PN-ABQ-298

Final report on USAID/PSTC project number 936-5542.65

6.609

"Forced Flower Expression of Barbados Cherry"

The objectives of this project were:-

A. To determine efficient management systems for acerola trees with emphasis on watering regimen to initiate bloom and force flower expression, and cultural manipulation to control tree size to improve concentration of ripening and yield.

B. To investigate the interactions between Vitamin C, anthocyanin, and sugars as functions of harvest timing, post harvest handling and processing.

C. To apply findings to commercial production, to establish and promote acerola growing in the region.

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A team consisting of Dr. Robert Bates, a food technologist at the University of Florida; Dr. Carl Campbell, a horticulturist also at the University of Florida, and Stan Michelini, Director of the Fruit Experiment Station for the Caribbean, combined efforts on this project. They were assisted by Dr. Louis Chinnery and students from the Department of Biology, University of the West Indies.

Seven hundred orchard planted trees were involved in the experiments. Combinations of plant growth regulators (PGRs), water stress, water application, and fertilizers were applied to the plants and their effects monitored.

Management systems involving PGRs and irrigation scheduling were investigated (objective A). We found that:-

1. Despite early promise in our container trials (4,5), paclobutrazol (product of ICI, England) was an ineffective PGR in the field (2). Also ineffective in promoting flowering were foliar fertilizer and gibbereliic acid (Abbott Laboratories, USA) applications (2).

2. Uniconizol (Chevron, USA) was effective in controlling tree size, promoting flowering, while maintaining large fruit size (2).

3. Gibberellic acid promoted fruit setbehen sprayed on open flowers (unpublished).

4. Water should be withheld for 10 days past the tree's stress point, then applied in copious amounts to stimulate blooming, and fruit set, during the dry season. Microjet irrigation is superior to drip irrigation (2).

5. Poor pollination is the single largest factor in low fruit yield on established plantings. Pollen compatible cultivar combinations will give greater yields (1).

Harvested fruits were frozen and analyzed for their properties and reactions to various kinds of processing. With regard to processing, handling and Vitamin C and anthocyanin interactions (objective B), we found that:-

1. Acerola fruits can be pureed, canned, frozen and sold while maintaining quality. Puree can be concentrated in a TASTE evaporator without significant loss of colour, flavour or Vitamin C. Our most concentrated juice (67°Brix) yielded 13,050mg Vitamin C per 100g of juice, or just over 13% natural Vitamin C, after 11 months in cold storage (not published).

2. Fruits harvested at their peak Vitamin C content (green - ripe) and left at room temperature, turn red without losing Vitamin C content (6).

3. Rapid freezing gives lowest fruit and Vitamin C losses (6).

4. Simple processing equipment is available to process soft fruits properly and economically (3).

5. A "natural" essence can be made (we have samples from F & C International) which can approximate true essence of acerola. This was a goal for the manufacturing of acerola drinks with only a small percentage of acerola juice, enough to provide 100 to 500mg Vitamin C, the rest a blend of other juices (unpublished).

With regard to objective C, early results of thebeork were publicized through regional journals and meetings, local media, field days for invited guests, publication in international journals, and local use of acerola products.

In Barbados, commercial plantings have increased from 20 acres to about 200 acres since the beginning of this project. There has been considerable television and press attention. Field trips were well attended by every major regional and international institution. Other countries are now planting acerola on a commercial scale. Barbados Dairy Industries has embarked upon a "Bajan Cherry" drink, which is highly popular and sets the economic stage for marketing all local production. Presently, Barbados imports acerola puree to meet local demand.

Information gathered prior to and during the course of this project has been disseminated to major agricultural institutions in Barbados. Seven papers on acerola have been published in recent years, five in regional journals and two in international journals, with two more scheduled for publication in the future.

This project has coincided with the largest upsurge in fruit growing in Barbados history, with cherries leading the way in total acreage. The information gathered is valuable in averting production problems, and in recognizing processing options necessary for the development of the industry. It has been a project which reached all goals set at the beginning.

As a result of the programme, there is much greater confidence in the horticultural aspects of acerola growing. With the local dairy promising to purchase up to 25,000 pounds per month of acerola production, we now have a good internal market in Barbados. As production grows, this could easily turn into an export market.

Technical Findings

Most of the technical findings are provided in the attachments which consist of:-

1. Manuscripts of presentations to the Caribbean Food Crops Society's meetings in Antigua, Jamaica and Guadeloupe. These will be published in the Society's Proceedings.
2. Xerox copies of the published versions of papers presented to the Inter-American Society for Tropical Horticulture's meeting in Colombia, and to the International Society for Horticultural Science's plant growth regulator meeting in Canada.

Information not yet published includes the Vitamin C data below and some additional data which will be presented at another conference in 1990.

Table: Brix and Vitamin C (Ascorbic Acid, AA) content of acerola juice. Raw filtered, pasteurized or concentrated.

Samples	°Brix	mg AA $100ml^{-1}$ * mg AA $100g^{-1}$ **
ARL - Raw juice, light variety	6.2	1,167
ARD - Raw juice, dark variety	5.2	903
APL - Pasteurized, light	4.5	1,434
APD - Pasteurized, dark	5.1	888
APR - Pasteurized puree	-	550
ACL 41 - Concentrate, light	39.5	7,275
ACD 40 - Concentrate, dark	38.0	7,200
ACD 60 - Concentrate, dark	60.9	10,670
ACL 67 - Concentrate, light	67.3	13,050

* All concentrates were assayed as Ascorbic Acid $100ml^{-1}$
** All single strengths were assayed as AA $100g^{-1}$ juice

Following previous arrangements, any future manuscripts, and publications, presenting data gathered during the conduct of these experiments will be forwarded to USAID.

USAID Associated Publicity

Coverage was obtained through television broadcasts in which USAID's sponsorship was prominently displayed. Additionally, USAID sponsorship was a preface to all presentations, field days, and the seminar. Included is a menu from the culmination of one field day attended by representatives of USAID, the United Nations' FAO, the Organization of American States, the British High Commission, the Canadian International Development Agency, the European Development Fund of the EEC, the Barbados Ministry of Agriculture including the Chief Technical Officer, and members of the press. The menu featured fruits grown at FRESCA.

Also included is an activity sheet showing the seminar FRESCA hosted. The seminar was attended by 40 persons, including invited professionals from the Ministries of Agriculture of Antigua, Barbados, Dominica, Guyana, St. Lucia, and Grenada, the Barbados Minister of Agriculture, a lecturer from the UK, Dr. Bates and Dr. Campbell from the USA, professionals from USAID, EEC, CARDI, IICA/OAS, CIDA, UN/FAO, staff and students from the University of the West Indies, local farmers and members of the local press.

Included are photographs showing changes in fruit colour. We have included a photograph showing relative amounts of Vitamin C in acerola juice and orange juice. We have numerous slides and other photographs should they be requested.

Synopsis of events during the project

June 1987 to January 1988

Dr. Robert Bates, the Food Technologist collaborator, arrived at the beginning of the project. He considered the available crushing and pressing equipment, evaluated freezer space, packaging capability, infrastructure, local costs, and other parameters relevant to commercial processing.

While in Barbados, Dr. Bates met with private processors, at their plants, and with government representatives to hear of their plans. It was determined that the appropriate processing equipment was not available on the island. Dr. Bates offered to evaluate all options available in the US and to make a recommendation.

The recommended processing equipment, consisting of a crusher, press, and filter were ordered and arrived. The first press run was successful and produced approximately 350 pounds of juice from 450-500 pounds of fruit. This was frozen and held for testing.

Dr. Bates and Mr. Michelini independently met with Dr. Walt Kender, Director of the Lake Alfred Research Center, who agreed to allow us to run acerola juice through the testing facility and report to us the results of trial runs. As the Center has small scale, necessary for our small volumes, but modern commercial equipment, the information is extremely valuable in mapping the processing strategy and for assessing options.

Dr. Carl Campbell visited Barbados in June, 1987. We looked at the experimental planting and discussed the treatments to be used for control of plant growth, flowering and fruit set. To allow Dr. Campbell to get a better idea of the acerola production

situation in Barbados, many acerola plantings around the island were visited. A meeting with USAID officials was also part of the itinerary. Our horticultural plans were finalized and arrangements made for a return visit by Dr. Campbell.

In the field, all the treatments were applied to the trees, caliper and height measurements recorded, some harvesting work accomplished, and additional experiments undertaken. The technicians were trained in record keeping, experimental techniques and material application when concentration is critical to meaningful results.

While the acerola trees were in good shape, the bloom was not setting well. We discussed the options and came up with alternate plans to increase bloom set. A variation in the original GA treatments improved fruit set. We simply sprayed the GA on during full bloom.

A trip was made to Orlando, Florida, to attend the American Society for Horticultural Science meetings. While there, contacts were made with Dr. Kender, regarding the fruit processing; Dr. Eric Curry, who arranged for some fruit setting chemicals and discussed the current status of plant growth regulators; Dr. Tom Davenport, who advised on techniques for water stress documentation; with horticulturists, including Dr. Campbell, on the work underway; with mechanical harvesting specialists on the parameters for efficient mechanical harvesting; and a computer specialist on data entry systems for experiments.

January 1988 to July 1988

During this period, field work was progressing well. The principal activities were:-

1. The successful forced expression of acerola bloom by water application.
2. Definition of the drought intensity and duration necessary to initiate flower bud development in acerola.
3. The successful comparison of the gibberellic acid (GA) biosynthesis inhibitors (Paclobutrazol and Uniconizol), with significant differences appearing in their effects on tree growth, flower stimulation and fruit size.
4. The implementation of a harvesting procedure which is a precursor to future mechanical harvesting.
5. Air-freighting of 6,000 pounds of cherries, which were put into cold storage for the evaporator run at the University of Florida's Citrus Research facilities at Lake Alfred.
6. The collection of data on the effects of treatments on shoot growth.
7. The recording of flowering data from three successive blooms.

The first three months of the new year were intermittently wet, with no dry period extending sufficiently to water stress the trees. By April, the dry weather had set in, and the trees become uniformly stressed. We felt that the drip system was adequate for initial growth water demands, but was insufficient to bring about blooming except following the driest weather. We changed from the drip system in the orchard to the microjet system, which allows for faster water application and an improved wetting pattern, increasing the percentage of roots receiving water.

In late April, we began watering the sections and were able to bring all trees into bloom. We then initiated the water stress treatments. The onset of drought stress was observed visually, by experience, and further confirmed as the time when all three

tensiometer readings at the multilevel stations were at or above 60 mb pressure. Following the appropriate length of stress, the trees were irrigated and flowering or a vegetative flush occurred about 1 week later.

The data showed that the 10 day cycle causes a return to bloom with less tree debility than the 15 day cycle.

All the experimental trees were tagged for shoot extension measurements. The number of nodes per six inches of branch were recorded at three locations on each tree. Uniconizol showed significant growth restriction, other changes were not significant.

Harvested cherries were frozen and pressed, or simply washed and pressed. Juices were filtered and bottled or put into plastic lined pails and the juice frozen. The juice was sent to the University of Florida to be processed using their evaporator.

A residue test was initiated with fruit samples from two successive fruitings. Mean fruit weights for all GA inhibitor treatments, plus the control, were taken, the fruits freeze dried at the University of the West Indies, and the samples sent to Dr. Eric Curry, USDA, Wenatchee, Washington. Paclobutrazol treated fruits had a residue of 8 ppb (parts per billion). As this PGR is not registered for use on food crops in the USA, this is an unacceptable residue. However, fruits so treated are allowed into Europe.

In July, I attended the International Society for Horticultural Science Symposium on Plant Growth Regulators (PGRs). The meeting included theoretical aspects of plant response, plant physiology, practical considerations, new compounds, relative activity of certain PGRs, experimental methods, and effects of PGRs on specific crops.

While there, two poster presentations were made based on the acceptance of two articles now published in Acta Horticulturae.

Also in July, Dr. Carl Campbell flew to Barbados to review the status of the trees and the experiment. We looked at the impact of treatments on tree growth habit and flowering, reviewed the data and discussed future experiments. We met with USAID personnel in Bridgetown to discuss our results to date and plans for the future.

August 1988 to January, 1989

The primary events were:-

1. The juice concentrate run at the University of Florida.
2. Delivery of essence to flavour companies for manufacturing of natural source essence.
3. Continued orchard management and studies.
4. Presentation of processing results at the Caribbean Food Crops Society meeting and horticultural results at the Inter-American Society for Tropical Horticulture meeting.
5. Definition of problem areas in fruit set.

The harvested cherries were tested with a concentration run using a commercial quality juice concentrator. The dark juice was introduced into the evaporator. Beginning Brix was approximately 5.5°. We took samples of juice concentrate at 40 and 60°Brix. One subsample of raw juice was put through a plate pasteurizer, and a whole frozen fruit sample was made into puree using the laboratory equipment. Twelve 6oz. canned samples of each of the five cherry products were marked, as raw juice, raw puree, pasteurized juice, and 40 and 60°Brix juice concentrates, quick frozen and stored.

The light juice was treated similarly, but the beginning Brix was 6.5° and the ending Brix 67°. This represents a ten-fold concentration of the beginning raw juice. Samples of each kind of juice were analyzed for Vitamin C content. These tests and subsequent assays showed that concentration has a minimal effect on Vitamin C content.

Samples have been used to respond to growing commercial demand. Presently, one company has orders for 100 metric tons per year from only one client.

Essence from cherry processing was collected, topped with nitrogen gas, frozen and stored. Several vials were sent to flavor companies, one of which sent us a bottle of their manufactured essence. The company, F & C Flavors International, has retained the formula for the essence and will make the essence available, should it come into commercial demand. The essence may be used when mixing a small proportion of cherry juice, enough to give the recommended daily adult requirement of Vitamin C, in a bland juice base, with the essence added back to give a representation of the original acerola cherry juice.

A paper on the initial processing was presented at the Caribbean Food Crops Society's meeting in Jamaica.

A manuscript containing results from the initial plant growth regulator and water studies was prepared for the Inter-American Society for Tropical Horticulture (ISTH) meetings in Santa Marta, Colombia. The paper was presented to an audience exceeding 300 persons, and was received with interest. As a follow-up, letters have been written and manuscripts sent to interested participants. Subsequently, the edited paper was published in the ISTH proceedings.

While at the ISTH meetings, several discussions were held with Dr. Campbell over the status of the experiments and some decisions were reached about the proposed action plan. We decided to proceed with pollen studies, to spray blooms with an insecticide to minimize flower loss due to chewing insects, and, in spite of the occasional rains, to establish the water trials at an earlier date.

Initial pollen viability was found to be below 5%. We pursued detailed pollen analysis and ways to overcome low viability. As a result of hand pollination studies we determined that pollination requirements were not being met by all cultivars, and that there was significant variation between cultivars.

Dr. Campbell came to Barbados to offer final assistance with our problems and to wrap up our mutual work. His and Dr. Bate's last visits were coordinated with the field day and workshop/seminar attended by participants from other countries.

This seminar was attended by approximately 40 persons from many disciplines and agencies. Mr. H. Batson attended on behalf of USAID. At the seminar we presented all previous manuscripts, two new manuscripts, and some unpublished material. We encouraged active participation from the Windward and Leeward Island representatives, and were graced by the attendance of the Barbados Minister of Agriculture at the field day.

Articles on Acerola, prepared at FRESCA

1. 'Assessment of acerola pollen characteristics from a Barbados planting' by S. Michelini, D. Murray and L.E. Chinnery. Presented at the 25th Annual Meeting of the Caribbean Food Crops Society, Guadeloupe, FWI, July, 1989.

2. 'The use of plant growth regulators and irrigation to control flowering of the acerola or Barbados cherry, *Malpighia glabra* L.' by S. Michelini and L.E. Chinnery. Proceedings of the Inter-American Society for Tropical Horticulture 32:65-73, 1989.

3. 'Throughput and costing of soft fruit processing' by S. Michelini. Presented at the 24th Annual Meeting of the Caribbean Food Crops Society, Jamaica, August, 1988.

4. 'Enhanced multiple cropping in paclobutrazol treated acerola' by S. Michelini and L.E. Chinnery. Acta Horticulturae 239:281-284, 1989.

5. 'Paclobutrazol increases fruiting in container grown pummelo and Barbados cherry' by S. Michelini and L.E. Chinnery. Presented at the 23rd Annual Meeting of the Caribbean Food Crops Society, Antigua, August, 1987.

6. 'Post harvest changes in Barbados cherry fruit' by S. Michelini. Presented at the 22nd Annual Meeting of the Caribbean Food Crops Society, St. Lucia, September, 1986.

7. 'A cost analysis for establishing a Barbados cherry (*Malpighia punicifolia*) orchard in Barbados' by S. Michelini. Presented at the 21st Annual Meeting of the Caribbean Food Crops Society, Trinidad, October, 1985.

8. 'The early performance of non-traditional crops in Barbados' by S. Michelini. Proceedings the Caribbean Food Crops Society 18:104-108, 1982.

N.B. There seems to be some confusion over the correct scientific name for the acerola. Although we, like other authors, have used the names *Malpighia glabra* and *M. punicifolia*, according to the latest volume of 'The Flora of the Lesser Antilles' the correct name is *M. emarginata*.