16

BARD

FINAL REPORT

PROJECT NO. US-770-84

Engineering Systems for Production and Harvest of Fruit Grown in High Density Dwarf-Tree Orchards

P. Chen, Y. Sarig, F. Grosz, H. Pasternak, A. Erez

19
630.72

BAR/CHE

2nd copy

1990

32945

000000152358

2012.10.15.18

17-4-1990

Date: March 8, 1990

BARD

P.O. Box 6

Bet Dagan, ISRAEL

BARD Project No. US-770-84

Title of Research Project:

Engineering Systems for Production and Harvest of Fruits Grown in High-Density
Dwarf Tree Orchards

Name of Investigators:

Principal Investigator: Pictiaw Chen

Cooperating Investigators: Y. Sarig, F. Grosz, H. Pasternak, and A. Erez

Name and Address of Affiliated Institutions:

Principal Institution: The Regents of the University of California
University of California, Davis Campus
Office of Research, 275 Mrak Hall
Davis, California 95616

Cooperating Institution: Agricultural Research Organization
The Volcani Center
Bet Dagan, Israel

הספרייה המרכזית
המרכז הלאומי
ב"ד-117

Project's starting date: October 2, 1985

Type of Report: 1st Annual _____ 2nd Annual _____ Final X

Pictiaw Chen
Signature
Principal Investigator

Marilyn Rush
Signature
Institution's Authorizing Official

Marilyn Rush
Research Officer

APR 4 1990

630.72 , 634 : 631.3 : 631.35
BAR/CNB

2nd copy

Summary:

Results of recent studies have shown that high-density orchards of dwarf trees can produce a much higher yield per unit area and give a product much earlier than standard orchards. However, the success of this new fruit production method depends on the availability and proper utilization of suitable equipment.

A joint project between Israeli and U. S. researchers was initiated in 1985 to develop an engineering system for harvesting and cultural operations in such high-density dwarf-tree orchards. The general concept was to develop a multi-use system consisting of an over-the-row machine (a carrier) and detachable equipment modules for various cultural and harvesting operations.

The Israeli team has developed a fruit handling system for hand harvest operation. The system consists of a self-propelled power frame and a fruit handling module equipped with elevators and over-the-row conveyors for transporting fruits from the pickers to the receiving bin under the power frame. The power frame is also equipped with a mechanism for retrieving and lifting the empty containers from the ground, positioning them below the discharge elevator, and subsequently placing the filled containers on the ground.

The U. S. team has developed an over-the-row self-propelled carrier and equipment modules for spraying, hedging, pruning, and cultivating operations in high-density peach orchards. This machine is uniquely designed so that its inside clearance can be easily adjusted from 1.8 m wide by 1.2 m high to 2.8 m by 2.6 m. The adjustment is accomplished through hydraulically powered parallel four-bar linkages and can be done within 17 minutes.

Test results indicated that the concept of using an over-the row carrier and detachable equipment modules worked well in high-density dwarf-tree orchards. The results also provided useful information for further improvements of some of the equipment modules.

Objectives of the original research proposal

1. To determine engineering requirements for various cultural and harvesting operations.
2. To develop equipment to meet these engineering requirements.

Final Report for BARD Project US 770-84R

**AN ENGINEERING SYSTEM FOR PRODUCTION AND HARVEST OF FRUITS
GROWN IN HIGH DENSITY DWARF TREE ORCHARDS**

by

P. Chen, Y. Sarig, F. Grosz

Introduction

In recent years the possibility of increasing yield through tree spacing closer than that in current use has been explored in several places with encouraging results. Carry (1981) cites experiments in Australia, California, Florida, Japan and other areas where early yields were more or less proportional to number of trees. Although few long-term experiments have been carried out to completion, the trend to higher planting density will continue, driven by economic forces and a potential yield in an ideal orchard that might approach (in citrus, for example) 100 MT/ha (Wheaton et al., 1978).

There is evidence (Passos and Boswell, 1979) that high quality fruit can be produced on closely spaced trees, provided that excessive crowding is avoided.

Although increasing yield is a valid goal by itself, the major thrust for the intensification of orchards is due to rising costs of land, energy, chemicals and primarily, labor. An inadequate seasonal labor force, especially in Israel and other countries with similar labor shortage situation, make it almost mandatory to change from the traditional orchard to dwarf trees grown in more intensive systems.

Extensive field research in Australia on citrus has shown that a bud-transmissible dwarfing factor, when inoculated into orange growing on specific rootstocks, offers potential to reduce normal tree size while maintaining tree health, early cropping and fruit quality.

An alternative method, currently under extensive experimentation in Israel, also with citrus, is dwarfing through root restriction by drip irrigation, supported by other growth restriction elements (Golomb, 1988).

Another example of the intensive dwarf orchard is the peach meadow-orchard concept which has been developed and explored extensively in Israel (Erez, 1976).

While orchard dwarfing and intensification show significant advantages in terms of convenience of tree-care, plant protection operations and harvesting, they also present new engineering problems (Chen and Studer, 1984). Because the trees are small and planted at high density, existing machines are now suitable for such orchards. Success of this fruit production

method depends, therefore, on the availability and proper utilization of suitable equipment for cultural, harvesting and fruit handling operations.

Objectives

The aim of this research was to develop an experimental machine with equipment modules for various cultural operations in high-density dwarf orchards. The specific objectives were to (a) determine the desired tree density and planting configuration based on economic and horticultural considerations; (b) develop proper equipment for all cultural operations in a high-density orchard and specifically to develop a fruit handling system for harvesting operations.

The research is a joint project of Israel and U.S. researchers attempting to develop a multi-use system for all high-density dwarf-tree fruit orchards.

While the original objectives were aimed only for genetically dwarf deciduous trees, the concept of high-density dwarf orchard applies, in principle, to all fruit trees.

Economic and Horticultural Considerations

An analysis was made to evaluate the influence of distance between rows in a high-density simulated orchard on production costs (Pasternak et al., 1988). This is essential for the determination of the mode of operation of the machine, as it has a direct influence on the final design.

The analysis assumed a constant in-row spacing of 2 m, and compared production costs of two orchards with row spacings of 2.5 m and 3.0 m, respectively. Increasing the distance between the rows has resulted in fewer rows per unit area and thereby reduced the total yield per unit area. On the other hand, increasing row spacing provides for better radiation and hence increased yield per row.

Although most orchard activities and inputs are row-dependent (in a drip irrigation-fertilization orchard), the reduction in production costs resulting from increasing row spacing is outweighed by the loss in yield due to the decrease in the foliage volume. To pursue the objective of minimizing

production costs, we should aim for the maximum number of rows possible, providing that the row spacing is still acceptable from the horticultural and operational points of view.

Although the system is aimed to be applicable to a variety of fruits, horticultural requirements may differ. While for an apple orchard, for example, alternating planting of two species of trees is needed to provide for optimum pollination which will result in high yield and high quality fruits, such a requirement does not apply for citrus. The limiting factor in this case may be, primarily, a functional one and determined on the basis of the optimal size of the picking crew on the one hand, and engineering design on the other.

A proposed orchard configuration, shown in Fig. 1, provides for simultaneous operation in four consecutive rows. This configuration is not mandatory, but its advantage is that it lends itself also to an apple orchard where harvesting of two different varieties is required at different dates without mixing the two. If there is a single variety of trees in the grove, the number of tree rows between access ways can be increased to five rows as shown in Fig. 2.

Description of the Experimental Systems

Harvesting and handling system

An experimental system was designed for harvesting and handling both deciduous and citrus fruits in high-density dwarf orchards. The system is a modified and more versatile version of the IMAG system (van Lookeren Campagne and van de Werken, 1984) which consists of a self-propelled power-frame, (an existing 'UPRIGHT' Co. prime-mover was utilized after modifications as the power frame in our experiments) which moves along the access way where the fruit containers have been distributed prior to harvesting.

The power frame is equipped with a fruit handling system comprised of a conveying system, a controlled fruit-discharge system and a system for lifting empty containers from the ground. The proposed system is shown in Fig. 3.

The conveying system

Over-the-row cross conveyor. Two over-the-row cross conveyors are mounted on the two

sides of the prime mover (due to lack of funds, actually only one side has been constructed). The conveyors are provided with hydraulic cylinders to adjust their inclination up to $\pm 15^\circ$ from ground level to conform with differences in the orchard terrain and topography. The over-the-row conveyors can be hydraulically folded into transporting position parallel to the prime-mover. Two rails are provided on the side of the conveyors on which the elevators can move along the length of the conveyors.

Elevators. There are three elevator conveyors on each side of the machine for lifting fruits from the pickers to the over-the-row conveyor. The elevators are pin suspended as a pendulum on a carriage which can move along the rails on the over-the-row conveyor. The system enables adjusting to the ground slope and the row spacing. The elevators are provided with a conveying belt with rubber fingers for a gentle handling and elevating the harvested fruit to the cross conveyor. The elevators are electrically driven for flexibility and noise suppression. An electric power generator on the prime mover provides power for the elevators through flexible cables.

Each elevator can serve one to two workers. Thus, a harvesting team may consist of 6 to 12 pickers plus one driver.

Central conveyor. The central conveyor receives the fruit from the cross conveyors and transfers them to the bin filler conveyor.

Fruit-discharge system

Bin filler conveyor. A vertical belt conveyor is provided with rubber fingers to hold the fruits and handle them gently onto the bin. An electro-hydraulic sensor system provides for the lifting of the conveyor according to the fruit level in the bin. Hence, during its work the conveyor rises up to the maximum possible level where it stops automatically.

Rotating table. The rotating table ensures an even filling of the bin (uniform fruit distribution). The table is provided with a hydraulic system and a fork mechanism to ensure the lowering of the table and to transfer the filled bin to the forks on which it will slide down onto the ground. Hence, the forks could be unloaded by simply moving forward.

As soon as the full bin is left on the ground, the table will rise back to the normal position. The

bin table is hydraulically driven and is also equipped with a positioning system to stop it in the designated position for unloading. The rotating table can accommodate a standard bin and rotates at about 10 r.p.m.

Technical data corresponding to the various components of the conveying system are given in Table 1.

Construction of the Experimental System

Due to budget restrictions only one side of the fruit handling system was built. The over-the-row conveyor and the elevators were built only for one side. For the other side, a counter-weight was provided to compensate for the temporary absence of the complementing section. For the same reasons, the system for lifting empty containers from the ground was not constructed. Figure 4 shows the experimental harvesting system being tested in a high-density citrus orchard.

Equipment for Cultural Operations

The U. S. team has designed and built an over-the-row self-propelled carrier for carrying different equipment modules in high-density orchards. The machine has four-wheel drive and four-wheel steering capabilities and is powered hydraulically. This machine is uniquely designed so that its inside clearance can be easily adjusted from 1.8 m wide by 1.2 m high to 2.8 m by 2.6 m . The adjustment is accomplished through hydraulically powered parallel four-bar linkages.

The following equipment modules have been designed and built: a spraying unit, a tree hedging unit, a mechanical aid for hand pruning, and a cultivating unit. The general design criteria for these equipment modules are as follows: 1) the module should be easily fabricated, and commercially available components should be used whenever possible; 2) the module should be easily attached to, or detached from, the carrier; and 3) each unit should perform its function well.

The spraying unit consists of six 40-cm Span Spray fan-type spraying heads, capable of uniformly delivering 935 L/ha, mounted on a frame under the carrier. The spray heads can be positioned around the tree so that they blow the spray into the tree from all directions (top and two

sides). The high-speed air from different fans shakes the branches and helps improve penetration of the spray into the dense foliage.

The hedging module consists of two 1.2-m Chisholm-Ryder vineyard trimmer cutter bars vertically attached to a frame which is mounted in front of the carrier. The horizontal distance between the two cutter bars and their vertical position are adjustable. One of the cutter bars can be rotated 90° into horizontal configuration for trimming the tops of the trees.

The pruning unit is a worker's aid. It consists of a frame suspended under the over-the-row carrier. The frame has four seats, two on each side of the row, for the manual pruners to sit on while pruning the trees with hydraulically powered pruning shears.

A one-meter wide Howard rotavator is used for cultivating. The rotavator is mounted on a vertical frame suspended under the over-the-row carrier. A hydraulically powered, spatial, parallel-bar linkage between the vertical 3-point frame of the rotavator and the vertical mounting frame on the carrier provides both powered up and down and free horizontal motions.

Figure 5 shows the Over-the-row machine, equipped with the hedging module, in operation in an orchard of genetically dwarfed peach trees. More detailed descriptions of the machine and equipment modules have been presented by Chen et al., 1988.

Experimental testing

Experimental harvesting work was carried out in two places: in the experimental plot for peach meadow-orchard at the Volcani Center, Bet-Dagan, and at the Dwarf Grapefruit plot, Kibbutz 'Gadot'. The existing plots were not planted for machine harvesting, thus, the full advantage of the proposed system was not manifested.

The cultural operation modules were tested (in California) in an experimental orchard of genetically dwarfed peach trees planted at 4 feet spacing within the row and 11 feet between rows. The trees were planted in 1981 and had not been hedged or pruned previously.

A chemical thinning test was conducted in an experimental orchard of 6-year-old genetically dwarfed peach trees planted at a density of 2500 trees/ha. A total of 32 trees were selected. Three

equally spaced branches from each tree were tagged on April 1, 1987, and the number of young fruits (the seed length was approximately 8 mm) on each branch were counted. The trees were divided into four groups of eight trees each. The four groups were sprayed on April 10 with ethephon solutions of four different concentrations: 0, 30, 60, and 90 ppm. In addition to the 32 tagged trees, a separate group of ten trees with very heavy fruit set was sprayed with a highly concentrated (200 ppm) ethephon solution.

In mid June, the fruits remaining on the tagged branches were counted and the number was recorded. Whole-tree fruit counts were made on three trees that were sprayed with 200 ppm ethephon solution and on three untreated trees of comparable size. The dimensions and weights of 30 fruits from the treated trees (200 ppm) and 30 fruits from the untreated trees were measured and recorded.

Results and Discussion

Harvesting operation

Grapefruit harvesting. Only partial time studies were made with a crew of 3 workers (excluding the driver). The measured field capacity was one container (holding approx. 300 kg) in 5 minutes. Fruit quality was the same as that obtained by conventional methods. While the results do not show an advantage over the conventional manual method, the expected potential advantage should be viewed in light of the overall advantages of the system. Thus, while the results of the rate of picking reflect the actual time studies' measurements, the daily average output would, conceivably, be higher. The mechanical system provides for better picking environment, thus eliminating the need to carry the picking bag and walking long distances for dumping onto the containers. In addition, the system should not be evaluated on the basis of its contribution to the picking operation only, but as a comprehensive, integrated system, which is capable of performing all orchard operations.

Peach harvesting. Since only an experimental peach meadow-orchard was available for our experimentation and not the truly genetically dwarf orchards, no time studies were made.

Extrapolation from the citrus orchards' experiments show, however, that rate of picking would be similar or slightly higher than that obtained with conventional manual picking. Nevertheless, the less experienced the pickers - which is typical of labor storage conditions - the more significant is the advantage of using the mechanical system. Peaches are more sensitive to mechanical damage, and especially that which shows up at a later date after harvesting.

Results of mechanical damage incurred during harvesting of peaches are given in Table 2. While the results show a significant reduction in fruit quality due to light and severe marks of pressure, a subsequent close observation has traced its origin to the intersection between the fruit elevators and the over-the-row belt. This can be easily changed and hence fruit quality should be comparable to that obtained from conventional methods.

Other cultural operations

Hedging. A hedging test was conducted in April, 1986. The cutter-bars were set 4 feet apart for vertical cuts. Both sides of the trees were cut at the same time. Then one of the cutter bars was rotated and set in a horizontal position 5 feet from the ground, and the trees were topped off at 5 feet. The cutter-bars worked well with branches under 2 cm in diameter. The blades were frequently stopped by larger branches, especially those which were oriented in such a way that the angle between the branch and the cutter-bar was less than 45 degrees. After the hedging operation the trees remained in good hedged rows for the entire year.

Cultivating. A cultivating test was conducted in the spring of 1987. A 1.2-m wide strip of ground extending laterally from the center of the tree row was cultivated. The cultivator performed well in chopping up the weeds under the dwarf trees. When the cultivator came in contact with the tree trunk, it automatically swung away from the tree. However, the force created by the rototilling action was not strong enough to pull the cultivator back into the original position. This problem can be alleviated by using a spring or a hydraulic cylinder to assist the return swing of the cultivator. We plan to make modifications to correct this problem.

Spraying. The over-the-row machine equipped with the spraying module was tested in

the spring of 1983. A preliminary test with water indicated that the spray droplets could penetrate the extremely dense foliage of genetically dwarfed trees. The spraying system was used successfully to control mites on three-year-old dwarfed peach seedlings in the summer of 1983.

Height and width adjustment test. A test was made to determine the time required to change the clearance width and height of the carrier. Height change from high to low or vice versa took only 2 minutes. Width change from the smallest dimension of 1.8 m to the largest dimension of 2.8 m required about 15 minutes. The total time required to change from the smallest inside clearance of 1.8 m wide by 1.2 m high to the largest clearance of 2.8 m wide by 2.6 m high was only 17 minutes.

Chemical Thinning

The results of fruit counts on a total of 96 branches (24 branches per treatment) are shown in Table 3. The average fruit count on April 1 (before spraying treatment) was about 160 fruits per branch. Foliage spraying of ethephon solutions at 30, 60, and 90 ppm concentrations had a significant effect on fruit thinning. Fruit thinning increased as the concentration of the ethephon solution increased. Fruit counts on June 12 indicated that the average percent of fruit remaining on each branch for 0, 30, 60, and 90 ppm treatments were 29.0, 22.5, 17.5, and 13.5%, respectively. The differences between the controlled (0 ppm ethephon) and the other three treatments are significant at the 5% level. The difference between the 30 ppm and 60 ppm treatments is not statistically significant, but that between 30 ppm and 90 ppm treatments is significant.

The effect of spraying with 200 ppm ethephon was conspicuous. While most of the branches on the untreated trees were loaded to the ground, and some were broken, the branches of treated trees were all upright and had visibly fewer and larger fruits. The results of whole-tree fruit count of three treated and three untreated trees are presented in Table 4. Untreated trees averaged 589 fruits/tree, whereas treated trees averaged only 225 fruits/tree. The average weight and dimensions of the fruits on the treated trees were significantly greater than those of fruits on the

untreated trees.

Conclusions

The production costs of high-density orchards can be minimized by maximizing the number of tree rows, providing that the row spacing is still acceptable from the horticultural and operational points of view. Specially designed machines needed for harvesting and cultural operations in high-density orchards have been built and tested. The concept of using an over-the-row carrier and detachable equipment modules worked well in high-density dwarf-tree orchards.

References

1. Chen, P., J. J. Mehlschau, G. Huang, and Y. Sarig. 1988. An over-the-row machine for high-density dwarf-tree orchards. *Applied Engineering in Agriculture* 4(2):111-117.
2. Chen, P. and H. E. Studer. 1984. High-density culture of dwarf-tree orchards -- engineering problems and challenges. *Proc. Int. Symposium of Fruit, Nut, and Vegetable Harvesting Mechanization*. ASAE Publication 5-84. St. Joseph, MI 49085, pp 382-388.
3. Hansche, P. E. and W. Beres. 1980. Genetic remodeling of fruit and nut trees to facilitate cultivar improvement. *HortScience* 15(6):710-715.
4. Van Lookeren Campagne, P. and J. van de Werken. 1984. Onderzoek van het plukbanden-systeem voor de oogst van appels en peren in volveldsbeplantingen. Rapport 64. Instituut voor Mechanisatie, Arbeid en Geobiwen (IMAG, the Netherlands).

Table 1. Conveyor system's technical data

	Elevator	Over-the-row conveyor	Central conveyor	Bin filler conveyor
Length (m)	2.7	7.6	0.9	1.65
Width (m)	0.23	0.35	0.38	0.38
Belting	Belt with fingers	Belt with carriers & V-shape centering	Belt with carriers & V-shape centering	Belt with fingers
Driving	Electric motorized drum	Hydraulic motor	Hydraulic motor	Electric motorized drum
Belt velocity (m/min)	15.6	~22	~22	21.6

Table 2. Mechanical damages of peaches ('Texas' variety) incurred during harvesting with the proposed system.

Fruit Quality (%)				
Pressure marks	With cuts	With light pressure marks	Without damages	
5	-	-	95	Manual harvesting
21	1	23	55	Fruit from the central conveyor
24.5	1.5	28	46	Fruit from the container

The damages were examined 48 hours after harvesting.

Table 3 Effect of spraying with ethephon solution on fruit thinning

Ethephon concentration	Number of branches	Number of fruits/branch (mean $\pm$ standard deviation)	
		April 1, 1987 (before spraying)	June 12, 1987
0 ppm	24	164.8 $\pm$ 25.8	47.3 $\pm$ 11.5 a*
30 ppm	24	159.6 $\pm$ 24.4	35.9 $\pm$ 11.9 b
60 ppm	24	159.1 $\pm$ 10.7	27.8 $\pm$ 12.3 b c
90 ppm	24	161.9 $\pm$ 13.5	22.0 $\pm$ 8.9 c

*Numbers followed by the same letter are not significantly different at the 5% level.

Table 4 Result obtained with spraying the trees with high concentration (200 ppm) ethephon solution

Treatment	No. of Fruits per tree	Fruit weight g	Fruit dimensions, mm		
			Length	Width	Thickness
Untreated	589 $\pm$ 46	47.3 $\pm$ 9.1	46.2 $\pm$ 3.8	40.6 $\pm$ 4.3	44.8 $\pm$ 3.5
200 ppm	225 $\pm$ 38	76.6 $\pm$ 13.3	53.7 $\pm$ 3.7	49.7 $\pm$ 6.2	53.6 $\pm$ 3.6

Figure 1 Proposed configuration and working team for a two-variety orchard

Figure 2 Proposed configuration for a single-variety orchard

Figure 3 The proposed fruit handling system showing two cross conveyors, one on each side of the machine, and six elevators.

Figure 4 The experimental fruit handling system being tested in a high-density citrus orchard

Figure 5 The over-the-row machine, equipped with the hedging module, is being tested in a high-density orchard of genetically dwarfed peach trees.

Description and Results of Cooperation

Activities of the Israeli team focussed on the economic evaluation, design, and construction of a semi-mechanized integrated system for harvesting fruits in dwarf intensive orchards. The U. S. team directed research efforts toward developing and testing various equipment modules for cultural operations in high-density dwarf-tree orchards and investigating methods for thinning fruits on genetically dwarfed peach trees.

The Israeli team leader, Dr. Yoav Sarig, made a trip to the U.S. in the summer of 1987 to discuss research plans of both teams. Plans were made for both teams to complement each other's research and to avoid unnecessary overlapping of work. Dr. Sarig spent his sabbatical leave in Davis, California, from September, 1988 to September, 1989. During this year, additional field testing of the Israeli harvesting system were planned, and extramural funding was obtained for evaluating the application of the machines developed by this project to commercial high-density peach orchards in California.

The final project report was written jointly by researchers from both teams.

Evaluation of the Research Achievements

This research project resulted in the development of an experimental fruit harvesting and handling system and an over-the-row machine and equipment modules for various cultural operations in high-density dwarf-tree orchards. The Israeli team has established design requirements for a fruit harvesting and handling system based on economic and horticultural studies of high-density dwarf-tree orchards. The proposed system has been designed, and one half of the system has been built and tested.

The U.S. team has designed and built an over-the-row machine with detachable equipment modules for spraying, hedging, pruning, and cultivating operations. The machine and different equipment modules were tested in a genetically dwarfed-peach orchard. The U.S. team also conducted chemical thinning tests on genetically dwarfed-peach trees, and obtained promising

results.

This research provided useful information for developing equipment for high-density orchards. Although the use of the harvesting system may not increase the picking rate nor improve the quality of the fruits, the system does provide a fruit handling method needed for harvesting fruits in high-density orchards. The common problem of excessive cost of single-purpose machines can be alleviated by using a multi-purpose power frame and detachable equipment modules.

The row spacings of many existing high-density fruit orchards are limited by the available machines. The availability of over-the-row equipments would enable growers to increase tree density (within horticultural limit) and further improve the efficiency of fruit production.

List of Publications

1. Chen, P., J. J. Mehlschau, G. Huang, and Y. Sarig. 1987. An over-the-row machine for high-density dwarf-tree orchards. ASAE Paper No. 87-1034. For presentation at the 1987 Summer Meeting, American Society of Agricultural Engineers, Baltimore, MD, June 28-July 1, 1987. (Published in *Applied Engineering in Agriculture* 4(2):111-117. 1988)
2. Chen, P. and Y. Sarig. 1988. Experimental machines for harvesting and cultural operations in high-density dwarf-tree orchards. AG ENG Paper No. 88.087. For presentation at AG ENG 88, Agricultural Engineering International Conference, Paris-March 2-5, 1988.
3. Pasternak, H., Y. Sarig, F. Grosz, and P. Chen. 1988. Evaluation of cost parameter effects of a semi-mechanized integrated system for harvesting dwarf intensive orchard. AG ENG Paper No. 88.283. For presentation at AG ENG 88, Agricultural Engineering International Conference, Paris-March 2-5, 1988.
4. Sarig, Y., Grosz, F., Chen, P., Kendel, R., Pasternak, H. 1988. Preliminary evaluation of an engineering system for production and harvest of citrus fruit grown in high density dwarf tree groves. Proc. 6th Int. Citrus Congress Middle East, Tel Aviv, Israel 4:1811-1817.