[3]
Sevin (7 appl.)[1]	2.0	10% Dust	100
Sevin	1.5	85% W.P.	100
DDT	2.0	2#/gal. Emul.	98
Sevin	1.0	85% W.P.	97
Sevin (5 appl.)[2]	2.0	10% Dust	95
Sevin	0.75	85% W.P.	93
Guthion	1.0	1.5#/gal. Emul.	92
Dibrom	2.0	3#/gal. Emul.	87
Dibrom	1.0	8#/gal. Emul.	75
Toxaphene	3.0	6%/gal. Emul.	70
Dylox	2.0	50% S.P.	68
Trithion	1.0	4#/gal. Emul.	57
Delnav	1.0	4#/gal. Emul.	55
Ethion	0.5	4#/gal. Emul.	52
Ethion	1.0	4#/gal. Emul.	38
Check			10

[1] Applications made on May 6, 8, 10, 12, 14, 16 and 18.
[2] Applications made on May 6, 8, 10, 12 and 14.
[3] Means paralleled by the same line are not significant at $P = .05$, as determined by Duncan's test.

Table 2. Effect of water gallonage, pressure and oil on corn earworm control with DDT.

Weslaco, Texas, 1959

Treatment[1] Gallonage/A	*Pressure*	*Damage Free Ears per 15 Ears Examined*
Without oil		
5	30	2.3
5	60	4.0
10	30	4.0
10	60	4.8
20	30	5.8
20	60	4.5
30	30	7.5
30	60	4.8
40	30	6.8
40	60	6.8
With oil (1.5 gal/A)		
10	30	9.5
10	60	10.8
40	30	12.0
40	60	10.8
Check		0
	For gallonage	F = 4.1^{**}
	For pressure	F = 0.3 n.s.
	Pressure vs. gal.	F = 1.5 n.s.
	10 gal. + oil vs. 40 gal. + oil	F = 1.5 n.s.
	10 gal. vs. 10 gal. + oil	F = 33.0^{**}
	40 gal. vs. 40 gal. + oil	F = 21.5^{**}

[1] DDT (25% Emul.) applied at .75 lbs. actual per acre.

An increase in water gallonage will enhance the effectiveness of DDT. This effect of gallonage is probably greater when oil is not used. More data will be required before statements can be made with regard to the effect of gallonage when mineral oil is added to DDT. Since a linear relationship existed between the worm control and water gallonage in this test, the optimum volume of liquid has not been determined. Apparently, it is somewhat greater than 40 gallons per acre.

SUMMARY

Corn earworm (*Heliothis zea*, Boddie) tests were conducted in the spring of 1959 on sweet corn to evaluate insecticides and compare various pressures and water gallonages for worm control.

Only a limited number of insecticides gave satisfactory earworm control. DDT at 2 lbs. per acre and Sevin at 1.5 and 1.0 lbs. per acre were

the most effective. Dibrom* (0,0-dimethyl-0-(1,2-dibromo-2,2-dichloroethyl)phosphate) and Guthion* (0,0-dimethyl S-(4-oxo-3H-1,2,3-benzotriazine-3-methyl) phosphorodithioate) were superior to the remaining materials tested. A linear relationship existed between earworm control and water gallonage. Increasing control resulting from higher amounts of water when the gallonage was varied from 5 to 40 gallons per acre. Pressure had no significant effect upon corn earworm control.

*Registered Trademark

Pre-Emergence Chemical Weed Control in Cabbage[1]

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Hand-weeding of fall-seeded cabbage is costly in the Rio Grande Valley of Texas. Weed-control measures are most critical just after planting, since weed competition is greatest during early stages of growth. Applications of 20 lb/A of trichloroacetic acid (TCA) or 10 lb/A of octachlorocyclohexenone (OCH) were satisfactory for pre-emergence weeding of cabbage on muck (Guzman and Wolf, 1955). In Virginia, Danielson (1957) found that 2-chloroallyl diethyldithiocarbamate (CDEC) had practical possibilities for control of annual grasses and certain broadleaf weeds in cabbage when applications were made immediately after planting. In Florida, pre-emergence applications of CDEC controlled annual weeds in organic soils without effect on yield or quality of cabbage (Guzman, 1957).

The main objective of the experiments reported here was to evaluate CDEC and certain other herbicides, alone and combined, for residual and contact pre-emergence weed control in cabbage.

PROCEDURE

Experiment 1

Harlingen clay was disked and then listed into beds and furrows. On October 1, 1957, Marion Market cabbage was seeded ⅓ in. deep in a single row on beds 12 in. wide. Each plot was composed of one bed, 25 ft. long.

Residual pre-emergence treatments were made to air-dry soil, one day after seeding. Herbicides were sprayed in a pattern 18 in. wide on each plot. The herbicides[1] applied in 40 gpa (gallons per acre) of aqueous solution are as follows: 2-chloro-4,6-bis(diethylamino)-*s*-triazine (chlorazine), isopropyl *N*-(3-chlorophenyl) carbamate (CIPC), *sec*-butyl *N*-(3-chlorophenyl) carbamate (BCPC), 1-chloro-2-propyl *N*-(3-chlorophenyl) carbamate (CPPC), CDEC, ethyl *N*, *N*-di-*n*-propylthiolcarbamate (EPTC), TCA, 1-*n*-butyl-3-(3,4-dichlorophenyl)-1-methylurea (neburon), chlorazine plus CIPC, chlorazine plus TCA, and a-chloro-*N*-ethyl-*N*-phenyl acetamide.[2] Rates of application are shown in Table 1. Three

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[1] Cooperative study of the Texas Agricultural Experiment Station and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture. Rio Farms, Inc., Monte Alto, Texas and McManus Farms, Progreso, Texas cooperated in these studies. Mr. Amon Dacus, Rio Farms Research Representative, was especially helpful.

[1] Many of the herbicides mentioned in this report have not been registered for use on cabbage and therefore cannot be recommended as of April 6, 1960.

[2] Herbicide 6936, Monsanto Chemical Company, St. Louis, Missouri.

of 6 replications of plots treated with 9 lb/A of CIPC were hand-raked before treatment in an attempt to provide a smoother surface for better spray deposit and weed control.

Contact pre-emergence treatments of Stoddard solvent were made 5 days after seeding at 20 and 40 gpa. OCH was applied at 10 and 15 lbs. in 40 gpa of Stoddard solvent. A number of weeds and a few cabbage plants had emerged.

All treatments were replicated 3 times in a randomized-block design. Weeds in furrows were controlled by a tractor-mounted cultivator.

Plots were furrow-irrigated one day after the first treatments and approximately every 2 weeks thereafter. Rainfall of 0.03 in. was recorded 7 days after treatment. Mean maximum and minimum temperatures for a one-week period after residual treatments were 92.1° F. and 65.1° F., respectively, and for a 3-week period, 89.4° F. and 67.7° F.

Experiment 2

Willacy fine sandy loam was disked and then listed into beds and furrows. On September 11, 1959, Globe Y. R. Cabbage was seeded ¼ in. deep in 2 rows spaced 12 in. apart on beds 38 in. wide. Plots consisted of 2 beds, each 17 ft. long.

Pre-emergence treatments were made the day of seeding to air-dry soil in 100 gpa of aqueous solution. Herbicides were CDEC, CIPC, EPTC, TCA, CDEC plus CIPC, CDEC plus EPTC, CDEC plus TCA, and EPTC plus CIPC. Rates of application are listed in Table 2. Herbicides were sprayed on each bed in a pattern 18 in. wide. Treatments were replicated 3 times in a randomized-block design. Weeds in furrows were controlled by tractor cultivation.

Plots were furrow-irrigated just after treatment and approximately every 2 weeks thereafter.

Recorded rainfall was 2.50 in. 23 days after treatment. The mean maximum and minimum temperatures for a one-week period after treatment were 93.0° F. and 67.5° F., respectively, and for a 3-week period, 93.7° F. and 72.2° F.

Fresh cabbage from check plots and plots treated with 6 and 8 lb/A of CDEC was shredded and presented to a panel of 14 judges for triangular taste analyses[1] (Roessler et al., 1948).

RESULTS AND DISCUSSION

Experiment 1

The weed population was composed mainly of carelessweed (*Amaranthus palmeri*), watergrass (*Echinochloa colonum*), and purslane (*Portulaca oleracea*). Weeds were satisfactorily controlled by applications of

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[1] Sampled from the second harvest.

10 and 15 lb/A of OCH, 4 and 6 lb/A of EPTC, 6 lb/A of chlorazine, CDEC, and a-chloro-*N*-ethyl-*N*-phenyl acetamide, 2½ and 5 lb/A of neburon, 20 and 40 gpa of Stoddard solvent, and 3 lb/A of chlorazine plus 6 lb/A of CIPC (Table 1).

Applications of CIPC and BCPC controlled grasses but failed to control broadleaf weeds. Applications of CDEC and neburon controlled broadleaf weeds more effectively than grasses.

Chlorosis and necrosis were observed in leaf tips of cabbage plants treated with neburon. Applications of 6 lb/A of EPTC caused fused terminals and temporary stunting of cabbage. Chlorazine, applied at 6 lb/A, produced severe chlorosis of leaves and stunting of maturing cabbage; phytotoxic effects from the 3-lb. rate were slight. Necrosis of cabbage leaves was observed in plots treated with 15 lb/A of OCH.

The only treatments which reduced the stand were 6 lb/A of chlorazine and 2½ and 5 lb/A of neburon; applications of 15 lb/A of OCH and 9 lb/A of CIPC (hand-raked plots) tended to reduce stand (Table 3).

Treatments which decreased the total yield of cabbage were 6 lb/A of chlorazine, 10 and 15 lb/A of OCH, 2½ and 5 lb/A of neburon, and 9 lb/A of CIPC (hand-raked plots) (Table 3). Yield reductions were caused by treatment effects on stand of cabbage. Other treatments had no significant effect on yield. When hand-raking after seeding exposed cabbage seeds to the herbicide spray, applications of 9 lb/A of CIPC reduced stand and yield.

There was no effect of pre-emergence applications of herbicides on maturity or head size of cabbage (Table 2).

Experiment 2

The weed population was composed mainly of carelessweed. Soil-surface applications of 8 lb/A of CDEC controlled weeds effectively (Table 2). CDEC, at 4 lb/A, failed to control weeds when applied to the soil surface but controlled weeds effectively when incorporated or covered with soil. All other herbicide treatments failed to control weeds. Soil incorporation or covering failed to enhance the performance of 6 lb/A of CIPC and 3 lb/A of EPTC.

Herbicide treatments had no significant effect on stand of cabbage (Table 4). Weed competition tended to reduce cabbage yield, but the reduction was insignificant as indicated in the comparison of yields from hand-weeded and undisturbed checks. Herbicide treatments had no significant effect on yield or head size of cabbage.

Pre-emergency applications of 6 and 8 lb/A of CDEC had no effect on taste of cabbage; 6 of 14 judges determined a flavor difference.[1]

[1] Nine of 14 judges must consistently determine a flavor difference for statistical significance (5%).

SUMMARY

Two field experiments were conducted to evaluate certain herbicides, alone and combined, for residual and contact pre-emergence weed control in cabbage.

The outstanding herbicide was CDEC.

Table 1. Effect of pre-emergence applications of herbicides on weed control in cabbage. Exp. 1. Harlingen clay.

		No. of weeds in 3 sq. ft. in each plot[1]		
Herbicide	*Rate (lb/A)*	*Broadleaf weeds*	*Grass weeds*	*Percentage weed control*[1, 2]
chlorazine	3	23	32	53
	6	13	14	77
CIPC	6	16	7	73
	9	23	7	57
CIPC[3]	9	21	7	72
BCPC	9	19	7	70
CPPC	6	21	16	62
	9	27	26	60
CDEC	4	11	21	72
	6	1	18	82
EPTC	4	6	12	80
	6	7	4	88
TCA	6	16	24	58
	12	32	14	43
neburon	2½	9	18	78
	5	4	13	87
OCH	10	3	8	92
	15	2	3	97
a-chloro-*N*-ethyl-*N*-phenyl acetamide	4	19	11	72
	6	25	27	75
chlorazine + CIPC	3+6	16	6	77
chlorazine + TCA	3+8	16	11	73
None, hand-weeded check		0	0	100
None, undisturbed check		25	35	45
Stoddard solvent	20 gal.	10	7	87
	40	14	12	75
L.S.D. 5%		11	17	18

[1] Data obtained 4 weeks after seeding; plots were then hand-weeded and maintained weed-free, thereafter.
[2] Visual estimates.
[3] Hand-raked plots.

Experiment 1

On a Harlingen clay, pre-emergence applications of 6 lb/A of CDEC controlled weeds without injury in cabbage; the 4-lb. rate of the herbicide failed to control weeds. Applications of Stoddard solvent, EPTC, and chlorazine plus CIPC were promising although the growth of cabbage was temporarily stunted by 6 lb/A of EPTC. Herbicides that failed to control weeds were CIPC, BCPC, CPPC, a-chloro-*N*-ethyl-*N*-phenyl acetamide, TCA, and chlorazine plus TCA. Herbicides that reduced the yield of cabbage were neburon and OCH. Chlorazine failed to control weeds at the 3-lb. rate and reduced the yield of cabbage at the 6-lb. rate.

Table 2. Effect of pre-emergence applications of herbicides on weed control in Globe Y. R. cabbage. Exp. 2. Willacy fine sandy loam.

Herbicide	*Rate (lb/A)*	*Percentage control of broadleaf weeds*	
		Plant counts[1]	*Visual estimates*
CDEC	4	51	53
	6	56	60
	8	75	82
CIPC	6	37	22
	8	32	26
	10	29	27
EPTC	3	28	33
	6	50	44
TCA	8	50	25
	12	28	20
CDEC[2]	4	77	82
CIPC[2]	6	44	29
EPTC[2]	3	57	42
CDEC[3]	4	83	86
CIPC[3]	6	57	48
EPTC[3]	3	17	43
CDEC + CIPC	3+4	60	51
CDEC + EPTC	3+2	51	42
CDEC + EPTC	4+3	60	62
CDEC + TCA	3+6	47	61
EPTC + CIPC	3+4	32	31
None, hand-weeded check		100	99
None, undisturbed check			11
L.S.D. 5%		28	11

[1] Average count in each herbicide treatment individually compared with that of undisturbed check. Average broadleaf weed count in undisturbed checks was 23.8 per sq. ft. of row. All data collected 4 weeks after treatment; plots were hand-weeded and maintained weed-free, thereafter.

[2] Soil-surface applications were incorporated with the surface 1½ in. of soil, with a rake.

[3] Soil-surface applications were covered with ½ in. of soil.

Table 3. Effect of pre-emergence applications of herbicides on stand, yield, head size and maturity of Marion Market cabbage. Exp. 1. Harlingen clay.

Herbicide	*Rate (lb/A)*	*Harvested from one plot*[1]			
		No. of heads[2]	*Total weight (lb)*	*Total weight from first 3 harvests (lb)*	*Av. weight per head (lb)*
chlorazine	3	16.0	37.6	13.5	2.31
	6	10.3	23.4	6.5	2.37
CIPC	6	18.3	41.6	20.9	2.20
	9	17.0	40.6	19.3	2.36
CIPC[3]	9	12.6	32.2	12.2	2.54
BCPC	9	18.0	41.7	21.0	2.34
CPPC	6	18.6	40.8	24.0	2.29
	9	18.3	43.0	19.0	2.33
CDEC	4	17.3	39.0	23.8	2.34
	6	20.0	42.7	26.5	2.17
EPTC	4	18.6	46.9	23.5	2.52
	6	15.6	35.9	22.6	2.37
TCA	6	18.6	44.1	20.9	2.38
	12	16.6	38.0	21.1	2.32
neburon	2½	10.6	26.0	13.1	2.40
	5	8.3	16.7	6.3	1.37
OCH	10	14.0	24.4	13.3	1.93
	15	12.3	32.4	11.2	2.62
a-chloro-*N*-ethyl-phenyl acetamide	4	19.0	42.8	28.9	2.30
	6	17.6	40.7	22.9	2.30
chlorazine + CIPC	3+6	16.6	38.4	18.7	2.36
chlorazine + TCA	3+8	14.6	36.1	15.3	2.42
None, hand-weeded check		18.6	46.6	30.7	2.40
None, undisturbed check		18.6	44.6	21.7	2.41
Stoddard solvent	20 gal.	18.3	42.5	32.8	2.35
	40 gal.	20.6	45.4	19.5	2.20
L.S.D. 5%		6.5	13.1	13.6	N.S.

[1] Averages of 3 replications. Treatment data compared with average of all check plots. Harvests made January 21 and 31, February 13 and 24, and March 5, 1958.

[2] Stand of cabbage after the thinning operation.

[3] Hand-raked plots.

Contact pre-emergence treatments compared favorably with residual pre-emergence treatments in weed control.

There was no treatment effect on maturity or head size of cabbage.

Experiment 2

On a Willacy fine sandy loam, application of 8 lb/A of CDEC controlled carelessweed without crop injury. The 4-lb. rate of CDEC, applied to the soil surface and followed by furrow irrigation, failed to control weeds; it performed satisfactorily when applications were incorporated or covered with soil before furrow irrigation. Other herbicide treatments that failed to control weeds were 6 lb/A of CDEC, 6, 8, and 10 lb/A of CIPC, 3 and 6 lb/A of EPTC, 8 and 12 lb/A of TCA, and 4 combined-herbicide treatments.

Applications of 6 and 8 lb/A of CDEC had no effect on flavor of cabbage.

Table 4. Effect of pre-emergence applications of herbicides on stand, yield and head size of Globe Y. R. Cabbage. Exp. 2. Willacy fine sandy loam.

Herbicide	*Rate (lb/A)*	*Plants on one plot*[1] *(no.)*	*Total wt. per plot*[1,2] *(lb)*	*Av. wt. per head (lb)*
CDEC	4	20.6	39.1	2.02
	6	24.0	51.7	2.33
	8	22.0	41.7	2.11
CIPC	6	23.6	42.8	2.08
	8	24.3	42.5	2.06
	10	17.3	35.9	2.13
EPTC	3	18.6	31.4	1.81
	6	17.6	34.0	1.98
TCA	8	27.3	47.5	1.98
	12	21.0	32.8	1.93
CDEC + CIPC	3+4	30.0	49.0	1.92
CDEC + EPTC	3+2	20.3	41.4	2.22
CDEC + EPTC	4+3	23.3	41.7	2.02
CDEC + TCA	3+6	18.6	37.5	2.31
EPTC + CIPC	3+4	25.0	30.8	1.85
None, hand-weeded check		24.6	50.9	2.35
None, undisturbed check		26.3	39.3	1.91
L.S.D. 5%		9.5	15.7	N.S.

[1] Average of 3 replications. Harvests made December 30, 1959 and Jan. 8, 18, 28, and Feb. 4, 1960. Data recorded from one row per bed since high salt concentrations in soil prevented cabbage seed germination in the second row.

[2] Mean plot yield from 8 lb/A of CDEC was compared with that of hand-weeded check, whereas mean yields from other treatments were individually compared with that of undisturbed check since only 8 lb./A of CDEC controlled weeds effectively.

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The Effect of Row Spacing on Green Bean Varieties

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The average yields of green snap beans in Texas are lower than in other areas of production. Yield data published in Western Canner and Packer magazine (1955), shows Texas has comparatively low yields ranging from .9 tons to 2.4 tons per acre, compared with Oregon's high yield of 8.1 tons per acre and California with 7.4 tons. The major part of the crop of green beans grown in Texas are bush type beans, while Oregon and California grow more productive types of pole beans. The green beans grown in Texas are mostly grown for processing and must compete on the market with beans grown and processed in other sections of the nation. In order to more economically compete with other bean producing areas, improved cultural practices and subsequent higher yields are required of Texas. Increased plant populations by revisions in plant spacings and row widths have been studied by a number of workers.

Matthews (1933) studied the effect of spacing green bean plants closer together in the row and found that 3-inch plant spacing of both Refugee and Burpee varieties resulted in earlier and in larger total yields. Warren (1950) used 2, 4, and 8 inch spacing in 1947 and 1, 2, and 4 inch spacing in 1948 between Henderson bush lima bean plants in rows 36 inches and 30 inches apart and found the yield per plant decreased yet the yield per acre increased progressively as the rate of seeding was increased. Neither rate of seeding had any effect on maturity as measured by percentage of white beans when harvested. Larson and Li (1948) using spacings of 2, 4, and 8 inches reported that close spacing gave the highest yields of Henderson bush lima beans. Vittum, et al (1958) reported that English pea seeds were sown in 7-inch spaced rows at the normal rate of 337,000 plants per acre, half-normal by doubling the spacing of rows, 2/3 normal by adjusting row spacing and 2/3 normal by reducing row density. The higher the seeding rate the higher the yield per plant. Maturity was unaffected by spacing but seed size was significantly reduced by doubling the spacing of rows.

The purpose of this investigation was to study the effects of row spacing on yield and sieve size of pods of green beans. Also the effect of row spacing on seed and fiber percentage and possible sensory differences of the pods of the canned product due to closer spacing of rows of beans.

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

METHODS AND MATERIALS

The beans for this experiment were grown at Substation 15, Texas Agricultural Experiment Stations, and canning evaluations made by the U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas. Three varieties of green beans, Topcrop, Topmost and Pearlgreen were planted the fall of 1958, one row in the center of a 38-inch bed, and in paired 14-inch rows on beds 38 inches wide. In the spring and fall of 1959 the paired 14-inch rows on beds were replaced by paired rows 12 and 6 inches apart on beds 38 inches wide and 3 additional varieties, Harvester, Earligreen and Tenderwhite, were included in the tests. The test design was that of a randomized block with 4 replications; the plots were 40 feet long. The beans were harvested twice during the season and the yield in pounds of pods per acre was calculated. The bean plants were counted in all plots and plant spacing in the rows determined. An early frost the fall of 1959 reduced total yields of pods.

Composite samples of pods from the row spacing plots were size graded in a commercial type green bean grader, into 1 to 3's inclusive, 4's, 5's and 6's and larger, and the percentage for each sieve size calculated. The pods of sieve size 5 only were canned. Sufficient pods to fill 6 No. 303 (303x406) cans for each row spacing were blanched 2½ minutes at 185° F. and vertically packed hot, 310 grams into each can. All cans were filled with boiling 2% brine, closed and processed 25 minutes at 250° F.

After approximately one month storage at room temperature the cans were opened and the pods evaluated for percentage seed and percentage fiber in the pods, according to the U. S. Standards for Grades of Canned Green Beans and Canned Wax Beans (1953).

A sensory panel of 9 judges evaluated the canned pods for differences due to row spacing. The triangle taste test method of Roessler, et al (1948) was used to make the evaluations. Each member of the panel was presented 3 samples of pods, 2 alike, consisting of pods from rows spaced 38 inches apart, and 1 different, pods from rows either 14, 12, or 6 inches apart, and asked to pick the different sample. The order of sample presentation was changed and the process repeated.

RESULTS AND DISCUSSION

The row spacing tests of green beans in the fall of 1958 showed that spacing the rows 14 inches apart on beds increased total yield of pods over the 38-inch spaced rows by 71 to 95%, depending on variety (Table 1). An examination of data also indicated that pods from rows spaced 14 inches apart on beds were possibly less mature than pods from rows spaced 38 inches apart, because the percentage seed and percentage fiber in the pods were less for the pods from paired 14-inch rows. However, there were neither consistent differences in percentage of sieve sizes due to row spacing, nor could a sensory panel detect differences in pods of canned sieve size 5 due to row spacing.

Because there was increased yields from the closer spaced rows of beans and possible differences in percentage seed and percentage fiber in the canned product, the design of the experiment was changed the spring and fall of 1959 to include paired rows spaced 12 inches apart and 6 inches apart on 38-inch beds. The plots were planted so that additional rows of bean plants per plot would not be increased but the rows would be closer together; therefore, competition for available water and nutrients and other physiological changes could influence yields per acre.

The varieties Harvester, Earligreen and Tenderwhite were included in the test to obtain more information on additional varieties that may become commercially important in this area.

All but one of the varieties included in the spring and fall of 1959 tests increased in total pod production per acre when rows were spaced either 12 or 6 inches apart, compared with rows spaced 38 inches apart (Tables 2 and 3). A poor plant stand in plots with rows 12 inches apart of Harvester variety, in the fall of 1959 caused a decrease of 19 per cent in total yield below that of rows spaced 38 inches apart.

Topcrop variety which increased 95 per cent in total pod production in 1958 with rows spaced 14 inches apart over rows spaced 38 inches apart, increased 80 per cent in the spring of 1959 with rows 12 inches apart over 38-inch rows, but increased only 62 per cent for rows spaced 6 inches apart over the 38-inch rows. It appeared this variety would produce more pods per acre with rows 12 or 14 inches apart but in the fall of 1959 (Table 3) the rows spaced 6 inches apart produced 70 per cent more pods per acre than rows spaced 38 inches apart and 22 per cent more than rows 12 inches apart. The 3 seasons this variety has been tested the closer row spacing, either 12 or 14 inches apart, has increased production over rows spaced 38 inches apart. Rows of Topcrop spaced 6 inches apart decreased in total production the spring of 1959 and increased the fall of 1959. This may be attributed to less cold wind damage to plants when rows are spaced closer together.

The spring of 1959 Topmost increased 82 per cent in total pod production for rows spaced 12 inches apart over rows spaced 38 inches apart (Table 2). Beans in rows spaced 6 inches apart increased in yields only 50 per cent or 32 per cent less than rows spaced 12 inches apart. In the fall of 1959 the same relationship existed between row spacing and total yield of pods per acre. Beans in rows spaced 12 inches apart increased 42 per cent over the 38-inch spaced rows, while rows spaced 6 inches apart increased only 24 per cent over 38-inch spaced rows. Spacing the rows of beans 6 inches apart for Topmost apparently crowds the plants, which reduces total yields of pods per acre.

Pearlgreen followed the same general trend in the production of pods as did Topmost. In the spring of 1959 there was an increase in total production of 107 per cent for rows spaced 12 inches apart over rows spaced 38 inches apart, and a 35 per cent increase in the fall trials. The beans in rows spaced 6 inches apart increased in total production for both

Table 1. Results of row spacing tests of green bean varieties, Fall 1958.

Variety	Row Spacing in.	Plant Spacing in.	1-3's %	Sieve Sizes 4's %	5's %	6's + %	Total lbs./Acre Yield	Processed Quality % Seed	% Fiber
Topcrop	38	3.1	17.7	16.8	30.6	34.9	3821	4.5	.04
	14	3.0	16.5	16.0	30.2	37.3	7450	4.4	.03
Topmost	38	2.7	14.6	16.7	29.4	39.3	4093	5.0	.03
	14	2.7	18.3	17.4	29.5	34.8	6990	3.4	.01
Pearlgreen	38	3.9	19.5	22.0	42.6	15.9	3568	4.4	.03
	14	4.6	18.5	20.8	40.8	19.9	6158	3.3	.02

Table 2. Results of row spacing tests of green bean varieties, Spring 1959.

Variety	Row Spacing in.	Plant Spacing in.	1-3's %	Sieve Sizes 4's %	5's %	6's + %	Total Yield lbs./Acre	Processed Quality Seed %	Fiber %
Topcrop	38	3.7	10.8	12.9	35.5	40.8	5206	9.5	.09
	12	3.9	12.5	12.3	33.2	42.0	9380	11.6	.06
	6	3.8	13.5	15.8	32.1	38.6	8433	11.3	.07
Topmost	38	3.7	13.9	14.3	36.8	35.0	4667	5.9	.08
	12	4.0	13.9	13.3	32.2	40.8	8495	5.9	.09
	6	4.0	11.8	13.9	32.8	41.5	6992	6.7	.07
Harvester	38	4.1	41.7	41.1	16.4	.8	3054	12.4	.15
	12	4.1	40.7	41.6	16.5	1.2	5571	15.5	.15
	6	3.8	34.4	42.0	21.6	1.5	4174	16.3	.18
Pearlgreen	38	3.5	14.7	24.7	51.0	9.6	3785	9.5	.09
	12	3.8	14.0	23.0	51.8	11.2	7848	10.4	.10
	6	3.9	15.0	25.6	50.3	9.1	7270	9.7	.09
Earligreen	38	4.5	22.9	44.4	32.7	.0	2300	7.7	.14
	12	4.2	16.2	39.8	42.6	1.4	4387	8.6	.15
	6	4.3	16.6	38.6	42.6	2.2	4858	9.0	.15
Tenderwhite	38	4.7	18.4	33.1	45.6	2.9	1913	7.1	.08
	12	4.2	15.8	24.9	52.4	6.9	4391	7.1	.12
	6	4.0	17.3	26.4	49.2	7.1	3420	8.6	.09

Table 3. Results of row spacing tests of green bean varieties, Fall 1959.

Variety	Row Spacing in.	Plant Spacing in.	1-3's %	Sieve Sizes 4's %	5's %	6's + %	Total Yield lbs./Acre	Processed Quality Seed %	Fiber %
Topcrop	38	4.3	26.5	23.0	38.3	12.2	3505	6.5	.02
	12	4.1	23.3	25.0	38.8	12.7	5185	8.8	.03
	6	4.3	21.9	23.7	39.8	14.7	5960	8.3	.04
Topmost	38	3.6	34.1	27.4	30.4	8.1	3950	4.1	.03
	12	4.3	32.6	25.5	32.9	9.0	5591	4.4	.04
	6	4.2	33.2	28.9	29.7	8.2	4883	5.0	.06
Harvester	38	6.2	70.8	24.3	4.9	.0	2042	6.4	.05
	12	13.2	67.9	25.6	6.4	.0	1659	6.4	.07
	6	8.0	64.9	28.8	6.3	.0	2433	6.5	.14
Pearlgreen	38	3.5	38.3	34.4	25.1	2.2	4012	4.5	.06
	12	3.7	36.9	33.2	27.5	2.4	5419	5.4	.06
	6	3.8	34.8	34.8	28.3	2.1	5247	6.3	.07
Earligreen	38	3.2	64.3	31.2	4.5	.0	3183	5.2	.08
	12	4.6	63.9	31.4	4.7	.0	4170	3.3	.09
	6	4.8	58.2	36.4	5.4	.0	3998	6.2	.16
Tenderwhite	38	6.3	51.5	37.0	11.5	.0	2194	3.4	.02
	12	10.0	44.4	40.0	15.5	.0	2990	3.8	.06
	6	5.2	50.0	38.2	11.8	.0	3850	3.0	.05

seasons over 38-inch spaced rows but the increase was less than the increase obtained from rows spaced 12 inches apart.

Two of the 3 new varieties included in the tests the spring and fall of 1959 increased in total production of pods for rows spaced 12 inches apart over rows spaced 38 inches apart. Two of the 6-inch plantings showed, however, a decrease from the 12-inch planting in the spring of 1959. Poor plant stands in the fall trials caused abnormally poor yields of pods. Yields of Harvester and Tenderwhite in the spring trials increased 82 per cent and 130 per cent respectively for rows spaced 12 inches apart over rows spaced 38 inches apart, but increased only 37 per cent and 79 per cent respectively for rows spaced 6 inches apart over rows spaced 38 inches apart. In the fall trials Harvester yields were actually decreased by rows spaced 12 inches apart over rows spaced 38 inches apart, but average plant spacing in the row was 6.2 inches for 38-inch spaced rows and 13.2 inches for rows spaced 12 inches apart (Table 3). Tenderwhite increased in total yields of pods 36 per cent for rows spaced 12 inches apart over rows spaced 38 inches apart. This percentage is low because the plant spacing in the row was 6.3 inches for rows 38 inches apart and 10.0 inches for rows 12 inches apart.

The total yields of pods of Earligreen in the spring 1959 trials with rows of beans spaced 12 inches apart increased 91 per cent in total pod production over rows spaced 38 inches apart, but rows spaced 6 inches apart increased 111 per cent over the 38-inch spaced rows. Then in the fall 1959 trials, rows of beans spaced 12 inches apart increased in pod production 36 per cent over rows spaced 38 inches apart, but increased only 26 per cent for rows spaced 6 inches apart. This indicates that other row spacing distances may be more desirable for this variety.

In these experiments spacing the rows of beans closer together did not consistently increase or decrease the percentage of sieve sizes of pods for Topcrop, Topmost, Pearlgreen and Tenderwhite. Spacing the rows of beans as close together as 6 inches did not cause a decrease in sieve sizes 1 to 3's and an increase in sieve sizes 6 and larger as might be expected because of increased competition for water and nutrients resulting in more rapid maturity. Harvester and Earligreen were exceptions because plots harvested in both spring and fall 1959 decreased in sieve sizes 1 to 3's inclusive, for rows spaced 38 inches apart as compared to rows spaced 6 inches apart and increased in the larger sieve sizes. Also the percentage seed and fiber increased as row spacing decreased from 38 inches to 6 inches (Tables 2 and 3). These increases were not large the spring of 1959 and the larger increases in the fall of 1959 could have been due to factors other than row spacing. Additional tests of Harvester and Earligreen varieties would more adequately establish the row spacing most desirable. The varieties Topcrop and Topmost consistently produced the highest percentages of sieve size 6 and larger pods. An early frost the fall of 1959 made it necessary to harvest the plots early, which accounts for the reduction in large sieve size pods for all varieties (Table 3).

The first planting of beans in the fall of 1958 which indicated closer spacing of rows might have contributed to a decrease in percentage seed development and percentage fiber in the pods did not hold true for the spring and fall 1959 tests. As an example, Topmost which decreased from 5.0 per cent seed and .03 per cent fiber in the pods for rows spaced 38 inches apart to 3.4 per cent seed and .01 per cent fiber for rows spaced 14 inches apart in the fall 1958 tests increased instead of decreased in the spring and fall 1959 tests (Tables 2 and 3).

The 9 sensory panel members in their examinations of the canned pods failed to detect differences due to row spacing of Topcrop, Topmost, Pearlgreen, and Tenderwhite varieties. According to the table of probability in triangular taste tests calculated by Roessler, et al (1958), 6 members of the sensory panel should consistently pick the different sample to establish significance at the 5 per cent level. The samples of pods of Harvester and Earligreen varieties spaced 6 inches apart from the fall 1959 tests increased in fiber content of pods from .05 and .08 per cent for rows spaced 38 inches apart to .14 and .16 per cent for rows spaced 6 inches apart. Eight of the 9 panel members could consistently detect this increase in fiber content however they were unable to detect the smaller increases in fiber content of pods harvested the spring of 1959 (Tables 2 and 3).

SUMMARY

The yields of beans used in these experiments were increased from 31 per cent to as much as 130 per cent by paired rows spaced 12 or 14 inches apart on 38-inch beds as compared to production from rows spaced 38 inches apart. The results of spacing beans in paired rows 6 inches apart on 38-inch beds were inconsistent with variabilities between varieties and seasons.

These results indicate 12-inch spacing between rows is the minimum distance on which to obtain the highest production from Topmost, Pearlgreen and Tenderwhite. An intermediate spacing between 12 and 6 inches between rows is the most desirable for Topcrop, Harvester and Earligreen.

Planting the rows of beans close together did not influence the sieve sizes of pods of Topcrop, Topmost, Pearlgreen or Tenderwhite. Neither did closer row spacing influence the percentage seed development nor fiber percentage of canned pods of sieve size 5 of Topcrop, Topmost, Pearlgreen or Tenderwhite. Harvester and Earligreen decreased in small sieve sizes, increased in large sieve sizes, and increased in percentage seed and fiber content of canned sieve size 5 pods from rows spaced 38 inches apart as compared to rows spaced 6 inches apart.

A sensory evaluation of the canned pods by a panel of trained judges could not detect differences due to row spacing of Topcrop, Topmost, Pearlgreen or Tenderwhite.

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Evaluation of Green Bean Varieties Suitable For Processing

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According to Canned Food Pack Statistics (1958) the pack of green snap beans reached an all time high in 1954 with 23,883,037 cases (basis 24/2's) packed in the United States. There were more than 20,900,000 cases packed in 1955, 1956 and 1957, and 23,876,412 cases packed in 1958. Texas production of canned green snap beans amounted to 1,191,-442 cases (basis 24/2's) in 1954 and more than 1,000,000 cases for 1955, 1956, 1957 and 1958. The production and processing of green beans is an important enterprise in the vegetable economy of Texas and the nation.

Yield is a very important factor in selecting a suitable variety of green beans for processing, but other characteristics are also essential. Some of the more important characteristics required have been outlined by Gould (1954) as follows: stringless and low in fiber content, long, straight, smooth pods, uniform dark green color, completely white seeded at maturity, uniform setting and maturation of pods, round pods with uniform bright flesh color and having the same flesh and pod wall coloring after processing; good flavor and odor, pods free of sloughing, and small seeds completely surrounded by parenchyma tissue. Another characteristic becoming increasingly important is a variety of green beans which can be successfully machine harvested. Hollis, Kramer and Stark (1957) evaluated 9 snap bean varieties grown in Maryland and reported that some varieties set pods low in the plant and plants were sometimes small, thus reducing mechanical picking efficiency.

The purpose of this investigation was to evaluate and present information on yield and canning quality of several green bean varieties grown in the lower Rio Grande Valley of Texas.

MATERIALS AND METHODS

The beans were grown at Substation 15, Texas Agricultural Experiment Stations, and canning evaluations made by the U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas. The varieties and strains of beans being tested were planted in a randomized block with 4 replications. Each plot consisted of 2 rows 35 feet long and 38 inches apart. Irrigation and other cultural practices were consistent and applied as needed during the growing season.

The varieties and strains were harvested 3 times, at 4 to 11 day intervals, when they reached optimum maturities to produce the greatest

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

tonnage of pods. The temperature, wind and moisture conditions during the harvest period governed the interval between harvests. The yield per acre and the plant and pod characteristics reported in the tables are averages obtained from the 4 replications and 3 harvest dates. Twenty pods were selected at random from each replication and evaluations made for length, shape, color, straightness and roughness. The elevation of the pods in relation to the soil was obtained by examining 50 plants in each plot. Topcrop variety was used as the standard for evaluating each characteristic, with the exception of the varieties grown in the fall of 1957. Topcrop variety was not included in the plantings.

The varieties of beans grown in 1954, 1955 and 1956 were not size graded. In 1957 a commercial size grader was obtained and utilized to segregate the sieve sizes into 1 to 3's combined, 4's, and 5's and larger. In 1958 an additional grader was obtained and utilized to segregate the sieve sizes into 1 to 3's combined, 4's, 5's, and 6's and larger.

The pods were prepared for processing by sorting, snipping by hand and washing sufficient pods to fill 8 plain No. 2 (307x409) cans. The varieties canned in 1954, 1955 and 1956 were blanched 4 minutes at 200° F. and processed 25 minutes at 240° F. The sieve size 4 pods of varieties and strains canned in 1957 were blanched 3 minutes at 185° F. and processed 25 minutes at 240° F. The pods were considered to be slightly soft, therefore in 1958 sieve size 4 was blanched 3 minutes at 185° F. and processed 23 minutes at 240° F. and sieve size 5 was blanched 3½ minutes at 185° F. and processed 25 minutes at 240° F. The pods of sieve size 6 and larger for varieties Topcrop, Topmost and Pearlgreen were blanched and processed the same times and temperatures as pods for sieve size 5. All pods were vertically packed, 310 grams of blanched pods per can, then boiling 2% brine solution added and the cans closed with a minimum center-can temperature of 180° F.

The processed quality of pods grown in 1954, 1955 and 1956 was determined by calculating the percentage increase in drained weight and making a sensory evaluation for color, stringiness and texture. In 1957 and 1958, in addition to drained weight and sensory evaluations, determinations were made on the color of the pods, the percentage seed and percentage crude fiber in the pods.

The drained weight and percentage seed in the pods were determined according to the U. S. Standards for Grades of Canned Green Beans and Canned Wax Beans (1953). The percentage crude fiber in the sieve size 4 pods evaluated in 1957 was determined according to the procedure outlined by Guyer and Kramer (1951). In 1958 the crude fiber was determined according to the U. S. Standards for Grades of Canned Green Beans and Canned Wax Beans (1953).

Color values for beans evaluated in 1957 and 1958 were determined by use of a Hunter Color and Color Difference Meter.[2] Two hundred

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

grams of beans were deseeded and the pods blended with 50 ml. of distilled water for 3 minutes in a Waring Blendor.[2] The sample of blended pods was deaerated and the Hunter Rd, a and b readings obtained after prior standardization of the instrument to the values for the standard color plate LG1; Rd 47.7, a −17.2 and b +5.5.

The sensory evaluations for color, stringiness and texture were made by a panel of eight or ten experienced judges. A ten-point hedonic scale was used to evaluate the samples. Topcrop variety was given an evaluation of 7 and presented as a reference sample to each judge and he was asked to evaluate the other varieties as more desirable, the same, or less desirable than the reference sample.

RESULTS AND DISCUSSION

Evaluations of yield, pod characteristics and processed quality were made on 18 varieties and 7 strains of green beans for 1 to 6 seasons. The new varieties and strains of green beans were incorporated into the trials as they became available. Some were dropped from the trials because seed could not be obtained each season and others were eliminated because of inferior characteristics for production or processing.

Because of seasonal variations and necessary changes in processing procedures it is difficult to compare varieties and strains grown one season with varieties and strains grown during another season. However, some characteristics of varieties and strains are consistent from season to season and are important factors in their selection or rejection.

The 1954 fall season was good for green bean production in the Lower Rio Grande Valley. The first picking of beans of all varieties tested matured in 62 to 68 days (Table 1). The varieties Hyscore and Tenderbest matured pods 6 days later and Processor 4 days later than the other varieties tested. It is desirable to have early maturing varieties of beans, especially for fall plantings, because cold weather frequently reduces the yield of the last harvest. Hyscore and Tenderbest were higher in total yield when compared with the other varieties. Processor and White Seeded Tendergreen varieties were 1 to 2 tons per acre lower in total yield than the higher yielding varieties. These same varieties produced a large percentage of short stubby pods when compared with the other varieties. Although the average length was 4.8 inches and 4.5 inches, respectively, the amount of short stubby pods was very noticeable. Longreen variety produced pods 5.8 inches in length, slightly rough and very curved, which made these pods difficult to handle in the canning operation. Supergreen and White Seeded Tendergreen varieties produced pods which were very rough.

Processor was the only variety tested that set its pods so low in the plant that mechanical harvest might be difficult. Hollis, et al (1957), noted the same characteristic in their evaluation of this variety.

The 1954 sensory evaluation indicated only small color differences among all of the varieties, with a maximum score difference of only 0.7,

Table 1. Yield and plant and pod characteristics of green bean varieties, fall 1954.

			Pod Characteristics[1]					
Variety	*Days to Mature*	*Yield lbs./Acre*	*Length Inches*	*Shape*	*Color*	*Straightness*	*Roughness*	*Elevation of Pod Relation to Soil*
Topcrop	62	6978	5.3	oval	medium	sl. curved	sl. rough	touches soil
Hyscore	68	9447	5.5	heart	very dark	sl. curved	sl. rough	touches soil
Processor	66	4998	4.8	oval	light	sl. curved	sl. rough	touches soil badly
Tenderbest	68	7762	5.3	round	medium	straight	smooth	touches soil
Longreen	62	6350	5.8	heart	medium	very curved	sl. rough	well above soil
Supergreen	62	6644	5.3	heart	medium	sl. curved	very rough	well above soil
Wade	62	6899	5.0	round	dark	straight	smooth	touches soil
White Seeded Tendergreen	62	4351	4.5	round	medium	sl. curved	very rough	touches soil
L.S.D.	.05	1591						
L.S.D.	.05	2040						

[1] Words used to describe pod characteristics:
Shape – flat, oval, heart, round, creaseback.
Color – very dark, dark, medium (Top Crop variety), light.
Straightness – straight, slightly curved, very curved, cured in 2 directions.
Roughness – very smooth, smooth, slightly rough, very rough.
Pod Elevation – well above soil, clear of soil, touches soil, touches soil badly.

Table 2. Processed quality of green bean varieties, fall 1954.

		Sensory Evaluation[1]		
Variety	*Drained Wt. Increase %*	*Color*	*Stringiness*	*Texture*
Topcrop	6.1	6.9	6.4	6.1
Hyscore	3.7	6.8	6.8	6.3
Processor	3.4	6.0	6.6	6.5
Tenderbest	4.3	6.6	6.8	6.4
Longreen	4.9	7.1	6.5	6.0
Supergreen	7.7	7.0	6.5	6.3
Wade	6.3	7.1	6.3	6.4
White Seeded Tendergreen	6.6	7.3	6.7	6.3

[1] These numbers represent numerical opinions of the judges. The word description of each number in the scale is:

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

except for the lighter green of the Processor variety which received the low score of 6.0. The White Seeded Tendergreen variety with the best color had the highest score of 7.3.

None of the varieties tested were objectionable due to excessive strings, however, Wade received a slightly lower sensory evaluation score because some of the large pods had tough strings. The large pods of Topcrop and Longreen developed a fibrous sheath in the wall of the pod and were scored a little lower in texture than the other varieties.

The varieties evaluated the spring of 1955 matured their pods in 68 to 75 days. Hyscore variety matured 5 days later than any of the other varieties evaluated (Table 3). Topcrop matured pods in 68 days and produced 8321 pounds of pods per acre, which was 1719 pounds per acre more than Processor, the second highest producer. White Seeded Tendergreen produced 3857 pounds per acre, the poorest of the varieties evaluated. White Seeded Tendergreen, Processor, and Tenderlong 15 produced a large number of short stubby pods. The pods of varieties Processor, Slendergreen and Tenderbest were light green in color when compared with the other varieties evaluated. All varieties produced pods which were straight or only slightly curved. Tenderlong 15 was the only variety that produced very rough pods.

The canned samples of pods of Processor and Tenderbest varieties were slightly lighter in color than the other varieties and were given the lowest scores of 6.9 and 6.8 (Table 4). They were a little lighter in color than the other varieties tested. The pods of Seminole variety were noticeably stringy and fibrous. A fibrous sheath developed in the wall of both small and large pods. The large size pods of Improved Tendergreen were also fibrous. Seminole variety received a score of 6.4 because all sizes of pods were fibrous but Improved Tendergreen received a score of 6.5, or about the same score because only large sized pods were noticeably fibrous.

Three of the 9 varieties evaluated in the fall of 1955 matured pods in 58 days (Table 5). Hyscore variety matured pods 10 days later. All the varieties evaluated were retarded by cold weather, consequently, total yield of pods was low. The comparisons made among varieties are valid, however, because all varieties were affected by the cold temperature. The varieties Hyscore, White Seeded Tendergreen, and Wade were lower in total yield than the other varieties tested. The average length of pods of White Seeded Tendergreen was 4.2 inches due to a large percentage of short stubby pods. Seminole was the only variety with pods lighter in outside color than Topcrop, and also the only variety that produced very curved pods. Improved Tendergreen and Topmost produced pods which were very rough.

In the sensory evaluation of the varieties, pods of White Seeded Tendergreen, Wade and Hyscore were given the highest ratings for color: 7.3, 7.2 and 7.2 (Table 6). Pods of Pearlgreen had the lightest green color and was given a rating of 6.5. Topcrop was given the lowest rating

Table 3. Yield and plant and pod characteristics of green bean varieties, spring 1955.

			Pod Characteristics[1]					
Variety	*Days to Mature*	*Yield lbs./Acre*	*Length Inches*	*Shape*	*Color*	*Straightness*	*Roughness*	*Elevation of Pod in Relation to Soil*
Top Crop	68	8321	4.19	oval	medium	sl. curved	sl. rough	touches soil
Hyscore	75	6426	4.71	oval	dark	sl. curved	sl. rough	clear of soil
Tenderbest	70	4725	3.95	round	light	sl. curved	sl. rough	clear of soil
Processor	70	6602	3.55	oval	light	straight	sl. rough	touches soil
Seminole	68	6343	4.40	round	medium	straight	smooth	well above soil
Tenderlong 15	70	5460	3.55	oval	medium	sl. curved	very rough	clear of soil
Slendergreen	70	5347	4.00	round	light	straight	smooth	
Improved Tendergreen	68	5576	4.06	round	medium	sl. curved	sl. rough	well above soil
White Seeded Tendergreen	68	3857	3.42	heart	dark	sl. curved	sl. rough	touches soil
L.S.D. .05		1785						
L.S.D. .01		2453						

[1] See Table 1.

Table 4. Processed quality of green bean varieties, spring 1955.

Variety	Drained Wt. Increase %	Sensory Evaluation[1]		
		Color	Stringiness	Texture
Topcrop	7.2	7.2	7.2	7.0
Hyscore	7.2	7.4	7.5	6.8
Tenderbest	6.6	6.8	6.7	6.9
Processor	4.3	6.9	7.2	6.7
Seminole	8.6	7.0	6.1	6.4
Tenderlong 15	6.9	7.6	6.9	7.0
Slendergreen	8.0	7.1	7.0	6.6
Improved Tendergreen	5.8	7.6	7.2	6.5
White Seeded Tendergreen	6.6	7.3	7.1	6.9

[1] See Table 2.

Table 5. Yield and plant and pod characteristics of green bean varieties, fall 1955.

Variety	Days to Mature	Yield lbs./Acre	Pod Characteristics[1]					
			Length Inches	Shape	Color	Straightness	Roughness	Elevation of Pod Relation to Soil
Topcrop	58	3686	4.5	heart	medium	sl. curved	sl. rough	touches soil
Topmost	58	3895	4.5	heart	medium	sl. curved	very rough	touches soil
Pearlgreen	58	4583	4.5	round	medium	sl. curved	sl. rough	touches soil
Hyscore	68	2186	4.8	round	dark	sl. curved	smooth	clear of soil
Tenderbest	62	3010	4.7	heart	dark	sl. curved	smooth	well above soil
Seminole	60	3169	4.9	oval	light	very curved	smooth	touches soil
Improved Tendergreen	60	3773	4.8	round	medium	sl. curved	very rough	well above soil
Wade	60	2876	4.5	oval	dark	sl. curved	sl. rough	touches soil
White Seeded Tendergreen	60	2359	4.2	round	dark	sl. curved	sl. rough	well above soil
L.S.D.	.05	649						
L.S.D.	.01	885						

[1] See Table 1.

Table 6. Processed quality of green bean varieties, fall 1955.

Variety	*Drained Wt. Increase %*	*Sensory Evaluation*[1] *Color*	*Stringiness*	*Texture*
Topcrop	8.0	6.8	6.4	6.7
Topmost	9.6	7.0	6.8	6.6
Pearlgreen	9.6	6.5	7.1	7.1
Hyscore	5.8	7.2	7.0	6.9
Tenderbest	6.6	6.9	7.3	6.9
Seminole	7.5	6.7	7.0	6.3
Improved Tendergreen	9.6	7.0	6.7	6.6
Wade	6.1	7.2	6.6	6.6
White Seeded Tendergreen	6.6	7.3	7.1	6.4

[1] See Table 2.

for stringiness, 6.4. Seminole was rated 7.0 for stringiness but received the lowest rating, 6.3, for texture because a fibrous sheath developed in the walls of the pods. White Seeded Tendergreen was fibrous also and received a low rating for texture.

The varieties of beans evaluated the spring of 1956 matured in 67 to 74 days (Table 7). The highest producer of total pounds of pods per acre was Seminole variety with 9626 pounds and the lowest producer of pods was Tenderbest, 5531 pounds per acre. The color of the pods of Pearlgreen variety was lighter green than the other varieties evaluated. The pods of Pearlgreen and Seminole varieties were straight and smooth, while pods of Hyscore variety were very rough.

The sensory evaluation scores for color of the canned pods were high for all varieties tested (Table 8). Although the fresh pods of Pearlgreen were considered to be light in color, the processed product was judged about the same color as Topcrop. In addition to being stringy, the texture of Seminole was judged unacceptable with a texture score of 4.4. The pods of Tenderbest, Topcrop and Topmost also were considered to be a little more fibrous than the other varieties and received lower texture scores. The pods of Pearlgreen received the highest scores for stringiness and texture.

A frost the last week in November, 1957, reduced the total yields of pods per acre for all varieties and strains (Table 9). Woodruffs Exp. 2244 strain was the earliest and matured pods in 54 days, and Kingreen variety and Northrup King 103 were both late, maturing their pods 14 days later. The varieties Earligreen, Pearlgreen, Tenderwhite, Topmost and strains Woodruffs Exp. 2244 and B-3095-3 were higher in yield of pods per acre than the other varieties and strains evaluated. Hyscore and Kingreen and strain Northrup King 103 produced less than 1 ton of pods per acre. Each variety or strain tested except Topmost produced 70 per cent or more pods sieve size 1 to 4's, inclusive. The cold weather which occurred during the harvest period had much to do with the small sieve sizes which in turn tended to reduce total yield. Topmost produced 35 per cent of its pods sieve size 5 and larger, while Processor variety produced only 8 per cent of its pods sieve size 5 and larger. In addition to being small, a large percentage of pods of Processor variety were stubby and not well filled. Hyscore was the only variety that produced pods which were noticeably very curved and very rough.

The percentage seed in the pods of all varieties and strains was low because only sieve size 4 was used in the processing evaluations (Table 10). A limiting rule for percentage seed in the pods as established by the U. S. Standards for Grades of Canned Green Beans and Canned Wax Beans (1953) stipulates the trimmed pods contain not more than 25 per cent by weight of seed or pieces of seed. All of the varieties and strains evaluated were well below the 25 per cent limit. The pods of Processor variety had the highest percentage seed, 6.2 per cent, and the pods of Kingreen contained 2.1 per cent which was the lowest. The pods of Hyscore variety did not have a high percentage of seed, but the

Table 7. Yield and plant and pod characteristics of green beans, spring 1956.

Variety	*Days to Mature*	*Yield lbs./Acre*	*Pod Characteristics*[1]					
			Length Inches	*Shape*	*Color*	*Straightness*	*Roughness*	*Elevation of Pod in Relation to Soil*
Topcrop	68	7530	4.1	round	medium	sl. curved	sl. ruogh	touches soil
Topmost	68	7651	4.4	oval	medium	sl. curved	sl. ruogh	touches soil
Pearlgreen	67	9221	4.4	heart	light	straight	smooth	touches soil
Hyscore	74	7640	4.6	oval	dark	sl. curved	very rough	clear of soil
Tenderbest	70	5531	4.6	oval	medium	sl. curved	sl. rough	clear of soil
Seminole	69	9626	4.6	round	medium	straight	smooth	
L.S.D.	.05	2118						
L.S.D.	.01	3001						

[1] See Table 1.

Table 8. Processed quality of green bean varieties, spring 1956.

Variety	*Drained Wt. Increase %*	*Sensory Evaluation*[1]		
		Color	*Stringiness*	*Texture*
Topcrop	7.7	7.0	6.6	6.4
Topmost	8.0	7.4	6.8	6.4
Pearlgreen	6.3	6.9	7.0	7.0
Hyscore	4.0	7.4	6.9	6.7
Tenderbest	6.1	6.9	6.3	6.5
Seminole	7.2	7.2	5.2	

[1] See Table 2.

Table 9. Yield and plant and pod characteristics of green bean varieties, fall 1957.

Variety or Strain	*Days to Mature*	*Yield lbs./Acre*	*Sieve Sizes 1-3's %*	*4's %*	*5's + %*	*Pod Characteristics*[1] *Length Inches*	*Shape*	*Color*	*Straightness*	*Roughness*	*Elevation of Pod in Relation to Soil*
Topmost	60	2766	35	30	35	3.9	heart	dark	sl. curved	sl. rough	touches soil
Pearlgreen	58	3383	31	40	30	4.1	oval	medium	sl. curved	smooth	touches soil
Hyscore	64	1709	38	37	25	4.2	oval	very dark	very curved	very rough	touches soil
Earligreen	58	3856	47	40	12	3.7	round	light	sl. curved	smooth	clear of soil
Corneli 14	62	2466	50	35	15	4.1	heart	medium	sl. curved	smooth	touches soil
Tenderwhite	60	3041	45	40	15	3.9	round	medium	sl. curved	smooth	clear of soil
Processor	62	2404	51	41	8	3.7	oval	medium	sl. curved	smooth	touches soil badly
Northrup King 103	68	1700	40	42	18	4.2	round	medium	sl. curved	sl. rough	well above soil
Woodruffs Exp. 2244	54	3555	29	44	27	3.9	round	dark	straight	smooth	touches soil
Kingreen	68	1315	49	33	18	4.8	oval	dark	sl. curved	very smooth	touches soil
B-3034-1-2[2]	58	2533	42	45	13						touches soil
B-3095-3[2]	55	2972	36	46	18						touches soil
L.S.D. .05		918									
L.S.D. .01		1233									

[1] See Table 1.

[2] Strains B-3034-1-2 and B-3095-3 were included for observation and were not included in the replicated plantings.

seed were large, resulting in a rough appearing pod.

There was no measurable amount of crude fiber, as evaluated by the quick method of Guyer and Kramer (1951), in any of the varieties and strains evaluated. The use of the Waring Blendor,[2] recommended in this method, so completely disintegrated the deseeded pods that no fiber remained on the screens after washing.

The color values of the canned pods obtained by the Hunter Color Difference Meter[2] showed Hyscore variety, with Rd 14.9, a −3.6 and b 20.5, had the dargest green color, and Earligreen variety, with Rd 18.6, a −4.3 and b 21.5, had the lightest green color. The Hunter Rd value is the dominant factor with respect to lightness or darkness; the former increases as the Rd increases. The color is concerned with the ordinates −a and +b for green beans. Decreasing −a values reflect a shift toward more green, and increasing +b values represent more yellow, as shown in Table 10, changes in the −a and +b values among the varieties was not great. The largest changes occurred in the Rd values.

The sensory evaluation scores for color were 5.8 for Earligreen, the lightest colored variety, and 7.1 for Hyscore, the darkest colored variety. In general the color scores increased as the Rd values decreased, with increasing darker colored pods. The sensory evaluation scores for stringiness and texture were much the same for all varieties tester. This would be expected because only sieve size 4 pods were processed. The Hyscore variety was the exception and was given a texture score of 6.0. Each judge commented, however, that the pods were soft or mushy and the lower texture rating was not due to excessive fiber.

The varieties and strains evaluated the spring of 1958 matured their pods in 67 to 70 days. Earligreen produced 10,240 pounds of pods per acre, which was 1521 pounds per acre more than Topmost, second highest producer. Northrup King 104 strain produced 3853 pounds of pods per acre, which was the lowest producing strain or variety. Topmost produced 77 per cent of its pods sieve size 5 and larger, 45 per cent of which were sieve size 6 and larger. Topcrop produced 78 per cent pods sieve size 5 and larger and 43 per cent were sieve size 6 and larger. An undesirable characteristic of these two varieties was a tendency to produce large sieve sizes. As a comparison, varieties Corneli 14, Earligreen, Runnerless Ranger, Tenderwhite and strain B-3034-1-2, each produced pods which were less than 10 per cent sieve size 6 and larger. Strain B-3034-1-2, Northrup King 103 and Runnerless Ranger produced the highest percentages of short stubby pods and a large percentage of the pods of Runnerless Ranger were flat. Earligreen, Runnerless Ranger and Tenderwhite were light green in external pod color. The pods of Hyscore, Topcrop and Topmost were very rough. The percentage seed in the pods (Table 12), was not an indication of the roughness of the pod. The seed percentage of Runnerless Ranger was higher than any of the other varieties and strains but was judged as having smooth pods. The pods of sieve size 5 of strain B-3095-3 had .16 per cent crude fiber and the same sieve size of Earligreen variety had .19 per cent crude fiber.

Table 10. Processed quality of green bean varieties, fall 1957[1].

Variety or Strain	*Drained Wt. Increase %*	*Seed %*	*Rd*	*Hunter Color Notation a*	*b*	*Sensory Evaluation[2]*		
						Color	*Stringiness*	*Texture*
Topmost	11.4	4.0	15.7	−3.8	21.1	6.8	6.7	7.0
Pearlgreen	6.6	3.3	17.1	−4.2	21.4	6.3	7.0	7.1
Hyscore	6.1	3.6	14.9	−3.6	20.5	7.1	6.9	6.0
Earligreen	7.7	4.4	18.6	−4.3	21.5	5.8	7.1	7.0
Corneli 14	9.4	2.8	16.9	−3.8	21.6	6.9	7.1	7.0
Tenderwhite	8.0	2.7	16.4	−4.1	21.2	6.8	7.2	7.1
Processor	7.7	6.2	17.9	−4.4	21.5	6.4	7.1	7.1
Northrup King 103	6.1	4.0	16.9	−4.2	21.2	6.5	7.1	7.0
Woodruffs Exp. 2244	8.0	4.7	17.5	−4.3	21.4	6.3	7.2	7.1
Kingreen	4.0	2.1	15.6	−3.5	20.9	6.8	7.0	6.7
B-3034-1-2	8.3	6.1	16.7	−3.7	21.7	6.5	7.0	6.6
B-3095-3	10.9	5.0	15.8	−3.6	21.2	7.1	7.1	7.0

[1] Only sieve size 4 processed
[2] See Table 2.

Table 11. Yield and plant and pod characteristics of green bean varieties, spring 1958.

Variety or Strain	*Days to Mature*	*Yield lbs./Acre*	*1-3's*	*4's*	*5's*	*6's +*	*Pod Characteristics[1]*					
							Length Inches	*Shape*	*Color*	*Straight-ness*	*Rough-ness*	*Elevation of Pod in Relation to Soil*
Topcrop	62	7901	10	12	35	43	4.3	oval	medium	sl. curved	very rough	touches soil
Topmost	62	8719	11	12	32	45	3.8	heart-oval	medium	sl. curved	very rough	touches soil
Pearlgreen	62	8604	12	20	45	23	4.3	heart	medium	straight	sl. rough	touches soil
Hyscore	70	6267	17	23	38	22	4.4	heart-oval	dark	sl. curved	very rough	touches soil
Earligreen	67	10240	16	33	47	4	3.8	oval	light	straight	smooth	clear of soil
Corneli 14	67	7629	17	32	44	7	4.3	oval	medium	straight	smooth	touches soil
Tenderwhite	69	6912	20	30	44	6	3.9	oval	light	sl. curved	smooth	clear of soil
Northrup King 103	76	4285	22	30	37	11	3.5	oval	medium	straight	sl. rough	well above soil
Northrup King 104	70	3853	12	18	39	31	3.9	heart	medium	straight	sl. rough	well above soil
B-3034-1-2	68	6238	20	44	33	3	3.5	oval	dark	straight	smooth	touches soil
B-3095-3	65	8217	14	32	43	11	3.9	oval	dark	straight	smooth	touches soil
Runnerless Ranger	62	8188	17	36	40	7	3.5	oval-flat	light	straight	smooth	touches soil
L.S.D. .05		1979										
L.S.D. .01		2667										

[1] See Table 1.

Table 12. Processed quality of green bean varieties, spring 1958.

Variety or Strain	Sieve Size	Seed %	Crude Fiber %	Hunter Color Notation			Sensory Evaluation[1]		
				Rd	a	b	Color	Stringiness	Texture
Topcrop	4's	5.9	.04	18.9	–2.9	20.1	7.0	6.9	6.3
	5's	11.2	.06	19.5	–2.7	20.3	7.0	7.0	6.4
	6's+	13.6	.12	19.2	–2.5	20.4	6.9	7.0	6.6
Topmost	4's	9.9	.05	18.0	–4.4	20.5	7.4	7.1	7.1
	5's	5.5	.05	19.2	–4.4	20.7	7.4	7.0	7.1
	6's+	8.0	.10	19.1	–4.4	21.1	7.4	6.9	7.1
Pearlgreen	4's	4.7	.05	20.2	–4.4	20.7	7.4	7.1	7.5
	5's	7.9	.12	20.9	–4.6	20.6	7.4	7.0	6.7
	6's+	10.6	.21	21.0	–4.3	21.3	7.2	6.8	6.1
Hyscore	4's	2.7	.04	19.4	–4.1	20.6	7.4	7.5	7.2
	5's	3.9	.04	20.1	–4.2	20.6	7.3	7.1	7.2
Earligreen	4's	4.9	.08	22.5	–4.3	21.3	5.7	6.7	7.0
	5's	10.6	.19	23.7	–3.9	21.2	5.6	6.4	6.5
Corneli 14	4's	4.9	.04	20.7	–4.4	21.0	7.3	7.2	7.4
	5's	8.7	.09	20.0	–4.4	21.2	7.6	6.9	6.9
Tenderwhite	4's	3.8	.05	19.9	–4.2	21.1	7.2	6.9	7.0
	5's	5.6	.07	20.6	–4.1	21.2	7.0	6.7	7.0
Northrup King 103	4's	3.3	.02	18.5	–4.5	20.2	7.0	7.1	7.1
	5's	6.3	.05	18.6	–4.6	20.3	7.1	7.2	6.9
Northrup King 104	4's	4.4	.05	18.8	–4.6	19.8	7.1	7.0	7.1
	5's	9.1	.07	18.7	–4.5	20.4	7.2	7.0	7.1
B-3034-1-2	4's	9.0	.05	19.9	–4.3	21.5	6.7	6.6	6.9
	5's	13.8	.10	20.6	–4.5	21.3	6.7	6.6	6.7
B-3095-3	4's	4.4	.07	19.0	–4.2	21.1	7.3	6.8	6.6
	5's	7.9	.16	19.8	–4.5	21.1	7.0	6.0	6.2
Runnerless Ranger	4's	11.9	.09	20.4	–4.5	21.0	7.1	6.7	6.6
	5's	18.9	.11	21.4	–4.6	20.9	6.7	6.5	6.7

[1] See Table 2.

Pods of sieve size 5 of this strain and variety exceeded the .15 per cent crude fiber allowable in the U. S. Standards for Grades of Canned Green Beans and Canned Wax Beans (1953). Sieve size 6 and larger of Pearlgreen variety had .21 per cent crude fiber and would be graded substandard.

The pod color of Earligreen variety measured by the Hunter Color Meter[2] was Rd 22.5, a –4.3 and b 21.3 for sieve size 4 and Rd 23.7, a –3.9 and b 21.2 for sieve size 5. The color was lighter green than any of the other varieties or strains and was consistently rated low in the sensory evaluation. The pods of strain B-3095-1-2 were given a sensory evaluation score for color of 6.7, which was slightly lower than the other varieties and strains, but was not in agreement with the Hunter Color Meter[2] notations. The –a and +b values were similar among the varieties and strains evaluated, except Topcrop variety. The –a value of Topcrop was consistently lower than the other varieties. When the –a values were plotted on the data and graph sheet for the Hunter Color Difference Meter[2] the focus of –a moved toward the red hue. The brown color of the seed coat of Topcrop leaches into the green pod and liquor during canning, causing a dull brownish green rather than a bright green. The color score given in the sensory evaluation was not in agreement with the Hunter Color Meter[2] notation. The sensory evaluation score for stringiness and texture was lower for sieve size 5 pods of varieties and strains which had high percentages of crude fiber than were the scores of sieve size 4 pods of the same varieties except Topcrop. The variety or strain with the highest percentage crude fiber did not in all instances receive the lowest score for stringiness or texture.

SUMMARY

Eighteen varieties and 7 strains of green beans were evaluated on the basis of yield, desirable pod characteristics, sieve size, seed percentage and percentage crude fiber. According to these tests conducted over 6 seasons the varieties which can be recommended for production and processing in the Lower Rio Grande Valley are Topcrop, Pearlgreen and Topmost. Limited data from 2 seasons indicate that Corneli 14, Earligreen and Tenderwhite may also have adaptation and use in this area.

Topcrop has a distinct disadvantage of having brown seed which results in discoloration of the pod and liquor in the canned product. Rapid pod growth is characteristic of this variety, often resulting in excessive sizes; however, it is consistent in yield, a characteristic very important to the grower.

Pearlgreen produces straight, smooth, well-filled, white seeded pods, which are characteristically lighter green color than Topcrop. Pearlgreen pods may develop fiber if not harvested at the proper stage of maturity.

Topmost is very similar in pod characteristics to Topcrop. The seeds are white, however, and the liquor of the canned product is clear. Sieve sizes may be excessive and in some seasons the pods may be very rough.

Corneli 14 produces smooth, straight pods of good color and low fiber content. The yields, however, have been a little low.

Earligreen produces good yields of smooth, straight pods which have a low percentage of sieve size 6 and larger. The color of the pods, however, may be light green and fiber may develop rapidly if harvest is delayed in an effort to gain yield.

Tenderwhite produces pods of desirable processing quality; however, this variety does not yield as well as other varieties.

Varieties and strains grown in the fall will mature 2 to 10 days earlier than the same varieties or strains grown in the spring. Hyscore produced pods late, both in the spring and in the fall. Although the variety generally produced pods with fair processing characteristics it was always late, consequently early frosts in the fall of 1955 and 1957 reduced yields by more than 2 tons per acre. It would be unwise to recommend Hyscore variety for fall planting in this area.

Fiber development was objectionable in the canned pods of some varieties. The pods of Seminole variety, for instance, developed a sheath of fiber in the walls of the pods each season the variety was grown. The development of fiber occurred in small as well as large size pods.

In these evaluations the percentage by weight of seed in the canned pods was neither an indication of maturity as measured by the fiber content of the pod, nor was it an indication of roughness of the pod. The pods of sieve size 5 and 6 and larger were in some instances very rough, yet the percentage seed in the pod was low. Examination of these pods revealed the development of a few large seed in the pod, while the rest of the seed failed to develop.

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Two Years' Observations of Leaf Spot and Blight Of Carrots in the Rio Grande Valley

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Leaf spot and blight of carrots *Daucus carota* L. var. *sativa* (DC.) are two separate foliage diseases which occur in the Rio Grande Valley of Texas with varying degrees of severity according to the character of the season. During 1958-59 and 1959-60, the two diseases appeared concurrently on the foliage, and therefore from the viewpoint of the grower they might constitute a single disease. Although the two diseases are caused by different fungi, symptoms are somewhat similar and are easily confused. These diseases reduce the yield of carrots; or the loss of foliage may weaken the tops, make pulling of the roots difficult, and consequently increase cost of harvesting. The optimum temperature range for spore germination and infection is nearly similar for both organisms (72° to 82° F.) (Doran and Guba, 1928); so the controlling factor which determines the severity of infections is precipitation. Prolonged rainy periods favor infections.

In a carrot-breeding program for the purpose of studying resistance to these diseases, it is important to differentiate the symptom expressions and the causal organisms. The purpose of this paper is to discuss distinguishing characteristics of the diseases and their causal fungi.

SYMPTOMS AND CAUSES OF LEAF SPOT AND BLIGHT

Leaf Spot. This disease, which is world wide, is one of the most important foliage diseases of carrot. It affects both wild and cultivated forms and several other species of *Daucus* (Thomas, 1943). Leaf-spotting may occur at any point on the leaf, but it is most common on the margins. The spots are circular except when their position on the leaf margins makes them semi-circular, they have a diameter of 2 to 5 mm., but often coalesce and form larger spots (Figure 1, B). Centers of the lesions are usually grayish-brown but they tend to be light tan when the humidity is relatively low. Foliar lesions are usually surrounded by a narrow yellow or straw-colored zone. On the lower surface of the spots a grayish weft of the fungus is sometimes visible to the naked eye. Linear darker lesions develop on the petioles, sometimes girdling them and killing the leaves. Distinguishing characteristics of leaf spot are the nearly circular, rather sharply defined lesions with a yellow halo. The disease is usually found on young leaves in contrast to blight which is most severe on older, outer leaves (Hooker, 1944). Leaf spot is usually not so severe as blight in the Rio Grande Valley and during 1958-59 and 1959-60 leaf spot did not appear until late in the season.

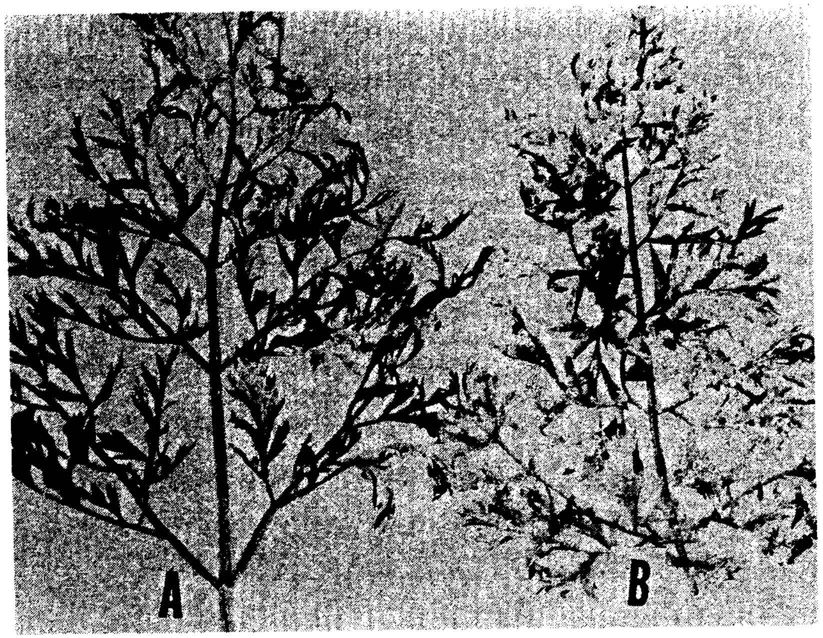

Figure 1. Carrot leaves showing (A) *Alternaria* blight (note dark, irregular lesions on leaves and stem); (B) *Cercospora* leaf spot with definite circular lesions.

Leaf spot is caused by the fungus *Cercospora carotae* (Pass.) Solheim. The fungus hypha penetrates through stomates (Thomas, 1943). The conidia (spores) are borne successively at the tips of clustered conidiophores, which arise through disrupted leaf tissue. Spores are hyaline or slightly darkened, tapered, several to many-celled, 2.2-2.5 by 40-110 microns.

Blight. This disease is likewise widespread in distribution. Of the two diseases, blight is usually the most prominent. During the last two seasons blight has caused the most severe losses in the Rio Grande Valley. Infections occur mostly on older leaves but during severe epiphytotics young plants may be attacked with nearly complete destruction of foliage. Blight first appears as indefinite brown to black areas with pale-yellow centers. Lesions are usually more irregular shaped and the necrotic areas are consistently darker than leaf spot lesions (Figure 1, A). Sometimes entire leaves turn yellow and then brown and black without conspicuous scattered darker lesions. Blight lesions are not so nearly circular or as sharply defined as are those of leaf spot. The mass symptoms of blight are more striking than are those of leaf spot. The foliage in a carrot field in which blight is severe may appear as if burned by heat.

The causal fungus, *Alternaria dauci* (Kuehn) Groves & Skolko, was first described in the United States as *Macrosporium carotae* Ell. & Langl. and is commonly referred to in the literature by that name (Walker, 1952). It is very similar in morphology and spore shape and size to species of Alternaria which cause early blight of potato and purple blotch of onion. Conidia (spores) are dark colored, frequently borne in chains and less often borne singly. Spores are variously shaped with both cross and longitudinal walls and vary from 30 to 100 microns in length.

DISEASE CYCLE AND CONTROL

Both fungi subsist between crop seasons as spores and in infected crop refuse. Spores are produced in abundance on old lesions in moist weather and are carried in air currents. According to Walker (1952) both organisms may be carried in or on the seed.

Spraying for both diseases will give satisfactory control if applications are made at regular 10-day intervals when the diseases are serious. Bordeaux mixture 6-6-100 and insoluble copper sprays are used in some areas (Walker, 1952). In the Rio Grande Valley zineb (zinc ethylene bisdithiocarbamate) 2 lbs. per 100 gals. of water has proved very satisfactory.

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Tomato Varieties for Production in a Plastic Greenhouse

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INTRODUCTION

Available "forcing" or greenhouse tomato varieties and one line from the regional tomato breeding trials were grown in replicated trials in a plastic greenhouse. The trials were conducted in the summer of 1959 and the winter of 1959-60. A trial conducted during the winter of 1958-59 has been reported (Dacus and Leeper, 1959).

Commercial production of greenhouse vegetables has been restricted to large population centers primarily in the northeast and midwest. The development of a practical system of evaporative cooling for greenhouses (DeWerth and Jaska, 1958) has made it possible to produce greenhouse vegetables farther south than formerly. In most of Texas, and especially in the Lower Rio Grande Valley, conventional methods of ventilating greenhouses are inadequate on bright sunny days even in mid-winter. When plastic is used to cover the greenhouse, a much cheaper type of framework may be used than is possible with glass. This greatly reduces the investment necessary to grow greenhouse vegetables.

GENERAL AND PRODUCTION PRACTICES

Plans for the construction of plastic greenhouses may be obtained from several institutions and private companies. Texas Agricultural Extension Service M. P. 341 (Paterson, et al, 1958) contains plans that are good. The following are some of the things that are usually emphasized in the various plans. Timbers, especially those placed near or in the ground, should be treated with a preservative that is not toxic to plants. Polyethylene, which is the most commonly used cover, becomes brittle after exposure to the ultraviolet rays of the sun, and generally will last from 4 to 8 months depending on the exposure. The use of heavier than 4 mil polyethylene extends the life of the covering very little and often 2 mil is recommended. Since the polyethylene covering is short-lived, it is important that the house be constructed to facilitate replacing it.

The pad and fan system of evaporative cooling is very effective for temperature control and ventilation. The heating should be adequate to maintain 58° to 60° temperature, and if toxic fumes or excess moisture are produced, the system must be vented to the outside.

Drainage and the absence of excess salts in the soil are important considerations in selecting the site for building a greenhouse. The fertility level and the physical condition of the soil may be built up and maintained if drainage is adequate and excess salts are not present. This

may be accomplished through the use of manure and commercial fertilizers, and should be started well in advance of the first crop. One schedule of fertilization (Porte & Smith, 1955) suggests 30 to 40 tons of barnyard manure, and about 250 pounds per acre each of P_2O_5 and K_2O before the crop is started. Soil tests are helpful in determining the fertility status of the soil.

About six weeks are required to produce plants for transplanting. Seed are usually sown in flats and transferred to pots about 10 days later. Peat, clay, or plastic pots may be used, and should be about three inches in diameter. Soil and pot should be sterilized, and workers who work the crop at any time should wash their hands in strong soap and water to avoid tobacco mosaic infection. A good plant for transplanting in the ground bed is strong and stocky with the first flower buds partially developed. Plants should be set an inch or two lower than the soil level in the pot. Chemical or steam sterilization is necessary for both potting soil and ground bed.

After transplanting, the plants are tied to an overhead wire with binder twine or similar heavy cord. The plants are pruned to a single stem which is twined around the string as the season progresses. Pollination is accomplished by vibrating the flower clusters daily beginning when the first flowers open, and continuing until about 40 days before the anticipated date of the last harvest. An electrical hand operated vibrator is commonly used.

Careful study of published information and experience are two of the most important ingredients of successful greenhouse tomato production. Neither will substitute entirely for the other.

MATERIALS AND METHODS

In each test, five plants of a variety comprised a replication, and five replications of each were supplied. Plants in the outside rows were excluded from the replicated test in order to eliminate border effects. The plants were spaced 15 inches apart in rows 30 inches wide. This spacing provided 3.13 square feet per plant or between 13,000 and 14,000 plants per acre.

The soil was sterilized with methyl bromide preceding the summer crop, and with Vapam and Terrachlor preceding the winter crop. Neither method was entirely effective against fusarium wilt and nematodes.

Fungicides were applied at about 10-day intervals throughout the growing season for the prevention of foliage diseases. Light infestations of fruit worm, cabbage loopers, and red spider were encountered during the growth of the two crops, but were readily controlled by the use of the appropriate insecticide. It is advisable to occasionally include an insecticide in the fungicide program as a precaution although no infestation is evident.

RESULTS AND DISCUSSION

Summer 1959:

On February 27, 1959, seed of the following varieties were sown:

- Sioux
- Step 314 (from regional breeding trials)
- Tuckcross "V" hybrid
- Tuckcross "O" hybrid
- Waltham Moldproof Forcing #56 (W.M.P.F. #56)
- Waltham Moldproof Forcing #2-22 (W.M.P.F. #2-22)

The plants were transplanted to the ground bed on April 10, 1959. Twenty harvests were made from June 5 through July 31 (Table 1).

Table 1. Yield and quality of tomatoes—summer 1959.

Variety	*Pounds/Plant*		*Marketable Fruit*	*Weight Per Fruit*	*Percent Fruit Affected With*	
	Total	*Marketable*	*Percent*	*Ounces*	*Blossom End Rot*	*Cracks*
Sioux	3.4	1.2	36	4.3	18	26
Step	5.4	3.2	60	5.2	12	24
Tuckcross "V"	7.0	3.6	51	3.1	9	34
Tuckcross "O"	7.2	3.8	53	3.2	11	20
W.M.P.F. #56	5.0	2.2	44	2.0	2	45
W.M.P.F. #2-22	5.1	3.1	60	2.3	8	20

Before the summer crop was started, the evaporative cooling pad area was increased from 80 to 152 sq. ft. in a further attempt to lower the temperature within the greenhouse. The air was pulled through the 80-ft. length of the house and considerable temperature buildup occurred before the air was exhausted. To a large extent, the temperature buildup could be avoided by pulling the air across the house. The readings in Table 2 were taken between June 27 and August 2, 1959 from hygrothermographs, one of which was inside the greenhouse about ten feet from the exhaust fans at a height of four feet, and the other was outside about 300 yards from the greenhouse. The average maximum temperature for the days included in the study was lowered from 94° outside to 86° F. inside. The range of maximum temperatures show that

Table 2. Temperature and humidity conditions outside and in the greenhouse (6-27 through 8-2-59).

Location	*Temperature Range*		*Temperature Average*		*Relative Humidity Range*		*Relative Humidity Average*	
	Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
Outside	70-76	90-101	73	94	28-46	83-87	36	85
Inside	72-77	81- 90	74	86	62-76	96-98	67	97

the temperature inside the house was maintained at 90° or below (Table 2).

Total production was quite good; however, for several reasons 40 to 64% of the fruit, depending upon the variety, were culls. The overall reason for poor quality was considered to be adverse temperatures and light conditions.

Blossom end rot was quite severe, with 18% of the fruit produced by the Sioux variety being affected. Calcium, applied in the form of calcium nitrate when nitrogen fertilization was required, seemed to reduce the incidence of the disease.

Cracking was very severe in all varieties, and was especially bad in variety W.M.P.F. #56, affecting 45% of the fruit. Harvesting more frequently than the usual 3 or 4 days, or harvesting the fruit at a slightly earlier stage of ripeness would probably reduce the losses from cracking.

Very small fruit accounted for most of the culls not caused by blossom end rot or cracking.

Partial shade to cut down the light intensity and help in further reducing the temperature might eliminate some of the difficulties encountered in producing greenhouse tomatoes during the summer months.

Varieties Tuckcross "O" and "V" show about the same potential for production and quality, and were superior to the other varieties. Tuckcross "V", the W.M.P.F. varieties, and Sioux, however, proved to be susceptible to fusarium wilt. Sterilization of the soil with methyl bromide and later with Vapam failed to eradicate the disease.

Winter 1959-'60:

On August 19, 1959, seed of the following varieties were sown:

- Step 314
- Tuckcross "V" hybrid
- Tuckcross "O" hybrid
- Waltham Moldproof Forcing #56 (W.M.P.F. #56)
- Waltham Moldproof Forcing #2-22 (W.M.P.F. #2-22)
- Michigan-Ohio Hybrid

Approximately 20 tons of manure and 75 pounds of Es-Min-El trace element mixture per acre were worked into the soil following the summer crop. The soil was sterilized with Vapam and Terrachlor two weeks before transplanting on October 5th.

Thirty-three harvests were made from December 16 through April 26. Data on yield and quality are shown in Table 3.

Step 314 and Tuckcross "O" produced about the same amount of marketable fruit, although Tuckcross "O" had the greater total yield.

Table 3. Yield and quality of tomatoes winter, 1959-'60.

Variety	Pounds/Plant Total	Pounds/Plant Marketable	Marketable Fruit (Percent)	Weight Per Fruit (Ounces)
Step 314	8.2	7.0	85	3.8
Tuckcross "O"	9.8	6.9	70	3.7
Michigan-Ohio Hybrid	8.1	6.3	78	3.5
Tuckcross "V"	7.1	5.4	76	3.2
W.M.P.F. #56	7.1	5.2	73	2.1
W.M.P.F. #2-22	6.6	4.9	74	2.6
Avg. Border Rows (Mixed Varieties)	13.4	10.9	81	3.8
Avg.—All Plants	10.0	7.9	79	....

Step 314 produced a higher percentage of marketable fruit and a slightly larger fruit.

Most of the culls resulted from catface and puffy fruit except in the case of the Waltham Moldproof and Tuckcross "V" varieties where size became a factor. The catfacing and puffiness of the fruit was attributed to low temperatures that prevented proper pollination of the flowers. Temperatures often went as low as 45° to 50°.

Crowding of the plants may have contributed to the rough and puffy condition of some of the fruit and certainly resulted in smaller fruit and lowered production. This is obvious when the total as well as marketable yield of the border rows is compared with that of the best variety in the replicated test.

Wider rows and more than 3.1 square feet of area per plant may be the answer. Running the rows north and south rather than east and west, as was the case in these studies, would allow better distribution of sunlight.

A number of plants of Tuckcross "V" and the Waltham Moldproof varieties were killed by fusarium wilt. The three top yielding varieties have good resistance to fusarium wilt, and both Tuckcross "O" and Step 314 have good resistance to common races of the leaf mold organism.

Cracking of fruit and blossom end rot were not a serious problem. A light infestation of root knot nematode was discovered on a few plants at the time of removal, reaffirming the necessity of soil sterilization.

SUMMARY

Step 314 and Tuckcross "O" were good varieties for greenhouse production in this area. Tuckcross "V" and the Waltham Moldproof varieties are susceptible to fusarium wilt, which in practice is very difficult to eradicate from the soil.

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Some Aspects of Vegetable Research in Mexico[1]

Ernest H. Cásseres[2]

Peppers, tomatoes and squash have been used in Mexico for several centuries but it has been only in the last decade that vegetable crops, as a group, have become really important to supply the growing demand for better and more diversified foods. Vegetables are frequently used only in limited quantities because they are not always available, nor are they of desirable quality or much food value.

Vegetable research in Mexico has been directed, therefore, towards these objectives:

1) Breeding improved varieties of locally known vegetables; 2) to a determination of the regional and seasonal adaptation of *other* introduced, superior varieties from abroad; 3) to find out what are the best methods for the production of fresh foods in home gardens and in commercial plantings. Projects which have these objectives are either on a short term basis while others are on a long term or continuing basis. In carrying out this work, the training of local personnel has been a parallel development. Twenty young men have taken part in the developments of these last nine years, out of which six different aspects will be discussed briefly in this paper.

1. *New Crops and Varieties*

Yearly trials in five different regions have provided sufficient data to make possible the distribution on recent field days of tables indicating what are the best varieties, dates of planting, spacing and other details for a dozen vegetables. Among these some have been relatively little-known in the past. The following improved varieties are examples of crops now being planted more frequently in the intermediate and highland areas:

1. Asparagus, variety UC 309
2. Artichoke, selections made in Toluca
3. Broccoli, varieties De Cicco and Waltham 29
4. Snap Beans, varieties Tendergreen and Contender
5. Summer Squash, variety Caserta

2. *Orange-fleshed Sweet Potatoes are Improvement over Local Types*

The high-yielding orange-fleshed sweet potato clones have recently

[1] Paper presented before the Rio Grande Valley Horticultural Society, Weslaco, Texas, January 26, 1960.

[2] Head of Horticulture Section, Rockefeller Foundation Mexican Agricultural Program; on loan from Inter American Institute of Agricultural Sciences.

been released as the new Cuitzeo and Catemaco varieties. The introduction of these new varieties will provide over twice the amount of sugars and over two more times the provitamin A found in white creole types. The latter, since dry, white, sweet potatoes are well known in some parts of Mexico, are often oversized, malformed and fibrous. Observations and yield tests over the last 4 years indicate Cuitzeo and Catemaco may yield from 16 to 24 tons to the hectare under normal favorable conditions. They are 2-3 months earlier and the crop is much more uniform in size and shape.

3. *The Tomato Is One of the Two Most Important Vegetables*

a) Cotaxtla 1, a tomato variety originated from a selection made by the Horticulture Section is being planted in increasing acreages in the Gulf Coast Area of the State of Veracruz. It has yielded well and shown some resistance to gray leaf mold and resistance to hot dry winds. Seed has been produced at the Cotaxtla Experiment Station and by the Ferry Morse Seed Company in California.

b) Row plantings and replicated yield trials conducted in Mexico as a part of the Southern Tomato Exchange Program provide prompt awareness of new varieties coming into importance (i.e. Indian River) and an opportunity to make selections that may fit our particular needs. In the latter case, for instance, STEP 272 and STEP 284 are promising at our Veracruz Station because they mature earlier and later, respectively, than our Cotaxtla 1 variety considered as the standard.

c) Breeding work continues with resistance to *P. infestans* and firmness of fruits as major objective.

4. *Multiple Forms of Squash Provide a Popular Food*

Squash has been a popular food in Mexico for a long time and it is grown all over the Republic under most diverse conditions. A large quantity of squash is consumed, especially in late fall cooked with brown sugar, and a part of the crop is stored for late use. Several botanical species of *Cucurbita* represent the native *calabaza*. *C. pepo* and *C. maxima* are more common in the highlands, while *C. moschata* is more frequently found in the warmer climates and lowlands. *C. mixta* is planted exclusively for its seeds. Among the first three species, forms sometimes are found which do not correspond to the commonly accepted species descriptions. A systematic study of the botanical interrelationships of these species is a long range objective of our squash project. An amazingly high degree of variability in quality, yield, size and coloration of fruits has come into being. Nearly 500 collections of squash have been made, and of these about half have been evaluated in trial grounds. Simultaneously we are working on the formation of more uniform lines by inbreeding. Quality tests of the better selections made the past two seasons by baking and steaming samples have indicated which lines have promise for commercial production or as a basis for a breeding program. Line 135-A, one of such lines is in its second year increase. This is a bright-orange-fleshed type with pear shaped fruit that has a thick solid neck. It is not as dry or as fine textured as we would desire it to be.

5. *A Seed Industry Begins*

Semi-desert climatic conditions in portions of North Central and North West Mexico are very suitable for seed production provided irrigation facilities are available. Experimental plantings initiated five years ago in the states of Nuevo León, Durango, Sinaloa and Sonora showed that good-seed of a dozen vegetables could be grown through adaptation of crop handling methods and mechanical processes. Today tomato seed is being produced under government supervision in Sinaloa and at least three companies have initiated production, not only of tomato seed but also of cantaloupe, watermelon and of other vegetables. The fourth consecutive crop of head lettuce seed with a low mosaic count is now being grown in Mexico's North West for United States' concerns. At the CIANO Experiment Station for the North West (located near Ciudad Obregón, Sonora) garden pea seed production has worked out quite satisfactorily and plots of onion and broccoli have been set out this year to study factors governing their seeding habits.

High prices of imported seed, lack of adequate varieties and low production costs are some factors that are contributing to the initiation of Mexican vegetable seed production on a formal basis and under rather favorable circumstances.

6. *Regional Value of Horticulture Research in Mexico*

As the preceding significant developments have been taking place, it has become increasily apparent that certain portions of the horticultural research methods and findings in Mexico could be put to good advantage by neighboring countries. Several international agencies have contributed towards the ideal of doing together that which individual countries cannot usually do well alone. Such an international agency is the Inter-American Institute of Agricultural Sciences which chose Mexico as the site for its III International Training Course in Horticulture offered in 1959 to 10 other countries besides Mexico. In this event the fine cooperation of the Rockefeller Foundation's Mexican Agricultural Program, through its Horticulture Section, was a key reason for the success of this educational effort. This helped to further the Bolivian concept of uniting the Americas through maximum use of well-developed national programs on a regional basis. The Horticulture Section served likewise, as the pivotal point of the V Annual Meeting in 1957 of the Caribbean Region of the American Society for Horticultural Science, and has continued since then, in cooperation with the Institute of Agricultural Sciences, to help promote the development of horticulture in the tropics and subtropics by providing headquarters for this regional group.

Another way in which the work in Mexico has had a regional value

is through the exchange of seeds and publications. Pepper, tomato, squash and sweet potato materials have gone across the borders. The quarterly publication "Novedades Hortícolas", probably the only extension bulletin of the Hemisphere in Spanish, is prepared by the Horticulture Section staff. Starting its 5th year of publication it not only helps the Mexican farmer, but also goes to a number of horticulturists and institutions in Central and South America.

The *regional application* of the successes where applicable, as well as the lessons learned from failures, is becoming one of the most significant means of meeting the problem of feeding the world adequately *today*, and will be a method of increasing importance, *tomorrow*.

The foregoing account of some of the accomplishments in vegetable improvement in Mexico should not be construed to signify that a steady stream of successes has taken place. Some failures and delays have occurred, as in most any developmental program. Neither is the job finished. New problems will arise to challenge the horticulturists as new areas are brought into production, and as population growth and increased international commerce impose higher requirements in quality, in food preservation and in lower costs.

MISCELLANEOUS

Prevention of Rain Damage on Vinifera Grapes By Use of Polyethylene Film

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Rain damage to the bunches at time of maturity is a major problem of potential grape growers in the Lower Rio Grande Valley. The most promising varieties of grapes mature in May and June when the Valley generally receives two to four inches of rain.

Rain damage on grapes consists of berry splitting and rotting of the fruit (See Figure 1). The two to three week period from the start of the translucent stage of berry growth to maturity is the period of greatest hazard from rain. Before the berries leave the hard-green growth stage, rain will not cause damage other than mildew and rots associated with the high humidity following the shower. These diseases can generally be controlled by fungicides.

During May and June of 1959 several experiments were initiated to determine whether polyethylene film could be used to prevent rain damage to the berries. Also, another objective was to determine whether the vines or fruit would sunburn under the plastic.

One test was on Suntex Farm near Rio Grande City on a vineyard of Perlette grapes. A second test was on E & S Farm near Rio Grande City on a vineyard of Thompson Seedless grapes.

Two mil strips of clear polyethylene plastic sixty inches wide were placed over the top of the vines and trellis. The vines were completely covered across the top and a slight overlap of the plastic occurred on both sides of the trellis. The material was held in place by clipping it with clothes pins at two-foot intervals to the trellis wires and canes of the vines. In order to prevent the wind from tearing it loose, binder twine was tied completely over and under the polyethylene and trellis at intervals of fifteen to twenty feet.

The plastic was put over the vines on May 21, 1959 and removed near the end of June after the grapes had been harvested. A two-inch rain fell on the plots in early June when the grape berries contained from 14 to 17 per cent total solids. At this growth stage rain damage normally occurs when water drops strike the berries.

The Perlette plots were harvested on June 10, 1959. Before harvesting, the relation of rain damage to position of the bunches on the vine was investigated. On the unprotected plots rain damage occurred on most of the bunches regardless of position on the vine. The bunches on the plastic-covered vines showed little to no damage depending upon the

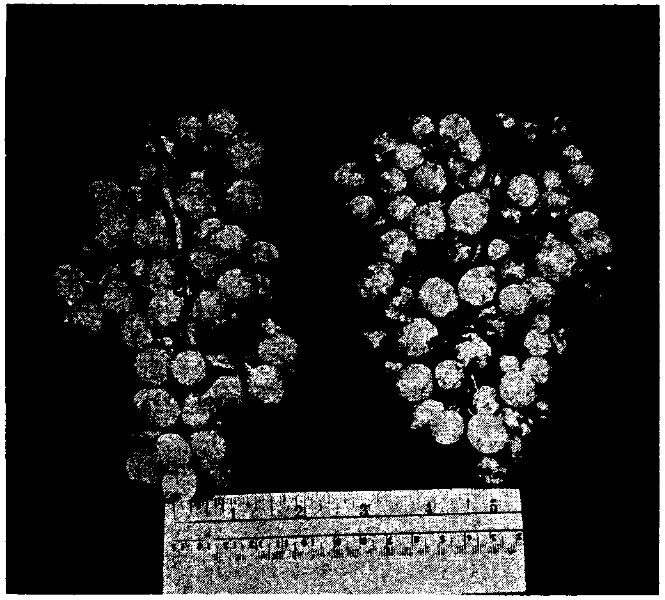

Figure 1. Bunch on left protected by plastic; no rain damage on berries. Bunch on right from unprotected vine; note splits on berries and disease around pedicels of many berries.

location of the bunch on the vine. The bunches near the edges of the plastic where rain could run off the top or where water could blow in from the sides showed some rain damage. All other bunches that were covered by the plastic were completely free of rain-damaged berries. The plastic protected an estimated seventy-five per cent or better of the grapes.

During the period that the experiments were in progress mid-day temperatures varied from 95° to 105° The only vine damage was some leaf burn on the leaves directly in contact with the plastic. After the plastic was removed the vines resumed normal growth with apparently no ill effects. Damage did not occur to the bunches from high temperature.

The comparison of non-covered and plastic-covered Thompson Seedless vines at E & S Farm gave the same results as did the Perlette plots on Suntex Farm. Polyethylene strips over the trellis and vines, even under high temperature conditions, gave adequate rain protection to grapes. The practice has commercial possibilities for the local grape industry.

An Infectious Mosaic of Jasminum

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Jasminum simplicifolium syn. *J. gracile* is commonly planted for landscape purposes in the Lower Rio Grande Valley of Texas. Six of 8 plants at the entrance to the U. S. Department of Agriculture, Fruit and Vegetable, Soil and Water Research Laboratory, Weslaco, show a conspicuous chlorotic pattern of mottling in the older leaves; the other 2 have appeared healthy, during 18 months' observation. Another lot of nursery stock including approximately 50 plants showed the same proportion of chlorotic mottled and healthy plants. The rooted stock originally came from Florida.

To test the possibility that the chlorotic mottling was caused by a virus, scions taken from mosaic plants were grafted to healthy plants. Symptoms appeared in these graft-inoculated healthy plants 7 months later, demonstrating that the cause was a graft-transmissible virus.

Symptoms were most striking during the warmer periods when growth was rapid. Older leaves were slightly chlorotic and were marked with typical mosaic patterns consisting of areas of dark green surrounded by chlorotic tissue (Figure 1). Ring spots were frequently pronounced. Symptoms were not distinct in new growth. Infected plants were not appreciably stunted and except for causing the variegated markings on the foliage the virus was innocuous. Leaves on infected plants showed some necrosis, particularly along the borders, during the winter. Symptoms on the graft-inoculated plants were similar to but milder than those on the original plants.

Symptoms are somewhat similar to those described by Hildebrand in Texas (1953) for the ringspot disease of privet (*Ligustrum ovalifolium*). However, attempts to graft Jasminum scions from mosaic plants to *Ligustrum* sp. were not successful. Even though unions remained alive for several weeks, definite symptoms were not expressed in Ligustrum.

Orton (1924) reviewed a report of an infectious chlorosis of Jasminum in England in "The Clergy-Man's Recreation: Shewing the Pleasure and Profit of the Art of Gardening" by John A. M. Lawrence, published in London in 1715.

Although a graft-transmissible virus (?) of *Jasminum* is listed by Weiss et al. (1950-53), the present report appears to be the first observation of a *Jasminum* mosaic in the United States.

The existence of an insect vector might be postulated; however the

Figure 1. Jasminum simplicifolium infected with mosaic virus. Note mottling and ringspot patterns.

most probable manner of transmission is clonal propagation from infected parental stocks.

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Stinging Caterpillars ("Asps") in the Lower Rio Grande Valley

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It has long been realized by entomologists that certain of the lepidopterous larvae possess urticating (stinging) properties localized in their spines or hairs.

In certain areas of the United States these urticating caterpillars have come to be known as "asps." The origin of this terminology can undoubtedly be associated with the horned viper *(Cerastes cornutus)* which was accredited with causing the untimely death of Cleopatra and was described as being an "asp." Thus, it would appear that the transition of the word asp from snake to insect had as its foundation the common knowledge that the latter is also the possessor of a virulent poison. The common European viper *(Vipera berus)* has long been referred to as an "asp," and it is quite probable that the origin and use of the word "asp" in entomology could be traced to misnomer rather than valid nomenclature. However, regardless of its origin, the word "asp," when used to define certain types of caterpillars, carries a profound meaning to most people familiar with their urticating qualities.

A careful investigation of the literature reveals little reference to lepidopterous "asps" but does reveal the fact that poisonous properties in larvae of this order are far from uncommon. It is recognized that a considerable number of urticating species occur in the United States, the Eastern Hemisphere and the tropics, but only the principal forms occurring in the Lower Rio Grande Valley will be dealt with in this particular paper.

It would appear that knowledge of the urticating nature of certain species of these caterpillars dates back to mediaeval times, since many of the early Greek naturalists mention *Cnethocampa pityocampa* (Den & Schif.) for its vesicating properties together with the Cantharis beetles. Then followed reports by Wills, 1848-1849; Morren, 1849; Keller, 1887; Fabre, 1916; Packard, 1895; Ingenitsky, 1896, and Holmgren's histological studies of the same year. It was not until 1903, seven years later, that Von Gorka again published on the subject and again in 1907 articles on the brown tail *Euproctis chrysorrhea* (Linn) were published by Tyzzer. In all, over thirty papers were discovered and read covering this interesting subject, the latest of which was Gilmer's papers of 1923 and 1925, Bishopp's 1923, followed by that of W. B. Herms, 1950, and D. W. Micks, 1952-1955. No extended discussion of the literature is intended, but reference to the more important publications that this subject matter embraces will be made when considered prerequisite to complete understanding of the specific subject.

The insect fauna of the Lower Rio Grande Valley is particularly rich, and native species are augmented to a great extent by migrants from nearby Mexico, thus it is not unusual to discover that the "asps" or urticating caterpillars are well represented.

Principal amongst the prevalent "asps" in the Brownsville, Texas, areas are the "puss" caterpillars, or "perrito," as they are called by our Spanish neighbors, (*Megalopyge opercularis,* S. & A.) and the io moth larvae (*Automeris io* Fab.). *Lagoa crispata* Packard and *L. pyxidifera,* S. & A., the flannel moths, are also common but their stinging propensities are not so highly developed. Both *Megalopyge* and *Automeris* are particularly common being nuisance pests on the plentiful hackberry (*Celtis* sp.), Turks Cap (*Malvaviscus* sp.), pyracantha, crepe myrtle, ash (*Fraxinus* sp.), mulberry (*Morus nigra,* etc.), willow (*Salix* sp.), and the abundant acacia shrubs.

Since these catepillars all appear to be omnivorous in their food selection it is obvious that that a multitude of host plants could be added to the foregoing list, and the very fact that the caterpillars can be involuntarily dislodged or directly descend from the trees to seek out more appealing herbage or merely hunt out a satisfactory secluded place to pupate, necessitates that mention be made of the risk of contacting the caterpillars on the ground, in the lawn grass or while they are innocuously exploring the planter or flower bed.

The "puss," "possum," Italian asp or "perrito" caterpillars (Fig. 1), *Megalopyge opercularis* (S. & A.), are perhaps the most common and best known "asps" in the Lower Rio Grande Valley. The term "puss" caterpillar originated no doubt from the close semblance of the caterpillar hairs to those of the common house cat, *Felis catus;* "Possum" from its sluggish and innocent appearance; "Perrito," the Spanish name for little dog, needs no explanation.

This particular caterpillar is approximately 1 to 1½ inches long when full grown. The head is light colored and the body resembles a soft cushion in appearance since it is clothed with long soft hairs which gives to the body the appearance of being one half as broad as it is long. These dense hairs are usually mouse gray or yellow and reddish brown; those near the posterior end are tufted of a darker color and form a tail-like projection. Seven pairs of prolegs are borne by abdominal segments 2 to 7 and 10; those on the forenamed segments are devoid of hooks.

Lagoa crispata (Pack.) larvae are very similar to the aforementioned "puss" caterpillars; they are cream white colored in the early instars and fawn shading to mouse gray when full grown. This particular "flannel moth" is widespread throughout the United States and consequently needs little description.

The urticaceous caterpillars, while seldom falling prey to hungry birds, do have a formidable threat to their existence in the form of insect parasites and bacterial disease.

During the past few years there has been great fluctuation in the annual "asp" bio-mass in the Lower Valley, and parasite recoveries from field-collected "puss" and "io" caterpillars. This periodicity does not appear to be associated with their effectiveness since in every case no high degree of parasitism has been determined in either species.

However, the incidence of parasitism in this area, while affecting both caterpillar populations, is difficult to determine in exacting degree. I have found that *Megalopyge opercularis* is more abundant certain years than *Automeris io* and vice versa. Thus, the degree of parasitism in the least abundant species should exhibit a greater inhibitory influence on the smaller population and be evidenced in the succeeding generation, but collections made during the past three years do not substantiate this conclusion.

During the Fall of 1955 repeated field trips resulted in the collection of but 57 *Automeris io* caterpillars. From this number, 6 succumbed as the result of bacterial disease, 11 yielded parasites, and one was mechanically injured and died.

Thus, 31.6 per cent were victims of natural control agencies. The tachinid parasite *Exorista flavirostris* (V.D.W.) was predominant with but a single specimen of *Chalcis ovata* (Say), the common hymenopterous parasite, emerging from one of the cocoons.

The abundance of *io* caterpillars in the following spring (1956) was particularly striking since they occurred following a year in which the population level was considered quite low. This could have been the result of the normal biological phenomena of balance, illustrating the population recovery of the host in advance of its attacking organisms, but since none of the parasites are host specific the answer must lie elsewhere.

The "puss" caterpillars have been found to be parasitized in varying degrees. Uniform collections of 200 caterpillars have been made during the past two years (1955-1956) from both the spring and fall broods of *Megalopyge opercularis* and the average parasitism was established to be approximately 38 per cent. Little difference existed between the levels of parasitism in the seasonal broods, but the degree of parasitism was slightly higher (8 per cent) in 1955 than that of the following year.

The tachinid parasites *Pharocera claripennis* (Macq.)*Carcelia lagoae* and *Exorista flavirostris* were the most dominant, with an occasional specimen of the ichneumonid *Composocryptus retentor* Brullé and the common hymenopterous parasite *Chalcis ovata* (Say) being recovered.

Thus, it would appear that the natural control agents collectively do not exert sufficient deleterious pressure upon the "puss" catepillar population to keep it at a minimum level, therefore, other factors must of necessity have an influence upon the insect's ability to build up.

Since the "asps" did not reach pest proportions in the two foregoing years their future population levels will be carefully checked and both climatological and biological effects together with their symbiotic relationships carefully evaluated.

The asps have in common a setaceous or bristlelike coat; the spines alternate with plumose hairs, one hair between two spines. The spines originate on the upper surface of a heavy chitinous mass that forms a ridge, the cuticula being particularly thick. The spines have at their base a form of cavitation, or bulb, from which a minute twisted tubule arises and journeys thru the chitin wall and connects with the hypodermis.

The hypodermis assumes a peculiar whorled appearance at the point of the tubule entrance, the center of which is occupied by a large gland-like cell.

Gilmer (1923) states that he has little doubt concerning the fact that the tubules themselves are occupied by living material, the cell nuclei occupying the broadest portion. Protoplasm can be determined issuing from the tubule and spreading into the bulb cavity.

Within the bulb itself, enclosed within the hypodermal lining is a cell containing a large mass of coarse granules. Since this cell completely fills the bulb, passes thru the fenestra and completely fills the lumen of the spine up to and including the apical point, there appears little doubt that Gilmer is correct in defining this as the poison gland cell.

Mush discussion has arisen regarding the nature of the poison contained in these cells; certain groups class it as a true venom combined with a protein vehicle while others class it as being a mucoid substance, but since the granules appear to be inert to all the recognized chemical reagents there would appear conclusive evidence to support Gilmer's conclusion that it is in itself not a protein. Various other workers have determined that the poison substance was not formic acid nor cantharadin, but there is strong support for Foote's (1922) belief that while it is not a protein in all probability the granular material commonly found in all poison cells is capable of being absorbed by protein molecules which are of course natural constituents of the gland cell cytoplasm.

Solving the problem of the chemical composition of the venom presents a real challenge to the research chemist. The tremendous problems that arise from such an undertaking are readily appreciated when we stop to consider the painstaking effort that it requires to isolate the venom, the exceedingly minute sample that it is possible to extract from the cells and its intractable nature, which all contribute toward making it a truly monumental task.

However, regardless of the chemical composition of the venom, the fact remains that contact between exposed surfaces of skin and the caterpillar's spines causes immediate irritation. The magnitude of the reaction varies to a great extent with the individual sufferer.

Under ordinary circumstances none of the asps possess a deadly poison, but literature records the case of a child that was poisoned by

a Megalopygid in the Valle de Cauca, Columbia, that was sufficiently severe to warrant being considered potentially fatal (Garcia 1910). Likewise there are records of fatal cases of pneumonic "Brown Tail Rash" which definitely incriminate the caterpillars of *Euproctis chrysorrhea*. Similar outbreaks of dermatitis sufficiently severe to require the closing of schools in San Antonio and other places in Texas are recent history (Micks 1952). It is generally accepted in most medical circles that certain forms of summer urticarias, and outbreaks of "hives" could have insects as their source, principally the urticaceous caterpillars whose hairs could be widely disseminated by the wind.

It is also reported that natives in tropical Africa employ caterpillar skins in preparing poison with which to dip their arrows, but the information is fragmentary and devoid of details concerning the insect species or the form of poison.

The number of families implicated is quite numerous and perhaps the soundest advice to the uninitiated would be to use extreme caution when handling caterpillars that have a pronounced hairy appearance, particularly if they are possessed of true pointed spines.

The lesions produced by the "sting" of these urticating asps usually result in an acute burning sensation that later subsides to an annoying itch; in some cases extensive inflammation occurs and may be followed by papules or vesicles.

While individual susceptibility and reaction to the sting of the caterpillars is acknowledged, the general reaction is one of alarm and excitement engendered no doubt by ignorance or exaggerated statements concerning the ill effects that are so frequently associated with insect stings.

Certain areas of the body are by nature more sensitive and the reaction from a sting these localities often result in very ill effects. It is recorded (Bishop 1923) that a sting that occurred on the neck on one man was sufficient to incapacitate and confine him to the hospital for six days. Other equally illuminating accounts of pain and incapacitation following the sting of an asp are numerous, some obviously fiction, others in some measure valid.

Experience has shown that the immediate reaction following a sting by these urticating caterpillars is one of an intense burning pain, accompanied or immediately followed by an irrepressible itch. The infected area immediately sprouts small white blister-like papules which become quite red with the increase in inflammation. Sometimes a local or even general swelling of the injured member takes place and this usually accompanied by a numbness or paralytic feeling. In very severe cases of infection, or those affecting young children, considerable fever, nervous symptoms, general nausea or vomiting often occur.

It is not uncommon for certain of these distressing factors to continue for 48 hours, but in the majority of cases the effects are nothing greater than intense local irritation devoid of any complications and subdue themselves in just a very few hours.

Micks states in his excellent clinical report that the outstanding findings of his study reveals the fact that in a matter of about 10 minutes after the sting occurs acute stabbing pains extending proximally to the adjacent trunk region were the general symptoms exhibited in the patients upon whom he reported.

The stage of larval development, its size, and the degree of pressure exerted upon its spines very definitely influence the severity of the sting, but in every instance I was unable to perceive any appreciable difference in the accompanying reactions.

The spines of these caterpillars long retain their nettling propensities as I was painfully made aware, when I inadvertently picked up the cast skin from an *Automeris* caterpillar following its moult. Thus, the shirt of Nessus still burns the veins of those who wear it, and of this we should be ever mindful when handling the cast integument of any and all of the urticaceous caterpillars.

In order to explore the possibility of extracting the poison in a manner similar to Fabre, a sample of 12 cast skins was immersed for 24 hours in ethyl ether ($C_2H_5OC_2H_5$). The liquid upon being removed was filtered and exposed to spontaneous evaporation, and in order to recover any substance still adhering to the caterpillar skins they were in turn rinsed and re-rinsed in ether. The ethereal infusion was reduced to a few drops after the process of evaporation and these were carefully absorbed into the gauze pad that is affixed to a ¾ inch wide band-aid; this was then placed on the underside of the wrist about the junction point of coat sleeve and flesh.

No immediate reaction was sensed but some six hours later an acute burning sensation accompanied by shooting pains and a mild paralysis which later subsided ,and an ever increasing itch, were evidenced. This condition continued at an uncomfortable level for almost five hours after which time the reaction was limited to an annoying itch which gradually lessened in intensity.

When the band-aid was removed some 24 hours later, the skin was found to be highly inflamed and covered with the characteristic pale lenticular swellings that I have learned to recognize by experience, as the result of a brush with the urticating caterpillars.

For almost 24 hours an exudation of serous fluid continued to trickle from each of the pustules; concomitant with its abation, the inflammation, and the irritation eased and slowly the skin dried and commenced to scale. Thus, at the end of a week all that remained was a local discoloration that very slowly disappeared.

This skin reaction was in direct contrast with those experienced by actual contact with the caterpillar, for without being immediate the action of contact is prompt, whereas the application of the extract removed from the cast integuments cause painful reaction only after a prolonged

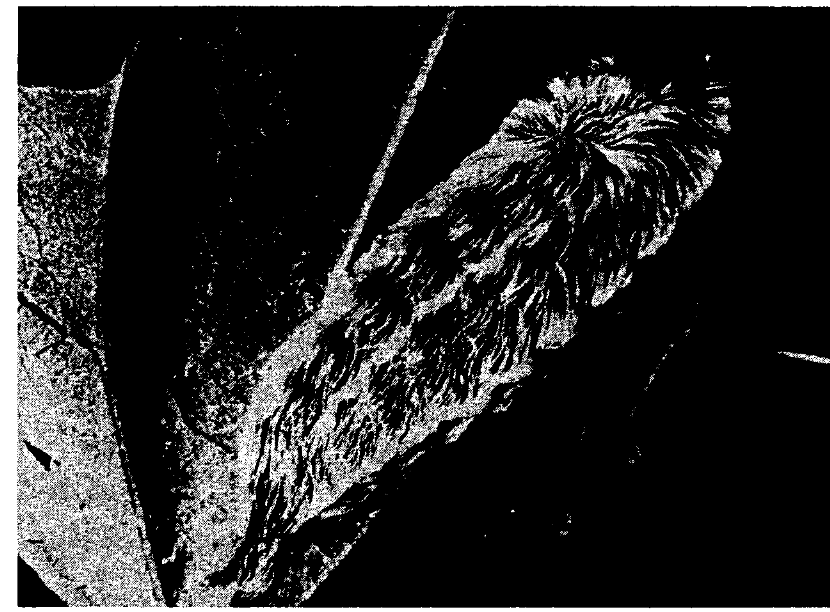

Figure 1. Megalopyge opercularis. The puss caterpillar or common asp.

Figure 2. Automeris io. The common spiny io moth caterpillar.

interval of time. What then does it require in order to produce a rapid ulceration? To all intent and purpose, the action of the spines, a theory advanced by Fabre many years ago.

Automeris io (Fig. 2), another gregarious caterpillar and almost omnivorous in its food selection, is very abundant in this Texas region. The full grown caterpillar is particularly beautiful; their body is a beautiful shade of green, ornamented with a laterial stripe of pink and creamy white. However, a veritable fortress of spiny tubercles are present on its dorsal and lateral aspects. I have found it to be most abundant on the Acacia species that are found to be so plentiful along the banks of the resacas, but it can also be found on such a multitude of wild and cultivated plants that to list them all would be superfluous to the need. Two distinct types of spines are present, the one most prevalent on the lateral tubercles, with the others on both the dorsal and subdorsal; both types can be found present on any single tubercle.

A rather long and slender seta is to be found at the apex of the most common lateral tubercles.

The functioning venomous spine is found more generally on the dorsal and sub-dorsal tubercles. The only readily distinguishable difference between the two types of spines is the pronounced slender form of the seta-bearing type. The venomous type spine possesses a heavy conical chitinous point, particularly keen and from light to dark brown in color. The actual length of this point or tip, together with its diameter, varies greatly but in every case their base fully occupies the apical area of the spine proper. Gilmer reveals the fact that there seems to exist a phylogenic relationship between the seta bearing spines and the sharp point bearing form, but the *Automeris io* spine in general is not what we would consider as being the true branching type in spite of its close approximation to that form but fits more nearly into a category intermediate or midway between the true branching and the low tubercle spine.

Both types of spines are to be considered poisonous; however, the seta bearing type has erroneously been referred to as an innocuous spine and from the actual standpoint of function this is probably so, since its willowy nature results in its bending under the slightest applied pressure and thereby makes its penetration power negligible. However, it was demonstrated that since direct inoculation was extremely uncertain, the severing of the apical tip of the spine with the gland cell intact and exercising sufficient pressure to rupture it and force the cell contents into a freshly inflicted minor wound on the hand did produce positive results.

The resultant reaction to the inoculation compared almost identically with those experienced when contact with the live caterpillar was made, but the degree of irritation was much intensified and of greater duration.

This discovery is not unusual if viewed in the light of the progressive ontogeny of the point bearing spine, for they are seta bearing in the early

larval instars and only develop the point characteristic with succeeding insect moults.

The general morphological features of the seta bearing spine are little opposed to that of the most efficient pointed spine, but this characteristic leads to the development of a more finely textured hypodermal lining. However, the gland cell is definitely smaller and in some specimens is paralleled by what is described by Gilmer as the trichogen cell.

Contrary to general belief, the point does not break off, only the very extreme tip; the whole apparatus instead functions much as a hypodermic syringe. Penetration of the flesh is most generally made at a hair follicle and the pressure exerted upon the spine by the point being thrust back into it, or the junction of point and spine becoming acutely bent, causes sufficient pressure to be brought to bear upon the large gland cell which forces a limited amount of the poisonous cytoplasm into the incision. Consecutive injections by the same functioning spine into different points on the anatomy does not reduce its efficiency or yet the potency of its venom, thus the efficacy of these so called "nettling" spines is continuous during their existence.

Whether voluntary victims of our curiosity or inadvertent sufferers thru accident, we all have the desire to seek relief from the infliction of the asp's poison, for while we must acknowledge that it is of benefit to know the origin of the harm, it is equally important to know a remedy.

Therapeutic remedies have had birth in rustic imaginations since the creation of man, but surprisingly often we find concoctions prescribed by the apothecaries of old that have unusual merit, particularly those counter-irritants and soothing balms that have as their base vegetative or dried herbs.

From the early writings of Reaumur we learn of a palliative that he employed to gain relief from the irritation caused by contact with an urticaceous caterpillar in those early ages. Without explanation as to what guided his action, he states that he applied the macerated leaves of common parsley, *Petroselinum crispum*, to the afflicted parts of his body and reports that he gained immediate relief!! Fragrant and fleshy as it is, little difficulty is encountered in crushing it and obtaining an emollient liniment of sorts but while I do agree that its action tends to relieve the acute burning sensation it persists at a discomforting level for a considerable time after treatment has been applied.

Another remedy that had birth in the fertile mind of an old apothecary was the application of freshly cut raw onion sections. This natural poultice has little proven merit.

Weak solutions of ammonia hydroxide is credited by some for alleviation of the irritation, and there are countless other such recommendations, many of them dating back to the materia medica of antiquity. However, perhaps the most practical recommendation made for those afflicted by the "sting" of the caterpillars when far removed from the facilities of the modern medicine cabinet with its rich provender of antibiotics and other recognized pharmaceutical counter-irritants, is simply collect any soft turgid leaf from nearby plant, vine or tree, crush it and apply the macerated mass to the injury. The mode of action of this botanical specific is difficult to define; perhaps Fabre's reference to Moliere's medical students explanation of the soporific properties of opium is worthy of reiteration.

"Quia est in eo virtus dormitava cujus est proprietas sensus assoupire." Thus, we might likewise state that: the macerated foliage relieves the burning itch because it possesses a relieving virtue whose property is to assuage itching. We must agree with Fabre that this statement contains greater philosophical virtue than would appear on the surface.

Relief without exposing oneself to the questionable effects from a plant unknown, the unsavory smell of the onion, or the garnish of parsley, is possible when near the home. An acceptable remedy for relief from asp irritation is provided in the form of a baking soda ($NaHCO_2$) poultice, which has the advantage of being amenable for use on the most delicate surfaces of the body, particularly those near the eyes, nose, mouth, etc.

I concur with Micks that when reactions are strictly local rather than systemic much relief can be obtained by the application of ice on the effected skin area.

Modern science has contributed a pharmaceutical prescription combining icyclomethycaine and thenylpyramine in a "vanishing" cream base that is prescribed for insect bites and stings. Nupercainal with its local anaesthetic quality makes it an excellent emolient salve. That there are many others is an accepted fact; it is regretted that medical science has not precisely determined the nature and properties of this insect poison that apparently rivals or exceeds the energy of cantharides. However, appreciative as I am of the research scientist's inalienable affliction, impecuniosity, it is not difficult to understand why little individual research effort has been undertaken since the cost would of necessity be quite high. Thus, for the present, we must be content with the privilege of perceiving the effect while being ignorant of the cause. However, it is particularly gratifying to learn that the mass culture of *Megalopyge opercularis* is being undertaken by D. W. Micks Laboratory of Medical Entomology ,University of Texas, Austin, Texas, in an effort to accumulate a sufficient reservoir of insects from which to collect venom in order to determine the exact nature and mode of action of the toxic principle.

SUMMARY

Urticating caterpillars erroneously termed "asps" have been found particularly abundant in the Lower Rio Grande Valley of Texas. *Megalopyge opercularis, Automeris io,* and *Lagoa crispata,* are the most prevalent.

These caterpillars have a setaceous or bristle-like coat composed of spines that are lined with a thin hypodermis, the center of which is in direct communication with the poison gland cell. The tip of the spine usually penetrates the human body at a hair follicle and the poison is injected into the wound by the pressure exercised in the downward thrust of the spine upon the poison cell. The efficacy of the "nettling" spines is continuous during their existence.

The precise nature and toxic principle of this insect poison has not been determined, but the caterpillar is capable of stinging in all of its stadiums of development. The severity of the sting increases progressively with the larval size and the pressure applied upon it.

Botanical specifics of various kinds have been prescribed for the relief of the acute irritation resulting from a brush with the "asps" urticating hairs. Modern pharmaceutical preparations have been found to contain certain pain relieving properties.

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Salinity Control Through Tile Drains In Hidalgo Clay Loam[1]

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The primary function of field installation of a tile drainage system is to provide an outlet for the removal of excess ground water affecting crop root zones. The need for tile drains is indicated by one of two conditions: (1) high water tables restricting the development of crop root systems, or (2) accumulations of soil salinity adversely affecting crop production. Performance of drainage systems under either condition may be affected by a complex of soil factors including structure, texture and stratification. These influence water movement through the soil. Agronomic practices, tillage practices, irrigation water management, and rainfall intensity also affect the degree and rate of removal of ground water through drains.

In the Lower Rio Grande Valley of Texas tile drains are installed primarily to control soil salinity. It is difficult, however, to predict their performance under the many different soil conditions encountered in the area.

A large part of the irrigated land in the area is represented by the Hidalgo Series. Soil salinity is a problem in some of the Hidalgo soils as in others in which the clay in the subsoil restricts water movement. One field installation of tile drains in Hidalgo clay loam was studied during its first year of operation. One objective of this study, which is the subject of this report, was to determine the reduction in soil salinity attributable to the performance of the drainage system.

PROCEDURE

The 30-acre field selected for this study lies approximately 50 miles inland from the Gulf of Mexico at an elevation of 65 feet above mean sea level. The field was leveled in 1953 for control of irrigation water but no crops were grown on the land before installation of the drainage system in April 1958. At that time the soil was very saline.

Standard 6-inch concrete drain tile was laid at a depth of 6½ to 7½ feet, spaced 200 feet apart with a grade of 0.05 feet per 100 feet. The normal practice of backfilling the line with base material excavated from the trench was followed.

[1] Contribution from Soil and Water Conservation Research Division, Agrcuiltural Research Service, U. S. Department of Agriculture, Texas Agricultural Experiment Station cooperating.

In-place measurements of hydraulic conductivity were made at the time drains were installed. The auger hole method (Kirkham, 1946) was used for these measurements. This method involves calculation of the hydraulic conductivity from measurements of the rate of rise water, following pumping, in a cavity of definite size and length drilled into the soil below the water table (Kirkham and Van Bavel, 1949). The average value for the 4- to 7-foot depth was found to be 0.10 inch per hour. Particle size distribution of the soil at this site is shown in Table 1.

Soil samples were collected in 1-foot increments to a depth of 6 feet in April 1958 and April 1959 for determination of change in soil salinity. Twelve sampling sites were selected in a line normal to the parallel drain lines, six adjacent to the lines and six at midpoints between lines, 100 feet from drains. Results of those analyses are shown in Table 2. Analyses of salt composition showed a predominance of calcium and magnesium salts (Table 3). Though the total salt concentration was high, no sodic

Table 1. Particle size distribution of a Hidalgo clay loam.

	Depth			
	0-1 Ft.	*1-2 Ft.*	*2-4 Ft.*	*4-6 Ft.*
	Percent	*Percent*	*Percent*	*Percent*
Sand (0.05 mm)	41.3	35.5	29.2	25.8
Silt (0.05-0.002 mm)	20.5	22.9	25.5	28.6
Clay (0.002 mm)	38.2	41.6	45.3	45.6
International System				
I. (2-0.2 mm)	12.7	10.7	8.6	6.8
II. (0.2-0.02 mm)	36.5	32.0	27.6	25.8
III. (0.02-0.002 mm)	12.6	15.7	18.5	21.8
IV. (0.002 mm)	38.2	41.6	45.3	45.6

Table 2. A comparison of salinity of the soil profile of a Hidalgo clay loam at the beginning and end of the first year of operation of a tile drainage system.

	Electrical conductivity of saturation extract		*Soluble salts per acre*		
Depth	*April* 1858	*April* 1959	*April* 1958	*April* 1959	*Reduction*
Feet	*mmhos/cm*	*mmhos/cm*	*Tons*	*Tons*	*Tons*
1	6.6	0.9	2.8	0.4	2.4
2	14.9	1.1	6.5	0.6	6.0
3	24.9	2.6	10.6	1.1	9.5
4	33.5	7.7	14.3	3.3	11.0
5	31.3	16.3	14.0	7.3	6.7
6	27.2	19.7	12.7	9.2	3.5
		Total	60.9	21.8	39.1

condition was apparent, indicating a possibility of reclamation of the field by leaching the soluble salts from the soil profile. Flow from drains was measured at selected intervals throughout the period of study depending upon occurrence of rainfall or irrigation applications. Samples of drain effluent for salinity analyses were collected each time flow was measured.

Water Applied to Field

During the first year of operation of the drainage system the field received 12 inches of irrigation water, applied in two irrigations of 6 inches each. Rainfall for the period was 30 inches, 17.9 inches of which fell during a period of high intensity storms in September and October 1958. This made a total of 42 inches or 1,260 acre-inches applied to the 30-acre field.

Water Removed Through Drains

The water-table level was approximately 1.7 feet above the minimum flow line in the laterals, or 4.5 feet below the surface of the field when the drains were installed. Initial rate of flow from drains was 10.0 gallons per minute from the 6,563 feet of drain line, or 8.0 gallons per minute per mile of drain. During the course of the study when the water table surface midway between laterals was 3.0 feet above the tile, roughly 3.5 feet below the soil surface, the flow rate was 23.5 gallons per minute or 18.7 gallons per minute per mile of drain. Total volume of sub-surface water removed from the 30-acre field through the drainage system was 216.0 acre-inches (7.2 inches per acre) for the year.

Water Table Salinity

At the time the drainage system was installed electrical conductivity of the drainage waters was 68.0 millimhos per centimeter. One year later, electrical conductivity was 50.0 millimhos per centimeter. Fluctuations in rate of flow from the drain had no apparent effect on salt concentration of the effluent. The weighted mean electrical conductivity of effluent during the year in which 216 acre-inches of water was removed from the field was 56.4 millimhos per centimeter (4.09 tons of salt per acre-inch of water). The calculated 883.5 tons of total dissolved salts in the measured volume of drain flow represented the removal of 29.5 tons per acre from the 30-acre field, through the drain.

Table 3. Calcium, magnesium and sodium relationship in the 0-3 foot depth of a Hidalgo clay loam before and after removal of 17.9 tons of soluble salts per acre.

Date	Saturation Extract				
	$ECe \times 10^3$ @25°C[1]	Ca + Mg meq/l	Na meq/l[2]	SAR[3]	ESP[4]
April 1958	15.5	83.6	71.4	11.0	13.0
April 1959	1.5	5.4	9.6	5.8	6.8

[1] Conductivity of saturation extract from the soil, expressed as millimhos per centimeter at 25° C.

[2] Calculated.

[3] Sodium adsorption ratio $= Na/\sqrt{\frac{Ca+mg}{2}}$; Ion concentrations are expressed in milliequivalents per liter.

[4] Estimated exhangeable sodium percentage of the soil as calculated from the Sodium Adsorption Ratio of the saturation extract.

DISCUSSION

The net reduction in salinity of the top 6 feet of the soil profile was 39.1 tons per acre (Table 2). The irrigation water applied contained 0.9 tons of salt per acre. Since 29.5 tons of salt per acre was removed from the field through the drainage system if appears reasonable to attribute approximately 74 per cent of the reduction in soil salinity to the performance of the tile drainage system.

Calculations show that only 2.6 inches of drainage water having the same salt concentration as the mean of that measured from the drain would have had to pass below the tile depth to account for the remaining reduction of salinity in the soil profile.

The field was planted to Coastal Bermuda Grass during the second leaching irrigation in August 1958. This grass is one of the most salt-tolerant plants adapted to this area. A complete cover of the ground surface was established before April 1959. The soil salinity was reduced to a level in April 1959 that would permit growth of most of the crops of low salt tolerance adapted to the Lower Rio Grande Valley (Table 2). Citrus and other adapted fruit crops will tolerate soil salinity indicated by electrical conductivity of saturation extract in the range of 2-4 millimhos per centimeter (U. S. Salinity Laboratory Staff, 1954).

Installation of 6-inch concrete tile at a depth of 6 to 7 feet with spacing of 200 feet represents an investment of approximately $175 per acre at 1959 prices. This may be considered a sound conservation practice if, when coupled with soil-improving agronomic practices and good irrigation water management, reduction in soil salinity similar to that found in this study can be attained.

The favorable reduction in soil salinity in this particular case may be unique in that the high intensity rainfall contributing to the supply of water for leaching the salts from the soil profile occurred soon after the heavy application of irrigation water. The soil profile was filled with water, allowing for movement of water from rainfall downward through the profile and into the drains. This can be attained also through timely management of irrigation water for leaching in the absence of rainfall when the land is leveled so that the water can be held on the land until infiltration is complete.

Salinity of the field under study was more severe than much of the land in the area having a salinity hazard. It appears reasonable to assume, however, that comparable results could be expected on other soils of the Hidalgo series.

SUMMARY

A tile drainage system in Hidalgo clay loam in the Lower Rio Grande Valley of Texas removed 29.5 tons of dissolved salts per acre from the top 6 feet of the soil profile during the first year of operation of the drainage system. The 6-inch concrete drain tile was placed at 6.5 to 7.5 feet below the field surface and spaced 200 feet apart, in the 30-acre field under study. Soil salinity was reduced in the top 3 feet of the soil profile to a level permitting the growth of crops of low salt tolerance. A fluctuating, highly saline water table, previously high enough to restrict crop root development, was lowered to permit leaching of salts from the soil profile by irrigation and high-intensity rainfall.

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