J. AMER. SOC. HORT. SCI.113(4):518–525. 1988.

Influence of Cultivars, Ground Covers, and Trickle Irrigation on Early Growth, Yield, and Cold Hardiness of Peaches on Fox Sand

Richard E.C. Layne and Chin S. Tan
Research Station, Agriculture Canada, Harrow, Ont. N0R 1G0, Canada

Additional index words. *Prunus persica*, drip irrigation, cover crop, flower bud mortality, xylem injury, foliation

Abstract. **Three cultivars (early, midseason, late), two ground covers (clean cultivation followed by temporary cover vs. permanent sod strips), and trickle vs. no irrigation were studied in a high-density (633 trees/ha) experimental peach orchard established in 1980 on Fox sand. Growth rate in the first 5 years was similar for all three cultivars. It was retarded up to 12% by permanent sod relative to temporary cover and enhanced up to 30% by trickle irrigation vs. no irrigation. Total marketable yields and that of large-sized fruit (>6.3 cm) were significantly influenced by cultivars in the first and second, but not the third year of production. Ground cover treatments did not influence total marketable yields, but did affect the yield of large fruit in one year. Irrigation increased total marketable yields each year and also increased the yield of large fruit. Yields were up to 30.7% higher in trickle vs. non-irrigated plots. Cold hardiness of flower buds and shoot xylem in 1982 was significantly influenced by cultivar and irrigation treatments, but not by ground cover treatments; In 1984, each of these factors affected cold hardiness. Foliation in 1984 was affected by ground cover and irrigation treatments but not by cultivars. The best treatment combination across cultivars for management of the orchard floor consisted of permanent sod strips of creeping red fescue (*Festuca rubra* L.) in the row middles combined with trickle irrigation in the tree row.**

Low yields per hectare and short orchard life are major factors adversely affecting the economics of peach production in northern areas (7, 9). Winter injury and perennial canker (*Leucostoma* spp.) infection greatly reduce fruit bearing surface and cause early decline and death of affected trees (5, 7). Nematodes, especially root-lesion nematode (*Pratylenchus penetrans* Cobb.), adversely affect orchard establishment and contribute to replant failures (8, 13, 16). Thus, an effective long-term strategy may lie in the development of cold-hardy, canker-resistant cultivars and nematode-resistant rootstocks (7, 8). Parallel with this is the need to develop fully integrated, intensive, highly productive systems of orchard management that optimize fruit production while avoiding stress on scions and rootstocks, which might otherwise increase their vulnerability to winter injury, perennial canker, and nematodes (9, 11).

In a previous study, we showed that a combination of high tree density (536 trees/ha) and season-long sprinkler irrigation, every 7 to 10 days, outyielded low-density (266 trees/ha), non-irrigated check treatments by 2.4 times. The combination also had the potential of extending orchard life by 3 to 5 years because irrigated trees withstood stress from canker and winter injury better than those non-irrigated (9). The only potentially negative effect noted from sprinkler irrigation was that it induced shallow rooting (9). This could increase the risk of mechanical root injury from cultivation and freezing injury from low soil temperatures (8, 9, 13).

Trickle irrigation has a localized effect on shallow rooting near the emitters, but dóes not induce shallow rooting outside of the wetted zone (12). If emitters are placed only in the tree row, the shallow rooting response can be confined there and mechanical injury from cultivation can be avoided because only the row middles would be cultivated and herbicides could be used to control weeds in the tree row (13).

Received for publication 5 Oct. 1987. We acknowledge the excellent technical assistance of H.O. Jackson, A. Cornelisse, and E. Lamoure and the statistical advice of V.A. Dirks. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Traditional orchard floor management for peaches in Ontario involves clean cultivation from April to July and a volunteer cover crop of weeds or a seeded cover crop of Italian rye grass (*Lolium multiflorum* Lam.) from July to April (13). Clean cultivation stimulates rapid warming of the soil in the spring and rapid uptake of nutrients, especially N_2, in the early part of the growing season. Cessation of cultivation early in July encourages the cover crop to compete with the tree for nutrients and water, thus slowing tree growth and enhancing cold acclimation. The weed or grass cover also aids snow retention and protects peach roots from low-temperature injury during the winter.

Permanent sod strips in the row middles and a weed-free strip in the tree row offer a number of advantages over the former method. This system provides ready access to the orchard for spraying or harvesting, even after heavy rains. It provides a firm surface for passage of heavy machinery and reduces soil compaction and erosion. The sod cover eliminates the need for any cultivation; thus, mechanical injury to peach roots from cultivation is avoided. Some grass species also help to suppress nematodes (13, 16). Creeping red fescue provides a dense, low-growing sod that does not require frequent mowing to control growth.

Our experiment was designed to test the hypothesis that in a high-density system, permanent sod strips with trickle irrigation in the tree row might be more effective in terms of orchard productivity and longevity than permanent sod strips without irrigation or conventional ground cover management with or without irrigation. Here we report the results of the first 5 years, a preliminary report of which was made in 1984 (10).

Materials and Methods

The experimental orchard was established in 1980 on Fox sand. The water retention characteristics of this soil type were described earlier (11). The experiment involved three factors: cultivars as main plot treatments, ground covers as sub-plot treatments, and irrigation as sub-sub-plot treatments for a split-split plot established in a randomized complete block with five replications. There were four trees per cultivar for each experimental unit. Tree rows were oriented north to south to optimize

Table 1. Trickle irrigation schedule (1981 to 1984).

Year	Liters/day per tree	Duration
1981	9	19 May–15 June
	18	16 June–15 Sept.
1982	27	19 May–15 June
	36	16 June–2 Sept.
1983	27	16 May–15 June
	36	16 June–6 Sept.
1984	27	23 May–15 June
	36	16 June–15 July
	54	16 July–6 Sept.

light interception. Trees were spaced 3.05 m in the row and 5.18 m between rows to provide a density of 633 trees/ha. A guard row of 'Cresthaven'/Siberian C surrounded each replication. All trees were trained to a modified central leader. Weeds in the tree row were controlled manually by hoeing in the first year and with one or more seasonal applications of 1,1'-dimethyl-4,4'-bipyridinium salts (paraquat) as needed in subsequent years.

A representative cultivar from each maturity group of regionally recommended cultivars was selected. Thus, 'Garnet Beauty', an early season bud sport of 'Redhaven', represented the early season group. 'Harbrite' represented the midseason group, and 'Canadian Harmony' the late-season group. Siberian C was the common rootstock.

Two ground cover treatments were compared. One was the standard system recommended for Ontario peach growers, and consisted of clean cultivation from April to June followed by a cover crop of Italian rye grass (*Lolium multiflorum* Lam.) seeded in early July and worked the following March. The other consisted of establishment of permanent sod strips of creeping red fescue (*Festuca rubra* L.) in the row middles.

No fertilizer was used in 1980, the year of planting. Each year, beginning in 1981, a broadcast application of 190.5 kg of 0N–10P–30K fertilizer was made in the spring. A banded application of NH_4NO_3 at the drip line of each tree was made annually in April, beginning in 1981. The rate increased by 0.06 kg·year^{-1} from 0.11 kg/tree in 1981 to 0.28 kg in 1984.

Irrigation treatments consisted of full-season trickle irrigation or no supplemental irrigation. The trickle irrigation system was installed in late Sept. 1980. Vortex emitters, with a flow rate of 4.5 liters·hr^{-1}, were inserted into 13-mm internal diameter polyethylene pipe, 0.6 m from the tree base on the north and south sides of each tree. In 1980, all plots were irrigated equally by overhead sprinklers to aid in tree establishment. In 1981 and thereafter, irrigation treatments were applied through the trickle system as shown in Table 1. The amount of water used per tree per day was determined using corrected long-term evaporation derived from a Class A pan at a nearby weather station, tree age and density, number of emitter per tree, and emitter flow rate along with soil moisture retention characteristics (4, 14). The daily water required per tree increased as the season progressed and the age of the tree increased. Irrigation began in mid-May and continued to early September. The end of the irrigation season coincided more or less with the final picking of 'Canadian Harmony', the late-season cultivar. All trees received the same amount of water in any given season.

In the fall of each year, trunk circumference was measured 0.3 m above the soil surface. These measurements were converted to trunk cross-sectional area (TCA).

All fruit were removed by hand in the first and second year to facilitate tree growth and canopy development. A light crop was permitted in the third year by regulating crop load by hand-thinning fruit and spacing them about 20 to 25 cm apart. In the fourth and subsequent years, full crops were permitted with fruit spaced 10 to 15 cm apart by hand-thinning to ensure suitable fruit size. Each cultivar was harvested at the firm-ripe stage in

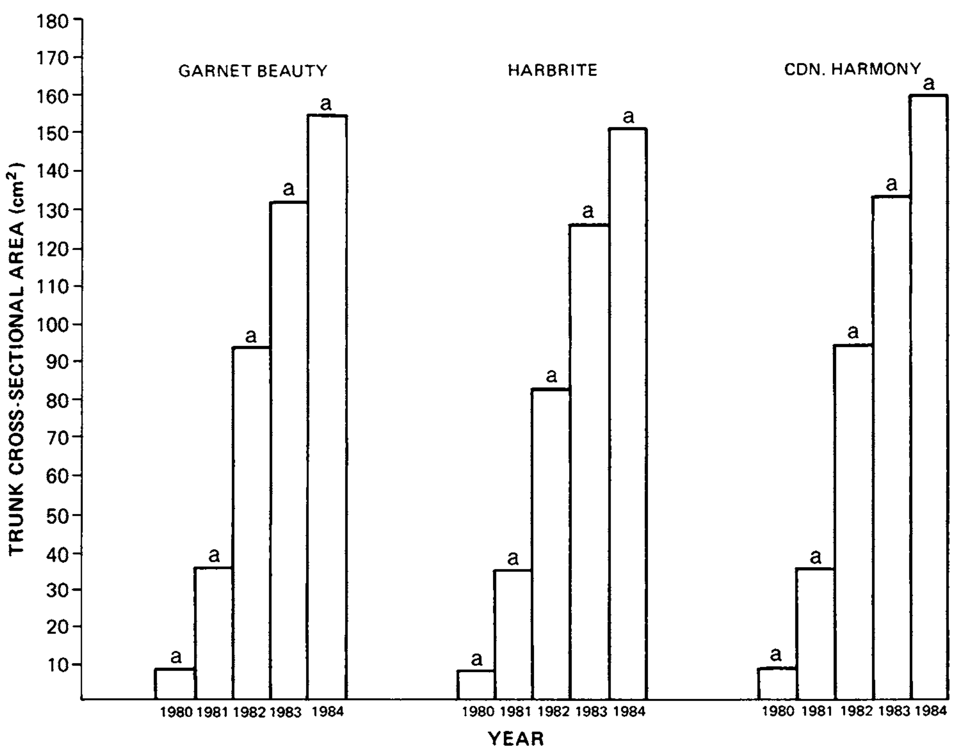

Fig. 1. Trunk cross-sectional area of cultivar (1980–1984). Vertical bars within years among cultivars having the same letter above the bars are not significantly different.

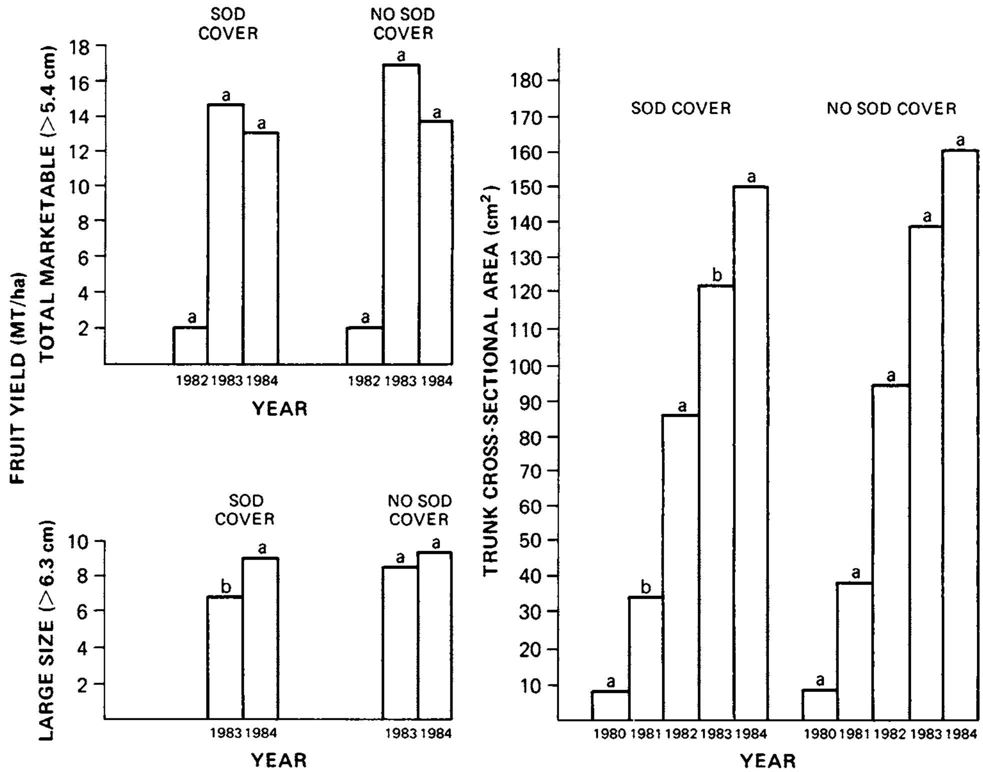

Fig. 2. Trunk cross-sectional area (1980–1984), total marketable yield (1982–1984), and yield of large-sized fruit (1983–1984) as related to soil cover. Vertical bars within years, within parameters, and between treatments having the same letters above the bars are not significantly different.

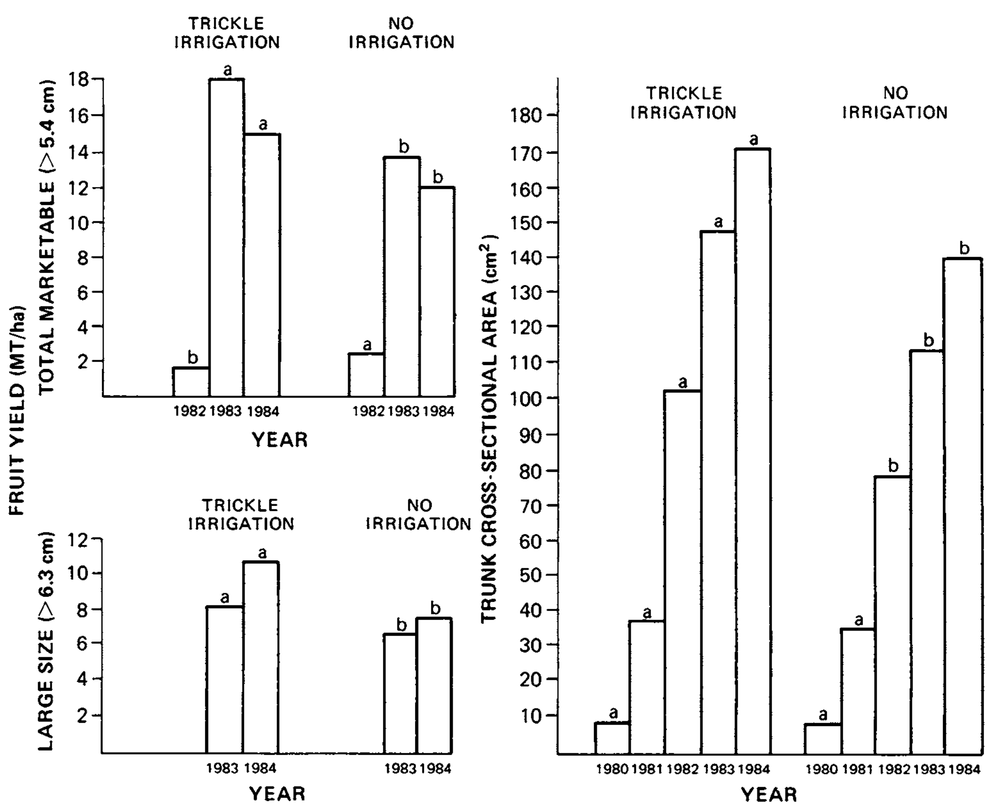

Fig. 3. Trunk cross-sectional area (1980 to 1984), total marketable yield (1982–1984), and yield of large-sized fruit (1983–1984) as a function of irrigation method. Vertical bars within years, within parameters, and between treatments having the same letters above the bars are not significantly different.

three or more pickings as required, and harvest weights were recorded in the field on a per-plot basis. Random samples of ungraded fruit, ≈20 kg per harvest per cultivar, were taken from each plot in each replication and first graded then weighed according to grade. The non-splits were graded into three size classes: small (<5.4 cm), medium (5.4 to 6.35 cm) and large (>6.35 cm). The proportion of fruit in each of the four grade classes was applied to the total yields to provide information on yields of marketable fruit. The yields of split pits and small-sized fruit were subtracted from total yields to give marketable yields. Marketable yields were further subdivided into yields of large and medium-sized fruit.

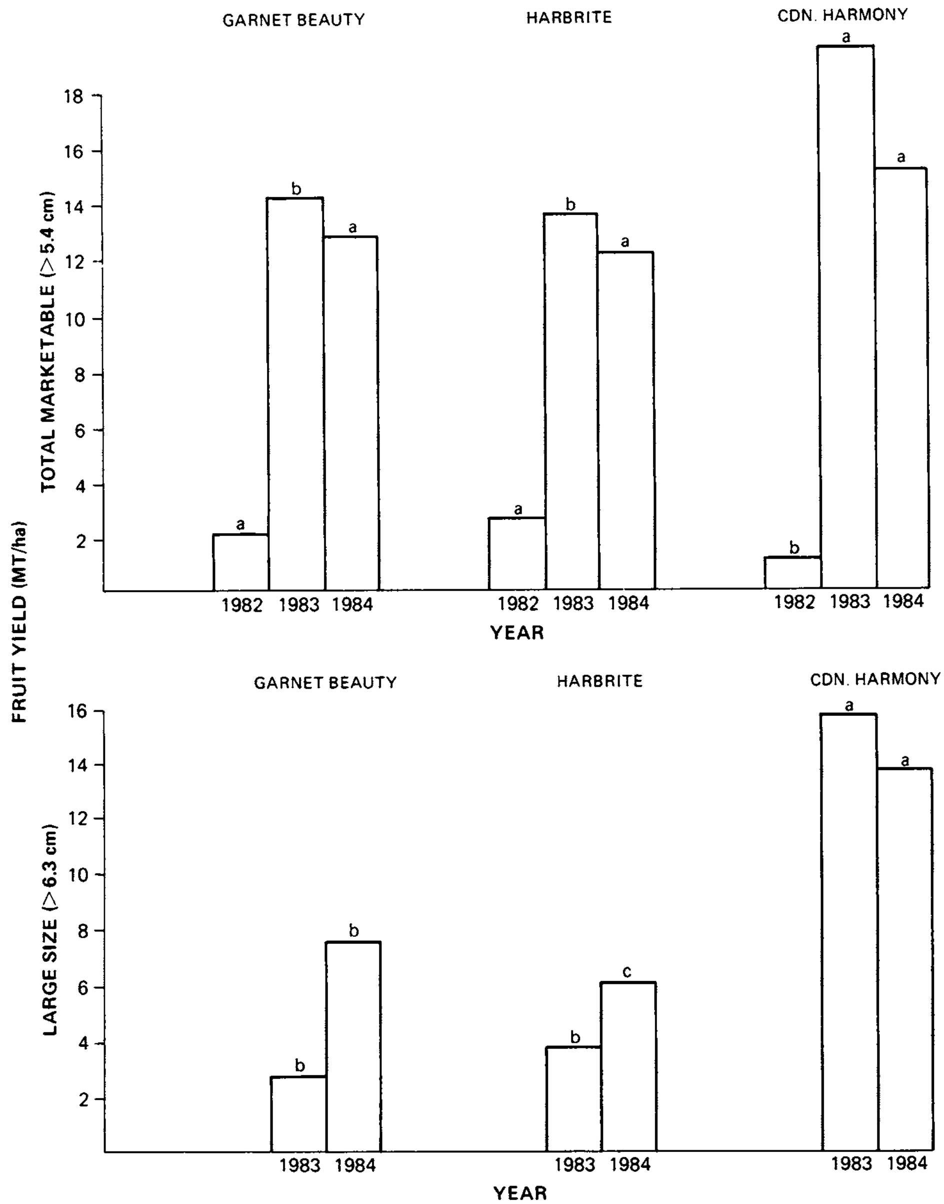

Fig. 4. Total marketable yields (1982–1984) and yield of large-sized fruit (1983–1984) of cultivars. Vertical bars within years between treatments having the same letters above the bars are not significantly different.

The winter of 1981–82 was severe with an outdoor minimum of −26.0°C being recorded in a standard weather shelter on 17 Jan. 1982. On 1 Mar., eight randomly selected shoots, including all of the previous season's growth, were collected from each plot. They were held in plastic bags at room temperature for 24 hr. The flower buds were dissected and rated as dead if the primorida were brown, or alive if green. Xylem injury was judged (5) and was based on a scale of 1 = no oxidative browning of xylem tissues to 5 = severe browning of all xylem tissues. The winter of 1983–84 was also very severe, with lows of −27.5°, −28.0°, and −19°C being recorded on 30 Dec. 1983, 26 Jan., and 1 Feb. 1984, respectively. On 20 Feb. 1984, 20 dormant shoots per cultivar per plot were collected from outdoors and flower bud mortality and shoot xylem injury were determined.

Trees were slow to foliate in Spring 1984 because of winter injury to the trees and suspected winter injury to the roots. Each tree was given a visual rating of foliation intensity on 8 June 1984 on a linear scale of 1 = none to 5 = heavy, where 1 = dead trees; 2 = trees with very sparse canopy and likely to die; 3 = trees with a light canopy of leaves and likely to survive, although in a weakened state; 4 = normal trees; and 5 = trees with a full canopy of leaves and appearing normal and healthy.

Each data set was analyzed first by analysis of variance (ANOVA) as a split-split plot in a randomized complete block. Single degree of freedom treatment comparisons were made for individual cultivars and interactions with multiple comparisons. The appropriate LSD (5%) and SE values for the cultivar, ground cover, and irrigation means were obtained from the single degree of freedom ANOVAs.

Results and Discussion

Treatments and interactions affecting trunk cross-sectional area (TCA). The three cultivars (Fig. 1) had approximately linear and similar annual growth rates as measured by TCA in the first 5 years; the cultivar effect on TCA was not significant.

Clean cultivation from April to July combined with a temporary cover crop from July to April was less competitive than permanent sod strips in the row middles (Fig. 2). Tree growth was expected to be greater with the former than with the more

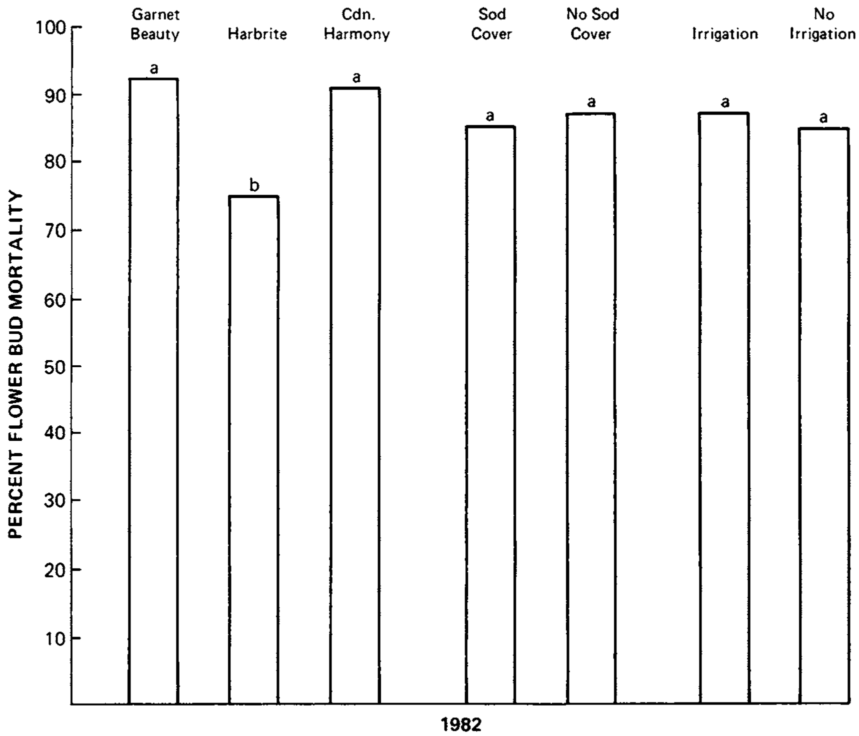

Fig. 5. Flower bud mortality as a function of cultivar, ground cover, and irrigation treatments (1982). Vertical bars within treatments having the same letter above the bars are not significantly different.

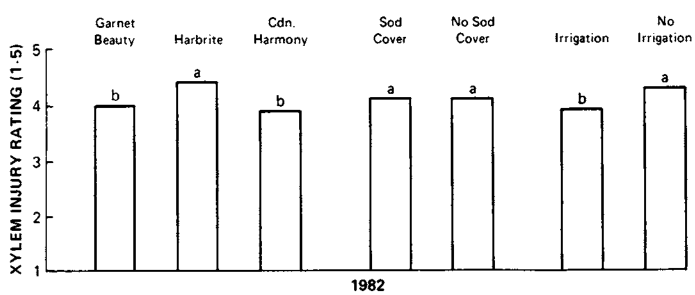

Fig. 6. Xylem injury amons cultivars, ground cover, and irrigation treatments (1 = none to 5 = severe; 1982). Vertical bars within treatments having the same letter above the bars are not significantly different.

competitive latter system, which was the case, but only in 1981 and 1983 were the differences large enough to be statistically significant.

Trickle irrigation (Fig. 3), compared with no irrigation, significantly improved TCA in the third, fourth, and fifth years, but had no effect in the year when this treatment was initiated. In 1980, all trees were uniformly irrigated with sprinklers to aid in tree establishment; thus, there was no irrigation effect on TCA. In previous work on this soil type, we showed that sprinkle-irrigated peaches grew better than those non-irrigated; those receiving a high rate of irrigation grew better than those receiving a low rate (9). Thus, it was anticipated that of the three factors studied, trickle irrigation would have the largest effect on growth, which it did (Figs. 1–3).

In 1981, the wettest of the five years (987 mm total precipitation), there was a significant cultivar × ground cover interaction on TCA but not in the other four years. Permanent sod strips retarded growth of 'Garnet Beauty' and 'Harbrite' relative to temporary cover, but had no effect on growth of 'Canadian Harmony', which is genetically more vigorous and later-maturing than the other two cultivars. There were significant ground cover × irrigation interactions on TCA in 1983 and 1984, the two driest of the four years with respective annual precipitation

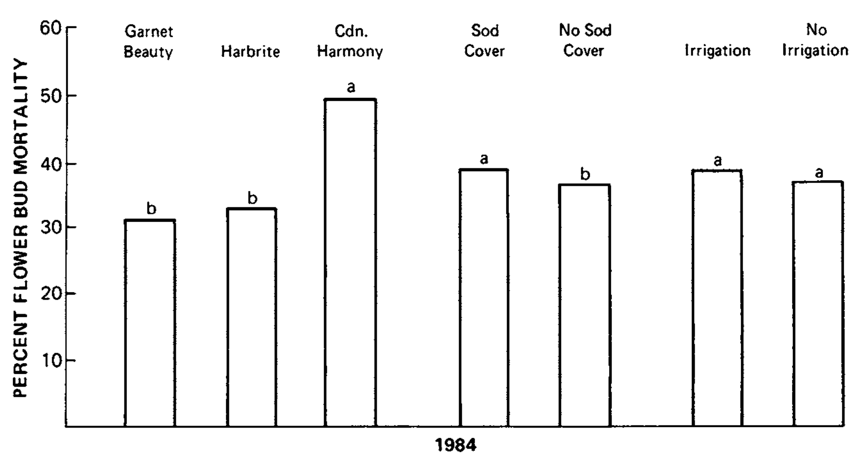

Fig. 7. Percent flower bud mortality among cultivars, ground cover, and irrigation treatments (1984). Vertical bars within treatments having the same letter above the bars are not significantly different.

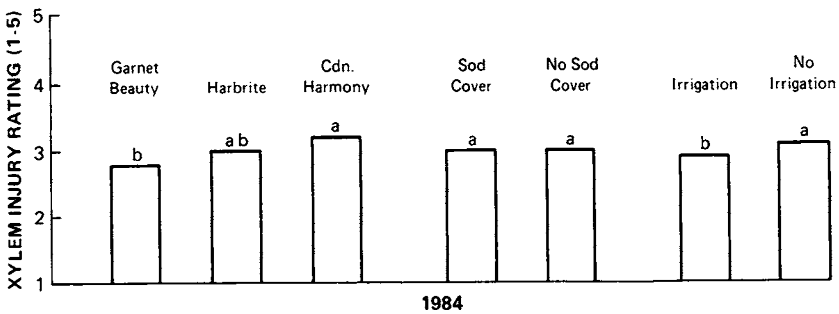

Fig. 8. Xylem injury among cultivars, ground cover, and irrigation treatments (1 = none to 5 = severe; 1984). Vertical bars within treatments having the same letter above the bars are not significantly different.

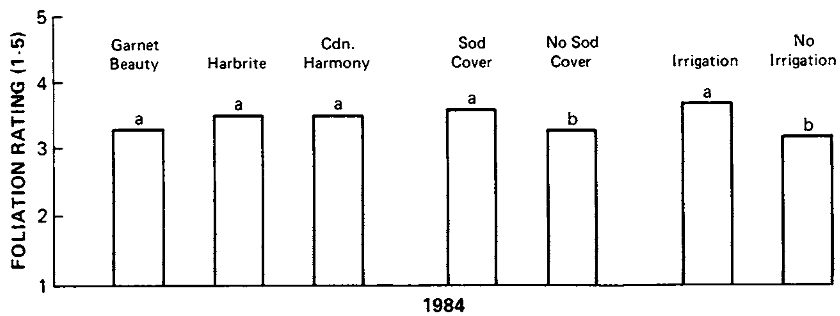

Fig. 9. Foliation rating among cultivars, ground cover, and irrigation treatments (1 = no foliation to 5 = complete leaf canopy; 1984). Vertical bars within treatments having the same letter above the bars are not significantly different.

of 844 and 846 mm. In 1983, the most growth was associated with temporary cover plus trickle irrigation followed in descending order by permanent sod plus trickle irrigation, temporary cover without irrigation, and permanent sod without irrigation. The average growth enhancement of trickle irrigation was 30%, while the average growth reduction of permanent sod was 12%. In 1984, growth was greatest under permanent sod plus trickle irrigation and was followed in descending order by temporary cover plus trickle irrigation, temporary cover without trickle irrigation, and permanent sod without trickle irrigation. Trickle irrigation improved growth by 23%, while permanent sod reduced growth by 6.6%.

Root injury was a factor in tree growth in 1984, but not in 1983, as will be discussed later. In 1984, the combination of permanent sod plus trickle irrigation presumably provided the most temperature protection of the four treatment combinations, and thus enhanced TCA the most.

Treatments and interactions affecting total marketable yields. Cultivars differed significantly in total marketable yields in 1982 and 1983, but not in 1984 (Fig. 4).

Precocity was a factor affecting cultivar differences in yields in 1982. 'Canadian Harmony' was the least precious of the three cultivars and had the lowest flower bud, bloom, and fruit set ratings (data not presented). Accordingly, this cultivar had a significantly lower yield than 'Garnet Beauty' or 'Harbrite', while the latter two responded similarly.

Fruit size was a factor affecting cultivar differences in total marketable yields in 1983. 'Canadian Harmony' consistently had larger fruit size than 'Harbrite' or 'Garnet Beauty'. This accounted for the significantly higher total marketable yield of 'Canadian Harmony' than of the other two cultivars in 1983. A similar trend was evident in 1984, but the difference was not large enough to be statistically significant.

Ground cover treatments did not affect marketable yields in the first three years of fruit production (Fig. 2). However, there was a significant cultivar × ground cover interaction in 1984. 'Harbrite' (midseason) and 'Canadian Harmony' (late-season) had reduced yields in permanent sod relative to temporary cover, while the opposite was the case for 'Garnet Beauty' (early season). Heat and drought stress were factors affecting yield in 1984. The early season cultivar was presumably affected the least because it had a shorter exposure to stressful conditions prior to harvest than the mid- or late-season cultivars.

Trickle irrigation significantly enhanced total marketable yields in 1983 and 1984 compared with no irrigation. By contrast, irrigation reduced yields in 1982 (Fig. 3). The negative effect of trickle irrigation on yields in 1982 was expressed as the tendency for irrigated trees to be more vegetative than those not irrigated. This resulted in a lower set of flower buds, and lower bloom and fruit set ratings than on non-irrigated trees (data not presented). Increased yields from trickle irrigation in 1983 and 1984, on the other hand, arose primarily from improved tree size, fruit bearing surface, and fruit size associated with irrigated vs. non-irrigated treatments. Other studies with sprinkler irrigation and trickle irrigation (2, 3, 9, 15) report similar results. Total marketable yields in 1983 and 1984 were 31% and 25% higher, respectively, in trickle-irrigated vs. non-irrigated plots.

There was a significant ground cover × irrigation interaction on yield in 1984. Yields in plots with temporary ground cover were similar whether irrigated or not. However, yields in plots with permanent sod were 58% higher with trickle vs. no irrigation. This indicated that the sod system was more competitive for water and nutrients than temporary cover, especially in a dry year. It further indicated that trickle irrigation was effective in overcoming the added competition imposed by permanent sod strips in the row middles.

Treatments and interactions affecting yield of large-sized fruit (>6.3 cm). There was a significant cultivar effect on the yield of large-sized fruit in 1983 and 1984 (Fig. 4). 'Canadian Harmony' outyielded 'Garnet Beauty' and 'Harbrite' each year, while the latter two cultivars had similar yields. Indeed, the greater part of the total marketable yields of 'Canadian Harmony' each year consisted of large-sized fruit (Fig. 4).

Ground cover treatments also differed significantly in their effect on yield of large-sized fruit in 1983, but not in 1984 (Fig. 2). Yields were 16% lower under permanent sod than under temporary cover in 1983.

Irrigation treatments had a larger and more consistent influence on yields of large-sized fruit than ground cover treatments (Figs. 2 and 3). Trickle-irrigated trees outyielded those not irrigated by 24% in 1983 and 43% in 1984. In 1983, there was a significant ($P = 0.01$) cultivar × irrigation interaction affecting yield of large-sized fruit. 'Canadian Harmony' responded more to irrigation than either 'Garnet Beauty' or 'Harbrite', while the latter two cultivars responded similarly. The late-season cultivar had a longer period of exposure to drought stress than the early and midseason ones and was therefore expected to respond more favorably to irrigation.

A premium price is paid for large-sized peaches on most markets. Thus, treatments that enhance fruit size are important. Our studies show that the choice of cultivars (Fig. 4) and use of irrigation (Fig. 3) have important influences on fruit size. If permanent sod is used in the row middles, then irrigation becomes even more important than if only temporary cover is used (Figs. 2 and 3) because the sod strip system is more competitive than the traditional system.

Treatments and interactions affecting cold hardiness. Low winter temperatures in 1982 (minimum air temperature = −26.0°C) caused high levels of flower bud kill, which ranged from 75% for 'Harbrite' to 91% for 'Canadian Harmony' and 92% for 'Garnet Beauty' (Fig. 5). 'Harbrite' had significantly less bud kill than the other two cultivars because it is genetically the most bud-hardy of the three (5, 6). Ground cover and irrigation treatments had no effect on bud kill. However, there was significant ($P = 0.01$) cultivar × irrigation interaction. 'Garnet Beauty' and 'Harbrite' had slightly higher levels of bud kill in irrigated vs. non-irrigated plots, while the opposite effect was noted with 'Canadian Harmony'.

There was a cultivar effect and an irrigation effect on shoot xylem injury, but no ground cover effect (Fig. 6). None of the interactions was significant. 'Harbrite' had more xylem injury than 'Garnet Beauty' and 'Canadian Harmony', which were similar to each other. There was more xylem injury in non-irrigated than irrigated plots, regardless of cultivar, which confirmed our earlier findings with sprinkler irrigation (9).

The winter of 1983–84 was more severe than that of 1982 (minimum air temperature = −28.0°C), but caused less flower bud kill than in 1982 (Fig. 7) because the environmental conditions were more favorable for cold acclimation. There was an important cultivar effect on flower bud mortality with 'Garnet Beauty' and 'Harbrite', which sustained only 31% and 33% bud kill, respectively, while 'Canadian Harmony', sustained 49%. The latter cultivar is typically less bud-hardy than the other two in most winters (5, 6). Ground cover treatments differed significantly in their effect on flower bud kill, being 7% higher under permanent sod than under temporary cover. Permanent sod placed more stress on the trees than temporary cover and contributed to the higher bud kill. Irrigation treatments had no effect on bud kill. None of the treatment interactions was significant except the cultivar × ground cover interaction. Bud kill was higher under permanent sod for 'Harbrite' and 'Canadian Harmony' than under temporary cover, while the opposite was found for 'Garnet Beauty'.

Shoot xylem injury in 1984 was significantly affected by cultivar ($P = 0.05$) and irrigation ($P = 0.01$), but not by ground cover treatments and none of the treatment interactions was significant (Fig. 8). 'Garnet Beauty' had the least xylem injury, 'Harbrite' was intermediate and 'Canadian Harmony' had the most. There was more xylem injury associated with non-irrigated than irrigated plots. This was also the case in 1983 (Fig. 7) and in our previous work with sprinkler irrigation (9). Both findings show that irrigation plays an important role in stress reduction, which, in turn, reduces stress-related disorders such as winter injury and perennial canker (*Leucostoma* spp.) infection (9). These disorders play major roles in reduced orchard life of peaches in northern areas (1, 7). Irrigation, besides reducing stress on trees, also promotes wound healing, which, in turn, decreases the risk of canker infection (1).

Treatments and interactions affecting foliation. Marked differences were noted in the rate of foliation in Spring 1984 following a severe winter characterized by unusually low air and soil temperatures. Minimum soil temperatures for the winter occurred during an absence of snow cover and were recorded 26 Dec. 1983 at a nearby weather station on a similar soil type. Under bare soil conditions, free of vegetation or snow cover, minimum soil temperatures recorded at the 50, 100, and 200 mm depths were −15.0°, −13.3°, and −11.1°C, respectively. Corresponding temperatures at the same depths but under a grass sod were −4.4.°, −4.1°, and −2.8°, respectively. The grass sod provided an average of 9.4° of temperature protection in the upper 200 mm of soil. On the basis of controlled root freezing studies conducted previously with Siberian C (8), it was evident that soil temperatures under bare soil were cold enough to cause root injury, while those under sod were not.

If above-ground injury were a major factor affecting foliation in 1984, then a significant cultivar effect would have been expected because the three cultivars differ in wood hardiness; however, such was not the case (Fig. 9). Only the ground cover and irrigation treatments affected foliation in 1984. The treatment combination expected to provide the greatest protection from cold penetration into the soil was permanent sod plus trickle irrigation, and it apparently did, because this combination was associated with the highest degree of foliation. By contrast, temporary cover without irrigation would be expected to provide the least protection of peach roots from deep cold penetration into the soil. Indeed, this combination had the slowest rate of foliation of the four ground cover × irrigation treatment combinations. Creeping red fescue used for the permanent sod strips provided a thicker, denser sod than Italian rye grass used for the temporary cover crop. It apparently also provided more temperature protection to peach roots than Italian rye grass, as indicated by the significantly higher foliation of peach trees under the former than under the latter cover crop (Fig. 9).

This is an interim report, halfway through a planned 10-year experiment, summarizing the early growth and yield data thus far. At this stage of the experiment, the best system of orchard floor management consists of permanent sod strips of creeping red fescue in the row middles combined with trickle irrigation in the tree row when the following factors were considered: tree growth, fruit production, fruit size, and protection from winter injury. The poorest system was the use of permanent sod strips without irrigation. Intermediate to these was conventional ground cover management with or without trickle irrigation.

Literature Cited

1. Biggs, A. and R.A. Cline. 1986. Influence of irrigation on wound response in peach bark. Can. J. Plant Pathol. 8:405–408.
2. Black, J.D.F. 1976. Trickle irrigation—a review. Part 1. Hort. Abstr. 46(1):1–7.
3. Black, J.D.F. 1976. Trickle irrigation—a review. Part 2. Hort. Abstr. 46(2):69–74.

4. Karmeli, D. and J. Keller. 1975. Trickle irrigation design. Rain Bird Sprinkler Mfg. Corp. Glendira, Calif.
5. Layne, R.E.C. 1982. Cold hardiness of peaches and nectarines following a test winter. Fruit Var. J. 36:90–98.
6. Layne, R.E.C. 1984. 'Harson' peach. HortScience 19:134–136.
7. Layne, R.E.C. 1984. Breeding peaches in North America for cold hardiness and perennial canker (*Leucostoma* spp.) resistance—review and outlook. Fruit Var. J. 38:130–136.
8. Layne, R.E.C. 1987. Peach rootstocks, p. 185–216 In:R.C. Rom and R.F. Carlson (eds.). Rootstocks for fruit crops. Wiley, New York.
9. Layne, R.E.C. and C.S. Tan. 1984. Long-term influence of irrigation and tree density on growth, survival, and production of peach. J. Amer. Soc. Hort. Sci. 109:795–799.
10. Layne, R.E.C. and C.S. Tan. 1985. Effect of cultivar, ground cover and irrigation on growth and yield of peach. HortScience 20:273. (Abstr.)
11. Layne, R.E.C., C.S. Tan, and R.L. Perry. 1986. Characterization of peach roots in Fox sand as influenced by sprinkler irrigation and tree density. J. Amer. Soc. Hort. Sci. 111:670–677.
12. Levin, I., R. Assaf, and B. Bravdo. 1979. Soil moisture and root distribution in an apple orchard irrigated by tricklers. Plant & Soil 52:31–40.
13. Marks, C.F., W.J. Saidak, and P.W. Johnson. 1973. Effects of soil management on numbers of the root-lesion nematode *Pratylenchus penetrans* in soils of Ontario peach orchards. Can. J. Plant Sci. 53:181–185.
14. Rass, D.S., P.A. Parsons, W.R. Detar, H.H. Fries, D.D. Davis, C.W. Reynolds, H.E. Carpenter, and E.D. Markwerdt. 1980. Trickle irrigation in the eastern United States. Northeast Regional Agricultural Engineering Service, NRAES-4.
15. Reeder, B.D., J.S. Newman, and J.W. Worthington. 1979. Effect of trickle irrigation on peach trees. HortScience 14:36–37.
16. Townshend, J.L., R.A. Cline, V.A. Dirks, and C.F. Marks. 1984. Assessment of turf grasses for the management of *Pratylenchus penetrans* and *Pratylenchus projectus* in orchards. Can. J. Plant Sci. 64:355–360.

J. AMER. SOC. HORT. SCI. 113(4):525–529. 1988.

Endomycorrhizal Status of Certified Strawberry Nursery Stock

William J. Robertson, C. David Boyle, and Heidi L. Brown
Nova Scotia Research Foundation Corporation, Dartmouth, N.S. B2Y 3Z7, Canada

Additional index words. *Fragaria* ×*ananassa*, soil fumigation, red-stele (*Phytophthora fragariae*) resistance, inoculation

Abstract. **Roots of several cultivars of strawberry (*Fragaria* ×*ananassa* Duchesne) were examined for mycorrhizae at the various stages required to produce nursery stock. First-year screenhouse plants were always non-mycorrhizal, but colonization of plants growing in fumigated foundation (2nd year) and certified (3rd year) fields was highly variable. As a result, certified stock being sold from Nova Scotia is often non-mycorrhizal. When present, mycorrhizae appeared to correlate with the presence of viable propagules in the soils after fumigation. In a greenhouse inoculation trial, all cultivars tested, including those with resistance to red stele disease (*Phytophthora fragariae* Hickman), became equally infected. Since mycorrhizae were also responsible for significant increases in growth and fruit production, inoculation of strawberry plants at the screenhouse stage is being considered.**

From an agronomic perspective, the primary function of endomycorrhizae is their ability to increase the transfer of nonmobile nutrients, such as P, to plants (13). Mycorrhizae also have numerous other effects that generally improve plant vigor (6).

In today's agriculture, fumigants commonly used to control soil-borne pathogens may also destroy beneficial mycorrhizal fungi. Plant growth in fumigated soils is often poor unless mycorrhizal fungi are introduced (12). Since fumigants are used in the production of certified strawberry plants, these plants might also benefit from inoculation. In the first year, nuclear plants are propagated in steamed soilless mixes in screenhouses. In the spring of each of the next 2 years, they are transplanted into fumigated fields (foundation and certified, respectively). Plants receive applications of various pesticides if required. Each autumn the explants are placed in cold storage. In Nova Scotia, a wide variety of cultivars are produced, some of which have been selected for resistance to fungal diseases, such as red-stele (*Phytophthora fragariae*).

Received for publication 13 Aug. 1987. This work was supported by the Canada/Nova Scotia Agri-Food Development Agreement. We express our appreciation to Ches Lockhart and Nancy Nickerson, Agriculture Canada, and nurserymen Gilbert Allen and Charles Keddy. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

The primary objective of this study was to investigate the development of endomycorrhizae in certified strawberry nursery stock. In addition, diverse cultivars, including some with red-stele resistance, were examined to determine if they differed in their susceptibility to colonization. Greenhouse inoculation trials were also conducted to test whether mycorrhizae can improve strawberry production.

Materials and Methods

Mycorrhizal status of certified stock and identification of endophytes. Certified strawberry plants of each available cultivar were collected from three nurseries in Nova Scotia in Spring 1985. In the laboratory, plants were shaken vigorously to remove adhering soil. The mycorrhizal spores associated with each cultivar at a nursery were recovered (3) and identified using the synoptic keys of Trappe (16). Root samples of each cultivar from each nursery were cleared and stained (10) using 0.1% Trypan Blue. To determine the intensity of infection, 60 randomly chosen 26-mm segments from 10 plants were examined under ×120 magnification using three points of observation on each segment.

In late Oct. 1986, certified nursery stock was collected from the fields. Ten plants from each of the seven most popular cultivars were randomly sampled from two of the nurseries. A secondary root containing many tertiary roots was removed from each plant. Entire root samples from each plant were individ-