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Development of a Mechanized Meadow Orchard System for Fresh Market Peaches

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INTRODUCTION

This project engaged 9 scientists* in three disciplines in 7 departments in 3 institutes in Israel and the U.S. The result of this collaborated work of 4 years of experimentation is presented here.

During this period, climatic disasters caused an almost complete loss of all peach fruit crop in two years in the South-Eastern U.S. This did effect this work, and the extention of the project from 3 to 4 years partly compensated for it.

The subject of developing a mechanized meadow orchard system for fresh market peaches was dealt rather extensively from different aspects and along new approaches. The potential of new peach growing systems, with various cultivars, and the performance of newly planned and constructed peach harvesting machines was evaluated in both countries.

The limiting factors in the complex plant-machine system were defined and evaluated. Although the goal of a completely mechanized peach orchard was not fully attained, we are much closer to reach it than ever before.

Nineteen papers appeared so far from this project.

*The participating scientists in this project were:

A. Erez	Horticulture	Israel
Y. Alper and I. Wolf	Agricultural Engineering	Israel
R. Ben-Arie	Post-Harvest	Israel
D.C. Coston	Horticulture	S. Carolina
R.E. Williamson & C.E. Hood	Agricultural Engineering	S. Carolina
E.T. Sims Jr.	Post-Harvest	S. Carolina
G.A. Couvillon	Horticulture	Georgia

Abstract

Peach meadow orchards were found to be an annually fruiting system only under long enough growing season and with the right cultivars. With the cultivars tried in Georgia and South Carolina not enough flower buds differentiated on the regenerated new growth. Rooting of both softwood and hardwood cuttings for the meadow orchard was improved considerably by the team.

Yields obtained in the 2nd year were equal or higher than that of a fully bearing conventional orchard. Planting density trials, in which in-row spacings of .5 to 1.0 m were checked, did not show any strong effect on yield per unit of area when number of flowers per tree was not limited. Fruit size on the other hand was positively affected by increased spacing. Studies on light interception in the meadow orchard revealed a higher level in denser plantings only in early spring and after heading the trees back at harvest. % light penetration a month prior to harvest was correlated with total soluble solids in the fruit.

Paclobutrazol (pp333) was found to control strongly vegetative growth in peaches grown in a meadow orchard. Soil applied material in a drip irrigated meadow orchard was extremely efficient. Side by side with the vegetative inhibition, increase in fruit size and in cover color was noted. Also an improved flower bud formation was recorded with a poorly differentiating cultivar.

Analysis of the optimal nitrogen nutrition in a continuous feeding experiment revealed 75 mg N/l to produce the highest crop with good quality fruit. Trees grown on their own roots were at least as efficient in root distribution and in leaf mineral content as same trees grafted on conventional rootstocks.

Tests were conducted with a peach harvester prototype that cuts the trees, detaches the fruit on a horizontal conveyor and transfers it into field containers. These tests proved that peaches grown in a meadow orchard system could be harvested

mechanically with a high rate of fruit recovery and low rate of bruising. Lack of uniform ripening of the fruit and the rapid softening of the fruit of some of the tested cultivars, were the two main problems.

Trials using other approaches led to the development of the Canopy Agitation Harvester which detaches the fruit from the non-pruned meadow orchard trees. This approach is adapted to the intensive meadow orchard that will suit better the conditions of shorter growing seasons. Very good levels of fruit detachment and minimal bruising were noticed with the first prototype.

Objectives of the Research

The following objectives were put forward for this research:

1. To develop an integrated mechanized system for production and harvesting peaches in the meadow orchard.
2. To evaluate fruit quality and yield produced in the meadow orchard in comparison to conventional plantings.

Scientific report

1. Horticultural studies
- 1.1 Peach Meadow Orchard Performance
- 1.1.1. Performance and Production - ISRAEL

In Dec. 1979 a 1.7 ha of the 2 cvs Maravilha and Earligrande peaches was planted from hardwood cuttings in Talme Yaffa located in the Southern Coastal Plain in Israel. This orchard was used for this project over 4 consecutive seasons.

The orchard was trained and maintained according to the mechanized meadow orchard system (Erez A. 1982 Peach meadow orchard: Two feasible systems. HortScience 17:138-142). In spring 1981 prior to first bloom 2 rest breaking treatments were applied to get as uniform as possible bloom. The effect was mostly on some advancement of bud break notably leafing while the number of flowers that opened per tree were only marginally affected (Table 1). The first yield harvested in May-June 1981 was rather heavy and reached about 25 T/ha with Earligrande and 20 T/ha of Marvilha. Part of this orchard was picked mechanically.

Tree regeneration was very good with no or only occasional tree loss. Considerable losses were recorded only in one case following trunk girdling in 1981, a practice not repeated later. Determination of tree height was obtained in autumn by controlling water supply. Whenever the targeted height was reached, water supply was cut off completely, usually in September. After setting of a terminal bud continued irrigation in October did not result in growth resumption. The preferred tree height was ca 1.70 m above ground. In a few cases

topping at this height was performed in autumn thus getting a uniform tree size better adapted for the harvester.

Flower bud differentiation was always high with Maravilha (120 to 320 flowers/tree). But too low for Earligrande in 2nd and 3rd seasons (185 flower/tree in the first season vs. about 30 in the 2nd and 3rd seasons). This low level in Earligrande was responsible for the relatively low yields obtained with this cultivar in the 2nd and 3rd seasons (Table 2). The data presented are of actual shipped fruit hand picked from 0.3 and 1.0 ha of Maravilha and Earligrande respectively. Fruit losses mostly due to too soft fruit mounted to 25 to 30%. This resulted from the rapid maturation and fruit softening of these two cultivars and from uneven ripening. An analysis of levels of fruit ripening can be seen in Table 1 in section 2.2.1. A 3 day delay in picking had reduced level of firm fruit from 70.1% to 32.1% this rapid fruit softening with the Earligrande as well as with the Maravilha cv. is definitely a major disadvantage for mechanical picking.

The performance of the harvester on those two dates with respect to picking efficiency is demonstrated in table 3. Clearly no difference in performance was observed. The relatively high level of fruit left on the trees results from losses from too short trees that were not caught by the belts and from some fruit drop on impact with the saw.

When the lower branches were raised and kept higher than the plain of the circular saw losses of fruit falling to the ground was considerably reduced. (Table 3).

A trial meant for evaluating the performance of the harvester during night time was performed on May 10 1981. Data obtained showed an equal or better

Table 1. The effect of rest breaking treatment on no. of flowers per tree in 2 cultivars in Talme Yaffe 1981 (1st season, Treated on January 15 1981, Checked on Feb. 17 1981).

Cultivar	Rest breaking treatment		
	Control	6% oil-DNOC	6% oil-DNOC + 1%TU+7%KNO ₃
Earligrande	118	113	89
Maravilha (Almog)	319	376	373

Table 2. Commercial yields in Talme Yaffe meadow orchard.

Cultivar	Shipped fruit (T/ha) ¹		
	1981 (in season)	1982	1983
Earligrande	19	10 ²	10 ²
Maravilha	16	20	20

1. Fruit losses of soft fruit reached 25-30%.
2. Yields low due to poor flower bud differentiation.

Table 3. Efficiency of mechanical harvesting. ($\pm$ S.E)

Date	% Fruit distribution			
	Picked by harvester	Left on tree	Lost on ground	Total picked (kg).
May 26 1983	79.4 $\pm$ 1.1	7.4 $\pm$ 1.0	13.3 $\pm$ 0.6	285.7 (5 rows)
May 29 1983	76.5 $\pm$ 1.5	6.2 $\pm$ 0.8	17.3 $\pm$ 1.6	271.0 (5 rows)
May 29 1983	82.3	7.5	10.2	56.8 (1 row)

Table 4. Comparison of harvesting efficiency during the day and the night.

Time of harvester operation	% Fruit distribution			
	Picked by harvester	Left on tree	Lost on ground	Total picked (kg).
14 ⁰⁰	83.3	2.4	14.2	162.8 kg.
20 ⁰⁰	89.6	2.0	8.4	261.1 kg.

performance (table 4 and table 11 in section 2.2.5). This result points to a potential use of the harvester around the clock. The risk of excessive heat during fruit maturation may on one hand enhance ripening but on the other prevent picking due to partial turgor loss from the fruit. Night picking may be, under these circumstances, a valid solution.

Fruit sizes were affected too by the once-over mechanical picking. This was due to the picking of immature or not fully mature fruit. This fruit even if marketable was smaller than the firm ripe fruit. A typical fruit size distribution is shown for Earligrande from a 151.9 kg sample.

Fruit diameter (mm)	< 50	50	55	60	65
Portion (%)	16.8	26.7	36.0	17.6	2.7

of these fruits 10.5% were rated unripe and 37.8% rated too soft.

Tree regeneration after heading back was very good indeed. Dimensions of the trees of the two cultivars on trial Earligrande and Maravilha are shown in Table 5. for early November. The trees practically gained their original size. Maravilha seems better adapted to the meadow orchard system due to its higher height: width ratio of 2.18 vs 1.80 with Earligrande and to its better flower bud differentiation level. Foliage of the newly growing shoots was generally in very good shape till late December. Sporadically, deficiency symptoms appeared late in summer, especially in trees that were not headed back. Foliar analysis in August or in October (Table 6) generally revealed a low Zn level in the chlorotic leaves with sometimes too low phosphorous.

Table 5. Tree dimensions by the end of the 2nd growing season (November 1981).

Cultivar	Tree height (cm)	tree width (cm)	No of main branches/tree	Trunk Circum- ference (cm)
Earligrande	158.0 $\pm$ 1.7	87.9 $\pm$ 2.3	2.9 $\pm$ 0.1	14.0 $\pm$ 0.3
Maravilha	168.2 $\pm$ 3.2	77.0 $\pm$ 5.0	1.7 $\pm$ 0.1	14.8 $\pm$ 0.6

Table 6. Foliar mineral analysis in peach meadow orchard in August and October.

Time	Plant material	Element level (dry weight basis)				
		% N	% P	% K	ppm Fe	ppm Zn
August	Earligrand mature intensive meadow orchard.	-	0.14	1.79	100	11
	Earligrande young mechanized meadow orchard.	-	0.28	1.72	107	25
October	Earligrande deficient	3.50	0.22	2.70	112	16
	" healthy	3.05	0.19	2.45	120	27
	Maravilha deficient	3.60	0.21	2.60	115	16
	" healthy	3.60	0.16	2.60	123	29

1.1.2. Performance and Production - S. CAROLINA

Peach meadow orchards were established using own-rooted scion cuttings. Spacings were 2 x 0.5 m resulting in 10,000 trees/ha. All cultivars tested produced yields in the second year of orchard life equal to or higher than traditional peach orchards at full production (Table 1). Full production in traditional orchards is not achieved until 6 or 7 years.

Table 1 - Yield in 1983 from a meadow orchard established in 1982 in Clemson, South Carolina.

Cultivar	Harvest Date	Yield (mt/ha)	Mean Fruit Weight (g)
Camden	3 June	16.7	59.8
Springcrest	9 June	27.0	64.2
Bicentennial	13 June	57.3	64.7
Candor	17 June	23.6	83.2
Redhaven	8 July	29.8	102.3

The concept of removing the entire tree canopy as part of the harvesting operation was not satisfactory for high annual production from meadow orchards in South Carolina (Table 2). Regrowth and production from trees topped at harvest time were reduced considerably compared with trees topped earlier in the growing season.

Table 2 - Growth (1982) and yield (1983) of a meadow orchard established in 1981 and cut back in 1982.

Cultivar	Date of Cut	Tree Height	Flowers/ Tree	Yield (1983) (mt/ha)	Mean Fruit Weight (g)
Springcrest	1 May	1.9	103	26.2	73.6
Springcrest	7 June	1.1	26	6.5	75.0
Bicentennial	1 May	1.8	125	38.3	69.7
Bicentennial	12 June	1.1	12	4.1	67.5
Candor	1 May	1.6	117	18.8	60.3
Candor	18 June	0.9	8	--	--
Correll	1 May	1.6	97	14.5	54.7
Correll	18 June	0.8	6	--	--
Harbelle	1 May	1.8	112	25.3	86.0
Harbelle	25 June	0.6	2	--	--

In another experiment trees were propagated using the semihardwood technique (Couvillon and Erez, HortScience, 15:41-43) and the sprouted nodal technique (Robitaille and Yu, HortScience, 15:579-580). Trees were allowed to grow without pruning. The semihardwood cutting trees had multiple leaders and the sprouted nodal trees grew with a single central leader. The sprouted nodal trees produced a higher fruit yield and the fruit had a larger proportion of the skin covered with red color (Table 3). Skin color is a major part of the grading system for peaches with higher percent color more desirable.

Table 3 - Characteristics of 'Camden' meadow orchard fruit in 1984.

Type of Propagation	Yield (mt/ha)	Mean Fruit Weight (g)	Percent Red ¹	Percent Fruit Set ²
Sprouted Nodal	37.6	55.2	46	30
Semi-hardwood cuttings	24.9	57.1	32	31

¹Percentage of fruit surface covered with red blush.

²(Number fruit/number flowers) x 100 on non-thinned trees.

The central leader shape of the sprouted nodal trees also resulted in more uniform distribution of fruit in the tree canopy (Table 4). On the semihardwood cutting trees most of the fruit was in the lower portions of the canopy. The central leader shape of the sprouted nodal system resulted in more uniform light distribution and consequently more uniform flower bud formation and higher yields.

Table 4 - Distribution of fruit in 'Camden' meadow orchard in 1984.

Height From Ground (m)	Type of Propagation			
	Sprouted Nodal		Semi-Hardwood Cuttings	
	Weight (g/tree)	Percent	Weight (g/tree)	Percent
0 - 0.5	852	23	1117	51
0.5 - 1.0	1374	37	860	38
1.0 - 1.5	1077	29	224	10
1.5 - 2.0	453	12	20	1

The meadow orchard system results in large peach yields early in the life of the orchard. However, with our cultivars, cutting trees as part of the harvesting operation will not result in annual production. Thus, we are examining methods to have all or part of the tree canopy remain intact for the entire growing season so that numerous flower buds will form for the following season's crop.

We are also working to develop modified meadow orchard system that will be well adapted to the harvesting technologies being developed by agricultural engineers at Clemson.

A third area that will continue is development of systems to control excessive tree vigor. Even with the high yields achieved and without irrigation or fertilization during the season of production,

vegetative growth has been excessive. This excessive growth has competed with fruit growth, has caused shading in the canopy consequently less fruit color, and has made pest control difficult because of problems with spray penetration.

1.1.3. Own rooted cultivars vs. cultivars propagated to various rootstocks -

GEORGIA

Couvillon (1982) reported that peaches on their own roots absorbed more calcium and magnesium than trees on 'Lovell', 'Nemaguard', 'Siberian C' or 'Halford' rootstocks. These differences are thought to be due to the presence of a graft union "per se" since leaf tissue of 'Redhaven' grafted onto own rooted 'Redhaven' cuttings had lower Ca levels than leaf tissue of own rooted 'Redhaven' plants (Couvillon unpublished data).

Own rooted 'June Gold' peach trees bloomed significantly later than did 'June Gold' propagated to 'Nemaguard' or 'Lovell'. On the other hand there were no differences in bloom date between own rooted 'Jefferson' peach trees and 'Jefferson' on 'Lovell' or 'Nemaguard'. The same was true for 'Redhaven' on its own roots compared to 'Redhaven' on 'Redhaven', 'Nemaguard', 'Lovell', 'Halford', 'Siberian C', 'Damas 1869' or 'St. Julian'. It seems that peach rootstock effects on bloom of peach are minimal.

'Redhaven' peach trees on their own roots did not differ in trunk diameter or flower bud numbers per cm of trunk diameter from 'Redhaven' on 'Nemaguard', 'Lovell' or 'Halford'. 'Redhaven' on 'Siberian C' rootstock trees were larger and had a greater number of flower buds per cm of trunk diameter than did trees on the other rootstocks.

'Redhaven' peach on its own roots, 'Nemaguard', 'Lovell', 'Halford' and 'Siberian C' rootstocks, and 'June Gold' on its own roots, 'Halford', and 'Nemaguard' rootstocks growing in sand were water stressed then watered and the percentage of the nodes that defoliated was recorded. With both cultivars, trees on their own roots had significantly fewer defoliated nodes than did those on rootstocks. There were no differences in defoliation between rootstocks. These differences are probably due to the characteristics of the root systems of the own rooted material versus seedling rootstocks. The own rooted material had numerous fiborous roots whereas the seedling rootstocks did not have the number of fiborous roots of the own rooted material. Thus, own rooted material was able to encompass a maximum amount of soil thus extract more water than the seedling rootstocks.

Own rooted peach trees of 'Coronet', 'Bicentennial' and 'Springold' did not differ from the same cultivars on 'Lovell' rootstock in trunk cambial browning (cold injury) or bacterial canker resistance.

In all cases own rooted material performed at least as well as peaches on the various rootstocks tested.

1.1.4. Mechanical transplanting of rooted peach cuttings in a meadow orchard -

GEORGIA

Rooted semihardwood peach cuttings of 'Junegold' were manually planted or planted with a standard vegetable transplanter. There was no difference in survival rate or yield of trees that developed from cuttings planted by the two methods. Trees that developed from mechanically transplanted peach cuttings did not differ in performance or other parameters from trees developed from hand transplanted cuttings.

1.2. Tree propagation from cuttings

1.2.1. Improving the rooting of cuttings - GEORGIA

Unrooted hardwood peach cuttings of 'Harvester', 'Redhaven', and 'Bicentennial' were planted directly in the field. Survival decreased with planting dates from November to January. Basal wounding increased survival of all cultivars. The use of hardwood peach cuttings (as described in this study) for the production of peach trees would result in the least expensive peach tree of any propagation method. This increases the feasibility of the annual meadow orchard as previously proposed (Amer. Fruit Grower, August 1980).

1.2.2. Tree propagation - S. CAROLINA

Trees used in peach meadow orchard trials were propagated from scion cuttings. Several new systems were developed.

Semihardwood cuttings were taken in August, wounded, and treated with 2500 ppm IBA (indole butyric acid). The bases of the cuttings were put in a box and received intermittent mist as did the tops of the cuttings. Rooting percentages ranged from 75 to 95%. These cuttings were successfully transplanted and orchards established this way have produced high yields.

Another system developed involved sticking semihardwood cuttings directly in the field. Cuttings were prepared as described above. A mist line was placed above the cuttings and mist was on from sunrise to sunset. A preliminary test in July resulted in 123 of 125 cuttings developing roots. In a larger test (August) 50 to 90% rooting was obtained with improved response closer to the mist line. Orchards developed using this propagation produced high yields. This system, however, is not as practical as hardwood cuttings taken in November because of the mist necessary in the summer system.

1.3. Production of Inexpensive Peach Trees from Rooted Cuttings

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Abstract

High density peach plantings require an inexpensive source of trees. Peach trees were successfully rooted from either semihardwood cuttings placed in a mist propagation bed or from dormant hardwood cuttings stuck directly in the field. Rooting of semihardwood cuttings is not dependent upon cultivar and requires well drained rooting media. Hardwood cuttings root easily when wounded and treated with 5000 or 10,000 ppm IBA. 'Harvester' or 'Redhaven' hardwood cuttings treated with 5000 or 10,000 ppm rooted equally well.

Introduction

High density planting systems require an inexpensive source of trees if establishment costs are to be minimized. Own rooted peach trees can be produced by tissue culture, but the least expensive method that requires the smallest capital investment and least amount of labor is the rooting of cuttings. Peaches have been successfully rooted using either semihardwood or hardwood cuttings (Couvillon, et al, 1980; Erez, et al., 1981; Issell, 1976a, 1976b; Seyit, et al., 1983). Propagation by hardwood cuttings is the simplest and least costly of all propagation methods, and rooting of hardwood cuttings "in place" in the field would be the least expensive. This latter procedure is feasible if the cuttings are stuck when soil temperatures are 12°C or greater (Erez, et al, 1981; Erez, 1984).

Current information suggests that own rooted peach trees perform as well as trees budded to currently recommended rootstocks. Own rooted peach trees absorb and/or translocate nutrients as well as or better than trees budded to 'Lovell', 'Halford', 'Siberian C' or 'Nemaguard' rootstock (Couvillon, 1982). Chamberlain has reported (1982) that peach trees on their own roots are superior to grafted trees. Also, 'Stanley' prune (*P. domestica*) trees grafted to *P. cerasifera* Ehrh. are often injured by a constriction and decline disease but 'Stanley' on its own roots have lower mortality rates (Jim Cummins, Personal Communication).

This paper describes methods used for the rooting of hardwood and semihardwood cuttings as developed in Georgia, USA.

Materials and Methods

Semihardwood cuttings

Effect of propagation date and cultivar on rooting of semihardwood cuttings

Twenty-five to 35 cm long peach cuttings were removed from eight year old trees of 'Redhaven', 'Blake', 'Cardinal', 'Cornet', 'Loring', 'Golden Monarch', 'Springgold', 'Redskin', 'Lovell' and 'Namaguard' on August 1 and of 'Baby Gold No. 5' on June 23, July 23 and August 23 of 1980. All but the upper 4 to 6 leaves were removed from the cuttings. The cuttings were wounded by removing a 5 cm longitudinal section of bark on opposite sides of the cutting base by scraping with a knife blade and then treating with a 5 second dip in a 2500 ppm alcohol/water solution of Indole-3-butyric acid (IBA). Following treatment cuttings were inserted into a vermiculite filled mist bed. The mist cycle was set at 2.5 seconds per minute and the cuttings were misted only during daylight hours except for the initial 24 hours following cutting insertion when they were misted continuously. Cuttings began to root 10 to 15 days following insertion; then the mist cycle was reduced to 2.5 seconds every 5 minutes per week until the cuttings were no longer misted.

Effect of rooting media on the rooting of semihardwood cuttings.

Semihardwood cuttings treated as previously described were placed in either pine bark (*Pinus taeda* L.) or vermiculite. After 20 and 30 days, cuttings were removed from the medium, percentage rooting was determined and the cuttings visually rated as follows: 1=callus, 2=poor, 3=fair, 4=good, 5=excellent.

Particle size distribution was determined for each of the rooting media by using a dry screening method (Brown, et al., 1975). Percentage air-filled pore space was determined by the method of Buscher and Van Doren (1973).

Hardwood cuttings

Infield rooting of peach hardwood cuttings

Hardwood cuttings from 'Bicentennial', 'Harvester', and 'Redhaven' peach trees were taken on October 20, November 20, and December 20, 1981, and on January 20, 1982. Cuttings were of wood produced in 1981 that was about 0.6 cm in diameter and 30 cm in length. Leaves were stripped from the October cuttings, but leaf fall had occurred by November 20. On some cuttings the base was wounded by making a 1-cm-long incision into the bark on each side of the cutting base; the bark was not removed as previously described

(Couvillon, et al, 1980). The base of each cutting was dipped for 5 sec in 1000 ppm indolebutyric acid (IBA) in 50% ethanol solution. Following treatment, cuttings were inserted to a depth of 15 cm directly into a well-cultivated Cecil sandy loam soil. The experimental design was a randomized complete block with 4 replications. Each replication consisted of 50 cuttings spaced 15 X 15 cm in such a manner that a 135 X 60 cm rectangle was formed. Cuttings were evaluated on June 6, 1982. Survival ratings were based on trees achieving at least 20 cm shoot growth; cuttings with less growth were considered too poorly rooted to produce a profitable tree.

The effect of IBA concentration on the rooting of hardwood peach cuttings.

Dormant hardwood cuttings were removed from trees in January 1984, wounded as described previously, treated with either 0, 1000, 5000, 10,000, or 15,000 ppm IBA, and inserted in vermiculite filled pots which were on a greenhouse bench. The greenhouse was held at 20°C (+ 5°C). Following 45 days in the rooting medium cuttings were removed from the pots and rated for root development on a scale of 1 to 5 (1=no roots, 2=poorly rooted, 3=fair rooting, 4=good rooting and 5=excellent rooting) and percentage rooting was determined.

Results and Discussion

Semihardwood Cuttings

Influence of date of propagation and cultivar on rooting of semihardwood cuttings

Semihardwood cuttings taken in June and late August did not root as well as those taken in July (Table 1). There seems to be a "window" during which semihardwood cuttings can be taken and maximum rooting percentages will be obtained. This period follows growth cessation in summer and cuttings taken during this time should have a dormant terminal bud present. Also, the presence of a basal wound results in improvement in root quality of the rooted cuttings. Rooting of semihardwood cuttings was not cultivar dependent (data not presented).

Effect of propagation media on rooting of semihardwood cuttings

A comparison of pine bark and vermiculite as rooting media for semihardwood peach cuttings revealed that cuttings rooted as well in pine bark as in vermiculite following 20 days under mist (Table 2), but the root quality of cuttings rooted in vermiculite was superior to those rooted in pine bark. This difference was lost following 30 days in the rooting media. The poorer root quality of

cuttings rooted in pine bark following 20 days under mist probably lies in the reduced air and pore space of bark as compared to vermiculite (Table 3). Although the use of pine bark as a rooting medium would significantly reduce the cost of rooting peach cuttings, care should be taken to reduce the mist cycle from that used in this study so that adequate early rooting is obtained. Also, care should be taken when media of fine particle size such as pine bark (30% of particles <0.42 mm) is used because of the potential of waterlogging. The mist cycle should be such that a sufficient but not excessive quantity of water is applied to the medium, but sufficient moisture is applied to retain a film of water on the leaves.

Hardwood cuttings

In field rooted hardwood cuttings

There was a striking effect of wounding on survival of rooted hardwood peach cuttings (Table 4). The percentage survival was nearly twice for wounded as compared to unwounded cuttings. The higher survival rate of the wounded cuttings was due to the increased root quality derived from wounding (data not presented).

Cultivars significantly influence survival (Table 4) as previously reported (Erez, et al, 1981; Issell, 1976b). 'Harvester' cuttings had a higher survival rate than did 'Redhaven' or 'Bicentennial'. (Table 4): Issell (1976b) reported rooting percentages that ranged from 40% to 95% for 9 peach cultivars rooted from hardwood cuttings.

Plant survival was highest with the earliest planting date and decreased with each planting date thereafter (Table 4). This was probably due to the higher soil temperatures in October (Erez, 1984). Cuttings taken at times when the soil temperatures are below 12°C would probably have to be precalloused or rooted indoors in greenhouses and then transferred to the field. Cuttings propagated in October grew better and produced larger trees than did cuttings propagated on the other dates. Trees from October-planted cuttings grew to a height of 90 cm at the end of the growing season in spite of the very high densities.

Effect of IBA on the rooting of hardwood cuttings

Best rooting percentages and root quality were obtained when dormant hardwood cuttings of 'Harvester' and 'Redhaven' peach were treated with either 5000 or 10,000 ppm IBA (Table 5). There was no difference in rooting percentage or quality between cultivars when 5000 or 10,000 ppm IBA was used as the hormone treatment.

Table 1 - Influence of date of propagation on the rooting of peach semihardwood cuttings.

Propagation Date	% Rooting (Arc Sine) ²
June 23	17a
July 23	44b
August 23	9c

²Mean separation in rows or columns by Duncan's multiple range test, 5% level.

Table 2 - Effect of propagation media on % rooting and root quality of semihardwood peach cuttings, CV. Jefferson.²

Rooting media	Days in rooting media	% Rooting (Arc Sine)	Rooting Rating (1=no roots) (5=excellent)
Vermiculite	20	69.08a	3.14a
	30	79.48b	3.81c
Pine bark	20	65.40a	2.20b
	30	84.29b	3.86c

²Mean separation in rows or columns by Duncan's multiple range test, 5% level.

Table 3 - Percent air space, total pore space, and water retention of pine bark and vermiculite no. 2 rooting media.^z

Rooting media	Percentage (volume)		
	Air space	Pore space	Water retention
Vermiculite No. 2	21.6a	96.3a	74.7a
Pine bark	14.5b	88.6b	75.8a

^zMean separation in rows or columns by Duncan's multiple range test, 5% level.

Table 4 - The influence of wound, cultivar and planting date on the survival of peach hardwood cuttings.

Date of planting	Survival (%)	
	Not wounded	Wounded
<u>'Harvester'</u>		
Oct. 20	28.0b ^z	64.0a
Nov. 20	40.0b	30.7b
Dec. 20	28.6b	9.3d
Jan. 20	2.6d	14.6d
<u>'Redhaven'</u>		
Oct. 20	16.0c	46.0b
Nov. 20	2.6d	19.3c
Dec. 20	2.0d	12.6d
Jan. 20	1.3d	0.6d
<u>'Bicentennial'</u>		
Oct. 20	8.6d	24.0b
Nov. 20	0.7d	2.7d
Dec. 20	2.0d	5.3d
Jan. 20	0.6d	6.0d

^zMean separation in rows or columns by Duncan's multiple range test, 5% level.

Table 5. Influence of IBA concentration on percent rooting and root quality of dormant hardwood cuttings of 'Rehaven' and 'Harvester' peach.

IBA concentration (ppm)	Percent rooting		Root Rating	
	'Harvester'	'Redhaven'	'Harvester'	'Redhaven'
0	0	20	0.6	0.7
1000	20	50	1.0	1.6
5000	100	90	2.9	2.9
10000	90	90	2.3	2.9
15000	0	80	0.8	2.4

1.4 Tree Nutrition

1.4.1 Nitrogen Nutrition in the Meadow Orchard - ISRAEL

A special attention was given to nitrogen nutrition in the peach meadow orchard. The work was conducted with Earligrande peach trees that were raised from cuttings and were grown in 50 l containers filled with volcanic tuff and were fertigated with a half Hoagland solution excluding nitrogen. Nitrogen was added at a 1:2 ratio of NH_4 to NO_3 in 5 levels: 10, 37, 75, 150, and 250 mg/liter. Application was continuous with irrigation till fruit ripening when fertilization was stopped. Tree growth was analysed by measuring leaf area, total leaf dry weight, tree trunk cross section area, and total dry matter of the whole tree (including the root system). Fruit was analysed at harvest for total soluble solids, skin color, weight and yield per tree. The experiment started with 3 months old trees raised from hardwood cuttings and lasted two years. Only one fruiting season was followed. Data on vegetative tree development are shown in table 7.

An increase in leaf area and leaf number with increase in N level applied is evident. Yields (table 8) show the highest values in the 75 and 150mg N/l treatments. Fruit weight was best in the two highest N treatments. T.S.S. values were highest in the 37mg/N treatment and color showed a trend for improvement the lower the N level.

Analyzing fruit production efficiency on a few different bases (fig. 1) reveals the best efficiency in the 75 mg/l N treatment. This is true on trunk cross section area, on total tree dry weight and on total leaf area per tree. The poor performance of the low N treatments (10 and 37mg/l) was due to N deficiency resulting in poor flowering (with the 10mg/l) and to small fruit. The highest N treatments resulted in excessive vegetative growth and low flower bud differentiation (250mg/l treatment).

Fig 1: The effect of nitrogen nutrition level on yield of Earligrande peach trees grown in 50l tuff filled containers on yield expressed on a few bases.

Table 7. The effect of nitrogen level on vegetative development of Earligrande peach trees. Data collected at harvest, June 1982)

Nitrogen level (mg/l)	Leaf area/ tree (m ²)	Leaf weight/ tree (g.d. wt.)	Leaf No/ tree
10	1.45 C	78 C	459 C
37	5.88 B	332 B	1509 B
75	6.93 B	365 B	1800 AB
150	10.15 A	476 A	2225 A
250	10.18 A	486 A	2247 A

Table 8. The effect of nitrogen nutrition on yield and fruit characteristics of Earligrande peaches.

Nitrogen level (mg/l)	Yield/ tree (g)	Fruit wt. (g)	T.S.S. (%)	Fruit color (1-4) ¹
10	585 C	70 C	6.55 B	2.92 A
37	3557 B	104 B	7.96 A	2.72 A
75	6684 A	116 AB	7.58 AB	2.60 A
150	6319 A	124 A	7.40 AB	2.57 A
250	3563 B	124 A	7.36 AB	2.24 A

1) Cover color expressed as quarters of colored surface.

1.5 Plant density trials

1.5.1 Studies in ISRAEL

In order to evaluate the optimal planting density a trial was set up in Bet-Dagan Israel in winter: 1980/81.

Three cvs.: Desertgold, Maravilha (almog) and Earligrande (Texas A-170) all early maturing varieties were planted as cuttings in three planting spacings: 1.8 x 0.5m, 1.8 x 0.75m and 1.8 x 1.0 m. The 1.8m between the row spacing was chosen according to previous experience. The orchard was raised according to the mechanized meadow orchard system. The first crop was obtained in 1982. Regeneration of the trees after heading back at harvest was good with Maravilha and Earligrande, and poor with Desertgold due to an extreme sensitivity of this cultivar to leaf hoppers (cycades). Therefore Desertgold was omitted from the trial and its training system changed to the intensive meadow orchard.

Maravilha was the better adapted cv to the system, due to an excellent regeneration and good flower bud formation on the new growth Earligrande on the other hand although regenerated the tree very quickly failed to differentiate enough flower buds needed for producing a full crop as was already discussed above (1.1 peach meadow orchard performance). Although thinning work was saved with Earligrande, this did not compensate for the low yield. The yield data are shown for the first 3 cropping seasons in table 9 for Maravilha and in table 10 for Earligrande.

Maravilha exhibited a higher production in the denser spacing but this was not statistically significant. Yields ranged between about 30 to 33 metric tons/ha per year.

Earligrande (Table 10) on the other hand showed a considerably lower yields in all seasons. Especially low yields were recorded in 1983 and 1984, 2nd and 3rd cropping years respectively. This extremely vigorous cultivar responded favorably to higher planting density, probably as a result of increased tree to tree competition leading to smaller trees and better flower bud differentiation. Hence higher yields were recorded for the 0.5m in row spacing in the cumulative yield over the other two spacings. An average of about 22 metric tons/ha per year for 0.5m vs about 16 metric tons/ha per year for the other wider spacings.

Analysis of fruit quality obtained revealed little differences among the three spacings in the cultivars for total soluble solids content and color. Mean fruit weight however, did show an effect of planting density with a tendency of smaller fruit the denser the planting. Always a somewhat smaller fruit weight was recorded for the 50cm planting spacing than in the wider ones. (Table 11).

A closer inspection of fruit characteristics revealed an effect of plane of fruit location on both T.S.S. level and fruit weight as is shown in Table 11 for Earligrande and in Table 12 for Maravilha. In all three spacings, with both cultivars the higher the fruit location the higher the T.S.S. content. With Earligrande the higher the fruit location the bigger was the fruit weight. No effect was found to location on fruit color.

Table 9. Yield obtained over 3 years in a meachanized meadow orchard of the cv. Maravilha.

In row spacing (m)	Yield (kg/1000 m ²)			
	1982	1983	1984	1982-4
0.50	4243a	3444a	2255a	9942a
0.75	3648a	2988a	2301a	8937a
1.00	3299a	3190a	2384a	8873a

Table 10. Yields obtained over 3 years in a mechanized meadow orchard of the cv. Earligrande.

In row spacing (m)	Yield (Kg/1000m ²)			
	1982	1983	1984	1982-4
0.50	2926a	1678a	1977a	6581a
0.75	2271a	1572a	1407a	5250b
1.00	2324a	1058b	1222a	4604b

Table 11. The effect of fruit location on its characteristics at harvest
(Earligrande 1984).

In row spacings (cm)	Parameter	Height Above Ground (cm)		
		0-60	60-120	>120
50	Fruit wt (g)	77.4	87.0	95.4
	Fruit Color [*] (0-4)	1.25	1.16	0.91
	T.S.S. (%)	9.4	10.0	10.3
75	Fruit wt (g)	97.7	102.0	108.5
	Fruit Color [*] (0-4)	1.18	0.95	1.01
	T.S.S. (%)	9.2	9.6	9.8
100	Fruit wt (g)	99.6	100.0	110.3
	Fruit Color [*] (0-4)	1.25	1.08	1.22
	T.S.S. (%)	9.2	9.4	10.4

* Cover color, expressed as quarters of colored surface.

1.5.2. Studies in GEORGIA

The number of flower buds per cm trunk diameter on 12-month old trees planted in a meadow orchard was significantly less on trees spaced 25 cm within the row than on trees spaced to wider "in-row" spacings. There were no differences in flower numbers per cm trunk diameter on trees spaced 50, 75 or 100 cm within the row. On the other hand, trees that had been regenerated and spaced to the same in row spacings did not differ in flower numbers produced per cm trunk diameter and in all cases the flower bud per cm trunk diameter was low. There was a mean of 2.8 flower buds per cm/trunk diameter on regenerated trees compared to 55 flower buds per cm trunk diameter on 1-year-old trees. This very low production of flower buds on regenerated trees indicates that many current cultivars are not adaptable to meadow orchard production unless they are produced as annuals or in the alternate meadow orchard system. Fruit were not produced in 1983 due to a complete crop loss from late spring frost. In 1984, the yield was very low and uneconomical due to the small quantity of blooms produced by all treatments.

1.6 Light interception and distribution in the meadow orchard - ISRAEL

The three spacings tried in the meadow orchard (see plant density studies) were used for monitoring light interception and distribution in tree canopies.

In order to be able to follow integrated light regimes in plant canopies we have developed a system based on the photochemical reaction of decomposition of oxalic acid in the presence of Uranyl ions. The cell units developed were used in this study. The cells and their response in comparison to quantum sensors is described in detail in Appendix A.

A time course of the dynamic changes in plant canopy in the mechanized meadow orchard in 3 planes in 3 spacings of the Maravilha cultivar are shown in fig. 2. The exposure period of the test tubes was for 24 hrs.

A double cycle a year of canopy build-up is evident. A quicker increase of light interception in spring is evident for the canopy in the 50 cm spacing. The denser planting along the row seems to enhance canopy growth perpendicular to the row. The second cycle starting after harvest show a marked slower build up of light interception in the 1.0m spacing.

Topping about 2 weeks prior to harvest clearly lowered % light interception in all spacings although its effect was strongest with the 50 cm spacing.

Average values of % light interception over the year are shown for Earligrande in Table 13. A rather similar situation for all 3 treatments is evident with the exception of lower light interception in the widest spacing in Early Spring, and the period following heading back in June.

Light distribution in the canopy was checked a few times in the course of the annual cycle. A typical situation is presented for Earligrande prior to

Fig 2: Percent light interception at 3 levels parallel to the row axis and in 3 planting densities in the course of 1 year. 0,45, and 90 represent cm away from row axis. 0.5, 0.75 and 1.0m represent in-row planting spacings

harvest in Fig. 3. The 3 spacings with 9 measuring point in each of 3 planes is shown in 3 dimensional presentation.

Clearly % light penetration goes down with the measured plane, and with proximity to row axis. On the other hand relatively little variations were noted in the 3 measurements along the row axis. Critical levels of light irradiance lower than 20% of above canopy light were found in all measurements along the row at 40cm plane, in one out of 3 measurements of the 45cm parallel to row axis with 50 and 100cm spacings and in 2 out of 3 measurement with 75cm spacing. At the 80cm plane, two measurements at row axis and one at the 45cm parallel of light irradiance lower than 20% were found with both 50 and 100cm. At this plane, 75cm, spacing, showed light irradiance lower than 20% at the 3 measurements along the row and in 1 case in the 45cm parallel. Thus it seems that the densest canopy obtained at the examined period was obtained at the 75cm spacing.

In a few instances fruit was picked and analyzed separately for every layer. (see plant density studies). Correlation and regressions were sought for fruit characteristics and light irradiance. The data for TSS in the picked fruit and % light penetration is shown in Table 14.

A highly significant correlation was found between % light penetration as measured on late April and T.S.S. level in the fruit of both cultivars. No significant correlation was found between light regime in the canopy of the meadow orchard and fruit weight or color.

This finding points to a possible photosynthetic rather than a photomorphogenetic effect of shade in the lower part of the canopy.

Fig 3: Light penetration into

canopies of peach meadow

orchard planted at 3 densi-

ties prior to fruit

ripening. (Densities were

1.8 x .50 m - 3 left graphs,

1.8 x .75 m - 3 middle

graphs, 1.8 x 1.0 m - 3

right graphs).

Date are presented as % light

penetration in 9 points in

3 heights spread along and

perpendicular to the row

axis. Point 0 is tree

trunk.

Table 12. The effect of fruit location on its characteristics at harvest
(Maravilha 1984).

In row spacings (cm)	Parameter	Height Above Ground (cm)		
		0-60	60-120	> 120
50	Fruit wt (g)	65.2	63.2	70.6
	Fruit Color*	2.4	2.2	2.4
	T.S.S. (%)	8.1	8.9	9.2
75	Fruit wt (g)	64.9	69.4	64.8
	Fruit Color*	2.5	2.6	2.3
	T.S.S. (%)	8.8	9.1	9.6
100	Fruit wt (g)	67.2	69.5	77.0
	Fruit Color*	2.4	2.3	2.7
	T.S.S.	8.3	9.1	9.6

* Cover color expressed as quarters of colored surface.

Table 13. Percent light interception in the Earligrande peach mechanized meadow orchard over an annual cycle in three planting densities.

Date	Event	In-row spacing (cm)		
		50	75	100
Jan. 25	Prior to bud break	0	0	0
Mar. 20		56	54	28
Apr. 15		76	71	75
May 15	Topping & hedging	77	72	75
May 16		62	64	69
May 29		66	68	69
Jun. 5	Picking and pruning	0	0	0
Sep. 15		38	54	15
Oct. 15		51	69	56
Nov. 1		64	61	48
$\bar{x}$		49.0	51.3	43.5

Table 14. Correlation and linear regression analysis of light level and total soluble solids in peach fruit in the Earligrande and maravilha cvs.

Cultivar	$\underline{r}$	$\underline{a}$	$\underline{b}$
Earligrande	0.930*	8.956	1.81 10^{-2}
Maravilha	0.921*	8.005	2.85 10^{-2}

* Correlation coefficient significant at $P = 0.01$.

1.7. Control of Excessive Growth and Poor Flower Bud Differentiation

1.7.1. Flower Bud Development Studies - S. CAROLINA

Gerard W. Krewer conducted research for a Ph.D. degree under the sponsorship of this project. His dissertation was entitled "The Initiation and Development of Flower Buds in the Peach". The abstract of that dissertation is included here.

The meadow orchard system of peach production involves annual severe pruning at harvest to control tree height and renew the orchard. When early, mid and late season cultivars are grown under this system, flower bud production is poor. Research was conducted to determine the time and extent of flower bud initiation in meadow orchard and standard trees and to investigate factors influencing flowering.

Positioning whole trees in a horizontal position or branches in a horizontal or bent position decreased growth (Table 2). Total number of flower buds was always greatest on vertical trees or branches (Table 3). Defoliation of distal and basal shoot sections in late summer did not affect flowering the next year in most cases (Tables 4 and 5).

Crop load (0, 1, 2, 3, 4 fruit per shoot) affected flowering and vegetative growth on early and late season cultivars (Table 6). Three and four fruit per shoot usually reduced flowering and vegetative growth compared to not fruit. Flowering and growth on late season cultivars were inhibited by a heavy fruit load.

The peach was shown to be day-neutral, but exhibited a quantitative response in flowering to photoperiod (Tables 7, 8 and 9). When meadow orchard type trees were grown in the greenhouse January to July, the adult vegetative period lasted 22-24 weeks, but only 18 weeks when grown from May to October (Tables 13, 14 and 15). In field studies, where trees were coppiced during the summer, a significant drop in the number

of flower buds produced on regenerated growth occurred in trees cut 20 weeks or less before natural fall defoliation.

Flower bud differentiation started about 15 weeks after anthesis, approximately 10 days after terminal bud set of most lateral limbs with mature standard trees of 3 cultivars. Flower bud differentiation was found to occur simultaneously at the base and lower midsection of the shoot, followed by the upper section. Flower bud differentiation sometimes occurred at different times in flower buds on the same node.

Girdling was effective in increasing flowering in some years if applied in a severe manner in late summer (Table 18). Pruning height and shoot tipping had little effect on flowering in the course of these experiments (Table 19).

Many growth regulators were tested, but only paclobutrozol (2RS, 3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-1,2,4-triazol-1-yl-1-pentan-3-ol, was found to be consistently effective at increasing flowering and controlling vegetative growth (Tables 16 and 17).

TABLE 2. The Influence of Whole Tree Positioning on Flower Buds (F.B.) per cm of Shoot Length and Flower Buds per Node.

Treatment	F.B./cm	F.B./Node
Vertical	0.040 a ²	0.036 a
Horizontal	0.032 a	0.060 a

²Mean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 3. The Influence of Shoot Orientation on Flowering in 'Babygold 5' Peach.

Treatment	Flower Buds per mm of Shoot Diameter 1982-83	Flower Buds per Tree 1982-83	Flower Buds per mm of Shoot Diameter 1983-84
Vertical	0.273 a ^z	2.67 a	0.050 a
Horizontal	0.084 b	0.68 b	0.112 a
Bent	0.061 b	0.48 b	0.083 a

^zMean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 4. The Influence of Defoliation of Flower Buds per mm of Shoot Growth in 3 Cultivars of Peach.

Treatment	Clemson, SC 'Redglobe'		Attapulgus, GA 'Junegold'		Brooks Co., GA '71-A73-3'	
	Apical Area	Basal Area	Apical Area	Basal Area	Apical Area	Basal Area
All Leaves Removed	0.037 a ^z	0.032 a	0.018 a	0.071 a	0.023 a	0.058 a
Control	0.035 a	0.039 ab	0.018 a	0.061 a	0.041 a	0.050 a
Apical Leaves Removed	0.035 a	0.043 a	0.018 a	0.073 a	0.034 a	0.052 a
Basal Leaves Removed	0.031 a	0.030 b	0.025 a	0.070 a	0.018 a	0.058 a

^zMean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 5. Flower Buds on Regrowth after Defoliation and Hedging, Brooks County, GA - '71-A73-3' Peach.

Treatment	Flower Buds/mm of Shoot Length
Basal Leaves Removed	0.001
Control	0.002
Apical Leaves Removed	0.000
All Leaves Removed	0.000

TABLE 6. The Influence of Fruit Load on Flower Buds (F.B.) per mm of Shoot Length on 2 Peach Cultivars.

Treatment	Clemson 'Rio Oso Gem'		Attapulgus 'Junegold'	
	F.B./ mm Shoot	Shoot Growth	F.B./ mm Shoot	Shoot Growth
No fruit	0.050 a ²	132.6 ab	0.061 a	428.0 a
1 fruit	0.047 a	124.9 ab	0.045 ab	341.4 ab
2 fruit	0.041 ab	112.9 ab	0.042 ab	395.8 b
3 fruit	0.027 b	99.2 ab	0.030 b	244.1 b
4 fruit	0.024 b	82.4 b	0.025 b	236.1 b

²Mean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 7. The Influence of Photoperiod on Internode Length of Peach.

Day Length	Cultivars Combined		
	Lower Internode Length (mm)	Middle Internode Length (mm)	Upper Internode Length (mm)
Natural Day Length	21.92 a ^z	23.22 b	21.72 b
16-Hour Day	20.20 b	25.37 a	23.52 a
10-Hour Day	17.29 c	21.67 c	20.09 c

^zMean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 8. The Effect of Photoperiod on Average Internode Lengths of 3 Peach Cultivars.

Treatment	'Nemaguard' Internodes (mm)	'Redhaven' Internodes (mm)	'Springcrest' Internodes (mm)
16-Hour Day	23.40 a ^z	24.02 a	22.52 a
Natural Day Length	20.48 b	23.82 ab	22.35 a
10-Hour Day	17.90 c	20.97 b	19.82 b

^zMean separation within sections by Duncan's Multiple Range Test, 5% level.

TABLE 9. Flowering Response of Various Cultivars to Photoperiod.

Day Length	'Redhaven' Flower Buds/ mm of Shoot Diameter	'Springcrest' Flower Buds/ mm of Shoot Diameter	'Redhaven' Flower Buds/ Gram Shoot Dry Weight	'Springcrest' Flower Buds/ Gram Shoot Dry Weight	Flowers/ Tree Cultivars Combined
Natural Day Length	0.253 a ^z	1.188 a	0.090 a	0.418 a	8.23 a
16-Hour Day	0.069 b	0.159 a	0.021 b	0.052 b	1.81 b
10-Hour Day	0.014 c	0.026 b	0.003 c	0.008 c	1.46 c

^zMean separation within sections by Duncan's Multiple Range Test, 5% level.

TABLE 13. Length of Adult Vegetative Period in Peach.

Last Day of Growing Season	Flower Buds/mm of Trunk Diameter	
	Normal Shoot Flower Buds	Normal Shoot Flower Buds Plus Flower Buds on Damaged Terminals
<u>Clonal 'Springcrest'</u>		
March 23	0.000 c ²	0.000 d
April 20	0.000 c	0.000 d
May 10	0.000 c	0.000 d
June 1	0.013 c	0.013 d
June 16	0.011 c	0.027 d
July 1	0.200 c	0.833 ab
July 13	0.550 b	0.619 bc
July 27	0.130 c	0.170 cd
August 10	0.643 ab	0.723 ab
August 24	0.962 a	1.230 a
September 7	0.512 b	0.550 b
<u>Clonal 'Redhaven'</u>		
March 23	0.000 a	0.000 a
May 10	0.000 a	0.013 a
June 16	0.014 a	0.027 a
July 27	0.347 b	0.401 a
September 7	0.330 b	0.342 a

²Mean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 14. Length of the Adult Vegetative Period Experiment on 2nd Leaf Trees.

'Springcrest' Group #	Growing Seasons		Flower Buds/ mm of trunk Diameter in 2nd Year
	1st Year	2nd Year	
1	Dec. 24-May 23	July 11-Nov. 29	1.700 ab ²
2	Dec. 24-June 1	July 11-Nov. 29	2.563 a
3	Dec. 24-June 16	Aug. 16-Nov. 29	2.250 a
4	Dec. 24-July 1	Aug. 28-Dec. 16	0.648 b
5	Dec. 24-July 13	Sept. 25-Dec. 25	0.000 (killed by freeze)

Cultivar Difference, Group 3

'Springcrest'	2.250 a
'Redhaven'	1.850 ab
'Nemaguard'	0.960 b

²Mean separation within sections by Duncan's Multiple Range Test, 5% level.

TABLE 15. The Influence of Physiologic Age on Flowering in Field Grown Peaches.

Date of Cut	Flower Buds/ mm of Shoot Diameter
<u>'68-440' and 'Bicentennial'</u>	
May 18	0.2400 b ²
May 25	0.2337 b
June 1	0.4268 a
June 8	0.0984 bc
June 14	0.1693 b
June 21	0.0899 bc
June 29	0.1999 b
July 5	0.0020 c
July 14	0.0117 c
July 21	0.0163 c
<u>'Junegold'</u>	
April 26	0.814 a
May 26	0.122 b
June 22	0.009 b
July 18	0.000 b
August 25	0.000 b

²Mean separation within sections by Duncan's Multiple Range Test, 5% level.

TABLE 16. The Response of Peach to Various Growth Regulators.

	Athens 1981 'Harvester' Flower Buds/ mm of Shoot Diameter	Athens 1981 'Harvester' Shoot Growth After Treat- ment (cm)	Clemson 1981 '68-440' Flower Buds/ mm of Shoot Diameter	Clemson 1981 '68-440' Shoot Growth After Treat- ment (cm)	Athens 1982 'Blake' Flower Buds/ mm of Shoot Diameter	Clemson 1982 '68-440' Flower Buds/ mm of Shoot Diameter	Athens 1983 'Coronet' Lateral Shoot Flower Buds/ mm of Shoot Diameter	Athens 1983 'Coronet' Terminal Shoot Flower Buds/mm	Athens 1983 'Springgold' Lateral Shoot Flower Buds/ mm of Shoot Diameter	Athens 1983 'Springgold' Terminal Shoot Flower Buds/ mm of Shoot Diameter
Control	.165 bc ¹	19.91 ab	.036 a	22.44 ab	.738 a	.221 a	.316 a	.633 a	.530 a	1.07 a
SADH 1000 ppm ²	.092 c	8.06 c								
SADH 2000 ppm	.138 bc	17.29 ab					.252 a	.784 a	.273 a	.72 a
SADH 5000 ppm	.136 bc	18.39 ab								
Ethephon 250 ppm			.025 a	10.90 c			.399 a	.498 a	.193 a	.91 a
SADH 2000+Ethephon 250 ppm						.176 abc	.414 a	.937 a	.273 a	1.09 a
CBA 15281 ³ 360 ppm	.209 bc	19.27 ab								
CBA 15281 960 ppm	.174 bc	16.36 ab								
CBA 15281 1920 ppm	.112 bc	20.30 ab								
Ancymidol 10 ppm	.161 bc	20.30 ab								
Ancymidol 50 ppm	.226 b	20.31 ab					.374 a	.736 a	.336 a	.71 a
Ancymidol 100 ppm	.158 bc	19.35 ab								
Chlormequat 500 ppm	.178 bc	23.79 a								
Chlormequat 1000 ppm	.200 bc	21.77 ab								
Chlormequat 2000 ppm	.098 c	24.94 a								
Mepiquat Chloride 10 ppm			.025 a	19.78 b						
Mepiquat Chloride 100 ppm			.039 a	23.60 ab						
Mepiquat Chloride 1000 ppm			.052 a	20.84 ab	.594 ab	.103 c				
Benzyl Adenine 400 ppm					.394 b	.082 c				
Pronalin 100 ppm			.044 a	22.20 ab	.499 ab	.083 c				
Gibberellic Acid 50 ppm			.028 a	22.85 a						
Gibberellic Acid 100 ppm			.022 a	24.36 a						

¹Mean separation within columns by Duncan's Multiple Range Test, 5% level.
²1000 ppm = 100 mg/l; 2000 ppm = 200 mg/l; 5000 ppm = 500 mg/l.
³15281 = 15281 mg/l; 360 ppm = 360 mg/l; 960 ppm = 960 mg/l; 1920 ppm = 1920 mg/l.

TABLE 17. Paclobutrozo1 Effects on '68-440' Peach, 1982-84.

Treatment	Spring 1983	Spring 1984
	Treatment Flower Buds/mm Shoot Diameter	Residual Effects From Fall 1982 Application Flower Buds/mm Shoot Length
Control	0.221 a ²	0.412 b
Paclobutrozo1 2000 ppm	0.115 b	0.642 a

²Mean separation within columns by Duncan's Multiple Range Test, 5% level.

TABLE 18. The Response of Peach to Girdling, 1981-84.

	Athens 1981 '68-440' Flower buds/mm Shoot Diameter (cm)	Shoot Growth (cm)	Clemson 1982 'Blake' F.B./mm	Clemson 1982 'Babygold' F.B./mm	Clemson 1983 '68-440' F.B./mm	Clemson 1983 cv. Combined F.B./mm	Athens 1983 'Blake' F.B./mm	Athens 1983 'Springgold' F.B./mm	Athens 1983 'Bicentennial' F.B./mm	Athens 1983 'Lowling' F.B./mm	Athens 1983 'Blake' F.B./mm	Athens 1983 'June gold' F.B./mm
Control	.165 bc	19.91 ab	.221 a	.738 a	.013 a	.82 a	.32 ab	.63 a	1.27 a	1.09 a	.76 a	.24 a
3 mm complete girdle with saw	.351 a	6.04 c										
3 mm one-half girdle with saw	.176 bc	13.34 bc										
3 mm complete girdle Sept. with pocket knife			.205 a	.424 b								
4 mm complete girdle Oct. with pocket knife												
3 mm incomplete girdle August 4				.268 a								
3 mm incomplete girdle August 27-28					.013 a							
3 mm complete girdle August 27					.000 a							
5 mm complete girdle August 27						1.02 a	.73 a	1.09 a	1.40 a	.88 a		
3 mm complete girdle September 24						.94 a	.23 b	1.25 a	1.05 a	1.16 a		
5 mm complete girdle September 24											.84 a	.17 a
3 mm incomplete girdle July 23											.85 a	.70 b
3 mm incomplete girdle August 25								.54 a	.69 a			.073 ab
3 mm complete girdle August 25								.56 a	.42 a			.044 ab
3 mm complete girdle August 25												.123 a
3 mm complete girdle September 26												.052 ab
5 mm complete girdle September 26												.068 ab
6.5 mm complete girdle September 26												.101 ab

Flower diameter of shoot length
Shoot diameter values obtained by Duncan's Multiple Range Test, 5% level

TABLE 19. Response of Peach to Pruning and Tipping.

Tree Height After Pruning	Flower Buds/mm of Shoot Length on New Growth	Tipping Date	Flower Buds/mm of Shoot Diameter
Control	0.412 b ^z	Control	0.033 ab
1.5 m	0.004 c	Sept. 26, 1983	0.039 ab
2.0 m	0.000 c	Oct. 28, 1983	0.034 ab
0.5 m	0.000 c	Nov. 30, 1983	0.065 ab
1.0 m	0.000 c	Jan. 26, 1984	0.034 ab

^zMean separation within sections by Duncan's Multiple Range Test, 5% level.

1.7.2. Growth Control With Paclobutrazol of Peaches Grown in a Meadow Orchard System

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Abstract

Excessive vegetative growth of early ripening peach cultivars was controlled by use of paclobutrazol (pp333) applied as a foliar spray or to the roots under drippers. Strong growth retardation was obtained in the following year from soil application of the chemical in autumn at doses of 1.4 to 4.6 kg a.i./ha. This was accompanied by a marked increase in individual fruit weight. Very little vegetative growth was obtained in the next summer following heading back of the trees at harvest in mid-May. Tree growth was negatively correlated with the dose of paclobutrazol.

At doses of 12.5 to 125 mg/plant, in spring application under drippers, the chemical caused growth retardation in 'Earligrande' peaches grown in 50 l containers. The high dose of 125 mg resulted in growth retardation that started 2 weeks after application and lasted throughout the season. Shorter periods of growth retardation were obtained with lower doses, down to only 6 weeks with the 12.5 mg dose. From late April application (about 6 weeks prior to harvest) all levels caused an increase in fruit weight.

Foliar spray did not have a consistent effect. Moderate growth retardation was obtained with a midsummer spray of 0.1 or 0.2% a.i. followed by very strong retardation in the following growing season. This retardation effect was much reduced after the trees were headed back at harvest time, in May. On other occasions, very little effect was obtained from foliar spray, probably due to poor penetration and translocation. All treatments applied in the preceding season that still showed activity during fruit development, led to a marked increase in fruit size and weight. All treatments that were active during the current vegetative development increased flower bud differentiation.

Introduction

Peach trees respond normally to annual pruning by relatively vigorous vegetative growth. Under warm growing conditions, this response is accentuated. In the peach meadow orchard systems, where severe pruning is a regular procedure (Erez 1976, 1982), excessive growth is one of the main problems (Erez 1976, 1982). With early ripening cultivars of 75 to 85 days cycle, active vegetative development occurs side by side with fruit development until fruit ripening. Definitely, part of this vegetative development acts more as a competing sink than as a source for carbohydrates to the developing fruit. This competition is not limited to carbohydrates, but covers also mineral nutrients, water and probably also growth hormones.

Lately a powerful growth retardant was reported to inhibit strongly vegetative growth in apples (Quinlan, 1981); preliminary trials with peaches revealed a similar response (Erez, 1984).

In this paper the results of soil application and foliar spray of paclobutrazol to control excessive vegetative growth are described and the potential use of this chemical is discussed.

Materials and Methods

Paclobutrazol or PP-333 (2RS,3RS,1-(4 chlorophenyl) 4,4-dimethyl-2-(1-2-4 triazol-1-yl) pentan-3-ol) in a 25% emulsion was applied either as a spray or as a soil drench. When sprayed, a 0.025% of the spreader Synperonic or Triton x-100 was added as a surfactant. When applied to the soil, the said dose was diluted 1:10 with water and was poured under the dripper feeding the tree.

All the studies reported in this paper were carried out in peach meadow orchards of either the mechanized or the intensive system (Erez 1982). In the first system, complete removal of the tree top at harvest leaves a short stump from which new growth will regenerate the tree frame by the end of the growing season. In the intensive system, on the other hand, the tree is trained on two main scaffolds, each of which is shortened after harvest and is removed completely in winter in alternate years. New growth starts on the remaining stump of the removed arm in early spring and regenerates a branched scaffold that will fruit in the following year. The cultivars used were 'Maravilha' (13-72) and 'Earligrande' peach, planted at densities of 7140 to 10,000 trees/ha. When container-grown trees were used, 50 liters of volcanic tuff were used as the medium. In this case a diluted mineral solution was used: Nutricol 3 (product of Deshanim, Israel), consisting of $N:P_2O_5:K_2O$ at a ratio of 7.5:3:6, and a mixture of micro-elements.

In all experiments drip irrigation was employed, with a single dripper per tree. Four to six replicates of three to ten trees each were used in all experiments, except for the container grown trees, where there were five single-tree replicates.

Results

Spray of regenerated tops of 'Earligrande' peach trees in a mechanized meadow orchard in August 1982 resulted in a mild growth-retarding effect until the end of the growing season; the effect was a little stronger with the 0.2% than the 0.1% concentration. The next growth cycle (February to harvest time in May) showed a stronger growth retardation effect, especially with the higher concentration. The effect lasted until June 1983 about 10 months (Table 1). Later growth was similar to that of the control trees. Paclobutrazol improved flower bud differentiation, especially at 0.2% resulting in an increase in the number of fruits per tree. An increase in mean fruit weight at both paclobutrazol concentrations was also evident; thus, a marked increase in fruit yield was found (Table 1).

It was apparent from the first response of the peach to paclobutrazol that the chemical is not phytotoxic, but it was also

noted that the newly growing branches lost their negative geotropic characteristic and exhibited a weeping type of growth (Fig 1). Mature woody branches were not affected.

In October 1982 three doses of paclobutrazol were applied to 'Earligrande' trees grown in a mechanized meadow orchard system. These trees responded in an approximately 1-week early bloom, and in heavily retarded growth. The number of flowers per tree was low in all trees thus eliminating any possible fruit to fruit competition. Fruit weight was markedly increased in all paclobutrazol treatments (Table 2).

No dilution effect was noted when the TSS content was checked, nor was there any difference in fruit firmness at harvest, thus testifying to a specific effect of the inhibitor on fruit size and on carbohydrate accumulation at the expense of the retarded vegetative growth. Fruit form was affected to some extent, with fruit on treated trees being shorter and wider than on untreated trees. The average increase in mean fruit weight in all paclobutrazol treatments reached 36.8% over that of the control. As all doses of the inhibitor had a similar effect, it was deduced that all levels were probably too high. Further growth retardation of the trees was evident until May 1984 (when this report was prepared), whether headed back after harvest or not. Further treatments were designed to check lower dosages with the aim of obtaining a definite predictable growth-retardation response.

In October 1983, 125 mg paclobutrazol per tree (ca. 1kg/ha) was applied under drippers to 'Maravilha' peach trees grown in an intensive meadow orchard system. This dose was high enough to retard vegetative growth and increase fruit size (Table 3).

A comparison of spray vs. soil application with the 'Earligrande' peach treated in August 1983 revealed a more efficient response with soil application (Table 4). A higher efficiency in growth retardation in the same season, of about five fold, was evident per dose when applied to the soil than by spray. In all cases, advance budbreak of vegetative and floral buds was evident, with a maximal effect at 0.15% spray or 125 mg soil application.

In a few cases, spraying peach trees with paclobutrazol resulted in an erratic response. More than once, a poor to no response was obtained for unknown reasons. In no case was failure of response to soil application under drippers observed.

Further work was done in 'Earligrande' peach trees grown in 50 l containers pruned to the intensive meadow orchard system with volcanic tuff medium fed by a diluted nutrient solution. The chemical was applied under the drippers. Growth inhibition was observed with all levels, from 12.5 to 125 mg/tree, and was correlated with paclobutrazol dose. 12.5 mg had a growth retarding effect that lasted for 6 weeks; growth retardation was observed about 2 weeks after chemical application. Fruit weight was increased, as well as % total soluble solids, at all concentrations tested including 12.5 mg/tree.

Discussion

Excessive vegetative growth is a multi-faceted problem in warm climates with vigorous species. The direct effect of excessive vegetative growth is competition with the fruit for carbohydrates, minerals, water and plant hormones. The indirect effects are fruit shading, causing low fruit quality; reduced potential of fruiting in the shaded parts; elevation of the productive tree mantle; and an increase in the water requirement, due to greater transpiring area. Ways to correct this phenomenon are to use a dwarfing rootstock, and to practice regular pruning.

With peaches, reliable dwarfing rootstocks do not exist and pruning is therefore practiced regularly, winter and summer, to correct for this excessive vigor. With meadow orchard grown trees, excessive vigor is one of the main problems, as vegetative development is strongly enhanced. Paclobutrazol was reported to inhibit both GA biosynthesis (Anon., 1983) and excessive vegetative growth in apples and pears. (Quinlan 1981, Raese and Burts 1983 and Williams and Edgerton 1983). In this study it was shown that this chemical has a strong growth retarding effect also on peaches. The magnitude of paclobutrazol's effect and the duration of its persistence bring up the question of control of the effect. In other words, we have to be able to predict the duration of growth inhibition and then use it to our specific requirements. Spray of paclobutrazol was sometimes more efficient than in other times, so that the effect obtained was not predictable. This may be connected to uptake through the leaves and stems and translocation which are difficult. On the other hand, soil application under the drippers in an orchard which is drip irrigated and where root density under and around the dripper is very high was always very efficient. This seems to be the favored application method under dry growing conditions, where irrigation is practiced.

The dose to use should be the lowest active one. In the meadow orchard 25 mg/tree or about 200 g/ha, seems to have a definite temporary growth retarding effect. For a prolonged effect, or when the chemical is lost or fixed in the soil, increased doses are required. The low solubility of paclobutrazol in water (Anon., 1983) produces a slow release effect if the chemical is put in the irrigation water.

The enhanced fruit development in paclobutrazol treated trees which ends in producing bigger fruit (Tables 1,2,3,5) with equal or better sugar content (Table 5) points to an improved fruit sink power as compared with the vegetative one as a result of growth retardation. In order to obtain this positive effect, minimal vegetative growth has to be obtained prior to the retarding effect by the growth inhibitor to allow the build up of a photosynthetic area needed to support the fruit and the tree. This can be achieved by autumn soil application the effect of which increases gradually in spring. Alternately, late spring treatment has similar effect. Fruit appearance is affected too, the fruit becomes shorter along the longitudinal axis from stem to tip and wider along the radial axis. This may have a bearing on fruits with a pronounced tip that will appear rounder.

Another typical response to last year's treatment with paclobutrazol is early budbreak and bloom. An earlier budbreak of about 1 week was always evident. A typical response of vegetative growth upon growth resumption is the weeping growth pattern. This has a strong effect on canopy architecture: tree height is strongly reduced and the vegetative apices sink power is further reduced by the horizontal orientation. This growth pattern does not seem to have a negative effect on tree frame as long as it is built from 2 years old or older wood. On the other hand in a mechanized meadow orchard system, where the tree frame is regenerated annually, the tree loses its erect orientation completely.

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References

- Anon. 1983. Paclobutrazol, top fruit plant growth regulator. ICI, Plant Protection Division, Technical Data Sheet No. 2A. 15 pp.
- Erez, A. 1976. Meadow orchard for the peach. Scient. Hort. 5: 43-48.
- Erez, A. 1982. Peach meadow orchard: Two feasible systems. HortScience 17: 138-142.
- Erez, A. 1984. Dwarfing peaches by pruning and by paclobutrazol. Proc. Symp. Controlling Vigor in Fruit Trees (Beltsville, MD, 1983). Acta Hort. 146: (In press).
- Quinlan, J.D. 1981. Recent developments in the chemical control of tree growth. Acta Hort. 144: 141-151.
- Raese, J.T. and E.L. Burts. 1983. Increased yield and suppression of shoot growth of d'Anjou pear trees with nitrogen and paclobutrazol. HortScience 18: 212-214.
- Williams, M.W. and L.J. Edgerton. 1983. Vegetative growth control of apple and pear trees with ICI pp333 (paclobutrazol) a chemical analog of bayleton. Acta Hort. 137: 111-116.

Fig. 1: Typical "weeping" appearance of a peach tree cv. 'Earligrande' treated with paclobutrazol.

Table 1: The effect of summer spray of paclobutrazol on 'Earligrande' peach trees, in a regenerated mechanized meadow orchard, on vegetative and generative development (Trees sprayed on Aug. 22 1982; fruit picked in June 1983).

	Paclobutrazol concentration (%)		
	0	0.1	0.2
Flowers/tree	28.6 b*	33.1 b	42.2 a
Fruits/tree	17.6 b	21.0 b	29.0 a
Fruit wt (g)	114.4 b	137.9 a	132.9 a
Yield (kg/tree)	1.96a	2.60 b	3.85 c
Vegetative growth (% of control)			
June - Oct. 1982	100 a	87.8 b	84.8 b
Feb. - May 1983	100 a	50.1 b	28.4 c
June - Oct. 1983**	100	93.9	94.4
Feb. - May, 1984	100	93.0	95.0

* Within the same row, figures followed by different letters are significantly different by L.S.D. test at the 5% level.

**Trees were not headed back at harvest time.

Table 2: The effect of paclobutrazol application to 'Earligrande' peach trees in autumn, on the next year's crop. (Planted at a density of 8330 trees/ha, grown in a mechanized meadow orchard system; paclobutrazol applied under the drippers, in October).

Paclobutrazol (mg/tree)	Yield (kg/tree)	Fruit wt. (g)	Color (quarters of red color cover)	TSS (%)	Firmness (lbs)
0	1.18 b*	119.9 b	2.05	9.3	6.6
175	1.46 a	162.3 a	2.30	8.9	6.4
375	1.48 a	169.5 a	2.27	9.1	7.5
550	1.46 a	160.7 a	2.52	9.1	5.9
% of control (mean of 3 paclobutrazol treatments)	123.7	136.8	115.1	96.8	100

* within columns figures, followed by different letters are significantly different by L.S.D test at the 5% level.

Table 3: The effect of soil application of paclobutrazol on vegetative growth and on fruit development in 'Maravilha' peach trees. (Mean of four replicates of three trees; treated on Oct. 10, 1983; vegetative growth and fruit measurements on May 1, 1984; first harvest, on May 9, 1984).

	Mean extension growth (cm±S.E.)	Fruit diameter (mm±S.E.)	Fruit volume (cm ³)	Fruit wt. at 1st harvest (g±S.E.)
Untreated control	55.2±2.3	41.2±1.6	36.7	71.5±6.9
125 mg paclob./tree	14.2±5.8	47.0±0.8	54.5	98.6±5.0

Table 4: The effect of summer treatment with Paclobutrazol on extension growth, budbreak and bloom of 'Earligrande' peach. (Treated on Aug. 20, 1983; examined Feb. 22, 1984; four replicates of six plants per treatment).

Paclobutrazol treatment	Tree height (cm±S.E.)	Leafing (cm of new growth±S.E.)	Bloom* (1-4±S.E.)
<u>Spray</u>			
Control	145±6.4	0.5±0.2	1.7±0.2
0.10% (250 mg/tree)	105±8.7	1.1±0.4	2.2±0.2
0.15% (375 mg/tree)	97±8.5	2.7±0.4	2.8±0.1
0.20% (500 mg/tree)	77±1.4	2.0±0.3	2.3±0.5
<u>Soil application</u>			
control	145± 6.4	0.5±0.2	1.7±0.2
25 mg/tree	115± 9.6	1.2±0.4	1.6±0.2
75 mg/tree	90± 5.8	2.0±0.2	2.5±0.3
125 mg/tree	82±13.1	2.2±0.3	3.0±0

* 1 = bud swell, 2 = balloon stage,
3 = initial bloom, 4 = full bloom.

Table 5: Vegetative and fruit characteristics of peach trees treated with paclobutrazol on April 28, 1983 (Application under the drippers to 2-yr-old cv. 'Earligrande' trees grown in 50 l containers; five trees per treatments.)

Parameter	Paclobutrazol treatment (mg/tree)			
	0	12.5	50	125
Added growth, April 28 - June 13, (cm)	63.9	48.8	33.8	18.6
Fruit wt at harvest (g ± S.E.)	114.7±3.9	131.0±6.6	130.6±4.3	135.0±4.5
TSS (%)	8.6	10.3	10.1	9.7
Firmness (lbs)	4.8	5.0	3.3	11.5
Color (quarters of red color cover)	1.3	1.5	2.0	1.2

1.8. The Use of Meadow Orchard Trees as a Biomass Source - GEORGIA

The cut tops from meadow orchard trees (following fruit harvest) were evaluated as a potential biomass source. The data show that the caloric value of meadow orchard produced peach wood was as high as that reported for several hardwood tree species (Forest Sci. 25:455-461). The dry weight of the biomass produced per ha (9877.5 kg/ha) by meadow orchard grown trees was as good as that produced by short rotation coppice forest. The data also show that 17.6 kg/ha of potassium were removed from the growing area when the tree tops were used for biomass rather than ground up and returned to the orchard floor. This indicates that care should be taken to replenish the potassium and other elements contained in the plant material, including the fruit removed from the growing area. Although alcohol yields were not determined, the potential for using meadow orchard produced fruit and biomass for energy production through the production of alcohol is appealing and deserved study, as well as energy generation through combustion of the dried biomass.

- 2. Mechanical Harvesting and Fruit Evaluation
- 2.1. Horizontal Shaker - Harvester Performance in a Meadow Orchard in Israel
- 2.1.1. Introduction

Peaches like most other fresh market soft fruit have still to be picked manually, mostly because of intolerable mechanical damage (bruising) caused by the common methods of mechanized fruit harvesting. Research and development work on fruit harvest mechanization was, so far, directed towards the usual growing methods in which the fruit bearing canopy is multi-annual, and the harvest is carried out by shaking the fruit off the tree limbs and retrieving it by means of catching frames, constructed to suit the prevailing tree shapes and orchard (1).

With the development of the high density meadow orchard, new options have been opened for mechanical harvesting of peaches and nectarines. Cutting the whole fruit bearing canopy and conveying it onto a horizontal shaking conveyor for fruit detachment, likewise to a once over harvest of some vegetable crop, had promising prospects as the fall of the fruit can be reduced to as little as 20 to 30 cm., which would minimize fruit damage. The trees regenerate in the same year to bear next year's fruit which may then be harvested again in the same manner.

By following this option, the fruit could be harvested by means of a harvester which is driven along the orchard rows. The machine cuts the trees, picks them up and delivers them onto a shaking conveyor where the fruit is detached and conveyed to bins while the empty canopy is discarded from the rear of the harvester. The cut has to be neat and clean and at a desired height above the ground, in order to ensure fast and full regeneration of the trees.

The fruit bearing canopy has to be elevated onto the machine without loss of, or damage to the fruit on its way to the detachment device. The latter has to separate all the fruit without bruising it. The same is required of all the components of the fruit conveying and handling system.

The aims of this research and development work have been to establish a fully mechanized harvesting system for fresh market peaches and nectarines, consisting of a harvester and a crew of 1 to 2 operators, which drives along the orchard rows, harvests the fruit, with an acceptable damage and loss rate, and delivers them into bins.

The research work was carried out to a greater extent within the framework of a BARD project.

The development work of the harvester and the field tests have been conducted in full cooperation with the research team of the Decedious Fruit Department of the Orchard Institute, who established the experimental orchard at the Volcani Center and participated in establishing the semi-commercial meadow orchard at Talme-Jaffe, where the experiments have been carried out. All the fruit sampling and quality evaluation tests have been conducted by a research team of the Food Technology Institute.

2.1.2. Methods and Procedure of Developing the Mechanical System

Initial studies have been conducted to test mechanical components and methods required to carry out each stage or operation of the envisioned mechanical harvesting system, which will be integrated to form a harvesting machine for the meadow-orchard grown peaches and nectarines.

2.1.2.1. Tree Cutting Experiments

A 95 cm. diam. circular saw blade was employed in the initial tree trunk cutting test, after evaluating several other cutting devices. The saw was mounted sidewise to a tractor and was driven at 1500 rpm, so that its cutting edge operated with a surface speed of 75 m/sec. This produced a clean cut without disturbing the trunk stems left in the ground. However, the cut trees tended to fall vertically to the ground in front of the saw blade where they were cut again. To overcome this problem, a tree holding device was designed and mounted above the saw consisting of a pair of endless spring loaded heavy V belts, driven at approx. ground speed of the tractor. These gripped the tree tops prior, during and after the cutting, and transferred them in a rear and upward direction. An inclined flighted belt conveyor was mounted underneath the gripping device to assist in elevating the tree canopies and to retain eventually detached fruit and deliver them to the elevation required for fruit detachment. Both these devices form together a tree pick-up mechanism.

2.1.2.2. Fruit Detachment Tests

The most crucial operation for the feasibility of a mechanical harvesting system, is the detachment of the fruit from the cut canopies. This has been tested by running (hand-cut) canopies over the shaker-conveyor of a fresh market tomato harvester. The efficiency of the fruit removal was determined and the optimal combination of frequency values in the range of 130 to 140 rpm, with a 10 cm. amplitude was established which resulted in a high percentage of fruit detachment for most of the cultivars.

A max. period of 0.15 min with the above combination resulted in these experiments in 85% - 95% of fruit detachment. (1).

2.1.2.3. Development of the Harvesting Machine

The experience gained in these initial trials led to the design and construction of a prototype self-propelled harvester for meadow orchard grown fruit. The harvester comprises the following functional components :

A trunk cutting device, canopy pick up, shaker conveyor, cross conveyor, inspection belt with a station at its end to fill the fruit into field boxes and the self-propelled 4-wheel driven machine-frame. The harvester was powered by a 90 hp diesel-engine and driven through a hydrostatic transmission to provide infinite stepless speed control. All components of the harvester were driven by means of hydraulic motors and were powered from three fixed displacement hydraulic pumps, and provided with flow controls for individual speed adjustment of each component.

A 50 cm. dim. saw-blade was installed in front of the harvester for trunk cutting. The smaller blade was a practical choice, however it was driven at 3000 rpm in order to maintain the high surface speed of 75 m/sec. Two 60 cm. diam. castor-guage-wheels provide for adjustment of the cutting height from 15 to about 35 cm. above the ground. These wheels supported the whole front end of the pick-up unit underneath of which the cutting device is mounted. The pick-up unit consists of a spring-loaded-belt gripping device mounted above a 120 cm. wide belt conveyor provided with flights to retain the fruit detached during the pick-up process.

The height of the front end of the gripping device is separately adjustable to the height of the trees. The conveyor reaches from just above the cutting blade to a height of 220 cm. from the ground, from where the tree canopies are transferred to the shaker conveyor.

Powered gathering extensions have been installed in front of the gripping device, to replace the guiding bars used in the preliminary test. The gathering extensions comprised of a pair of endless V belts mounted at an angle of 45° to each side. These smooth gathering belts did not perform positively enough and had to be replaced by drive chains fitted with 5 cm. long gathering fingers mounted at 20 cm. intervals on the chain. Although having adjustable speed, the continuously driven gripping device, tended to pull at the still uncut trees whenever the travel speed of the harvester changed, especially when coming to a complete stop. To overcome this problem, a second and shorter section of spring loaded gripping belts was installed in front of the main unit. The new section was driven at ground speed by a special mechanism and so were the gathering extensions, in front of it. This provided automatic adjustment with the forward travel speed of the harvester.

The cut trees after having been picked up by the front section of the gripping device, were transferred to the main section, which was extended to the end of the elevator conveyor. The main section retained its continuous drive, permitting to unload the pick-up unit at stand still of the harvester.

A reciprocating horizontal bar-conveyor, based on the initial investigations, was used as a tree shaker for fruit separation. The tubing cross bars were acquired with 10 cm. long fingers. The steel tubing members and the fingers were padded with thick flexible rubber tubing. At first the oscillating motion of the shaker was obtained by running the upper part of the bar conveyor over a reciprocating frame. This system had two disadvantages:

1. branches and foliage tended to get caught in the gaps that opened and closed alternately at the loading and unloading ends of the conveyor because of the reciprocating frame, and
2. the unbalanced weight of the heavy reciprocating frame shook the whole harvester.

Both these problems have been solved by installing a different shaker mechanism, of which only the bar conveyor itself oscillates around its two stationary shafts. This type of shaker-conveyor operates with a balanced mass because as the upper part of the conveyor moves to one side the lower portion moves in to opposite direction and vice versa. Beside the reciprocating motion, the conveyor was also given a continuous motion to transfer the trees to the rear of the harvester. The combined motion was achieved by coupling the shaft of a hydraulic motor directly to the drive shaft of the shaker conveyor and by oscillating the housing of the same motor by means of a separately driven crank mechanism. (2).

2.1.2.4. Field Tests Experiments and Results

Harvesting tests have been conducted for several seasons in the experimental orchard at the Volcani Center and in the semi-commercial meadow orchard at Talme-Jaffe, to study the harvesting method and to evaluate the harvesters performance for fruit recovery and quality, for rate of harvests and for functional performances.

The fast rotating circular pruning blade sawed the trunks off with a clean cut and at a pre-determined height without disturbing the left over stump. The canopy pick-up consisting of the spring loaded endless belts with gathering extensions, performed well in holding the trees prior and during the cutting and in transferring it to the shaker conveyor provided the tree consisted of a single leader or the cut occurred below the branching point. However, if the cut was performed above the branching point, the shorter branches were not picked up by this device, and had to be caught by hand to prevent them from dropping to the ground.

In addition, some of the lower fruit bearing branches which were weighted down by the fruit to below the cutting level, dropped to the ground. To solve this problem, the low hanging fruit was hand picked prior to the mechanical harvest. The shaker performed well, provided the canopies were oriented length wise to it, so that some manual help was required to realign those trees which fell crosswise on the conveyor.

The shaker conveyor was operated at a frequency of 140 cycles per min. and an amplitude of 100 mm. This was found to be the optimal combination for fruit detachment as more aggressive shaking caused excess bruising and less aggressive treatment left too much undetached fruit on the canopies. 0.22 to 0.3 min of exposure to this treatment were required to achieve a satisfactory rate of fruit detachment. The discarded canopies were checked for attached fruit. Ground losses were also collected and counted.

The summary of these tests are shown in Table 1.

TABLE 1

Harvesting Performances in three consecutive seasons with Earlygrade in Talme-Jaffe

Percent of total fruit for fresh market.

	1980	1981	1982	Mean
Mechanically Harvested	85.5	90.4	79.3	85.1
Left on Tree*	2.5	0.7	7.0	3.4
Lost on Ground**	11.9	9.8	13.6	11.7

* Most fruits left on trees were unripe fruit attached to the main stem.

** Most of the fruit lost on the ground were borne either on low branches cut off by the saw on small trees that were not caught by the gripping belts of the pick-up unit.

The fruit retrieved by the harvester was sampled and checked for bruises and other damage shortly after the harvest and after several storage periods. The results of these tests and others are included in the paragraph dealing with fruit quality.

The harvest rate of the mechanized system was between 0.06 to 0.08 ha/h which was considered too slow for commercial operation. The rate of harvest is a result of the time required to detach the fruit and the length of the shaker conveyor which was 2 m. The harvester had to travel 6.6 to 9 m/min or between 400 to 540 m/h to expose the canopies between 0.22 to 0.3 min to the shaking operation, which resulted in the above harvest rates. These could only be increased by extending the length of the shaker conveyor. Therefore the shaker was extended by 50% to 3 m. in length. This called for major modifications of the harvester, as it required to extend the frame of the machine from its center and also to rebuild the cross conveyor and extend the fruit inspection conveyors and various hydraulic pipes and lines. However, the extended frame permitted to move the engine from its location at the rear of the harvester where it obstructed the discarding of the empty canopies, to the side of the machine. The modified harvester with its extended shaker conveyor was able to operate at 600 to 800 m/h, thus achieving harvest rates of between 0.09 to 0.12 ha/h (excluding turns and other delays).

An experiment was also conducted to increase the acceleration of the shaker conveyor for given frequencies and amplitudes. The idea had been to stop the continuous motion of the shaker conveyor during the phase of the opposed direction of the reciprocating motion. Unlike to the continuous motion, the resulting pulsing motion produces an acceleration which could be phased in and added to the acceleration of the reciprocating motion (in the same direction).

The pulsing motion was produced by means of a cam activated direction control valve which alternately stopped and started the oil flow to the hydraulic motor coupled to the conveyor shaft.

Measurements performed on the shaker conveyor showed an increase in the acceleration in this mode of operation over the regular one (with the continuous motion of the conveyor), however, no practical effect could be felt in actual operation.

2.1.2.5. References

1. Alper, Y., Erez, A. and Ben-Arie, R. 1979. A new approach to mechanical harvesting of fresh market peaches grown in a meadow orchard. ASAE paper No. 79-1056. Am. Soc. Agric. Engrs, and Can. Soc. Agric. Engrs, St. Joseph MI.
2. Alper, Y., Wolf, I., Ben-Arie, R., Elkin, I., Michai, G. and Antler, A., 1983. A mechanized harvesting system for fresh market peaches grown in a meadow orchard. No. 900-E 1983 series, The Agricultural Research Organization, Bet Dagan, Israel.

Tree Pick-up System

Peach Harvester
for
Meadow Orchard

The Shaker's
Hydraulic Drive

2.1.2.6. Conclusions

The mechanical harvesting experiments with fresh-market peaches and nectarines grown in a meadow-orchard showed that the fruit can be harvested efficiently by a machine which cuts the tree canopies, picks them up and transpires them onto a horizontal oscillating shaker conveyor from where the separated fruit is conveyed into bins and the empty canopies are discarded back to the ground.

The interaction between shaking parameters and fruit detachment was studied and defined for vibration of the precut canopies. Acceleration values around 2.5 g were found efficient for fruit removal, with amplitude apparently more efficient than frequency (1).

Post harvest studies show that this method of fruit separation causes relatively light damage to the fruit, if the right acceleration was used. Values of 75% to 85% marketable fruit of the total yield were obtained with all peach and nectarine cultivars examined.

A significant reduction in fruit separation was observed when the orientation of the tree's main branch during the shaking was perpendicular rather than parallel to the direction of the oscillating movement.

The practical operation of the method which seems to be feasible from the mechanical point of view, depends on the horticultural potential of the meadow orchard.

2.2. Fruit Quality - Israel

The objectives of the research conducted on the effect of mechanical harvesting in a meadow orchard on fruit quality were as follows:

1. To assess and to characterize the extent of damage to the fruit and to examine means to reduce it.
2. To obtain an earlier and more uniform maturation of the fruit by application of growth regulator sprays during the growing season.
3. To examine the postharvest effect of pre-harvest ethephon sprays applied to reduce the fruit removal force.
4. To impart additional firmness to the fruit prior to mechanical harvesting, in order to reduce bruise damage.
5. To examine the effect of air and fruit temperature at the time of harvest on the postharvest quality of the fruit.
6. To examine the effect of different tree spacing within the rows on the extent of fruit damage caused by mechanical harvesting.

2.2.1. Fruit Damage Incured by Mechanical Harvesting

Fruit of the Earligrande and Maravilha (13/72) cultivars was mechanically harvested in the commercial meadow orchard at Talmei Yaffe. The quality of the mechanically harvested fruit was compared to that of hand-picked fruit.

Earligrande

Fruit was harvested on May 26th and May 29th, from 5 orchard rows on each occasion. Fourty to fifty marketable fruits were sampled from each row

and compared to hand-picked fruit from adjacent rows, following cold storage and shelf-life. The results are presented in Table 1.

Table 1. The effect of mechanical harvesting on quality of 'Earligrande' peaches after cold storage and shelf-life.

Harvest Date	Firmness at Harvest (kg)	Harvest Method	Fruit Quality on June 5			
			% firm + healthy	% bruished	% soft	% rotten
May 26	7.3	Hand	70.1	12.2	29.9	0
		Mechanical	52.3	22.0	42.9	1.0
May 29	4.8	Hand	32.1	31.4	67.9	0
		Mechanical	33.7	38.6	65.0	2.2

Though the fruit was firmer on May 26th than on May 29th the damaging effect of the mechanical harvesting was apparent only on the firmer fruit. This was probably due to an improvement in the performance of the harvester introduced after May 26th.

Maravilha

This cultivar was harvested on June 5th at two frequencies: 130 and 140 r.p.m. The fruit was firm at harvest (10.3 kg) and there was no adverse effect of mechanical harvest at either frequency on fruit quality on the day following harvest: 85-87.5% of the fruit was unharmed, 5-8% was bruised and 4-9% decayed due to Rhizopus infection.

When the trees were not entirely suited to the harvester, it was considered advisable to hand-pick fruit from low-lying branches and from tree tops, where it would have been caught by the harvester. Under such conditions, there was no loss of marketable fruit in comparison with hand-picked fruit (Table 2).

Table 2. The effect of machine harvesting preceded by hand picking on the quality of 'Maravilha' peaches harvested in a meadow orchard.

	Hand picked (H.P.)	<u>Machine Harvested</u>	
		H.P. at bottom	H.P. top and bottom
Fruit harvested (kg)	49.3	68.0	88.0
Average fruit weight (g)	48.5	48.5	48.5
Fruit collected in bins (%)	100.0	74.0	74.3
Fruit remaining on trees (%)	-	7.2	7.8
Fruit Lost on the ground (%)	-	18.9	17.9
<u>Fruit in bins</u>			
- immature (%)	22.1	28.0	26.0
- soft (%)	16.6	5.9	8.5
- bruised or damaged (%)	0	2.0	1.7
- marketable (%)	61.1	64.0	63.8

One of the effects of mechanical harvesting noticed, was the accelerated post-harvest softening rate of such fruit compared to that of hand-harvested peaches (Table 3).

Table 3 The effect of mechanical harvest on fruit firmness following harvest and during storage and marketing

Harvesting method	Harvest date	<u>Fruit Firmness (kg)</u>		
		After harvest(a)	After storage(b)	After storage + shelf life(c)
<u>A. Earligrande</u>				
Mechanical	May 5	13.2	12.3	1.7
Hand		13.2	12.7	2.0
Mechanical	May 28	9.8	7.5	1.0
Hand		10.5	8.3	1.2
<u>B. Maravilha</u>				
Mechanical	May 14	10.8	9.8	1.0
Hand		13.3	12.2	1.6

(a) 24 hours after harvest, fruit held overnight at 0°C.

(b) Storage for 7 days at 0°C.

(c) 3 days at 20°C following 7 days at 0°C.

Two treatments aimed at abating this effect were examined:

- 1) hydrocooling the fruit as it was collected from the harvester.
- 2) packing the fruit with a 5g sachet of Ethysorb - a commercial ethylene absorbant. Neither treatment significantly decelerated the softening rate though hydrocooling had some slight effect in this direction (Table 4).

Table 4 The effect of treatments following mechanical harvest to reduce the softening rate of Earligrande peaches.

Treatment	<u>Fruit firmness (kg)</u>		
	At harvest	After storage	After storage + shelf life
None (control)	10.9	11.2	2.1
Hydrocooling		11.8	2.3
Ethysorb pack		11.7	2.8
None (control)	9.8	7.5	1.2
Hydrocooling		7.7	1.3
Ethysorb pack		6.3	1.1

2.2.2. The Effect of Stage of Maturity on Fruit Susceptibility to Mechanical Damage.

The extent of damage caused during mechanical harvesting was related to the stage of maturity at which the fruit was harvested (Table 5). However, though more mature fruit was more susceptible to bruising and softening, and the final percentage of marketable fruit was lower than for less mature fruit, the total loss due to mechanical harvesting was virtually the same at both stages of maturity (16-18%). The reason for this was that with the less mature fruit, more fruit was lost during the actual harvest operation.

Table 5. The effect of mechanical harvesting of meadow orchard peaches at different stages of ripening on the percentage of marketable fruit (cv. Earligrande).

<u>Harvest Date</u>	<u>Hand picked</u>		<u>Mechanically harvested</u>	
	<u>May 21</u>	<u>May 28</u>	<u>May 21</u>	<u>May 28</u>
Average fruit weight (g)	83.8	97.5	83.8	97.5
Fruit firmness (kg)	10.9	9.8	10.9	9.8
Fruit collected in bins(%)	100	100	89.3	93.5
Fruit remaining on trees(%)	-	-	1.8	1.5
Fruit lost on the ground(%)	-	-	8.9	6.5
<u>Fruit in bins</u>				
- unripe (%)	14.9	13.4	21.9	15.0
- soft (%)	0	21.3	0	24.4
- bruised or damaged (%)	0.6	2.3	0.5	4.1
- marketable (%)	84.5	63.0	77.6	56.5
<u>Marketable fruit(%)</u>				
fruit on trees	84.5	63.0	69.3	52.8
<u>Marketable fruit from mechanical harvest (%)</u>			82.0	83.8
" " hand picked.				

The high percentage of unmarketable fruit in the bins, as shown in Table 5, indicates the necessity of obtaining a more uniform maturation of the fruit. This was achieved to some extent by spraying a mixture of growth regulators at the time of pit hardening. The growth regulators applied were: 15 ppm 2,4,5-TP (2,4,5. trichlorophenoxy propionic acid)

100 ppm ethephon (chloroethyl phosphonic acid)

1000 ppm SADH (succinamic acid dihydrazide)

This combined spray treatment accelerated the maturation of the fruit but did not make it much more uniform as 19.2% of the treated fruit was unsuitable for marketing due to unsuitable maturity, as compared to 21.9%

of the non-sprayed fruit (Table 6). Therefore, the percentage of marketable fruit did not increase as a result of the treatment.

Table 6. The effect of growth regulator sprays applied at pit hardening on the ripening and the response to mechanical harvesting of meadow orchard grown peaches (cv. Earligrande).

	<u>Control</u>	<u>Treatment</u> ⁽¹⁾
Harvest Date	May 21	May 14
Firmness (kg)	10.9	13.7
Average fruit wt (g)	83.8	72.6
Fruit collected in bins (%)	89.3	89.4
Fruit remaining on trees (%)	1.8	2.7
Fruit lost on ground (%)	9.8	8.0
<u>Fruit in bins</u>		
- unripe (%)	21.9	14.9
- soft (%)	0	4.3
- bruised or damaged (%)	0.5	0.6
- marketable (%)	77.6	80.2
Marketable fruit/fruit on tree (%)	69.3	71.7
Fruit marketable after 7 days'		
storage at 0°C (%) ⁽²⁾	92.0	98.0

(1) Sprayed at pit hardening with 15 ppm 245-TP + 100 ppm ethephon + 1000 ppm SADH.

(2) Only healthy, undamaged fruit was placed in storage.

2.2.3. The post-harvest effect of pre-harvest ethephon sprays

In order to reduce the fruit removal force required to detach the fruit from the tree, a spray of 100 ppm ethephon at pH 7.0 was applied on the day before harvest. The harvested fruit was stored for a week at 0°C and allowed to ripen thereafter for 3 days at 20°C in order to examine

possible post-harvest effects of the pre-harvest treatment. The ethephon treatment had very little effect on the amount of fruit remaining on the tree, but the maturation of the fruit was noticeably accelerated (Table 7). This resulted in a higher percentage of soft and damaged fruit at harvest, though the final amount of marketable fruit was hardly affected. The ethephon-treated fruit, which was somewhat softer at harvest than the untreated fruit, was also softer after storage, but not significantly so.

Table 7. The effect of ethephon sprays prior to harvest on fruit removal and resistance to injury during and after mechanical harvesting (cv. Earligrande).

	<u>Control</u>	<u>Ethephon (100ppm)</u>
Fruit collected in bins (%)	78.9	80.3
Fruit remaining on trees (%)	9.6	8.3
Fruit lost on the ground (%)	11.5	11.4
<u>Fruit in bins</u> - unripe (%)	15.0	5.3
- soft (%)	24.4	29.4
- bruised or damaged (%)	4.1	13.1
- marketable (%)	56.5	52.3
Fruit firmness at harvest (kg)	9.8	9.1
" " after 7 days at 0°C (kg)	7.5	6.5
" " " " " " " + 3 days		
at 20°C (kg)	1.2	0.9

2.2.4. Orchard sprays aimed at imparting additional firmness to mechanically harvested fruit.

Calcium nitrate sprays were applied to the peach meadow orchard at Bet-Dagan, on the cv. Maravilha (Almog) once (7 days before harvest) or twice (17 and 7 days before harvest). Two concentrations (1% and 2%) were sprayed to 5 pairs of trees at each application time.

The fruit was hand-picked in once-over harvest, weighed and sorted according to size and ripeness (i.e. unripe, ripe, over-ripe). The maturity of ripe fruit of the predominant size was evaluated according to the following parameters: ground colour (value on Techwest meter), blush (%), firmness (kg), T.S.S. (%), titratable acidity (%), respiration rate and ethylene evolution. The remainder of the fruit was stored for 1 week at 0°C and reexamined for ripeness upon removal from storage.

The calcium nitrate sprays tended to delay ripening, with an increasing effect obtained as the amount of calcium applied increased (Tables 8 & 9). The fruit from the trees treated with two sprays of 2% $\text{Ca}(\text{NO}_3)_2$ was significantly less mature than the control fruit, in that it had more unripe fruit, less red coloration, less T.S.S. and more acid. However, there was no significant effect on fruit firmness of the ripe fruit at harvest. All calcium treated fruit produced significantly less CO_2 and ethylene following harvest (Table 10) and this probably accounts for the smaller percentage of soft fruit in these treatments after one week's cold storage (Table 9). However, after storage the respiration rate and ethylene evolution of treated fruit during shelf-life at 20°C, did not differ from those of the control.

In summary, though calcium nitrate orchard sprays had some effect in delaying ripening of Maravilha peach fruits, they did not impart any additional firmness to the fruit and therefore are unlikely to be beneficial in the prevention of damage by mechanical harvesting.

Table 8. The effect of calcium nitrate sprays on the harvest maturity of peaches cv. Maravilha grown in a meadow orchard.

Treatment	Ground* colour	Blush (%)	Firmness (kg)	T.S.S. (%)	Titratable acidity	T.S.S./ acid
Control	4.46	66.4	9.6	8.2c	0.89a	9.21c
1% Ca(NO ₃) ₂ x1	4.53	67.6	9.8	7.6b	0.90a	8.44b
1% Ca(NO ₃) ₂ x2	4.39	63.1	10.0	7.5ab	0.90a	7.89a
2% Ca(NO ₃) ₂ x1	4.74	66.9	9.5	7.0a	0.89a	7.87a
2% Ca(NO ₃) ₂ x2	4.43	52.9	9.9	7.2ab	0.92b	7.83a
	N.S.	N.S.	N.S.			

* Values measured on Techwest meter.

Table 9. The effect of calcium nitrate sprays on yield, fruit size and fruit softening at harvest and after storage.

Treatment	Yield kg/tree	Ave.no. fruit	Ave.fruit weight(g)	<u>At harvest</u>		<u>After Storage</u>	
				(24.5.82)		(1.6.82)	
				% soft	% unripe	soft fruit tip	% whole
Control	3.004	47	64.2	26.0	24.5a	6.9b	8.2b
1% Ca(NO ₃) ₂ x1	2.625	45	58.9	13.5	10.1a	3.8b	6.6b
1% Ca(NO ₃) ₂ x2	2.949	47	62.2	9.5	22.2a	0.8a	0 a
2% Ca(NO ₃) ₂ x1	2.747	49	56.4	13.3	23.9a	1.3a	0 a
2% Ca(NO ₃) ₂ x2	1.172	23	50.1	15.4	33.3b	-	-
				N.S.			

Table 10. The effect of calcium nitrate sprays on CO₂ and C₂H₄ evolution after harvest and after storage.

Treatment	<u>At harvest(24.5.82)</u>				<u>After storage(1.6.82)</u>			
	CO ₂		C ₂ H ₄		CO ₂		C ₂ H ₄	
	Peak day	mg/kg/h	Peak day	/kg/h	Peak day	mg/kg/h	Peak day	l/kg/h
Control	3.0	166b	3.0	14.5b	4.3	143	4.0	23.0
1% Ca(NO ₃) ₂ x1	2.5	122a	3.0	6.2a	3.8	140	5.8	20.4
1% Ca(NO ₃) ₂ x2	3.0	118a	3.0	7.6a	4.4	149	6.2	21.2
2% Ca(NO ₃) ₂ x1	2.4	113a	3.0	4.8a	5.0	159	6.5	13.0
2% Ca(NO ₃) ₂ x2	2.6	136a	3.0	6.9a	-	-	-	-
						N.S.		N.S.

2.2.5. The effect of time of harvest on the postharvest quality of the fruit.

Comparisons were drawn between fruit that was harvested at 11.00 and at 20.00 hrs. No differences in resistance to mechanical injury at harvest or in postharvest keeping quality were observed, even though the fruit harvested in the evening was firmer than fruit harvested near midday, both on the day following harvest and after 7 days storage at 0°C (Table 11).

Table 11 The effect of the hour of harvest on fruit firmness and the extent of damage caused by mechanical harvesting (cv. Earligrande).

Harvest hour	<u>11.00</u>	<u>20.00</u>
<u>Fruit firmness</u> at harvest (kg)	7.8	9.1
after 7 days at 0°C	7.4	8.4
after 7 days at 0°C+3 days at 20°C	0.9	0.8
<u>After 7 days at 0°C</u>		
soft fruit (%)	26.0	14.0
bruised and damaged fruit (%)	14.0	22.0
marketable fruit (%)	60.0	64.0
<u>After 3 more days at 20°C</u>		
soft fruit (%)	100.0	100.0
bruised and damaged fruit (%)	34.0	40.0

2.2.6. Tree Spacing

The Desert Gold cv. was planted at Bet Dagan at different distances between the trees within the row. These trees were mechanically harvested and data were collected for yield, fruit maturity and extent of damage due to harvesting. Spaces between trees are 50, 75 and 100 cm. No correlations were found between tree spacing and any of the parameters measured (Table 12). Fruit ripening was not uniform as can be observed by the high percentage of soft fruit on the one hand, and the firmness of the hard fruit on the other hand.

Table 12. The effect of distance between trees in the rows of a peach meadow orchard on the extent of damage caused by mechanical harvesting.

Tree distance (cm)	Hand picked	Mechanically harvested		
	50	50	75	100
Total harvested (kg) ¹	7.700	38.140	34.520	40.110
Immature fruit (%)	11.7	10.2	4.8	10.9
Soft fruit (%)	64.9	59.4	66.6	63.9
Damaged fruit at harvest (%)	-	2.1	1.2	2.3
Marketable fruit (%)	23.4	28.3	27.5	22.8
Firmness (kg)	9.8	9.8	9.9	10.5

1) For one row of the orchard

2.3. Physical and Biological Parameters Relating to Mechanized
 Harvesting of Meadow Orchard Peaches - S. CAROLINA

During the 1983 fruit growing season, Y. Chu, a graduate student in agricultural engineering, studied several physical and biological parameters relating to the mechanical harvesting of meadow orchard peaches for his M.S. thesis research study (Chu, 1984). Four cultivars ('Bicentennial,' 'Candor,' 'Redhaven,' and 'Spring Crest') grown in the meadow orchard planting at Lewis Field, Clemson, were used in this study. This orchard was established from rooted cuttings planted in March, 1982.

This investigation included three general properties which were fruit maturity, fruit detachment forces, and spatial location of the growing fruit at the time of harvest. Relationships between these properties were studied to gain information relating to efforts to mechanize harvesting and other operations in the meadow orchard cultural system.

2.3.1. Fruit Maturity Fruit maturity was investigated using several indices. These were fruit firmness, fruit skin ground color indices ("L," "a," and "b" values), and fruit mass and weight. Correlations between these indices were determined and found to be similar to the same correlations for fruit from conventional peach orchards. Ground color "a" was the color index most related to flesh firmness. Large variation of both fruit sizes and fruit maturity were found (both within individual trees and between trees) within each cultivar. A high degree of uniformity in maturity is important for economic success of once-over harvest.

2.3.2. Strength Properties Strength properties of the fruit-stem system were measured in the laboratory using an Instron Universal Testing Machine and various special-purpose fixtures which were constructed to hold and apply loads to the fruit. Data were collected for the following conditions as pertaining to the loading of the fruit-stem joint: direct- and inclined-axial tension, direct tension after repeated pre-bending loads, bending loads, and vibratory loads.

2.3.3. Spatial Location of Fruit This study included the distribution of fruit numbers, fruit size, and average fruit mass with respect to spatial position of the fruit on the tree. Diameters of the fruit bearing branches were also measured. This information was not available in the literature and should be useful in designing a harvester and other mechanized equipment for operations in the peach meadow orchard. The height of the trees used in the study was approximately 2 m except for 'Spring Crest' which was about 3 m in height at harvest time. The spatial distribution of the fruit was obtained by counting the number of fruit within each 0.30 m increment above the soil surface. The spatial distribution of fruit mass and fruit diameter was also determined using the 0.30 m increments of tree height.

2.3.4. Summary of Results Relating to Physical and Biological Parameters

The data were analyzed using the Statistical Analysis Software System (SAS) software package on a mainframe digital computer. The results of the analyses are summarized below:

1. The correlations among fruit numbers, fruit size, fruit flesh firmness, and skin ground color indices "L," "a," and "b" of the four meadow orchard cultivars tested were similar to those reported in the literature for conventional orchard peaches. Fruit mass had a good correlation with fruit diameter. Flesh firmness was negatively correlated with fruit diameter. Among the three color indices, "a" was most correlated with flesh firmness.

2. Fruit maturity levels and fruit sizes varied greatly within the same tree as well as between trees within each cultivar. This factor will be detrimental to the economic potential of the once-over harvesting system unless cultural techniques can improve the uniformity of fruit maturity in the orchard.

3. Fruit flesh firmness decreased rapidly with harvest time. Further study is needed to determine the optimum time for harvest.

4. The detachment force of the fruit-stem system decreased with increased harvest date but was independent of the elevation of the fruit above the soil surface.

5. The magnitude of the detachment force had no direct relationship with fruit maturity as measured by flesh firmness or ground color "a" value. This indicates that "shake-and-catch" techniques for detaching fruit has low potential for selective harvesting of mature fruit.

6. The detachment force showed no significant correlation with fruit size except for 'Spring Crest' peaches.

7. The detachment force which caused failure at the fruit-stem joint was usually smaller than when failure occurred at the stem-twigg joint. There was a tendency for detachment to occur at the fruit-stem joint rather than at the stem-twigg joint as the fruit ripened.

8. Cyclic pre-bending of the fruit stem before tensile loading to failure, drastically reduced the detachment force after 30 pre-bending cycles.

9. No significant differences in detachment force was observed for several inclined-tension angles.

10. Ninety percent of the fruit was located below 1.07 m height for 'Bicentennial,' 0.76 m for 'Candor,' 0.85 m for 'Redhaven,' and 1.68 m for 'Spring Crest.' For each of these cultivars, the height below which 90 percent

of the fruit occurred was approximately one-half the average height of the trees.

11. Fruit taken from the upper one-half of the fruit bearing region of the tree contained more fruit that was heavier than the overall average. Fruit taken from the lower one-half of the fruit bearing region was generally smaller than the overall average.

12. The average mass of the fruit was greatest in the second uppermost fruit bearing 0.30 m increment of the tree except for 'Spring Crest.'

2.4. Mechanical Harvesting Studies in the USA

2.4.1. Horizontal Shaker Trials -- 1981

Alper et al. (1980) reported a technique for mechanically harvesting meadow orchard peach fruit by cutting the tree near the soil surface. The tree was then lifted onto a horizontal shaker-conveyor where the entire tree canopy was shaken vigorously to dislodge the fruit. The fruit dropped onto a collection conveyor beneath the shaker-conveyor.

Alper's results with this unique harvesting technique were favorable for the conditions and cultivars in Israel but had not been tested for conditions of the Southeastern United States. An objective of this project was for agricultural engineers at Clemson University to study the technique under Southeastern United States conditions using commercially important cultivars.

A horizontal shaker-conveyor apparatus was prepared and tested during the 1981 season. The apparatus was similar to the shaker-conveyor harvester used by Alper et al. (1980) mentioned above. Three cultivars (Bicentennial, Harvester and Majestic) grown in the meadow orchard at Clemson, South Carolina and Athens, Georgia were used in the study.

ASAE Paper No. SER 82-015 by Settle, et al. (Attachment) described in detail the harvesting equipment used in 1981 at Clemson University. Meadow Orchard trees were cut near the ground before the fruit was removed, with the fruit subsequently removed by a mechanical shaker with various shaking frequencies and durations. The shaker used was a modification of a shaker originally designed as a component of a tractor-mounted tomato harvester reported by Alper, Hood, and Webb in 1976. Two trees were used for each replication with four replications per combination of shaking frequency and duration. A total of 16 treatments combinations (four frequencies and four duration times) were tested. After each tree was shaken for the specified duration, the number of fruit removed was counted and recorded.

Fruit detached by the shaker-conveyor, as well as hand harvested controls, was placed in 1°C storage as quickly as possible. The following day, the fruit was placed in Panta-Pac type trays with individual cells for each fruit and examined as described under "Combing Trials" section. These fruit samples were maintained at 22°C for a subsequent evaluation made two days later (third day after harvest).

No significant differences were found in percentage sound (marketable), cut, bruised, or scuffed 'Majestic' fruit between any of the shaker duration and frequency treatments or the hand harvested controls. There were no cut or scuffed 'Bicentennial' or 'Harvester' fruit on any treatments. There were no significant differences between treatments for fruit in either the sound (marketable) or bruised categories.

Details of the 1981 study were reported by Settle, et al. (1982). The basic conclusions were:

1. Harvesting fresh market meadow orchard peaches with the tree canopy positioned on a horizontal shaker appeared feasible for the three cultivars used

in the test. The amount of fruit damage (cuts and bruises) was not statistically different between fruit harvested using the shaker-conveyor and hand-harvested fruit.

2. Shaker-conveyor frequencies of 145 and 160 Hz produced the highest fruit removal percentages. The 160 Hz frequency caused no more damage than 145 Hz. Alper et al. (1980) determined 140 Hz to be optimum in their study since 160 Hz caused more fruit damage. However, the shaker amplitude in their study was 10 cm rather than 7.5 cm used in our study.

3. The optimum shaking duration was a function of the frequency. Seven seconds was optimum for the lower frequencies (115 and 130 Hz) and somewhat less at 145 and 160 Hz. This compares with nine seconds reported by Alper et al.

These studies with the horizontal shaker-conveyor were conducted only in 1981. Due to freezes in 1982 and 1983, there was no fruit for continuing this investigation during those years. However, it appeared that the results obtained in our studies were similar to results obtained in Israel. After a review with other cooperators, it was agreed that additional effort spent on these studies in the United States was not needed.

2.4.2. Harvesting Fruit from Standing Meadow Orchard Trees

One major disadvantage of the horizontal shaker-conveyor method of harvesting the fruit is that the entire tree must be cut a few cm above the soil surface at the time of harvesting. For cultivars which ripen late in the summer, regrowth of the tree during the remaining days of the growing season has not been sufficient to produce desired fruit yields in the Southeastern United States and possibly in Israel as well. A cultural technique investigated by A. Erez (as part of this project) provided for alternate sides of each tree to bear fruit each year while the other side of the tree was growing vegetatively. This

cultural technique seems to offer a greater yield potential for late-season peach cultivars which are grown in the meadow orchard in these areas.

The alternate-side technique requires that the fruit be removed from one side of the standing tree without damaging the tender new growth on the other side which must carry the next season's fruit yield. Two different techniques for removing fruit from standing meadow orchard trees were investigated. The first technique used a stationary mode combing action with the fruit being detached and collected by a set of combing tines. The second technique used a continuous-move tree canopy agitation device to detach the fruit which then fell to a catching surface.

2.4.2.1. Combing Trials

The first effort to comb fruit from meadow orchard trees occurred during the 1981 harvest season. During this year, testing of the previously described horizontal shaker-conveyor apparatus received the primary effort and ideas for alternate harvesting techniques were secondary. Initial feasibility of the combing technique was explored using two simple comb-like devices which were constructed during the progress of the harvest season. Meaningful testing of these devices was not possible during the 1981 season, but a number of observations with soft fruit indicated that the technique had enough potential to justify further investigation with shipping quality fruit and improvements in the apparatus.

A more usable apparatus for investigating the combing technique was designed and constructed for the 1982 season. This apparatus was mounted on a tractor equipped with a hydraulic front-mounted boom and consisted of a steel frame on which was mounted sets of approximately 20 combing tines on each side of the row of trees (Figure 1). The tines were retracted until the frame was in position

Figure 1. Combing tine apparatus mounted to hydraulic boom on front of tractor for testing.

Figure 2. Combing tines inserted into tree canopy near bottom of meadow orchard tree prior to lifting. (Some foliage has been removed for better visibility.)

with the tines low and projecting toward the row of trees. Each set of tines was then pushed toward the base of the trees until the ends of the tines on one side of the tree nearly touched those being pushed in from the opposing side. The branches of the tree were forced between the padded tines (Figure 2). When so positioned, the tractor lifted the entire apparatus vertically to the top of the trees combining the fruit from the limbs.

The combing tines consisted of 15.9-mm steel rods covered with a 13 mm closed cell foam padding. The foam padding was wrapped with a fabric-backed vinyl covering to prevent tearing of the foam. The tines were spaced so that there was approximately 15 mm of space between each tine. Limbs were drawn between the tines and the fruit was combed from the limbs. Each tine had the tip elevated by a built-in angle approximately 10 degrees above the horizontal to cause the fruit to roll down the tines to a collection tray on each side of the frame. The tractor on which the combing apparatus was mounted was driven straight down the row, straddling the stumps of previously cut trees and positioning the frame with a set of retracted combing tines on each side of the row. Trees which had been stripped were cut by hand before the tractor was moved forward to the next position.

Testing of this tree combing device was planned for 1982. However, no tests were possible during 1982 since all of the meadow orchard fruit in South Carolina and Georgia were killed by late-season freezing temperatures.

Late-season freezing temperatures occurred again in April, 1983 and killed all of the fruit available for mechanization studies in Georgia. A small number of trees were saved in the meadow orchard at Lewis Field (Clemson) by heating an area of the orchard. These trees were used to test the combing tine device during the summer of 1983 using 'Camden,' 'Bicentennial,' and 'Candor' cultivars. Immediately after harvesting and collecting the fruit, combing efficiency

was evaluated by dividing the fruit into the categories summarized in Table 1. Details of the general post-harvest procedure are presented in Appendix A.

Immediately after collecting data for the combing efficiency evaluations shown in Table 1, fruit samples were collected for storage tests. The purpose of the storage tests was to determine the amount of damage which was not readily visible immediately after harvest, but became evident after a period of storage. Only fruit from the category which showed no visible damage due to the combing tines was used in the storage tests. Hand-harvested fruit was collected from the same trees (prior to the combing operation) and placed in the storage for comparison with the fruit from the combing tests.

Three replicates of both hand- and tine-harvested fruit were taken to the laboratory. The following day, the fruit was classified as sound, cut, bruised, or with scuff damage and the number of fruit in each class was recorded. Considerable variation in the amount of quality deterioration was found among cultivars for both the tine- and hand-harvested fruit. Considering all three cultivars, approximately 80 percent of the tine-harvested fruit which appeared undamaged at harvest was marketable after six days storage at room temperature. This compares to approximately 90 percent of the hand-harvested fruit which was marketable after six days at the same storage conditions.

'Camden'. Three replicates were used for each treatment in a preliminary test with this cultivar. The fruit was harvested on June 7, 1983 and taken to the laboratory for evaluation. A considerable percentage of stripped 'Camden' peaches were damaged, compared to no damaged hand-harvested fruit (see Table 2).

A second harvest of 'Camden' peaches was made on June 10, with a mean firmness of 9.3 pounds (41N). These fruit were evaluated as before. All of the hand-harvested fruit were marketable one day following harvest. Of those

stripped from the trees, 75 percent were marketable, 7 percent were cut, 18 percent were bruised, and 3 percent were scuffed.

'Bicentennial'. This cultivar was harvested on two dates, June 13 and June 16, 1983. Fruit from the first harvest was evaluated over a three-day period for evidence of mechanical damage. Ten percent of the stripped fruit showed bruise damage by the second day (Table 3). Stripped fruit also had a higher percentage of scuff damage (15 percent one day after harvest). Hand-harvested fruit developed 8 percent rots on the third day, with only 2 percent of the stripped fruits becoming rotten. No cuts were found on fruit from either treatment.

'Bicentennial' peaches harvested on June 16 were evaluated daily over a ten-day period (Table 4). No cuts were found on either hand or machine-harvested fruit. None of the hand-harvested 'Bicentennial' peaches developed bruises during the storage period. No bruises developed on the machine harvested fruit until six days after harvest (June 22 with 3.5 percent). More of the hand-harvested peaches developed rots than those machine harvested, but the differences were not statistically significant. The percentage of machine-harvested fruit with rots did not increase after the sixth day of storage, while rots in hand harvested fruit increased considerable. The lack of significant differences between treatments indicates considerable variability among the replicates.

When the mean percentage of sound (marketable) 'Bicentennial' fruit on the first harvest were averaged over the entire observation period, there was a significant difference between those hand harvested (92.0 percent) and those harvested by machine (84.8 percent). There was no significant difference in bruised fruit between treatments. However, hand-harvested fruit developed a significantly greater percentage of rots compared to those machine harvested.

Table 1. In Field Observations with Combing Apparatus for Harvesting Meadow Orchard Peaches. Summary of Three Cultivars ('Camden,' 'Bicentennial,' and 'Candor'). Lewis Field, Clemson, SC, 1983.

Category	% of Total Yield
Fruit harvested and collected with no visible damage	50% - 60%
Harvested and collected but severely damaged	10% - 15%
Detached and dropped (either off the end of tines, through the tines, or over the side of the combing apparatus)	25% - 30%
Missed by the tines	1% - 2%
Too low for tines to get under	2% - 10%

Table 2. Damage on 'Camden' peaches harvested June 7, 1983 using combing tine device. Mean firmness 12.5 lbs (56N).

Attribute	Hand harvested fruit (%)	Stripped fruit (%)
Marketable	100	50
Cuts	0	8
Bruises	0	35
Scuff damage	0	10

²The placing of fruit in more than one category may cause the total to exceed 100%.

Table 3. Damage to 'Bicentennial' peaches harvested with combing tine device. Harvested, June 13, 1983.

Attribute	June 14		June 15		June 16	
	Hand	Strip	Hand	Strip	Hand	Strip
Marketable	100	78.3	100	75.0	92	71.5
Cuts	0	0	0	0	0	0
Bruises	0	6.7	0	10	0	10
Rots	0	0	0	0	8	1.7
Scuff	0	15	0	15	0	16.7
Shrivel	0	0	0	0	0	0

Table 4. The influence of harvesting method on 'Bicentennial' with the combing tine device. Harvested June 16, 1983 (second harvest).

Date June	% Marketable ^z		% Bruises		% Rots	
	Hand harvested	Tine harvested	Hand harvested	Tine harvested	Hand harvested	Tine harvested
16	100.0 a ^y	96.5 a ^y	0.0 a	0.0 a	0.0 a	3.5 a
17	100.0 a	96.5 a	0.0 a	0.0 a	0.0 a	3.5 a
20	87.0 a	96.5 a	0.0 a	0.0 a	9.0 a	3.5 a
21	87.0 a	93.0 a	0.0 a	0.0 a	9.0 a	7.0 a
22	82.5 a	93.0 a	0.0 a	3.5 a	13.5 a	7.0 a
23	82.5 a	93.0 a	0.0 a	3.5 a	13.5 a	7.0 a
24	78.0 a	93.0 a	0.0 a	3.5 a	18.0 a	7.0 a
25	73.0 a	86.0 a	0.0 a	10.5 a	23.0 a	7.0 a
26	73.0 a	87.5 a	0.0 a	14.0 a	27.0 a	7.0 a

^zThe placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

'Candor'. Two harvests of 'Candor' were made in 1983 (June 16 and again on June 17). On the first date, no cuts were found on either hand or machine harvested fruit (Table 5). there was little difference in the percentage of bruised fruit, whether hand or machine harvested over the storage period. More of the hand-harvested fruit developed rot five days after harvest, but this difference was not statistically significant. Very little scuffing damage was found from either treatment, although the machine-harvested fruit did develop slightly more scuffing injury. Scuffed fruit was observed to be more prone to develop rots later in storage. There were no significant differences in the percentage of marketable fruit between treatments at any observation date during storage.

'Candor' fruit harvested June 17 was evaluated on June 20, 22, 24, and 26. No cuts were found on hand- or machine-harvested fruit (Table 6). Fewer machine harvested fruit were marketable than those hand harvested at each date. By June 26, 91 percent of the hand and 80 percent of machine-harvested fruit was marketable. A greater percentage of machine-harvested fruit was bruised (7.8 percent compared to 0 percent hand-harvested). The percentage of bruised fruit did not change during storage. A greater percentage of machine-harvested fruit developed rots during storage; with no rots developing on machine-harvested fruit until five days after harvest and none on hand-harvested fruit observed until nine days after harvest. Very little scuff damage was found on fruit from either treatment. Considerably less shriveling was noted on these fruit than on those harvested June 16.

2.4.2.2. Canopy Agitation Technique

A second technique for removing fruit from standing meadow orchard trees was first tested in a very limited trial with one cultivar ('Redhaven') in July

Table 5. The influence of harvesting method on 'Candor' fruit harvested June 16, 1983. The combing time device was used.

Date June	% Marketable ^z		% Bruise		% Rot		% Scuff	
	Hand harvested	Time harvested	Hand harvested	Time harvested	Hand harvested	Time harvested	Hand harvested	Time harvested
16	100.0 a ^y	95.0 a ^y	0.0 a	2.5 a	0.0 a	0.0 a	0.0 a	2.5 a
17	100.0 a	92.5 a	0.0 a	2.5 a	0.0 a	0.0 a	0.0 a	5.0 a
20	90.0 a	92.5 a	0.0 a	2.5 a	10.0 a	0.0 a	0.0 a	15.0 a
21	79.0 a	88.8 a	0.0 a	2.5 a	10.0 a	0.0 a	0.0 a	2.5 a
22	79.0 a	83.3 a	0.0 a	0.0 a	10.0 a	1.7 a	0.0 a	1.7 a
23	69.7 a	83.8 a	0.0 a	0.0 a	10.0 a	3.8 a	0.0 a	1.3 a
24	65.0 a	81.3 a	0.0 a	0.0 a	10.0 a	6.3 a	0.0 a	1.3 a
25	53.0 a	73.8 a	0.0 a	0.0 a	10.0 a	6.3 a	0.0 a	1.3 a
26	44.7 a	71.3 a	0.0 a	0.0 a	10.0 a	6.3 a	0.0 a	1.3 a

^zThe placing of fruit in multiple categories will influence the percentage of marketable fruit.

Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Table 6. Comparison of hand and tine-harvested 'Candor' peaches. BARD.
Second harvest. June 17, 1983.

Attribute	June 20		June 22		June 24		June 26	
	Hand	Tine	Hand	Tine	Hand	Tine	Hand	Tine
Marketable	100	88.5	97	86	97	82.5	91	80
Cuts	0	0	0	0	0	0	0	0
Bruise	0	7.8	0	7.8	6	7.8	0	7.8
Rots	0	0	0	4.0	0	7.5	2	7.5
Scuff	0	3.8	0	3.8	0	3.8	0	3.8
Shrivel	0	0	3	2.5	3	3.8	7	6.3

Mean firmness at harvest 53N, 11.8 pounds (Magness-Taylor)

1983. This technique employed a device consisting of a vertical main shaft with 12 steel tines, each 0.4 m long and 16 mm diameter, projecting radially from the main shaft into the tree canopy (Figure 3). The tines were spaced 15 cm apart vertically and projected at various angles around the main vertical shaft. Each tine was padded with 13 mm thick closed-cell foam padding and wrapped with fabric-backed vinyl material to prevent tearing of the foam by the tree branches.

Two hydraulic motors were used to power the device. One of the motors was directly coupled to the main shaft providing a constant rotational motion. This rotation was synchronized with the forward speed so that the tines engaged the tree canopy smoothly without tending to drag or wrap the branches. Another hydraulic motor was used to provide an oscillatory motion to the tines by oscillating the first motor's main frame (and thus the main shaft) through an arc of approximately 45 degrees. A crank arm and connecting rod was used to superimpose the oscillatory motion on the constant rotational motion of the first motor. The resulting motion allowed the tines to intermesh with the branches and agitate the canopy while the device moved continuously along the row.

For initial testing (1983), the canopy agitation device (CAD) was mounted to the front of a tractor which was equipped with a hydraulic boom. The tractor was driven along side the row of trees to be harvested so that the main shaft of the agitation device (mounted on the boom and to the right side at the front of the tractor) was positioned a few cm from the near side of the row of trees with the tines engaging the tree branches. The oscillation motion was started and the tractor driven forward at a speed of about 1.2 km/hr so that the padded

tines engaged and agitated the tree canopy, detaching the fruit as the tractor moved along the row.

'Redhaven'--1983. A limited trial with one cultivar ('Redhaven') indicated that 75 percent of the yield potential was detached using the test apparatus as configured in Figure 3. Most of the detached fruit appeared undamaged when collected in carpet-padded catching trays positioned under the trees. Essentially all of the fruit not detached was located on the side of the tree away from the single agitator device or was below the level of the lowest tine. There appeared to be minimal damage to the branches as a result of canopy agitation.

On 'Redhaven' fruit used for evaluating the CAD, the average size was two inches and the average firmness was 92 as measured by a Type 00 Durometer. The first examination of these fruit was made on July 8, with subsequent examinations made daily through July 15 (Table 7).

The primary objective of this first trial with the CAD was to observe the effectiveness of the device for removing fruit while moving forward along the row at a reasonable speed. The data in Table 7 show that more bruises and rots occurred in the CAD-harvested fruit, but it was believed that the bruises could be reduced substantially with more suitable catching surfaces.

From these limited trials during the 1983 harvesting season, it appeared that the canopy agitation technique had considerably greater potential than the combing tine technique for further development. Therefore, no additional trials were conducted with the combing tines and plans were made for a more complete evaluation of the canopy agitation technique in full-size harvester prototype during 1984.

2.4.2.3. Prototype Design and Construction Construction of a harvester prototype was partially completed during the months between the 1983 and 1984 fruiting

Table 7. The influence of harvesting method on 'Redhaven' fruit harvested July 6, 1983 using a canopy agitation device (CAD).

Date June	% Bruises ^z		% Rots		% Marketable	
	Hand harvested	CAD harvested	Hand harvested	CAD harvested	Hand harvested	CAD harvested
8	5.0 a ^y	20.3 a ^y	0.0 a	0.0 a	95.0 a	79.7 a
9	5.0 a	20.3 a	0.0 a	0.0 a	95.0 a	79.7 a
10	6.7 a	20.3 a	0.0 a	0.0 a	43.3 a	79.7 a
11	3.3 a	8.3 a	3.3 a	15.3 a	93.3 a	73.0 b
12	1.7 b	10.0 a	5.0 a	18.7 a	93.3 a	71.3 b
13	1.7 b	8.3 a	6.7 a	20.3 a	93.3 a	71.3 b
14	1.7 b	6.7 a	6.7 a	22.0 a	86.7 a	63.0 b
15	1.7 b	6.7 a	6.7 a	22.0 a	86.7 a	63.0 b

^zThe placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit. Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Figure 3. Canopy agitation device mounted to hydraulic boom on front of tractor as tested during 1983.

Figure 4. Side view of over-the-row prototype harvester.

Figure 5. Front view of the prototype harvester showing agitating tines, overlapping flexible flops, and collecting conveyors.

Figure 6. Prototype harvester in operation in the meadow orchard:

seasons. The prototype was constructed by significantly modifying a used tobacco harvester. This modification resulted in a self-propelled over-the-row frame with approximately 1.8 m vertical clearance for the tree (Figure 4). The prototype was powered by a 40 kW gasoline engine with a hydrostatic transmission driving torque hubs on each of the four wheels. The hydrostatic transmission permitted infinitely variable adjustment of the travel speed. The front wheels were steerable while the rear wheels were fixed. Turning radius of the unit was 5.7 m and the wheelbase was 3.15 m.

The operator's seat and controls were repositioned and cantilevered from the main frame so that the operator was located low, between the trees, and just ahead of the left-front wheel (Figure 4, 5, and 6). From this position, the operator had a good view beneath the tree canopy to keep the machine aligned on the tree row. The operator reported good visibility and operator comfort from this position during the trials to date.

Two canopy agitation devices similar (a 5:1 speed reduction gear box was added to each CAD) to the device tested during the 1983 season were mounted to the prototype harvester frame as shown in Figures 5 and 6. One of these canopy agitation devices was mounted on each side of the harvester centerline with one agitation device mounted forward toward the front of the machine and the other mounted 0.91 m from the first toward the rear. The perpendicular distance from the harvester centerline to the main vertical shaft of each canopy agitation device (adjustable over a range of 0.20 m) was adjusted so that the tip of the tines reached to the centerline. In operation, the harvester was driven so that the centerline of the harvester was aligned with the row of trees and driven forward at a continuous speed in the range 1.0 to 1.2 km/hr. Trees were engaged

by the first agitator positioned on the left side and later by the second agitator located on the right side.

The canopy agitation devices were powered with two pairs of hydraulic motors operating in series. The first pair of motors rotated the main vertical shaft on each canopy agitation device (through 5:1 speed reduction gear boxes coupled to the shaft) at a constant speed to synchronize the rotation with the forward speed. This pair of motors was connected (in series) so that the tines on each agitation device rotated in opposite directions. The motor speed was regulated (manually) to enable the padded tines to move through the tree branches without wrapping and breaking the limbs as the harvester moved forward along the row.

The second pair of hydraulic motors provided the oscillating motion to the tines by oscillating the 5:1 speed reduction gear box, tine drive motor, and tine assembly as a unit. The oscillation drive motor was connected to the main speed reduction gear box through a crank and connecting rod arrangement. Thus, the main shaft, gear box, and the tine assembly were rotated through an arc about 45 degrees for each rotation of the second hydraulic motor. The two oscillation motors were also connected in series and the speed was adjusted using a variable flow control valve.

Fruit which was detached by the canopy agitators were collected on collecting conveyors and tree closure flaps beneath the tree. A collecting conveyor (0.40 m wide) was positioned along each side of the harvester parallel to the row of trees and between the wheels. The top surface of the conveyor belt was about 0.20 m above the ground surface when the conveyor was in its lowest position. These conveyors were about 2.5 m in length. Between the collecting conveyors was an opening approximately 0.7 m wide to allow passage of the tree trunks as the harvester moved along the row. A series of overlapping

flexible flaps were attached to a rail on the side each conveyor so that the flaps extended into this opening from each side to catch falling fruit. These flaps were angled upward and intersected at the longitudinal centerline (which would be the position of the tree row) of the harvester. The intent was to close the area beneath the tree with these flexible flaps which would catch the fruit and direct it by gravity onto the collecting conveyors. The entire assembly of agitators, collecting conveyors, and tree closure flaps were mounted on a separate floating mounting assembly for each side of the row. Each assembly could be raised and lowered hydraulically from the operator's seat.

Conveyors to elevate the fruit and place it into bulk bins were not constructed for the harvester evaluations conducted in 1984.

2.4.2.4. Prototype Field Trials

Trials of the harvester prototype were conducted during the summer of 1984 at Lewis Field in Clemson. Limited quantities of fruit from two cultivars ('Redhaven' and 'Coronet') and one numbered selection (68-440), all grown under the meadow orchard system, were available for mechanization studies. The harvester was operated at a forward speed approximately 1.2 km/hr with the tine oscillation frequency of 140 Hz.

The procedure used was to count the number of fruit in the trees in the test row, operate the machine and manually collect the fruit from each of the collecting conveyors into sample boxes, count the fruit left on the trees, then take the collected fruit to the laboratory for post-harvest storage evaluation. The results of the fruit detachment efficiency observations for the prototype field tests are summarized in Table 8.

Many of the fruit which was detached by the tines was not collected due to the unsatisfactory performance of the flexible flap arrangement used to close

around the tree. Many fruit fell through the flaps and were not collected. More importantly at this stage of development, it was observed that the canopy agitation tines were very effective in removing the fruit from the trees even though the trees were large. Also, it was observed that most of the fruit which was not detached was positioned very low on the tree, below the region where the tines were operating. Since many fruit are positioned very low on typical trees grown in the meadow orchard, some innovation is required in the design of the collecting surface and collecting conveyors to enable the harvester to harvest the extremely low fruit.

Storage evaluations were made as in previous years with the exception that the percentage of fruit with natural defects as well as those immature and/or undersized were also determined following harvest. Fruit in these categories were removed after harvest and sublots of apparently sound, marketable fruit were obtained and examined as in previous years to determine the extent and rate of development of bruises, rots, and scuffing damage.

68-440. This selection was harvested on July 3, 1984 with the new canopy agitation device previously described. The mean firmness of the fruit at harvest was 70.3N (15.8 lbs). The mean ground color score on the peach color chart was 5.1. Eleven replicates of machine-harvested fruit, and nine replicates of hand-harvested fruit were used for an initial examination for natural defects, cuts, bruises, and immature or undersized fruit. The results are presented in Table 9.

There were no significant differences in the percentage of 68-440 fruit with natural defects or those undersized. there were no cuts on the hand-harvested fruit, whereas 10.9 percent of the machine-harvested fruit had cuts. This difference was significant. The machine-harvested fruit had a slightly

Table 8. Percentage of Meadow Orchard Peaches Detached by the Prototype Over-the-Row Harvester Equipped with Canopy Agitating Tines. Lewis Field, Clemson, SC. 1984.

Date	Cultivar	% Removed	Fruit Firmness, N
July 2	68-440	88	70
July 5	Redhaven	88	70
July 5	Coronet	75	60
July 9	Redhaven	69	49

Table 9. Condition of hand and machine harvested 68-440 peaches following harvest with the over-the-row prototype canopy agitation device. July 3, 1984.

Attribute	Hand harvested	CAD harvested
	% fruit	
Marketable	75.2 a	69.7 a
Natural defects	8.9 b ^z	4.9 b
Cuts	0.0 c	10.9 b
Bruises	0.0 c	2.7 b
Undersized or immature	15.9 a	11.8 a

^z Compare hand versus machine harvested values within each attribute. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

greater percentage of bruises (2.7), although the difference was not significant.

Very little bruise development occurred during 10 days storage with only 1.5 percent of machine-harvested fruit and no hand-harvested fruit developing bruises (Table 10). A slightly greater (but statistically insignificant) percentage of hand-harvested fruit developed rots compared to machine-harvested fruit. The greatest increase in percentage rots from both treatments occurred between the fourth and sixth day of storage. Very little difference in the percentage of marketable fruit was observed between hand- and machine-harvested fruit through the eighth day of storage. On the tenth day after harvest, a greater percentage of machine harvested fruit was marketable, but the differences were not significant.

A summary of the overall effect of harvesting method on the marketability of the 68-440 selection and the two 1984 cultivars is presented in Table 16. Table 16 combines the initial damage found at harvest with that noted 10 days after harvest and is presented as the percentage of marketable fruit from hand-harvested and machine-harvested treatments.

'Redhaven'--First Harvest. The initial condition of 'Redhaven' peaches immediately following harvest is shown in Table 11. There were no significant differences in the percentage of fruit with natural defects or undersized/immature hand- or machine-harvested fruits. The machine did cause a significantly greater percentage of fruit to be cut (8.6 percent as compared to no cuts on hand-harvested fruit). The hand-harvested fruit had a slightly greater percentage of bruises but the difference was not significant. The mean firmness of the fruit at harvest was 69.8N (15.7 lbs). The mean ground color score on the peach color chart was 4.1.

Table 10. The influence of harvesting method on '68-440' fruit during storage. Harvested July 3, 1984 using the over-the-row prototype with canopy agitation device.

Days after harvest	% Bruise		% Rot		% Marketable ^z	
	Hand harvested	Machine harvested	Hand harvested	Machine harvested	Hand harvested	Machine harvested
2	0.0 a ^y	1.5 a ^y	0.0 a	0.0 a	100.0 a	97.3 b
4	0.0 a	1.5 a	1.4 a	0.8 a	98.6 a	96.5 a
6	0.0 a	1.5 a	2.6 a	1.4 a	97.4 a	95.9 a
8	0.0 a	1.5 a	2.6 a	1.8 a	97.4 a	95.5 a
10	0.0 a	1.5 a	2.6 a	1.8 a	86.3 a	95.5 a

^zThe placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit. Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Table 11. Condition of hand and machine harvested 'Redhaven' peaches following first harvest. Harvested with over-the-row prototype with canopy agitation device (CAD). July 5, 1985

Attribute	Hand harvested	CAD harvested
	% fruit	
Natural defects	3.0 a ^z	4.7 a
Cuts	0.0 b	8.6 a
Bruises	2.0 a	0.0 a
Undersized or immature	15.0 a	14.6 a

^zCompare hand versus machine harvested values within each attribute. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Table 12. The influence of harvesting method on 'Redhaven' fruit during storage. Harvested with over-the-row prototype with canopy agitation device (CAD). Harvested July 5, 1984.

Days after harvest	% Bruise		% Rot		% Marketable ^z	
	Hand harvested	CAD harvested	Hand harvested	CAD harvested	Hand harvested	CAD harvested
2	3.4 a ^y	0.0 a ^y	0.0 a	0.0 a	96.6 a	96.7 b
4	3.4 a	0.0 a	2.4 a	0.0 a	94.2 a	96.7 a
6	3.4 a	0.0 a	4.7 a	3.3 a	92.0 a	96.7 a
8	3.4 a	0.0 a	5.8 a	3.3 a	90.9 a	96.7 a
10	3.4 a	0.0 a	5.8 a	3.3 a	90.0 a	96.7 a

^zThe placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit. Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

On the first harvest of 'Redhaven' fruit, July 5, 1984, the trend of a greater percentage of hand-harvested fruit developing bruises which was evident at the initial examination was maintained during storage, even where the initial fruit used had no apparent bruises (Table 12). Further bruise development did not occur past the second day, with 3.4 percent of hand-harvested and no machine-harvested fruit showing bruises. A slightly greater but insignificant percentage of hand-harvested fruit developed rots during storage. Rot development did not increase past the eighth day of storage. A greater percentage of machine-harvested fruit was marketable at each examination date, although the differences were not significant.

Table 16 presents the total percentage of marketable hand- and machine-harvested fruit at harvest and following a 10-day storage period for the first harvest of 'Redhaven' as well as 68-440 and 'Coronet.'

'Redhaven'--Second Harvest. The condition of 'Redhaven' fruit harvested on a subsequent date (July 9) both at harvest and during storage is presented in Table 13. A slightly greater percentage of machine-harvested fruit was cut, although the difference was not significant. A slightly greater percentage of machine-harvested fruit was bruised at harvest, but by the second day, more of the hand-harvested fruit had developed bruises (9.5 percent), compared to 3.3 percent for machine-harvested fruit. No further bruise development occurred after the second day after harvest. The machine-harvested fruit likewise developed less rots during storage, although the differences were not significant. Rot development appeared to increase uniformly throughout the storage period, regardless of treatment. By the eighth day after harvest, there was little difference in the percentage of marketable fruit whether hand (74.0) or machine-harvested (76.5). This trend continued into the final examination, 10 days after harvest.

Table 13. The influence of harvesting method on 'Redhaven' fruit during storage. Machine was over-the-row prototype with canopy agitation device. Harvested July 9, 1984.

Days after harvest	% Bruise		% Rot		% Marketable ^z	
	Hand harvested	Machine harvested	Hand harvested	Machine harvested	Hand harvested	Machine harvested
0 (at harvest)	1.5 a	2.6 a	0.0 a	0.0 a	89.5 a	85.8 a
2	9.5 a	3.3 a	2.0 a	0.7 a	80.5 a	84.4 b
4	9.5 a	3.3 a	3.5 a	1.3 a	79.5 a	83.7 a
6	9.5 a	3.3 a	5.0 a	2.6 a	78.5 a	82.5 a
8	9.5 a	3.3 a	9.5 a	8.6 a	74.0 a	76.5 a
10	9.5 a	3.3 a	12.5 a	10.5 a	72.5 a	74.6 a

^zThe placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit. Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Table 14. Condition of hand and machine harvested 'Coronet' peaches following harvest. Machine was over-the-row prototype with agitation device. July 5, 1984.

Attribute	Hand harvested	Machine harvested
	% fruit	
Natural defects	3.0 a ^z	6.6 a
Cuts	0.0 b	7.8 a
Bruises	2.0 a	1.0 a
Undersized or immature	15.0 a	19.1 a

^zCompare hand versus machine harvested values within each attribute. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

^ySee Table 13.

'Coronet'. There were no significant differences in the percentage of 'Coronet' fruit with natural defects or undersized/immature from either the hand or machine harvested treatments at the initial examination made just after harvest (Table 14). The mean firmness of the fruit at harvest was 60.1N (13.5 lbs). The mean ground color score on the peach color chart was 5.6. The machine-harvested fruit had a significantly greater percentage of cuts (7.8 percent) compared to none of the hand-harvested fruit having cuts. Only 1 percent of the machine-harvested fruit were found bruised following harvest, while 2 percent of the hand-harvested fruit was bruised. These differences were not statistically significant.

As shown in Table 15, no further bruise development occurred in either hand- or machine-harvested fruit throughout the storage period. A slightly greater percentage of hand-harvested fruit developed rots during storage (3.7 percent by the tenth day), although the differences were not significant. Very little difference was found in the percentage of marketable fruit between hand- or machine-harvested treatments at any of the examination dates during storage.

Table 16 presents the total percentage of marketable hand- and machine-harvested fruit at harvest and following a 10-day storage period for 'Coronet' as well as 68-440 and the first harvest of 'Redhaven.'

In 1984, differences in the percentage of marketable hand- versus machine-harvested fruit were small (Table 16). For 68-440, 4.4 percent more hand-harvested fruit was marketable; for the first 'Redhaven' harvest 0.8 percent more hand-harvested fruit was marketable; and for 'Coronet' 7.2 percent more hand-harvested fruit was marketable. These values were obtained even after a more than reasonably long storage period at a much higher than commercially recommended storage temperature (10 days at 22°C).

Table 15. The influence of harvesting method on 'Coronet' fruit during storage. Machine was over-the-row prototype with canopy agitation device. Harvested July 6, 1984.

Days after harvest	% Bruise		% Rot		% Marketable ²	
	Hand harvested	Machine harvested	Hand harvested	Machine harvested	Hand harvested	Machine harvested
2	0.0 a ^y	0.0 a ^y	0.0 a	0.0 a	100.0 a	96.7 b
4	0.0 a	0.0 a	1.4 a	0.0 a	98.6 a	96.7 a
6	0.0 a	0.0 a	2.5 a	0.8 a	97.5 a	95.9 a
8	0.0 a	0.0 a	3.7 a	0.8 a	96.3 a	95.9 a
10	0.0 a	0.0 a	3.7 a	0.8 a	96.3 a	95.9 a

²The placing of fruit in multiple categories or in unreported scuffing or shrivelling categories will influence the percentage of marketable fruit. Increasing or decreasing percentages in a given category over time are the result of these fruit being placed in a different category, such as from bruise to rot.

^yCompare hand versus machine harvest values within each date and category. Means followed by the same letter do not differ at the 5% level of significance as determined by LSD.

Table 16. Overall effect of harvesting method on fruit marketability. Machine was over-the-row prototype with canopy agitation device. 1984.

Variety or selection	Firmness at harvest lbs/N"	Color at harvest (color chip)	% Marketable ²	
			Hand harvested	Machine harvested
68-440	15.8/70.3	5.1	86.3	81.9
'Redhaven'	15.7/69.8	4.1	88.9	88.1
'Coronet'	13.5/60.1	5.6	94.3	87.1

²Values reflect total damage (initial field damage plus latent damage following 10 days storage) as a result of harvesting method. Fruit selected for storage test were initially apparently sound as judged by visual observation.

Further refinements in the harvester should adequately reduce the number of fruit which are cut and bruised and increase the percentage of marketable machine-harvested fruit in future years. Very little attention was given to reducing bruises and cuts for this incomplete stage of prototype development. However, additional conveyors will be necessary which will expose fruit to more handling in the harvester.

2.4.2.5. Plans for Further Development of the Harvester Prototype A unique conveyor system is being designed to replace the collecting system used during the tests of the harvester prototype in 1984. This conveyor system will combine the functions of a collecting conveyor and an elevating conveyor. This conveyor (40.6 cm wide) will collect the fruit beneath the tree and elevate it directly to the top of the over-the-row frame where it can be placed in a bulk container or discharged onto a second conveyor and conveyed across the row to a fruit handling vehicle which would transport it from the orchard.

The unique feature of the experimental collecting/elevating conveyor is that the fruit will be carried on the inside of a large loop (approximately 12 m total belt length) of conveyor belt fitted with large cupped flights spaced at approximately 20 cm apart. One of these conveyors will be located on each side of the machine with the belt running very low in a horizontal position to collect fruit from the closure surface. Fruit will roll onto the belt from the closure surface or fall directly onto the belt when detached from the tree. Fruit will collect between the flights and be conveyed rearward at a speed of approximately 0.4 m/sec. At the rear of the machine near the end of the closure surface, the belt will turn upward at a steep angle and the fruit will settle against the flights. At a position above the frame, the conveyor belt will turn towards the front of the machine, discharge the fruit, and travel in a horizontal direction (above the frame) to a position above the front of the closure

surface where it will be routed downward and loop back to a horizontal position along the side of the closure devices. The belt will be supported on the edges by large-diameter V-belt sheaves bonded (to the surface containing the flights) about 1.9 cm from each edge of the conveyor belt to guide the belt on the sheave. Supporting and driving the belt from the edges is necessary to prevent interference with the fruit and flights which will be on the inside of the loop of belt.

The anticipated advantages of the experimental conveyor design are: the ability to operate very low near the soil surface, it will compactly elevate the fruit sufficiently to convey it across the next row of trees or to place it into a bulk bin, and has fewer transfer points to cause fruit damage when fruit is dropped from one conveyor to another.

Modifications are also being made to the closure surfaces to minimize fruit loss around the tree trunks. Commercially available "collector leaves" are being purchased and will be mounted to a rail along each side of the collector conveyors. These leaves will extend into the area under the tree and will angle upward toward the tree trunks to deflect the falling fruit onto the collector conveyor. Each spring-loaded collector leaf will pivot to allow the tree trunks to pass while the spring holds the leaf in contact with the tree trunk. This device will be of the type currently in use on commercial berry harvesters. Padding of the collector leaves will be considered.

A modification of the hydraulic circuit controlling the constant rotational component of the canopy agitation devices is planned. The circuit will be modified to hydraulically synchronize the rotation of the canopy agitation devices to the travel speed of the harvester. This modification is essential to prevent damage to the tree canopy and the agitator tines due to mismatches

between travel speed and tine rotational speed. By hydraulically synchronizing the rotational speed to the travel speed, a smooth flow of the tines through the tree canopy can be assured for the entire travel speed range from 0 to the maximum field speed. Speed of the agitator tines is presently adjusted manually. This arrangement is unsatisfactory for the desired results.

2.4.2.6. Other Possible Uses of the Prototype Over-the-Row Harvester Unit In addition to harvesting shipping quality fruit, the over-the-row prototype frame could potentially be converted for other operations which occur before or after the harvest season. By suitable design, the harvesting equipment and conveyors could be removed during the non-harvesting seasons and appropriate tanks, pumps, nozzles, etc. be installed to apply chemical sprays to the foliage. Coverage should be good and drift minimal with the over-the-row configuration.

It may also be possible to fit the frame with equipment to prune the trees in the manner required by the alternate-side tree technique of meadow orchard production. All of the attachments would need careful designing to allow quick conversion from one of these operations to another at a minimum cost of time and labor.

2.4.2.7. References

1. Alper, Y. A., A. Erez, and R. Ben-Arie. 1980. "A New Approach to Mechanical Harvesting of Fresh Market Peaches Grown in a Meadow Orchard." Trans. of ASAE 23(5):1084-1088.
2. Chu, Yuan-Nan, R. E. Williamson, and C. E. Hood. 1984. "Pre-loaded Vibration Study in Detaching Peaches." ASAE Paper No. 83.1567. ASAE, St. Joseph, MI.
3. Settle, D. C., R. E. Williamson, C. E. Hood, and E. T. Sims, Jr. 1983. "Fruit Removal by Horizontal Shaking of Severed Meadow Orchard Peach Trees." ASAE Paper No. SER 80-015. ASAE, St. Joseph, MI.
4. Chu, Yuan-Nan. 1984. "Physical and Biological Parameters Relating to Mechanized Harvesting of Meadow Orchard Peaches." Master of Sciences Thesis. Agricultural Engineering Department, Clemson University, Clemson, SC.
5. Alper, Y., Hood, C. E., and B. K. Webb. 1976. "A Two-Dimensional Shaker for Harvesting Fresh-Market Tomatoes." TRANSACTIONS of the ASAE 19(5):830-834, 839.

2.4.2.8. General Procedure for Post-Harvest Evaluations - S. CAROLINA

The overall objectives of the post-harvest phase of Clemson University's research was (1) to compare the quality and storage life of peaches grown under the meadow orchard system with conventionally grown fruit, and (2) to compare the quality and storage life of peaches grown under the meadow orchard system and harvested mechanically with those hand harvested.

Sampling. Prior to sampling for quality, the mean firmness of the fruit in each block and for each cultivar was determined just prior to harvesting by taking a random sample of 20 to 30 fruit from a minimum of four randomly selected trees. Firmness was measured on pared fruit cheeks with a Magness-Taylor pressure tester with a 0.794 cm diameter point.

To obtain the hand harvested lots, fruit were stripped from trees beginning at the top and descending until 40 or 60 fruit per replicate (depending on fruit availability) were obtained. In many cases, fruit from more than one tree was required to obtain a replicate. In such cases, sampling from the next tree also proceeded from the top down until the replicate was completed. Hand-harvested fruit was divided into two sublots of 20 to 30 fruit each. One subplot of at least four reps was used for an initial examination for cuts, bruises, rots, the presence of natural defects, undersized fruit, etc. In addition, a minimum of four replicates of 20 to 30 visually sound, marketable fruit were placed in trays for storage and ripening tests conducted as described below for machine-harvested fruit.

Machine-harvested fruit was collected from the sampling position at random until at least four standard three-fourths-bushel peach boxes (replicates) were either filled or partially filled, depending on fruit availability. An initial

examination of fruit was made (usually the day after harvest) for cuts, punctures, bruises, rots, and other injuries and defects by evaluating a minimum of 30 fruit from each replicate. All visibly injured fruit were discarded and 20 to 30 visibly sound fruit were selected at random from each replicate and placed into single layer corrugated boxes with separating dividers for subsequent periodic examinations. The identity of each fruit was maintained throughout the experiment. A bruised fruit was defined as one possessing any observable bruise, regardless of bruise size. Any cut, regardless of size or extent, placed the fruit in the cut category. Fruit was held at 22°C throughout the examination period.

3. Appendix A

3.1. A reliable actinometric method for characterizing
the light regime in plant canopies⁽¹⁾

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Abstract

The actinometric method based on photolysis of uranyl oxalate was adapted for measuring integrated light irradiance in plant canopies. The unique characteristics of the new actinometers are their small size, the avoidance of pressure build-up in the measuring cell, the very good correlation in response to light with quantum sensors and their response to the cosine law. The proposed system has the advantages of being inexpensive and reliable, integrating light measurement over a relatively long period, and needing little additional instrumentation. By this method numerous measurement points scattered in plant canopies can be determined simultaneously thus giving a more accurate picture of the light regime in fields and orchards. This paper describes such measurements in a peach meadow orchard planted at two densities, where 27 actinometers were dispersed in each replicate and density.

Orchard intensification, incorporating changes in tree dimensions and in planting densities, together with new agrotechnical approaches to orchard cultivation, pruning and fruit handling, have lately necessitated increasing attention on the light regime in the orchard (4,10,12,13).

Photon flux density and quality reaching the earth is constantly changing in the course of a day as well as a season, and depends on the height of the sun above the horizon, the cloud screen, and atmospheric pollution. This variability increases further when the light regime is evaluated in plant canopies.

In a continuous canopy the main factors determining flux density irradiation at any point are leaf area index (LAI) and leaf angle and orientation (10,18,21), whereas in orchard canopies the variations in light are

far greater and depend also on tree form and structure (2,8,18,19,20). Thus, a point measurement of light at a certain period of time can not represent the daily photon flux over time even for that given point. In order to characterize the light regime in an orchard canopy, it is imperative to have measurements integrated over relatively long periods, as well as to have multiple points of measurement. These requirements pose a difficult problem if electronic or electrical sensors and or integrated sensors are to be used for that purpose, because of the cost of the light sensing units and the data collecting and-processing instruments.

Attempts to overcome this problem have led to three approaches: Development of mathematical models based on climatic and geographical data concerning LAI, light angle, leaf extinction coefficient, light reflection from leaves, etc. (9,12,18,23). The use of fish-eye photography at various points in the canopy, and getting "percent sky", which correlates with diffused light reaching the examined point (5,14,15,22). And the utilization of actinometry based on photochemical reactions to quantify the flux density of light at the point of measurement (1,6,7,17,24). The most common reaction used in actinometry is the decomposition of oxalic acid in the presence of uranium ions to water CO_2 and CO on exposure to light (16). The chemical and physical characteristics of the reaction were examined in detail (16). The main conclusions were that the photochemical reaction is responsive to radiation at wave lengths of 220 to 490 nm, and that there is no activity in the dark. The reaction is independent of temperature over a wide range and that a simple quantitative analysis can be performed by titrating the residual oxalic acid left with permanganate. Heinicke (6,7) tried to characterize the light regime in an apple tree canopy using 20 x 150mm test-tubes covered with light-proof paint except for a 1-cm-wide clear band. These cells were hung at various points in the canopy. The drawback to

this system was its sensitivity to the light angle and orientation, as the cell was not cosine corrected. Furthermore, the tightly closed cell did not allow the gases formed in the reaction to escape, thus creating increased pressure in the system. Other researchers (1,17) have tried different cell forms that nevertheless were too big to use in large quantities in the orchard. The present paper describes an actinometric system adapted to field application, which addresses the above mentioned drawbacks.

Materials and methods

The reaction system. A stock solution of 104mM of uranyl sulfate and 540 mM of oxalic acid in water was prepared and kept in a dark glass bottle and left under room temperature. No decomposition was detected in a period of 1 year. The final system included: 26 mM of uranyl sulfate and 135 mM of oxalic acid. For tracing oxalic acid decomposition as a function of light intensity, four replicates of a black-plus white-painted 250 ml beaker containing 150 ml of uranyl oxalate, (U.O.) were exposed to artificial light, sun light, leaf shade in the open, or total darkness for various periods of time. At the end of each period a 2 ml sample in four replicates was titrated with KMnO_4 .

The photochemical cell. The cell consisted of a glass test-tube 45 x 12mm, having a hemispherical bottom. The test-tube was coated twice with oil paint, the first layer being black and the second white. The lowest 3 mm of the hemispherical bottom was left free of paint. Then, 2.6 ml of reaction solution was poured into the test-tube, which was closed with a rubber stopper into which a hypodermic needle was inserted. After filling, the test-tube was positioned upside down so that the level of the liquid reached the rim of the painted part of the test-tube. The needle end was located in the air bubble trapped in the hemispherical part of the test-tube (Fig. 1).

The photochemical cell was tested for its response to light intensity, by using 6 to 10 replicates for every light regime examined. In addition, 2x the number of light replicates were kept in darkness. After the exposure to light, titration of the remaining U.O. was carried out immediately or after keeping in the dark for up to 1 week. No further decomposition occurred during this period. Titration was according to Heinicke (6), with the following modifications: The sample of the reaction system was transferred to a 100-ml Erlenmeyer flask, with 25ml of water and 1ml of concentrated H_2SO_4 being added. The solution was heated to 70°C and titrated with 0.01M. of KMnO_4 . The end point was the appearance of a rose color stable for at least 1 min.

Quantum flux density in the visible range (400 -700 nm) was measured by a Licor-185B photometer using the Li 1905B quantum sensor. The following formulae served for calculations:

$$1) \% \text{ decomposed oxalate} = \frac{(A - B)}{A} \times 100$$

$$2) \% \text{ of light penetration} = \frac{(A - C)}{A - C} \times 100$$

$$A - C$$

$$3) \% \text{ light interception} = 100 - \% \text{ light penetration}$$

Where A = ml KMnO_4 titrated the oxalate in the test-tube kept in the dark; B = ml KMnO_4 titrated the oxalate in the test-tube kept in the light under the canopy and C = ml KMnO_4 titrated the oxalate in the test-tube kept in the light above the canopy.

For actual measurements of light penetration into plant canopies, a peach meadow orchard (3) planted at two densities was chosen. The orchard was planted in a hedgerow system with 1.8m between row spacings, and 0.5m or 1.0m within-row spacings in the higher and lower planting densities, respectively. The

actinometer test-tubes were mounted on small plastic holders attached to the southern side of 5-mm rigid wires that were placed every 25 cm along the row axis (three wires) and every 45cm between rows (three wires). On every wire three test-tubes were attached, at 40, 80 and 120 cm above ground. Nine such wires, holding 27 actinometers, were thus used per replicate. Four replicates were analyzed per planting density. The data were taken when tree height reached 1.80m and are presented as means of the three actinometers located along and in parallel to the row axis at every height level for every replicate.

Results and Discussion

The photochemical response: The rate of the photochemical reaction taking place with U.O. was checked under controlled light and temperature conditions. Light sources were high output cool white fluorescent tubes with added incandescent light ($300 \mu\text{E. m}^{-2} \text{ sec.}^{-1}$). In Fig. 2a, photolysis of oxalic acid is presented as a function of light flux density. The basic system of the reagent designated 1x included 26 mM and 135 mM of uranyl sulfate and oxalic acid, respectively. The lower the reagent concentration, the more sensitive was the photolysis reaction. Thus, 80% of 0.5x was lost after exposure to 30 Em^{-2} , while in the 1.5x sample 60 Em^{-2} was needed to reach the same level of response. The response curve obtained follows a linear function until 85% decomposition of the oxalic acid, as reported earlier (1,17). Linear regressions calculated only to that point exhibit a highly significant "r". Even better correlations were obtained with solar radiation, which gave a quicker response (Fig. 2b). A figure of 80% decomposition of oxalic acid was obtained after exposure to only 12 Em^{-2} and 18 Em^{-2} with U.O. levels of 0.5x and 1x, respectively. The difference in photolysis rates between artificial and solar irradiations stems from the spectral difference of these two sources, as the reagent is sensitive to light

mostly below 490nm (16). When photolysis data were plotted against time of exposure, a straight line was obtained similar to Heinicke's results (6).

The response of the photochemical cell: The miniature cell was checked to its photochemical response by exposing it to various light regimes of artificial or natural sources. The response of the cell to increasing exposures of constant fluorescent ($250 \text{ E. m}^{-2} \cdot \text{sec}^{-1}$), or combined fluorescent and incandescent light ($300 \mu\text{E. m}^{-2} \cdot \text{sec}^{-1}$), is shown in Fig. 3a. A linear relationship between light irradiation and percent reagent degradation was noted up to 70%. The greater efficiency of fluorescent light is explained by the higher sensitivity of the reaction to wavelengths below 490 nm.

Figure 3b represents the response of the photochemical cell to solar radiation during the four brightest hours of the day on four consecutive days. A more sensitive response was obtained with 0.5x. The total response followed a pattern of a power curve ($y = ax^b$), of which the initial part, which is shown, is practically linear up to 70%. The response of the photochemical cell is more sensitive to solar radiation than to artificial light (Fig 3). The choice of the concentration of U.O. used should therefore be the lowest possible that will not reach 70% degradation during the exposure period. Since the solar radiation in the summer in Israel reaches $2 \text{ mE. m}^{-2} \cdot \text{sec}^{-1}$, with long days, use of concentrations higher than 0.5x are required for a measurement period of 24 h. Comparisons of hourly readings between 08⁰⁰ and 14⁰⁰ h. on a clear day of the photochemical cells and an integrated light measurement with a quantum sensor produced similar data (Table 1). The linear function shows a highly significant correlation coefficient with -2.2% of mean difference between actual and calculated photochemical measurement while the power function reveals an almost perfect match between the two systems, $r^2 = 0.999$ with only -0.4% difference.

The rate of photolysis of U.O. in the actinometers was tested also with diffused light in heavy leaf shade. Concurrent integrated actinometric and photometric measurements were performed with diffused light, Figure 4 reveals a direct correlation between the two systems also at this low light irradiance. Hence, the potential use of these actinometers for both direct and diffused light measurements.

Light Orientation

Jackson and Palmer (11) stress the importance of obeying Lambert's cosine law by the light sensor and the inaccuracy of using light measurement techniques which respond uniformly to light coming from various angles.

In our study the hemispherical part of the test-tube allows equal passage of light from all angles, while the solution surface is situated horizontally, when the test-tube is hanging vertically. The photolysis reaction was compared to a Licor quantum sensor responsive to the cosine law. Exposure to light was done in a darkroom where the sole light source was a phosphor coated mercury bulb (HPLR) of 250W 12cm in diameter which could be oriented at different angles. Eight actinometers were exposed to 0° , 30° , or 60° from the vertical. Very good agreement was found between the two measuring techniques (Table 2).

Relative light penetration in orchard canopies

A detailed study done in mid-April (40 days after the start of leafing) of two planting densities is presented in Table 3.

At the higher density the four central measurement points (40 and 80cm height, 0 and 45 cm from the row axis) received 20% or less of the light falling on top of the canopy. On the other hand, in the wider planted orchard only one

point (40 cm height, at the row axis) received 20% while the other positions were exposed to over 30% of light falling on top of the canopy. Analysis of only the 0 and 45 cm planes (first two columns), which together comprise about 90% of the entire tree volume, show that two-thirds of the higher density planting received 25% or less of the total light falling on the orchard, vs. only one sixth in the wider density planting.

Conclusions

Uranyl oxalate actinometers were shown to respond in close agreement with quantum sensors under artificial and natural light sources.

A significant correlation was shown between the quantum sensors and the actinometers up to 70% photolysis of the reagent. It is therefore imperative that the reagent concentration chosen will not reach 70% of photolysis during the period of exposure. i.e., the concentration of reagents used should be determined according to light intensity, daylength, etc. It should be noted though that with increase in concentration, the sensitivity of the system decreases. With the right solution concentrations, considering the cosine response of the system, an integrated light measurement can safely be performed in plant canopies. The use of small units makes mapping of the light regime in plant canopies a relatively simple and inexpensive operation, as illustrated for the two planting densities of a peach meadow orchard.

Literature Cited

1. Begg J.E. and R.B. Cunningham 1974. Penetration of radiation into a eucalypt woodland. J. Aust. Inst. Agric. Sci. 40:160-4.
2. Cain J.C. 1972. Hedgerow orchard design for the most efficient interception of solar radiation. Effects of tree size, shape, spacing and row direction. Search Agr. 2:1-14.
3. Erez A. 1982. Peach meadow orchard: Two feasible systems. HortScience 17:138 - 142.
4. Folley R.R.W. 1973. An economist's review on the choice of tree form and planting system for commercial apple production. Scientia Hort. 1:205-19.
5. Fuchs M. & G. Stanhill 1980. Row structure and foliage geometry as determinants of the interception of light rays in a sorghum row canopy. Pl. Cell Envir. 3:175-82.
6. Heinicke D.R. 1963. The microclimate of fruit trees I. Light measurements with uranyl oxalate actinometers. Can. J. Pl. Sci. 43:561-8.
7. Heinicke D.R. 1966. Characteristics of McIntosh and Red Delicious apple as influenced by exposure to sunlight during the growing season. Proc. Am. Soc. hort. Sci. 89: 10-13.
8. Jackson J.E. 1978. Utilization of the light resources by high density planting systems. Acta Hort. 65: 61-70.
9. Jackson J.E. 1980. Theory of light interception by orchards and modelling approach to optimizing orchard design. Acta Hort. 114:69-79.
10. Jackson J.E. 1980. Light interception and utilization by orchard systems. Hort. Rev. 2: 208 - 67.

11. Jackson J.E. and J.W. Palmer 1972. Interception of light by model hedgerow orchards in relation to altitude, time of year and hedgerow configuration and orientation. *J. Appl. Ecol.* 9:341-57.
12. Jackson J.E. and J.W. Palmer 1980. A computer model study of light interception by orchards in relation to mechanized harvesting and management. *Scient. Hort.* 13:1-7.
13. Koo R.C.J. and R.P. Muraro. 1982. Effect of tree spacing on fruit production and net returns of "pineapple" oranges. *Proc. Fla. St. hort. Soc.* 95:29-33.
14. Lakso A.N. 1976. Characterizing apple tree canopies by fisheye photography. *HortScience* 11:404-5.
15. Lakso A.N. 1980. Correlation of fisheye photography to canopy structure, light climate, and biological responses to light in apple trees. *J. Am. Soc. hort. Sci.* 105:43-6.
16. Leighton W.G. and G.S. Forbes 1930. Precision actinometry with Uranyl oxalate. *J. Am. chem. Soc.* 52:3139-52.
17. Maggs D.H. and D. McE. Alexander. 1970. Tests of a uranyl oxalate light integrator for use in fruit tree canopies. *J. appl. Ecol.* 7: 639-46.
18. Palmer J.W. 1977. Diurnal light interception and a computer model of light interception by hedgerow apple orchards. *J. appl. Ecol.* 14: 601-14.
19. Palmer J.W. 1980. Computed effects of spacing on light interception and distribution within hedgerow trees in relation to productivity. *Acta Hort.* 114: 80-8.
20. Palmer J.W. and Jackson J.W. 1977. Seasonal light interception and canopy development in hedgerow and bed system apple orchards. *J. appl. Ecol.* 14: 539-49.

21. Ross J. 1975. Radiative transfer in plant communities. in: Monteith, J.L.-
[ed.] Vegetation and the Atmosphere. pp. 13-55. Academic Press.
London.
22. Stanhill G., M. Fuchs, Y. Bakker and S. Moreshet. 1973. The radiation
balance of a glasshouse rose. Crop Agric. Meteorol. 11: 385-404.
23. Thornley J.H.M. 1976. Light interception by plants and crops. in:
Mathematical models in plant Physiology. pp. 74-91. Academic Press,
London.
24. Verheij E.W.M. and F.L.J.A.W. Verwer. 1973. Light studies in a spacing trial
with apple on a dwarfing and a semi-dwarfing rootstock. Scient.
Hort. 1: 25-42.

Fig. 1: Details of the uranyl oxalate photochemical cell. a. hypodermic needle, b. rubber stopper, c. uranyl oxalate solution meniscus, d. glass walls, painted white over black.

Fig. 2: The response of three levels of uranyl oxalate solutions to varying levels of incandescent light (a) and solar irradiance (b). (1x represents 26mM of uranyl sulfate and 135mM of oxalic acid. Measured against Licor quantum sensor.)

Fig. 3: The response of uranyl oxalate actinometers to varying levels of irradiance by fluorescent light (3a, white symbols), fluorescent plus incandescent light (3a, black symbols), or solar radiation (3b). (1x represents 26mM of uranyl sulfate and 135mM of oxalic acid. Measured against Licor quantum sensor.)

Fig. 4: The response of uranyl oxalate actinometers to varying levels of diffused irradiance under leaf shade. (11x represents 26mM of uranyl sulfate and 135mM of oxalic acid. Measured against Licor quantum sensor.)

Table 1: A comparison of integrated hourly readings of light irradiation in the open between a quantum sensor and U.O. photochemical cell. (Readings taken on April 15 a bright day.)

Time of the day	Light irradiance ($\text{E.m}^{-2}.\text{h}^{-1}$)	Uranyl oxalate (% .h^{-1})	% difference of actual y from calculate y	
			$y = a + bx$	$y = a \cdot x^b$
08 ⁰⁰ - 09 ⁰⁰	3.78	9.2	-13.1	- 9.0
09 ⁰⁰ - 10 ⁰⁰	4.50	13.3	5.6	7.8
10 ⁰⁰ - 11 ⁰⁰	5.49	14.1	- 8.9	- 9.7
11 ⁰⁰ - 12 ⁰⁰	5.80	17.5	6.6	9.6
12 ⁰⁰ - 13 ⁰⁰	5.40	16.6	8.7	- 8.1
13 ⁰⁰ - 14 ⁰⁰	4.57	11.3	-12.3	6.9
mean	4.92	13.7	- 2.2	- 0.4

Linear function: $y = -.522 + 2.903x$ $r = 0.977$

Power function : $y = 2.273 \cdot x^{1.119}$ $r = 0.999$

Table 2: Comparison of the response of the actinometer and the quantum sensor to unidirectional light. (Light source 250W HPLK; Licor 195B quantum sensor and a uranyl oxalate actinometer.)

Light direction		Quantum sensor		Actinometer	
	Cos	E. m ⁻²	Values relative	M1	Values relative
		.sec ⁻¹	to the	KMnO ₄	to the
			perpendicular		perpendicular
0°	1.000	600	1.000	1.02	1.000
30°	0.866	500	0.833	0.88	0.863
60°	0.500	300	0.500	0.52	0.510

Table 3: Integrated light penetration measurement with uranyl oxalate actinometry in the canopy of a peach meadow orchard cv. 'Maravilha' at two planting densities. (Integrated time 24 h; presented as percent of irradiation above the canopy. Figure at every point represents 12 replicates. (Mean separation in every spacing by Duncan's Multiple Range Test, $p = 0.05$.)

Height (cm)	Distance from row axis (cm)		
	0	45	90
50 cm in row planting density			
40	9.4 c	11.0 c	58.4 b
80	17.5 c	22.6 c	78.9 a
120	58.2 b	28.1 c	88.4 a
100 cm in row planting density			
40	10.9 d	32.0 c	75.1 b
80	34.4 c	47.9 c	89.7 ab
120	71.3 b	54.0 c	96.5 a

Description of Cooperation

In this project, 9 scientists from 7 departments in 3 Institutes cooperated. In the course of the operation of the project mutual visits of the cooperating scientists took place. In these meetings performance of orchards and machinery was observed on a first hand. Discussion as to further work on the basis of the results obtained so far led to new approaches. The participation of members of the team in relevant International meetings exposing them to new ideas and approaches added to reach the achievements obtained. The strong connection formed between Agricultural Engineers, Horticulturists and Post-harvest physiologists was essential for operation of this project.

Conclusions and Benefit to Agriculture

The project dealt with the diverse aspects of the development of the extreme dense planting system of the meadow orchard to a fully mechanized system. Under a long enough growing season and with the suitable cultivar, the meadow orchard was shown to be an annually productive system. Although the fruit size was reduced and its maturation delayed. But even the best adapted cultivar tried, did not have the suitable fruit characteristics required for once-over-harvesting, namely a uniform ripening. This characteristic and firmer fruit are needed in order to allow the commercial use of the system from the Horticultural point of view. The trials with the Meadow Orchard Peach Harvester led to the perfection of the prototype to a level that may allow its commercial use once the adapted cultivars will be available. The Harvester excels in a high level of fruit detachment and a minimal fruit bruising, may operate day and night and could run at a speed of up to 800 m/hr. The final product is a high quality fresh marketable fruit.

A new harvester meant to pick peaches from standing trees in a meadow orchard - the Canopy Agitation Device, was constructed and checked during two seasons. Relatively good fruit removal was obtained and very little fruit bruising was found in the machine harvested fruit. This unit may operate at a speed of 1200 m/hr. With

further improvement of the prototype, this unit could become commercial and fit peach intensive meadow orchards or other similar systems.

In addition specific achievements were gained in a few related fields: Improved rooting of softwood and hardwood cuttings was obtained by using various techniques. Also development of specific actinometric units for monitoring the light regime in plant canopies is another outcome of this project. Specifying and quantifying the effects of paclobutrazol- the new gibberellin biosynthesis inhibitor- on peaches has a bearing on the peach industry in general.

List of Publications

1. Alper, Y., Wolf, I., Ben-Arie, R., Elkin, I., Michai, G. and Antler, A., 1983. A mechanized harvesting system for fresh market peaches grown in a meadow orchard. No. 900-E 1983 series, The Agricultural Research Organization, Bet Dagan, Israel.
2. Avidan, B. and Erez, A., 1985. A reliable actinometric method for characterizing the light regime in plant canopies. J. Amer. Soc. Hort. Sci. (in press)
3. Chu, Yuan-Nan. 1984. "Physical and Biological Parameters Relating to Mechanized Harvesting of Meadow Orchard Peaches". Master of Science Thesis. Agricultural Engineering Department, Clemson University, Clemson, SC.
4. Chu, Yuan-Nan., Williamson, R.E. and Hood, C.E. 1984. Pre-loaded Vibration Study in Detaching Peaches . ASAE Paper No. 83-1567. ASAE, St. Joseph, MI.
5. Coston, D.C. 1984. Peach meadow research in South Carolina. Compact Fruit Tree. (in press).
6. Coston, D.C. and Krewer, G.W. 1983. Air rooting of peach cuttings. Proceedings of International Plant Propagators Society. 32:414-417.
7. Coston, D.C., Krewer, G.W., Owings, R.C. and Denny, E.G. 1983. Air rooting of peach cuttings. HortScience 18(3):323-324.
8. Coston, D.C., Sims, E.T. Jr. and Williamson, R.E. 1985. Productivity of peach meadow orchards. Acta Horticulture . (in press).
9. Coston, D.C., Williamson, R.E., Sims, E.T. Jr. and Krewer, G.W. 1984. Peach meadow orchards. Proceedings of National Peach Council. 43:99-100.
10. Couvillon, G.A. 1982. Leaf elemental content comparisons of own rooted peach cultivars to the same cultivars on several peach seedling rootstocks. J. Amer. Soc. Hort. Sci. 107:555-558.

11. Couvillon, G.A. 1985. Propagation and performance of inexpensive peach trees from cuttings for high density peach plantings. Acta Horticulture. (in press).
12. Couvillon, G.A., Pokorny, F.A. and Scalabrelli, G. 1985. Production of inexpensive peach trees from rooted cuttings. Acta Horticulture. (in press).
13. Erez, A. 1985. Growth control with paclobutrazol of peaches grown in a meadow orchard system. 3rd symp. on High Density Planting. Acta Hort. (in press).
14. Erez, A. 1984. Peach meadow orchards. 1st symp. on the peach. Acta Hort. (in press).
15. Hassan, M., Couvillon, G.A. and Pokorny, F.A. 1984. Hardwood cutting propagation of peaches - Influence of IBA concentrations on rooting. Proc. SNA Res. Conf. 29:201-204.
16. Krewer, G.W. 1984. The initiation and development of flower buds in the peach Prunus persica (L). Batsch. Ph.D. Dissertation. Clemson University.
17. Krewer, G.W., Coston, D.C. and Evert, D.R. 1983. Peach meadow orchard establishment techniques. HortScience 18:582 (Abstract).
18. Sen, Mehmet Seyit and Couvillon, G.A. 1983. Factors affecting survival of "in field" rooted hardwood peach cuttings. HortScience 18:324-325.
19. Settle, D.C., Williamson, R.E., Hood, C.E. and Sims, E.T. Jr. 1983. Fruit Removal by Horizontal Shaking of Severed Meadow Orchard Peach Trees. ASAE Paper No. SER 82-015. ASAE, St. Joseph, MI.