High-density Apple Orchard Performance on an Orchard Replant Site: An 11-year Summary

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ADDITIONAL INDEX WORDS. slender spindle training, irrigation, fumigation, rid- onite, fruit size, yield, Malus domestica

SUMMARY. High-density apple (Malus domestica) orchard management techniques and productivity were evaluated on an old orchard replant site in North Carolina. Trees were planted at 5 × 10 ft (1.5 × 3.0 m), giving a tree density of 871 trees/acre (2152 trees/ha). Well-branched ‘Smooth Golden Delicious’ trees on ‘Mark’ rootstock were planted in 1990. Orchard-management factors which increased cumulative yield were supplemental irrigation (+17%), slender spindle training (+19%), preplant tree-hole fumigation (+21%), and fumigation + postplant mefenoxam (Ridomil) collar drench (+17%). Collectively, these factors increased cumulative yield by 55%. Supplemental irrigation was the only treatment to significantly impact fruit quality, increasing average fruit size by 20% over the 11-year study.

Dwarf, high-density orchards are the production systems of the future (Barritt, 1991; Williams and Barritt, 1991; Marini et al., 2001a). Dwarfing rootstocks that are productive are the key to high-density orchard success (Barden and Marini, 1999; Barritt et al., 1995; Ferree, 1995; Marini et al., 2000), but performance differences across climates need to be taken into account during orchard planning. Fernandez et al. (1997), documented the sensitivity of ‘Mark’ rootstocks to drought stress but across sites Mark has been one of the highest yielding rootstocks for ‘Gala’ (Marini et al., 2001a, 2001b). Irrigation is an important component in intensive orchard management (Drake and Evans, 1997).

Most high-density apple orchards will likely be planted in replant sites. Replant difficulties such as retarded growth, permanent tree stunting, delayed fruiting, reduced fruit production potential and/or reduced tree survival have been reported (Yadav and Doud, 1980; Traquair, 1984). These replant site problems have been attributed to many different factors (Slykhuis, 1990; Traquair, 1984) with equal diversity in treatments to overcome them. Preplant soil disinfection with biocides such as formalin (Covey et al., 1984) and methyl bromide (Koch et al., 1980) have resulted in improved tree growth. Monoammonium phosphate fertilizer has improved growth of apple seedlings in replant problem soils in northwestern U.S. (Neilsen et al., 1991; Slykhuis and Li, 1985). Preliminary tests in North Carolina indicated that preplant tree hole fumigation with methyl bromide alone or in combination with post plant, twice yearly soil drenches with mefenoxam (Ridomil M-91-97 formulation; Novartis, Greensboro, N.C.) greatly improved tree growth and fruiting in an old orchard replant site (Unrath et al., 1991).

Tree-training systems have become a focal point for optimizing early production and total performance of dwarf high-density orchards. Systems that have generated most interest include Central Leader (Heinicke, 1975); Vertical Axis (Granger and Philion, 1988; Lespinasse and Delort, 1986); Slender Spindle (Perry, 1990; Oberhofer, 1987; Wertheim, 1978) and many versions of the Spindle Systems (i.e., traditional, multirow, V-spindle and Y-spindle) (Robinson et al., 1991; Williams and Barritt, 1991). Training system and associated tree density can be strongly related to yield, but also depend on cultivar (Robinson et al., 1991).

The objective of this study was to evaluate which orchard management techniques contribute to enhance productivity of high density orchards in old orchard sites.

Methods and materials

ORCHARD ESTABLISHMENT. In
EXPERIMENTAL DESIGN. Overhead sprinkler irrigation was used on all plots to provide spring frost/freeze protection. A split plot design was used to evaluate supplemental over-tree irrigation, with half receiving only natural rainfall and the other receiving supplemental irrigation (SI) to achieve a minimum total application of 1 inch (2.54 cm) per week during the postfrost/freeze growing season. The two training systems and the four SA treatments were used as a 2 × 4 factorial design within each of the irrigation plots. Each plot consisted of eight trees and a ‘Snowdrift’ crabapple pollinizer separated each plot. Plots were replicated four times within each of the irrigation plots.

At harvest a 25-fruit random sample per plot was taken to evaluate quality. Total yield per plot was collected and used to calculate yield (all trees were defruited in the first two growing seasons). Yield data were analyzed using a split plot analysis with SI as the main plot factor and each of the eight seasons). Yield data were analyzed using a split plot analysis with SI as the main plot factor and each of the eight factorial treatments as subplots (Proc ANOVA; SAS Inst. Inc., Cary, N.C.). Mean separations were by Fisher’s least significant difference of SAS.

Table 1. Cumulative yield of ‘Smoothee Golden Delicious’ in response to irrigation, training system and soil amendment treatments growing on a replant site through eleven leaf.

| Soil amendments     | Yield (bushels/acre)
|---------------------|---------------------|
|                     | Mini central leader | Slender spindle
|                     | Supplemental irrigation | No irrigation | Supplemental irrigation | No irrigation |
| Check               | 5847                 | 5804                 | 8651                 | 4977                 |
| Fumigation          | 6783                 | 6270                 | 8556                 | 6480                 |
| Fumigation + mefenoxam | 7236              | 6074                 | 9008                 | 7216                 |
| Monoammonium phosphate | 4038              | 4463                 | 5712                 | 4721                 |

1 b bushel/acre = 0.047 t ha–1.

**Significance:** irrigation and training were significant at 5%, preplant treatment and the interaction of irrigation × training were significant at 1% and other two-way and the three-way interactions were not significant.

Table 2. Fruit size of ‘Smoothee Golden Delicious’ in response to supplemental irrigation in a replant site.

<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Fruit size (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3rd</td>
</tr>
<tr>
<td>Nonirrigated</td>
<td>156</td>
</tr>
<tr>
<td>Supplemental irrigation</td>
<td>178</td>
</tr>
</tbody>
</table>

**Significance**

1 g = 0.04 oz.

**Non** Significant or significant means at P = 0.05 or 0.01.
year yields in 1993, 1996, and 1998 and for cumulative yield in 1993–94 (data not shown), and did not persist to the end of the study (Table 1). The T × SA interaction was only significant in 1992, which had no impact on cumulative yield at the end of the study (Table 1). The three-way interaction of SI × T × SA was nonsignificant for all individual years, but was significant for cumulative yield in 1993, 1995 and 1996 (data not shown), however it was not significant at the end of the study (Table 1).

Collectively, the effect of SI, SS and T×R soil amendment improved cumulative yield by 55% over the nonirrigated, mini-central leader, non preplant treated, considered to be the control (Table 1), 9008 versus 5804 bu/acre (423.4 versus 272.8 t·ha–1), the control (Table 1), 9008 versus 5804 bu/acre (423.4 versus 272.8 t·ha–1), the nonirrigated, mini-central leader, proved cumulative yield by 55% over the central leader orchard was four times larger (data not shown). Through the eleventh leaf, the dwarf high density orchard required production through the seventeenth leaf to achieve a similar cumulative yield.

These data confirm the conclusion that irrigation is an essential management tool for optimizing intensive orchard management (Drake and Evans, 1997) and strongly agrees with the findings of Fernandez et al. (1997), that documented the sensitivity of ‘Mark’ rootstock to drought stress. Our soil amendment treatment results support the soil disinfection benefits of methyl bromide reported by Koch et al. (1980) and our preliminary findings with soil fumigation (Unrath et al. 1991) but disagree with the beneficial findings of MAP reported by Neilson et al. (1991) and Skyhuis and Li (1985). While they reported improved apple seedling growth with MAP in replant problem soils, our results with MAP showed a dramatic decrease in fruit production in our replant orchard site. These data collected in a high-density orchard setting support the suggestion of Robinson et al. (1991), that training system is strongly related to yield. Our results suggest that this association is related to both increased early production potential and to improved longevity of production.

These data demonstrate that dwarf, high-density apple orchards can be very productive in the climatic conditions of the southeastern U.S. Growers who will commit to providing the necessary orchard management (including preplant soil amendments, such as fumigation, to overcome soil replant problems, intensive tree training for optimal branch development and commit resources and close attention to the irrigation needs for dwarfing rootstocks can expect high, early and sustained production potential from these orchards. Such plantings should generate sufficient return to justify the high cost of orchard establishment (soil amendments, high tree numbers and tree support system costs).

Optimally productive, profitable dwarf high-density orchards will have to integrate appropriate rootstock size successfully for a specific training system into an acceptable orchard spacing, which will likely vary with cultivar vigor, as well as soil fertility and replant site considerations.

**Literature cited**


Amendment of Musk melon and Watermelon Transplant Media with Plant Growth-Promoting Rhizobacteria: Effects on Seedling Quality, Disease, and Nematode Resistance

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Additional index words. angular leaf spot, cantaloupe, Citrullus lanatus, Cucumis melo, gummy stem blight, root-knot nematode, transplant production

Summary. Greenhouse and field trials were performed on muskmelon (Cucumis melo) and watermelon (Citrullus lanatus) to evaluate the effects of six formulations of plant growth-promoting rhizobacteria (PGPR) that have previously been shown to increase seedling growth and induce disease resistance on other transplanted vegetables. Formulations of Gram-positive bacterial strains were added to a soilless, peat-based transplant medium before seeding. Several PGPR treatments significantly increased shoot weight, shoot length, and stem diameter of muskmelon and watermelon seedlings and transplants. Root weight of muskmelon seedlings was also increased by PGPR treatment. On watermelon, four PGPR treatments reduced angular leaf spot lesions caused by Pseudomonas syringae pv. lachrymans, and gummy stem blight, caused by Didymella bryoniae, compared to the nontreated and formulation carrier controls. One PGPR treatment reduced angular leaf spot lesions on muskmelon compared to the nontreated and carrier controls. On muskmelon in the field, one PGPR treatment reduced root-knot nematode (Meloidogyne incognita) disease severity compared to all control treatments.

In the state of Florida, over 13,659 ha (33,750 acres) of watermelons and 2,833 ha (7,000 acres) of muskmelons were grown in 1997–98 season (Florida Department of Agriculture, 1998). Florida growers currently face the loss of methyl bromide, the soil fumigant used to control many soilborne pathogens, nematodes, insects, and weeds. The Food Quality Protection Act (FQPA) also has accelerated the removal of other chemicals used in vegetable production from the market as industry declines to reregister older pesticides. This has resulted in research efforts focused on the development of agricultural systems based on reduced chemical inputs and an increased incorporation of biological control tactics. Plant growth-promoting rhizobacteria have been shown to enhance plant growth and protect roots from pathogens on many crops (Weller, 1988). One of these PGPR formulations, Kodiak (Gustafson LLC, Plano, Texas), is a biological seed/hopper box treatment for use in agronomic crops. Kodiak contains Bacillus subtilis (strain GB03) that has been shown to promote plant growth and increase yield in peanut (Arachis hypogaea) (Turner and Backman, 1991) and cotton (Gossypium hirsutum) (Branen and Backman, 1993, 1994).

Soilless transplant growth mixes are an ideal medium for delivery of PGPR in transplanted crops. This ap-