FEATURES

Peach Meadow Orchard: Two Feasible Systems[1]

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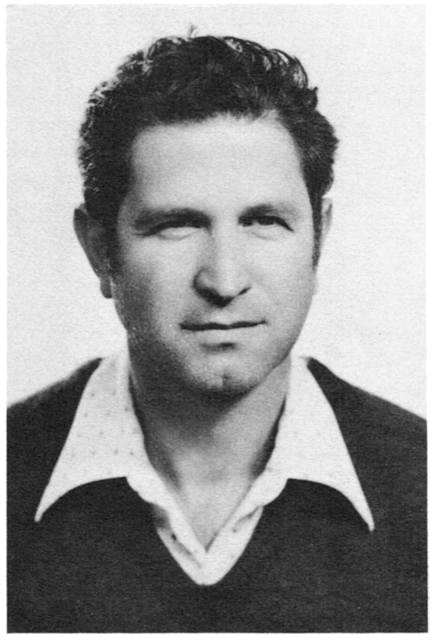
The shortcomings of conventional peach orchards make it increasingly difficult for growers to cope with production problems under the prevailing economic conditions. The large tree requires a relatively high labor input due to the location of a large portion of its fruit in the upper part and the reduced fruitfulness of the lower part.

These problems are inherent in the growing systems used. The conventional orchard (300–400 trees/ha) is planned to fit the dimensions of the mature bearing trees. The wide natural canopy of the peach, especially when trained to an open-center system, causes variations in performance of the various tree parts with age. The inner and lower parts are less exposed to sunlight than the upper and outer limbs, resulting in poor fruit production on the lower limbs and in stronger growth and fruiting potential of the upper portions. This imbalance is further accentuated by the annual pruning needed to enhance vegetative growth on which next year's crop is borne. In several cases, with advanced orchard age, the inner part of the lower limbs becomes totally bare. This frequently results in the most productive part of the tree being out of reach from the ground, thereby driving the labor input higher.

A solution to the excessive tree height is topping to a desired height, thus "lowering" the bearing canopy. However, this does not solve the problem, as the response to pruning is generally local, resulting in the production of intensive, vigorous growth at the pruning points, ending in the formation of an even denser "roof" above the topped plane. The new growth produced is more vigorous and fruitful than the lower growth, due to its better exposure to sunlight.

A preferable solution would be to top the tree to a level low enough so that the fruit developed on the new growth would be easily accessible from the ground. This was achieved by the meadow orchard system as described below.

A few approaches to utilizing severe summer pruning in a high-density orchard were tried. The common practice in all these systems was to minimize shading by green pruning. The Tatura system utilizes a rigid trellis on which the main tree limbs are held in an angled position, thus enabling both good light exposure and mechanized harvesting (3). The spindle systems used in Italy (2) and France utilize the tree to support itself and incorporate repeated pruning, especially in the upper part of the tree, to balance vegetative development (2). These systems are still in the experimental stage.



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Another approach to solve the big tree problem was to look for dwarfing cultivars or rootstocks that would result in a smaller tree that could be easily worked from the ground, would minimize shading, and would increase productivity. Such dwarfing rootstocks or high-quality dwarf peach cultivars are not yet available for peaches, as they are for apples. With apples, the availability of dwarfing rootstocks enabled the development of high-density orchards that were planted in a hedge with varying densities up to 8000 trees/ha (18, 21). An extreme case was described by Hudson, with about 100,000 trees/ha of apples on dwarfing rootstocks (13,14). This system was designated as the "meadow orchard," a term that was coined by Hudson to describe an ultra-high- density apple orchard meant for mechanical harvesting by mowing the trees with their fruit as grass in a meadow (14). In this system, full field cover was obtained, with no alleyways for machinery to pass between the trees. The tree was allowed to grow and induced to differentiate flower buds on 1-year-old wood. The following year, the tree set fruit that ripened in autumn, when it was harvested, and the tree was cut back to a short stump. A new biennial cycle started in the next year, with a new vegetative flush.

The apple meadow orchard, which seized the imagination of horticulturists in the early 1970s, eventually could not compete with other systems in England and elsewhere, since the system was based on biennial production. Flower buds had to differentiate on 1-year-old wood, not all cultivars responded favorably to the chemical induction of flowers by daminozide (4, 19), and the propagation unit used was a budded tree on clonal dwarfing rootstock, which made establishment costs too high. Although rooting of apple cuttings was reported (18), it was found to be rather difficult, and the trees produced on their own roots had excessive vigor for the system. Lastly, other options available for apple cultivars on dwarfing rootstocks offered a reasonable and more economical solution (18, 21).

Since all these drawbacks are not common for the peach, it was deemed desirable to examine the meadow orchard concept for this species.

The peach meadow orchard

The peach bears its fruit on 1-year-old wood. Thus, only 1 season's growth is required for bearing a crop, rather than the 2 common with the apple and other spur-bearing species. Therefore, if new vegetative growth could be obtained side-by-side with the bearing wood or even subsequent to fruiting, annual cropping could be achieved. The fact that relatively vigorous growth does not prevent flower bud differentiation led us to use pruning as a dwarfing technique in order to obtain the size restriction needed for the high-density orchard.

Another critical aspect of an extreme high-density planting is the increased establishment costs of plant material. This factor becomes prohibitive when grafted or budded trees were used. The simplest and cheapest vegetatively propagated unit is the cutting. Peaches were found to root relatively easily, with a high percentage of rooting when hardwood cuttings or semihardwood cuttings were used (5, 10, 12, 15, 16, 20) (Fig. 1). When the mean soil temperature at a depth of 20 cm during winter is 12°C or higher, rooting of cuttings *in situ* in the orchard soil was

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Fig. 1. Bases of 'Earligrande' peach 35 days after IBA treatment. Cuttings treated with IBA 1500 mg/liter and kept outdoors during winter (southern coastal plain of Israel) in moist sand.

Fig. 2. 'Earligrande' peaches ready to be harvested. Hardwood cuttings were planted *in situ*, January 1978. Photograph taken in May 1979 Bet-Dagan (coastal plain), Israel.

successful, thereby driving establishment costs even lower (12).

The mechanized system

The original peach meadow orchard system, designated also as the mechanized system (7, 9, 10), was developed for mechanized harvesting using a combine harvester that separates the fruit from a cut canopy. The idea was to detach the stem of the tree at harvest, allowing only a short stump, from which the regrowth would begin. The sequence of events in a peach meadow orchard would be: cuttings are planted in winter; 1 single shoot is allowed to develop during spring; when the shoot reaches a height of 60 cm it is headed back slightly to induce thicker laterals. By the end of the growing season tree height will reach 130 to 200 cm (depending on climate and cultivar), with many laterals. Normally, quite a few flowers developed on the 1-year-old wood. If fruit set conditions were favorable, a sufficiently large number of fruits developed to allow full cropping the second growing season (Table 1, Fig. 2). The size of the crop depends on cultivar, with early maturing cultivars producing yields similar to, or higher than, those of mature conventional orchards (Table 2a).

Lateral buds began to sprout from the stump left after harvest as early as 10 days after top removal. When harvest was early enough, the period to the end of the favorable growing season was sufficient to allow full regeneration of the tree skeleton, the main stem and laterals, as well as flower bud differentiation (Table 1). From observations made in the coastal plain of Israel (mean summer temperature = 24°C), it seems that 4 to 5 months are needed to complete the desired growth cycle. Of the new sprouts appearing, only 1 was left to grow and was treated similarly as in the previous year. Late vegetative development (which occurs in November in Israel) induced a delay in bloom and bud break next spring similar to what was found with peach trees that had a late vegetative flush after defoliation in mid-summer (6).

When heading back the tree, the bottom 5–10 cm of the basal 1-year-old wood bearing viable buds was left for regeneration. This technique led to a small elevation of the cutting plane every year. Not using rootstocks in this system was found beneficial, as the heading back was a strong stimulus for suckers to appear.

Preliminary experiments with a shaker-

Table 1. Fruiting potential and vegetative growth of some peach and nectarine cultivars, grown on their own roots.

Clone	Age (yr)	Meadow orchard system	Developing fruits per tree	Total tree height (cm) before bud break
Earligrande	2	Mechanized	12 ± 5[z]	179 ± 3
Earligrande	3	Mechanized	38 ± 5	193 ± 5
Earligrande	2	Intensive	64 ± 8	241 ± 9
1455	2	Mechanized	33 ± 4	140 ± 3
1455	2	Intensive	78 ± 12	187 ± 6
1372	2	Mechanized	137 ± 44	172 ± 5
Desertgold	2	Mechanized	52 ± 3	166 ± 7
Sunlite nectarine	2	Mechanized	49 ± 9	148 ± 8

[z] ± SE

Table 2. Yields in the meadow orchard, 1978–80. Data represent means of 5 to 10 single tree replicates in a full field orchard, with densities of 1.5 × 0.5 m (13,333 trees/ha). Orchard planted from hardwood cuttings in 1977, but for 'Earligrande' border row which was planted in 1976.

Clone	Row position	Yield kg/tree 1978	1979	1980	MT/ha/yr 1978–80	Mean fruit wt (g)
a. Mechanized system						
Earligrande	Inner	2.1	2.2	0.8	22.6	102.0
1455	Inner	2.0	2.3	2.1	32.1	94.3
1372	Inner	2.7	5.8	6.2	61.9	89.4
Desertgold	Inner	1.8	3.4	3.3	37.7	86.3
Sunlite Nect.	Inner	1.3	3.8	1.9	31.1	73.8
b. Intensive system						
Earligrande	Inner	[z]	5.1	2.8	53.8[y]	80.8
Earligrande	Border	3.0	3.2	3.4	42.7	98.4

[z]First crop obtained a year later due to a later planting, data taken from first crop in this system in 3rd year.
[y]Mean of 2 yr only.

Fig. 3. Eighth crop of the 'Sunred' nectarine that was headed back 7 times. Sde Moshe (southern coastal plain of Israel); planting density, 19000 trees/ha.

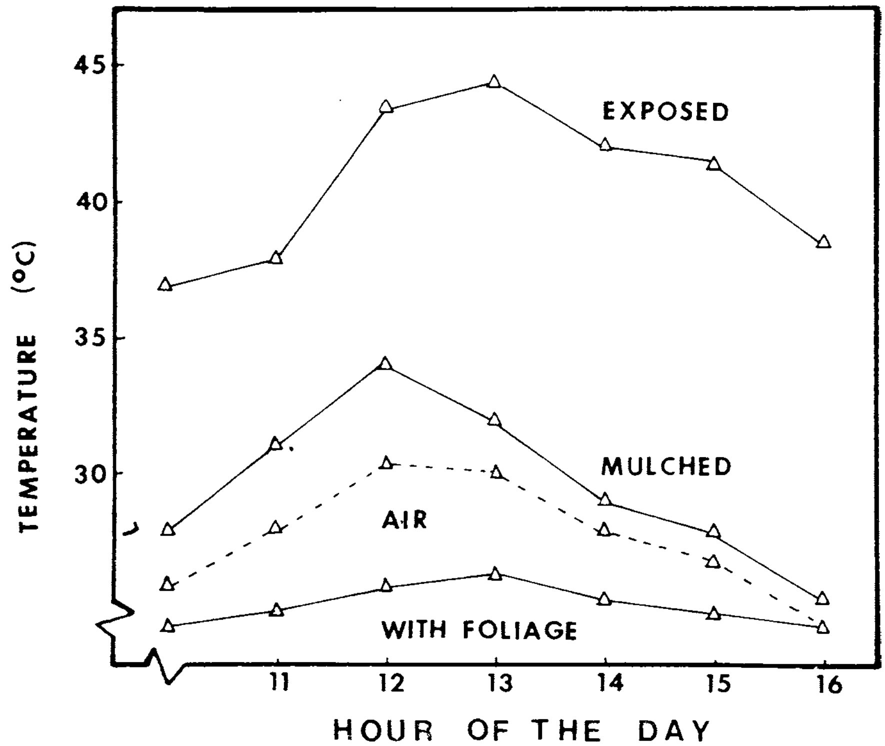

Fig. 4. Bark temperature of an exposed whitewashed stump and a stump shaded by the cut canopy in comparison with the bark temperature of an uncut tree and with air temperature in the shade (measured using 0.75 mm thermistor probes and a Grant Instruments miniature recorder).

conveyor unit (1) demonstrated the potential of separating peach fruits from a horizontally laid cut canopy with only little fruit damage. Studies with a built-to-order combine harvester gave promising results (Y. Alper, A. Erez, and R. Ben-Arie, unpublished).

The longevity of an orchard under the meadow system cannot be determined at this time. The first nectarine meadow orchard (7) has produced 9 crops (Fig. 3), but a peach meadow orchard planted on a poor soil suffered a heavy loss of trees and orchard decline following 4 crops. It seems that 2 factors influence the longevity of trees planted for the annually cut mechanized orchard: desiccation of the stump upon its exposure to direct sun irradiation, and nutrient deficiencies.

Temperature measurements of tree stumps exposed to direct sunlight showed values as high as 45°C even if the stumps were whitewashed. Probably the abrupt cessation of the cooling transpiration stream, together with the direct irradiation, contributed to trunk temperature elevation. Unless rapid leafing occurs, desiccation may prevent new growth from starting. By using the shredded tree tops as both mulching and shading material, heat stress could be alleviated considerably without negative effects (Fig. 4).

Nutrient deficiencies depend on the nutritional regime and the soil fertility. On poor sandy soils, microelement deficiencies appeared in the new growth from the stumps. Extremely low levels were found of 2 elements in particular: Zn and Fe. Continuous supply of these elements through the irrigation system overcame the problem, in most cases.

The mechanized peach meadow orchard has 2 main drawbacks: it is not suitable for cultivars ripening in mid- and late season, due to an insufficient time for top regeneration; and the shock to the plant is very severe due to complete removal of the green canopy, accentuating latent problems like a low level of certain elements, which lead to severe deficiencies. In addition, it was thought that with this severe operation the full potential of the high-density orchard could not be realized.

The mechanized system would provide advantages on a large farm, but would not suit the small family-farm due to the expensive machinery required. On the other hand, the advantages of an orchard of small trees that can be handled from the ground, has reasonable establishment costs,and is very precocious in cropping, are quite attractive for the small grower who is picking his fruit manually. Hence, another version of the peach meadow orchard was tried for that purpose.

The intensive system

This system separates pruning from harvesting and delays the former until late winter. The tree is trained to two main shoots rather than one, as in the mechanized system (11).

Every winter 1 of the 2 shoots is headed back to a short stump, allowing regeneration of new growth and flower bud formation in the course of the growing season. The other shoot is not pruned in winter; it fruits in summer, is headed slightly back after harvest to reduce shading on the adjacent growing shoot, and is pruned to a short stump next winter, so that every shoot fruits every second year (Fig. 5). In this system, annual fruiting could be obtained independent of time of harvest and the shock to the plant was reduced considerably by shifting the canopy topping from summer to winter.

Two main problems emerged with this system: one is how to obtain new vigorous annual growth from the shaded lower part of the tree; and the other is how to prevent shading of the lower part of the developing shoot by the remaining uncut shoot, so that flower buds would develop along the entire new shoot. By the removal of 1 arm in early winter, vigorous bud break was obtained on the cut shoot prior to leafing of the remaining intact shoot. This resulted in a reduction in shading and competition between growing apices of the 2 shoots, allowing for a vigorous start of growth on the cut shoot. The absence of leaf shade when the initial growth started from the low stump prevented the photomorphogenetic inhibition of growth (8). By the time leaf shade is produced in the tree, the growing young shoots are tall enough not to be affected. With early maturing cultivars, heading back of the bearing arm after harvest once or twice was needed to reduce shading on the lower part of the developing arm. With late-maturing cultivars, increased inter-row spacings seemed desirable; with arm orientation perpendicular to the row axis,and with annual pruning always on the same side of the row, shading from neighboring trees was reduced.

Yields on trees pruned by the intensive system (Table 2b, Fig. 6) increased considerably in comparison with the mechanized system. The intensive system had an increase in flower bud differentiation, fruit set, and yield per tree over the mechanized one. Enhanced fruit ripening also was achieved.

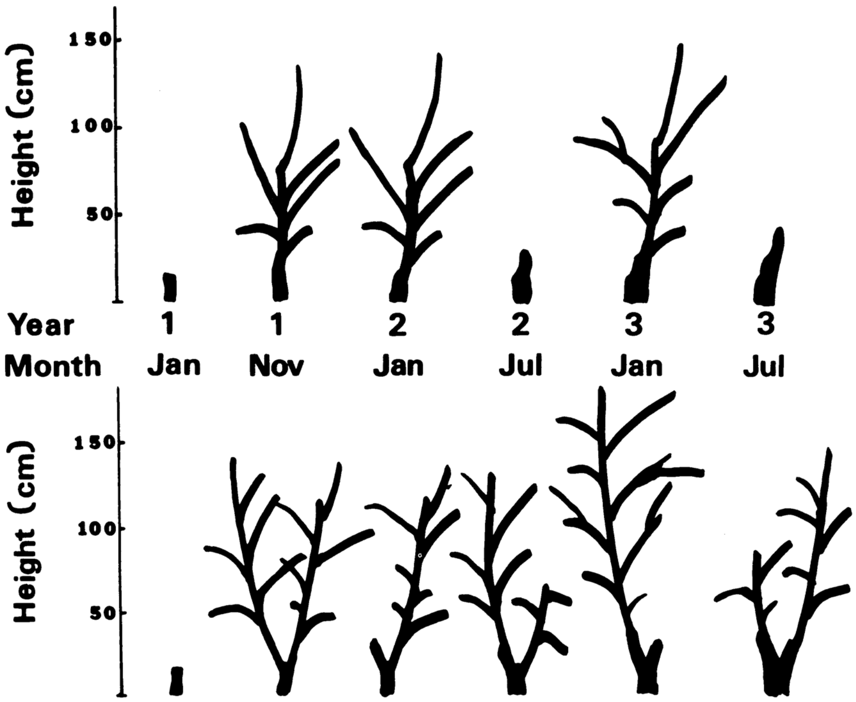

Fig. 5. A schematic comparison of the mechanized system (upper) vs. the intensive one (lower). Height as well as time of pruning are cultivar dependent.

Fig. 6. A fruiting arm in the intensive system. Cultivar 'Earligrande', tree height 2.2 m.

Both systems described excel in the tree's precocity in coming into bearing, in not requiring any tree support, and in the relatively simple and inexpensive means of establishing the orchard from rooted cuttings. This makes commercialization of the 2 systems feasible.

The mechanized system, although restricted to early maturing cultivars, provides an attractive method for high-volume production of high-quality peaches with a low labor input. The intensive system offers an orchard adapted for the small grower and for late-maturing cultivars. It also offers a high-yield system that can utilize mechanical aids well for orchard management.

The mechanized peach meadow orchard poses certain specific demands of the peach breeder: early maturation is required; the tree should be moderately vigorous in growth, with an upright growth pattern and a medium level of flower bud differentiation. The cultivar's cuttings should root easily and its fruit should be adapted to mechanical harvesting; i.e., be firm and non-melting when ripe, round in shape, large,and of course tasty and good-colored. Uniform bloom and ripening are important too. For warmer areas a low chilling requirement is an obvious demand. Introduction of nematode resistance to the cultivar is a trait that would be of benefit in nematode-infested peach-growing areas.

Optimal planting density will be the density that will produce a full field cover with foliage without creating too heavily shaded areas, so that maximum production will be obtained with high-quality fruit. This density depends on the cultivar and on the climatic and cultural conditions. Since from the practical point of view open alleyways along the rows are a necessity, the planting systems must be rectangular (Fig 7, 8).

In our experiments, densities of 1.30 × 0.4 m, 1.5 × 0.5 m and 1.8 × 0.6 m were tried with early maturing and vigorous peach and

Fig. 7. Partial view of a 2-ha commercial peach meadow orchard. 'Earligrande' peach planted January 1980; photograph taken in October 1980 at Talme Yafe (southern coastal plain, Israel).

Fig. 8. A single 'Earligrande' tree in a commercial meadow orchard. (Details as in Fig. 7).

nectarine cultivars. It was found that 1.5 m is the minimum between row distance and that 1.8 m is of advantage for the most vigorous cultivars. For the intensive system, planting at 1.5 × 0.5 m was definitely too close under our conditions (see Table 2b, inner and outer rows). Experiments with densities of 5000 to 10,000 trees/ha are in progress for both systems.

Mutual shading in the meadow orchard system can be a problem at certain critical stages. Even with extremely vigorous growth, shading on the regenerating canopy in summer and autumn is not a problem. However, heavy shade develops progressively from bud break until harvest the following year. With early maturing cultivars which leaf in early February and ripen in early May, this period is restricted to the last 4 weeks prior to fruit harvest. A layer of vigorous growth develops above the fruit level which casts shade on lower tree parts, similar to what was reported on apples (17). If the new growth is headed back above the fruiting area 1 to 2 weeks prior to harvest, uniform fruit ripening and enhanced fruit color are obtained. Excess vigorous growth can be reduced by crop loading and by preventing or reducing nitrogen application during the period between bud break and harvest.

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