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Raised Beds and Microirrigation Influence Peach Production

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Abstract. **The performance of peach trees [*Prunus persica* (L.) Batsch cv. Redhaven/Siberian C.] on raised beds as compared to the conventional flat (unraised) orchard floor surface was evaluated from 1982 to 1991. The raised bed was similar to the flat bed in cation exchange capacity (CEC), Ca, P, K, Mg, B, and Zn soil levels in the 0–15 cm depth. Microirrigation, using two 3.7 $L \cdot h^{-1}$ emitters per tree vs. no irrigation, was applied to trees planted in a north-south orientation on a silt loam, noncalcareous soil. Raised beds increased trunk cross-sectional area (TCA) and yield-efficiency over 5 years. Irrigation increased fruit mass mostly in years of highest evaporation. Significant year to year variations occurred in yield, fruit mass, TCA and yield efficiency. There were significant bed × year interactions for yield and TCA. Irrigation increased leaf boron content regardless of bed type. Leaf potassium was higher in flat beds. Nonirrigated trees had the lowest tree survival on the flat bed, but the opposite was true on the raised bed.**

Long-term performance of peach trees in Ohio and the Great Lake region depends on the management of the orchard floor, cultivar/rootstock selection, and cultural practices (Layne et al., 1994). Due to soils with high amounts of clay, more than 60% of Ohio soils require surface or subsurface drainage for optimal crop yields. Along with soil pH and soil fertility, soil water management is a major component determining increased total peach fruit volume and mass (Chessness and Couvillon, 1994). However, the interaction of tree canopy size, soil type, rainfall, and water use is complex (Funt et al., 1995). While there has been significant work in arid and semi-arid regions of North America with microirrigation (trickle) and peach production, irrigation practice in humid regions must consider additional water from rain. As a result, there is considerable inconsistency in peach yields due to seasonal variations in rain and stored soil moisture and differences in moisture in the root zone (Layne et al., 1994; Worthington et al., 1994). In almost every peach production area, irrigation of peach trees is recommended for optimal production and stress reduction. Trickle irrigation has reduced nematode populations (Funt et al., 1982b) and, by reducing stress on a peach tree, can increase yield, fruit size, cold hardiness, root distribution, and tree survival (Layne et al., 1994; Mitchell and Chalmers, 1982).

Many horticultural crops are grown on raised beds. On heavy soils, raised beds dry out more rapidly than flat or nonraised beds (Goulart and Funt, 1986). In previous studies with strawberries (*Fragaria×ananassa Duch.*) and raised beds, Goulart and Funt (1986) indicated that the upper two-thirds of soil on a raised bed contains less moisture, i.e., is drier, in May than the lower profile of the bed in June and July. Soil temperatures also fluctuate more widely on raised as compared to flat beds. The objectives of this experiment were to determine the cumulative effects of bed type (raised vs. flat) and irrigation for 5 years on specific characteristics of peach production.

Methods

A field experiment was conducted at the Overlook Research Farm near Carroll, Ohio (40° Lat. N, 82° Long. W), on a Cardington/Bennington (Cardington-Aquic Hapludalfs, fine, illitic, mesic; Bennington-Aeric Ochraqualfs fine, illitic, mesic) silt loam, noncalcareous soil. Ground limestone, P, and K were applied to the soil prior to planting according to soil test recommendations. In 1981, the soil, which had a sod cover, was plowed and cultivated. Raised beds were made using a road grading machine with a 3.7-m blade. The finished raised beds were 0.3 m high, 6.6 m wide at the bottom, and 2.1 m wide at the top. Additional surface grading was completed around the edges of the field to allow surface water to move away from the plots. Rows were 6.6 m center to center and were oriented north and south. 'Redhaven'/Siberian C peach trees were auger-planted at 3.9 m between trees in 1982. Replacement trees were planted in 1983. A soil probe was used to take samples at depths of 0–15 cm and 15–30 cm to determine nutrient availability in the upper and lower soil profile. Soil and leaf tissue samples from each replication were tested in 1988 at the same time to understand nutrient uptake in irrigated and nonirrigated plots. A single composite soil sample for a soil texture analysis was taken in 1994 from each bed type. Soil and leaf samples were sent to the Research and Extension Analytical Laboratory at the Ohio Agricultural Research and Development Center in Wooster for analysis (Dahnke, 1988).

A microirrigation system, using two 3.7 $L \cdot h^{-1}$ emitters per tree, was installed in 1982. The emitters were ≈1.0 m apart and 1.0 m from the trunk of the tree. Trees were irrigated daily beginning in mid-June and ending in early September using solenoid valves and time clocks. The amount of water (2.2 $L \cdot 0.3\ m^{-2}$) applied was based on full (1.0) Class A pan evaporation and the tree's downward projected canopy flat area. As the canopy size of the tree and the evaporation of the pan increased, the number of hours of irrigation was increased.

Soil matric potential (SMP; kPa) was measured with two sets of tensiometers in each bed type at 15-, 30-, and 45-cm depth (Fig. 1). They were placed in the center of the tree row between trees in the raised beds and the flat surface plots to account for the seasonal rainfall and stored moisture. Tensiometers were not placed near emitters and did not monitor irrigation. Tensiometers were read five times per week; an average weekly reading was calculated from each bed (nonreplicated) to graphically follow water infiltration from mid-June to mid-September. The tensiometer readings reflected the movement of water in both bed types.

Ground cover of 'Kentucky 31' fescue (*Festuca arundinacea* Schreb.) was established between rows including the sides of the raised beds. A weed-free area under the trees was maintained with herbicides throughout the entire experiment and was equal in width (2.1 m) in both types of treatments. Trees were pruned and fruit was hand thinned, when needed, to space fruit from 12.5 to 15.0 cm. N fertilizer was applied each year. Each mature tree received 0.11 to 0.20 kg actual N. Pesticides for insects and diseases were applied as recommended by The Ohio State Univ. Extension (Funt et al., 1982a).

Rainfall and evaporation were recorded using a Class A pan and hook gauge. Trunk circumference, measured at 10.5 cm above the bud union, was recorded at the end of each growing season. Trunk cross-sectional area (TCA) was calculated. Yield divided by TCA was used to determine yield efficiency. Fruit was harvested and weighed from 1987 to 1991. Ten fruits were randomly chosen and weighed to represent fruit size as mass per fruit. Harvest began during the last week of July, with three pickings over 7 to 10 days.

The experiment was a split-plot design with raised beds and flat surface as the main plots. There were two plots each of raised and flat beds. Within each main plot, there were five rows of six trees. Outer trees were used as

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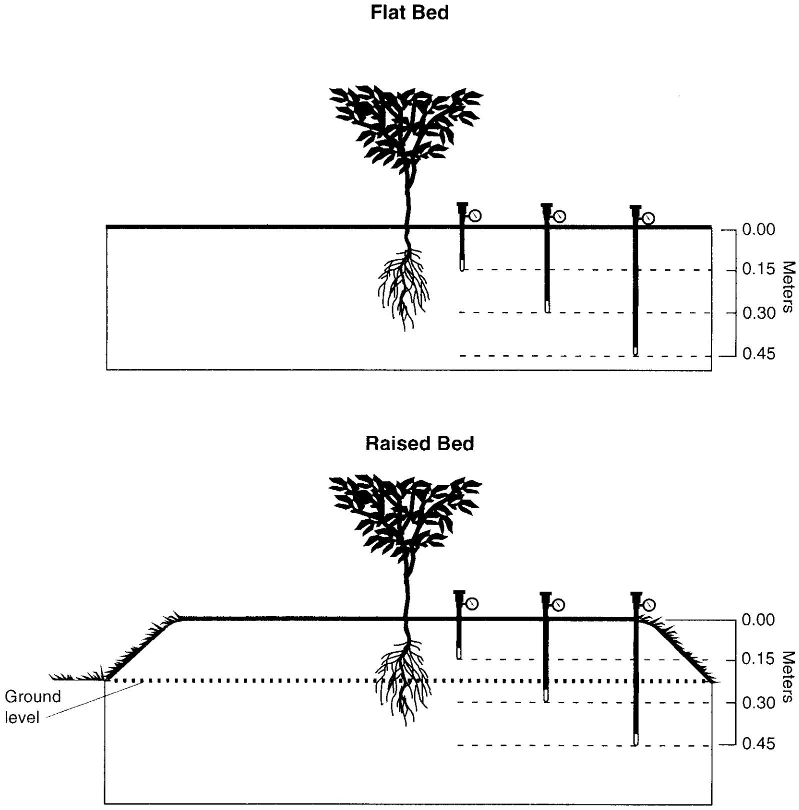

Fig. 1. Tensiometer depths in flat and raised bed of Redhaven/Sib C peach trees, Ohio.

border trees and irrigated and nonirrigated trees (two trees each/row) were randomly assigned. Irrigation or no irrigation was tested as a subplot. Analysis of variance techniques appropriate for a split-plot design were used to test for differences among factors. Irrigation × bed type interactions were tested in the subplots. Values for missing trees were adjusted. Probability values of 0.01 and 0.05 were considered to be highly significant or significant, respectively. Values from 0.051 to 0.125 were considered to be a trend but nonsignificant.

Results

Soil texture and fertility. The soil texture of the flat and raised beds was defined as a silt loam, noncalcareous soil regardless of bed type (Table 1). The percentage of sand at the 0–15 cm level was very similar for flat and raised beds.

At the 15–30 cm depth, the raised bed had 3.8% more sand as compared to the flat. The percentage of silt was similar in both bed types and at both depths. The raised bed had a similar percentage clay at both depths but the flat had 5.4% more clay at 15–30 cm depth than the 0–15 cm. The percentage of organic matter in the raised bed at the 0–15 depth was 0.13% lower than the flat but 0.28% higher at 15–30 cm depth. The pH of the raised bed was the same at both depths. The pH in the flat bed was 0.4 units lower for 0–15 and 1.2 units lower at the 15–30 cm depth than the raised bed.

There were no significant differences between bed types for CEC and mineral content. However, the raised beds tended to be slightly higher in CEC, Ca, P, K, and Zn at the 0–15 cm depth. The soil test results of the 0–15 cm depth for either bed type would be considered adequate for peach production in the midwestern United States (Cahoon, 1985). However, the pH (5.5) of the flat bed at 15–30 cm would be considered low.

Rainfall and soil moisture. The 1988 growing season had the highest daily average high and low temperatures and pan evaporation and the lowest rainfall for June to September during the years 1987 through 1991 (Table 2). The trees were in their seventh leaf and received the highest amount of water under the driest period from June to mid-July and the lowest amount from mid-July to mid-September. The 1989 and 1990 growing seasons were the coldest and trees received only the least amount of water per tree per day. The lowest winter temperature during the experiment was recorded at -28.9 °C on 22 Dec. 1989. The highest rainfall and lowest evaporation were in 1989. Rainfall was high during the first half of 1991, but was low during the second half of the harvest season. From establishment in 1982 to 1991, Ohio was subjected to many all-time weather records of cold, heat, rainfall and drought regardless of the season (data not shown).

The tensiometer readings at 15- and 30-cm depth for the driest year (1988) of the study show a majority of weeks above 40 kPa (Fig. 2). Only after significant rainfall (≈92 mm) in the 7th week were the readings of the flat and raised beds near 20 kPa for 1 week. From weeks 3 to 7, tensiometer readings were 10 to 30 kPa at the 45-cm depth for both bed types. Also, from weeks 11 to 14, the raised bed was erratic in moisture content at the 45-cm depth while the flat bed was steadily getting wetter.

In a wet year (1989), the tensiometers in the raised bed at all three depths started out at 70 to 80 kPa (Fig. 3). By the 4th week, the surface (15 cm) SMP was below 40 kPa and those at the 30- and 45-cm depths were approaching 40 kPa. The SMP of the flat surface began at 0 kPa and reached a peak in the 4th to 5th week being 50 at the 15-cm depth, 80 at 30 cm and 65 at 45 cm; then it declined to near zero at all three depths by the 7th week. The raised bed continued alternating with a dry to wet cycle, while the flat bed went to an opposite wet to dry alternating pattern every 2 weeks in the 15–30 cm depth. At the 45-cm depth, the raised and flat beds followed a parallel pattern below 40 kPa until the last week when the raised bed was drier than the flat bed.

Yield and fruit mass. There was a significant difference in yield between bed types (Table 3). Trees on raised beds were significantly higher in yield than those on flat areas. Trees on raised beds produced an average of 56% more mass per tree over the 5 years than those in flat areas. There was no difference due

Table 1. Soil characteristics and soil mineral concentration at 0–15 and 15–30 cm depth of raised and flat beds for peaches, Ohio.

	Raised (cm)		Flat (cm)	
Characteristic	0–15	15–30	0–15	15–30
Soil[z]				
Sand (%)	19.1	20.1	19.5	16.3
Silt (%)	63.7	62.6	62.9	60.7
Clay (%)	17.2	17.3	17.6	23.0
Organic matter (%)	1.33	1.12	1.46	0.84
pH	6.7	6.7	6.2	5.5
CEC[y, x]	8.7	---	7.9	---
Minerals[x]				
Ca	2673		2473	
P	92		73	
K	254		222	
Mg	544		568	
B	1.2		1.3	
Zn	12.8		8.0	

[z]Defined as a silt loam, noncalcareous soil regardless of bed type. Measurements taken in early 1994.
[y]CEC is in meq/100 g of soil and element levels are kg·ha^{-1} from soil samples taken from 0–15 cm depth in 1988.
[x]There were no significant differences ($P \leq 0.05$) between beds for CEC or nutrients.

Table 2. Average growing season temperature, rainfall, pan evaporation and daily amounts of irrigation per tree for peaches from 1987 to 1991.

	Seasonal temp (°C)[z]		Yearly		Pan evaporation	Irrigation per tree
Year	High	Low	Low (°C)	Rain (mm)[z]	(mm)[y]	(L·d^{-1})[x]
1987	27.9	19.0	–20.0	301	–234	14.8
1988	30.3	19.7	–20.0	243	–378	44.4 (43 d) 14.8 (52 d)
1989	26.1	18.3	–16.7	516	+9.4	14.8
1990	26.4	17.7	–28.9	380	–151	14.8
1991	29.9	20.2	–16.7	254	–280	14.8 (49 d) 59.2 (45 d)

[z]Average daily high or low for June through August and coldest temperatures. Year low occurred 23 Jan., 6 Jan., 9 Feb., 22 Dec. (89), and 16 Feb. from 1987 to 1991, respectively.

[y]Average for 3 months June–August from Class A pan.

[x]In 1988 trees had received 44.4 L·d^{-1} for 43 d in the early season and in 1991 trees received 59.2 L·d^{-1} to the end of the season for 45 d.

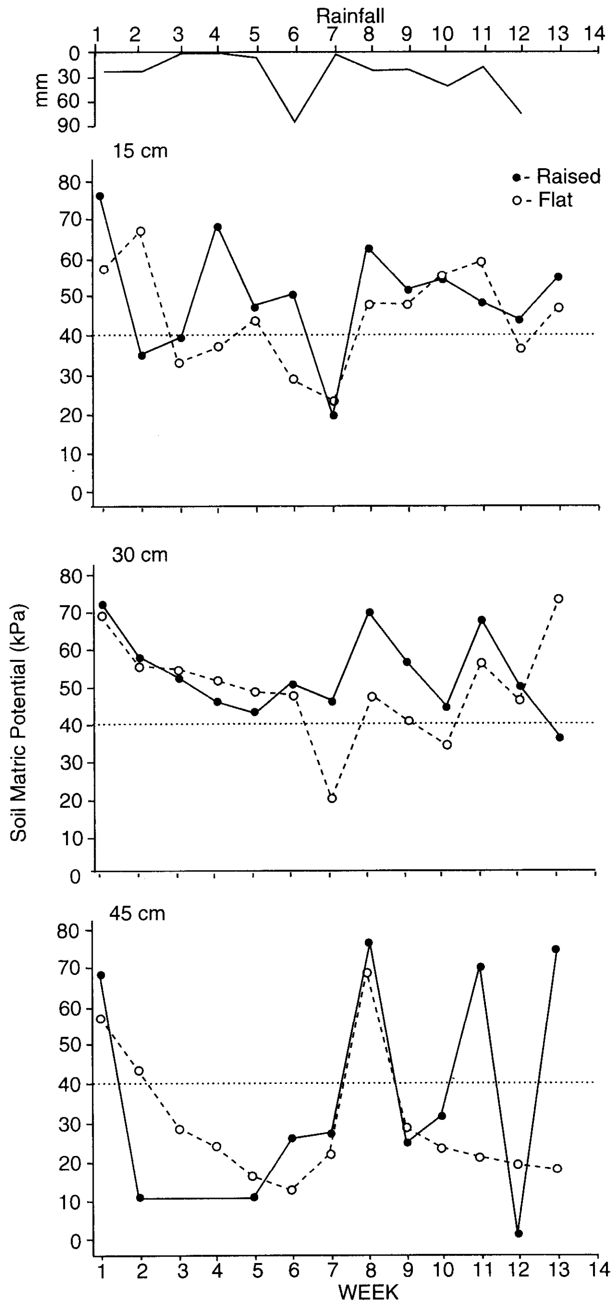

Fig. 2. Tensiometer readings in 1988 at 15, 30, and 45 cm deep in the soil beginning in mid-June and ending in mid-September on raised beds and flat surface planted to peach trees, Ohio.

to irrigation treatments or a bed × irrigation interaction. There was a bed × year interaction in yield. Trees on raised beds yielded more than those on flat beds in all years. However, the yearly differences in yield due to type of bed were smaller in the low producing year of 1990, being the likely cause for the interaction.

There were no significant differences among beds for fruit mass (Table 4). There was a trend for irrigation treatments: Trees on irrigated flat beds led to significantly heavier fruit in 1988 and 1989 ($P = 0.005$ and 0.021, respectively) than the nonirrigated flat bed (data not shown). Trees on irrigated raised beds had a higher fruit mass in 1991 ($P = 0.022$) and followed a trend for higher fruit mass in 1988 and 1989 ($P = 0.124$ and 0.123, respectively) than the nonirrigated raised bed (data not shown). There was no significant bed × irrigation or irrigation × year interaction.

There was a significant difference in fruit mass among years. When the treatment means were combined, the lightest fruit was in 1987 (0.123 kg/fruit). The fruit mass for 1988, 1989, and 1990 (0.191, 0.195, and 0.188 kg/fruit, respectively) was significantly higher than in other years; 1991 fruit mass was significantly higher than in 1987 but lower than in the previous 3 years.

Trunk cross-sectional area and efficiency. Trees on raised beds tended ($P = 0.066$) to have a larger TCA than trees on flat areas (Table 5). There was no difference in TCA among irrigation treatments nor a bed × irrigation interaction. There was an interaction between beds and year: Trees in raised beds had larger TCA in all years than trees on flat beds; however, trees on raised beds were more consistent in annual growth. When beds were combined in the analysis, there was a significant year to year increase in TCA. There was a trend for a bed × irrigation × year interaction. The major cause for the interaction is that year-to-year increases were more consistent for raised beds than for flat beds, particularly in 1988 and 1989 and in 1989 and 1990 on nonirrigated flat beds.

Trees on raised beds were significantly more efficient producers than those on flat beds (Table 6). Efficiency differed from year to year, with trees in 1990 being the least and those in 1987 the most efficient, regardless of bed type. There was no significant response due to irrigation or a significant bed × irrigation interaction for efficiency. There was a trend ($P = 0.11$) for an irrigation × year interaction.

Leaf mineral content. Only one leaf mineral analysis was conducted during the productive years (Table 7). Leaf N, P, Ca, B, and Zn concentrations were not affected by bed type. On the raised bed, Mg was significantly lower than on flat bed areas. Leaf K and B were significantly higher in trees on the flat than on raised beds. There was a trend for leaf P ($P = 0.097$) to be higher in the flat than in the raised bed. Leaf N and Zn were significantly lower on irrigated than nonirrigated trees on flat areas. Leaf P was higher in irrigated than nonirrigated flat trees. Irrigation significantly

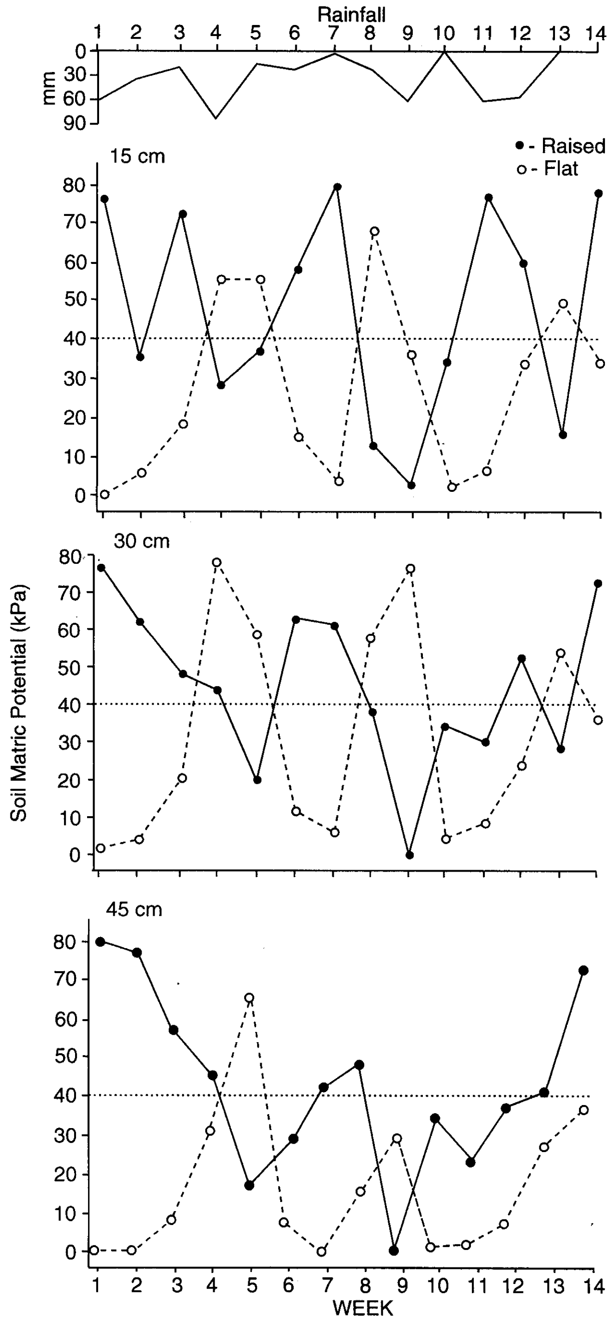

Fig. 3. Tensiometer readings in 1989 at 15, 30, and 45 cm deep in the soil beginning in mid-June and ending in mid-September on raised beds and flat surface planted to peach trees, Ohio.

increased leaf B on both bed types. There was no bed × irrigation interaction for B. There was a trend (P = 0.103) for K to be higher in irrigated plots.

There were 10 dead trees (25%) on the irrigated/raised bed and six (15%) on the non irrigated/raised bed at the end of the experiment in 1991. The irrigated/flat bed had six dead trees (15%) and the nonirrigated flat plots had 10 (25%). Dead trees showed severe trunk injury, trunk splitting, and branches separating away from the trunk.

Discussion

Yield, fruit, and tree size. Yield per tree is a function of fruit mass, number of fruit per tree and tree size. Trees on raised beds had significantly higher yield than those on flat beds. Fruit mass was not affected by bed type, which could be due, in part, to hand fruit thinning and the number of fruit per tree. Irrigation tended to increase fruit mass (P = 0.067) regardless of bed type, but there was a significant year to year variation, with smaller peaches in 1987 and 1991 than in other years. Fruit mass was increased by irrigation on raised beds in 1991 as compared to nonirrigated raised beds. However, there was a significantly higher fruit mass in irrigated flat beds in 1988 and 1989 as compared to nonirrigated flat beds.

Yield efficiency differed significantly between beds but was not affected by irrigation. Trees on raised beds had larger TCA and had higher yields as compared to those on flat beds. TCA increased in some years, but not in all years. This was a result of faster and more consistent growth on raised beds. Larger trees could have been a result of an improved root system with deeper roots in the raised bed while trees on the flat bed had restricted root volume.

Soil, soil moisture and irrigation. Root development may have been restricted in the flat bed treatments, resulting in smaller trees without any major difference in leaf elemental content. The leaf elemental content for all treatments was adequate. In Georgia, confining peach root systems to a 0.18-L container caused a 51% reduction in total dry weight and a 13-fold decrease in root volume (Rieger and Marra, 1994). Leaf area was reduced in the smallest container as compared to the largest; a decrease in leaf nutrient content was also observed. However, deficiency symptoms were not observed. They suggested that air and gas exchange were reduced by 29% and 39%, respectively, between the largest and smallest containers.

In Canada on Fox sand (89% sand, 8% silt, and 3% clay), photosynthesis (Pn) and stomatal conductance values of peach trees in each of 3 years, even in a dry year (1988), were similar among ground cover treatments (Layne et al., 1994). Irrigation treatments also had small effects on Pn and stomatal conductance in 1988. Thus, a portion of the root system must be able to extract sufficient water from deep in the soil (Layne et al., 1994). In our study, tensiometers measured soil moisture at 15-, 30-, and 45-cm depths. Tensiometer readings indicated that raised beds were drier, with moisture fluctuating more than for the flat at the 30- and 45-cm depths. It appeared that trees on the raised bed extracted moisture from lower depths than trees on the flat bed, particularly in 1988 and 1989 when trees on raised beds grew from 142 to 169 cm^2 while the flat bed trees grew from 108 to 127 cm^2 in TCA.

Strawberry plants on raised beds had a deeper, more uniform root distribution, indicating a more favorable environment for root growth as compared to flat beds (Goulart and Funt, 1986). A favorable environment for strawberry root systems consists of an optimal moisture availability between 20 and 40 kPa and some air filled pore space for gas exchange (Goulart and Funt, 1986).

In this study, a sod row middle and a herbicide clean culture system were used on the sides of the raised bed and to the drip line of the trees on the flat bed. A herbicide strip can promote surface rooting (Parker et al., 1993). Cultivar, ground cover, or irrigation treatments did not affect annual winter injury or canker incidence in peach (Layne et al., 1994). However, there was less canker in nonirrigated than irrigated treatments. Daily irrigated 'Redhaven', own-rooted peach tree roots had the greatest white root growth occurring after shoot growth had ceased and before leaf abscission in mid-October (Williamson and Coston, 1989). Cropping reduced length

Table 3. Yearly yield per tree of 'Redhaven'/Sib. C peach trees grown on raised or flat surface.

	Yield (kg/tree)			Significance,	
Year	Raised	Flat	Probability	bed	Mean[z]
1987	72.5	49.5	0.159	NS	61.0 a
1988	58.4	37.5	0.027	**	47.9 b
1989	50.6	27.8	0.064	NS	39.2 c
1990	14.2	9.7	0.106	NS	12.0 d
1991	46.4	30.8	0.032	**	38.6 c
Total	242.1	155.3	0.105	NS	
Mean	48.4	31.0			
Source	Probability	Significance			
Bed	0.0001	****			
Irrigation	0.248	NS			
Bed × irrigation	0.265	NS			
Year	0.0001	****			
Bed × year	0.008	**			
Irrigation × year	0.227	NS			
Bed × irrigation × year	0.662	NS			

[z]Mean separation in column at $P \leq 0.05$, LSD.

NS, **, ****Nonsignificant or significant at $P \leq 0.01$ or 0.0001, respectively, LSD.

Table 4. Fruit mass of 'Redhaven'/Sib. C peach trees grown on raised or flat surfaces, Ohio.

	Mass of peaches (kg/fruit)		
Year	Irrigation	Nonirrigated	Mean[z]
1987	0.126	0.120	0.123 c
1988	0.209	0.174	0.191 b
1989	0.207	0.183	0.195 a
1990	0.186	0.190	0.188 a
1991	0.168	0.162	0.165 b
Source	Probability	Significance	
Bed	0.654	NS	
Irrigation	0.067	NS	
Bed × irrigation	0.555	NS	
Year	0.0001	****	
Bed × year	0.879	NS	
Irrigation × year	0.378	NS	
Bed × irrigation × year	0.995	NS	

[z]Mean separation in column at $P \leq 0.05$, LSD.

NS, ****Nonsignificant or significant at $P \leq 0.0001$, LSD.

Table 5. Trunk cross-sectional area (TCA) of 'Redhaven'/Sib. C peach trees grown on raised or flat surfaces.

	TCA (cm^{-2})		
Year	Irrigated	Nonirrigated	Probability
	Flat Bed		
1987	95	87.5	0.336
1988	112	101	0.282
1989	128	109	0.072
1990	142	109	0.071
1991	194	149	0.096
Mean	134	111	
	Raised bed		
1987	119	133	0.260
1988	142	150	0.712
1989	162	169	0.732
1990	191	209	0.143
1991	235	231	0.255
Mean	169	183	
Source	Probability	Significance[z]	
Bed	0.066	NS	
Irrigation	0.688	NS	
Bed × irrigation	0.204	NS	
Year	0.0001	****	
Bed × year	0.002	**	
Irrigation × year	0.678	NS	
Bed × irrigation × year	0.103	NS	

NS, **, ****Nonsignificant or significant at $P \leq 0.01$ or 0.0001, respectively, LSD.

of white roots for 4 weeks, beginning at the second harvest date. The amount of shoot growth that can occur without subsequent root growth is limited by the root system's ability to supply water, mineral, nutrients, and hormones. Chalmers and van den Ende (1975) indicated a reduction in the annual increment of dry mass partitioned to the root system as peach trees aged. Increased fruiting is thought to be responsible for this reduction. Therefore, root development of young peach trees in August to September is of great importance to management. Further, Mitchell and Chalmers (1982) have shown that young peach trees can be grown quickly with a high evaporation replacement; after filling in their allotted space, a lower level of evaporation replacement can be used with no loss or even a gain in yield. In this study, peach trees were irrigated from establishment to the end of the project from mid-June to mid-September, and, therefore, received water during the critical time for young tree development. Since there were no differences among irrigation treatments, it appears that trees were able to acquire sufficient moisture.

In Maryland in 1977, trickle irrigation alone with Sunhigh/Sib. C peach trees on a silt loam soil, reduced certain nematode populations; irrigated trees had a significantly larger trunk circumference than nonirrigated trees. However, there was no difference among treatments in 1978, a wet year, as compared to the previous year when one-half of the 34-year average rainfall was recorded (Funt et al., 1982b). Siberian C rootstocks are more susceptible to nematodes than other rootstocks (Johnson et al., 1978). Thus, under ideal soil moisture conditions, regeneration of new roots can overcome the previous drought/nematode levels even on susceptible rootstocks. Further, tree survival was highest with irrigated trees.

Conclusions

Raised beds are capable of improving peach yields in Ohio in some years. Yields on raised beds are not affected by irrigation in that nonirrigated trees had similar total yields as irrigated trees. Raised beds improve yield efficiency over the conventional flat system with year to year variations. It appears that trees on raised beds are more capable of growing under adverse (wet to dry) conditions from year to year than these on flat beds, possibly because an environment that allows a high level of root regeneration and a root system capable of withdrawing more moisture deeper in the soil profiles.

There was no significant irrigation effect for fruit mass. However, irrigation tended to improve fruit mass on the flat-bed system, mostly in years of the highest evaporation. Even in 1989, a wet year, fruit mass on the conventional flat bed system was increased with irrigation. There was a trend for improvement of TCA with irrigated flat bed trees several years after the 1988 drought. There was no significant irrigation effect on raised beds for yield, TCA, yield efficiency or fruit mass except in 1991, a dry year.

Tree growth and yield are not solely dependent on leaf and soil elemental content. Optimal moisture conditions and space within the soil for the exchange of gases are necessary to provide a suitable environment for root growth and root regeneration laterally and vertically. These conditions are critical from planting until trees are mature for optimal production. Under Ohio conditions, raised beds provide an improved soil environment for improved tree growth and yield.

Table 6.Efficiency of 'Redhaven'/Sib. C peach trees grown on raised or flat surfaces.

Year	Efficiency (Yield/TCA[z]) Irrigated	Nonirrigated	Probability	Significance irrigation
		Flat bed		
1987	0.62	0.48	0.080	NS
1988	0.38	0.34	0.488	NS
1989	0.23	0.25	0.558	NS
1990	0.08	0.07	0.702	NS
1991	0.21	0.15	0.013	**
Mean	0.30	0.26		
		Raised bed		
1987	0.64	0.57	0.347	NS
1988	0.42	0.42	0.764	NS
1989	0.31	0.31	0.880	NS
1990	0.08	0.07	0.600	NS
1991	0.19	0.19	0.732	NS
Mean	0.33	0.31		
Source	Probability	Significance		
Bed	0.032	**		
Irrigation	0.316	NS		
Bed × irrigation	0.603	NS		
Year	0.0001	****		
Bed × year	0.364	NS		
Irrigation × year	0.110	NS		
Bed × irrigation × year	0.720	NS		

[z]Trunk cross-sectional area.

NS, **, ****Nonsignificant or significant at $P \leq 0.01$ or 0.0001, respectively, LSD.

Table 7. Leaf mineral content of 'Redhaven'/Sib. C peach trees grown on raised or flat surfaces, 1988.

Mineral	Treatment Irrigated	Nonirrigated	Probability	Significance irrigation
		Flat bed[z]		
% N	3.1	3.3	0.007	**
% P	0.28	0.23	0.040	*
% K	1.93	1.76	0.206	NS
% Ca	1.32	1.44	0.093	NS
% Mg	0.61	0.68	0.177	NS
B ppm	39.9	35.2	0.025	*
Zn ppm	24.3	27.5	0.001	***
		Raised bed		
% N	3.2	3.3	0.082	NS
% P	0.27	0.20	0.311	NS
% K	1.67	1.56	0.274	NS
% Ca	1.41	1.49	0.381	NS
% Mg	0.68	0.72	0.046	*
B ppm	36.4	31.9	0.016	*
Zn ppm	24.0	24.1	0.388	NS

	Significance Bed	Irrigation	Bed × irrigation
% N	NS	NS	NS
% P	NS	NS	NS
% K	**	NS	NS
% Ca	NS	NS	NS
% Mg	NS	NS	NS
B ppm	**	**	NS
Zn ppm	NS	NS	NS

[z]All levels of leaf mineral content are in acceptable range except for Ca where values should be above 1.5% (Shear and Faust, 1980).

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively, LSD.

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