or 48-cell market packs before being transplanted to the field 7 weeks after emergence. Early marketable and total yield were similar for plants held in plug trays for 1 to 4 weeks, despite the considerable differences in transplant size (Table 1). In comparing 5- and 7-week tomato transplants, Cooper and Morelock (1983) noted that 5-week-old plants had greater total yields, whereas 7-week-old plants yielded earlier. Liptay et al. (1981) indicated that plants with small stem diameters produced lower early and total yields. Weston and Zandstra (1986) used small transplants that were comparable in size to the 6- and 7-week plug plants used in this study, with similar reductions in early yield. Also, they reported that early yields increased with larger-size plants.

The results of this study indicate that plants of the same physiological age, but varying considerably in size at transplanting, produce similar early yields. Therefore, seedling plants may be held in plug trays for up to 4 weeks followed by 3 weeks of growth in a larger container and thereby reduce space that would be required for a full 6 weeks in the larger containers. Although no field studies were done to confirm production potential of plants held in plug trays, it appears that plants may be held for up to 6 weeks. By 6 weeks, however, some reduction in regrowth potential was observed in plants from the 406- and 648-plug trays. Field studies under differing environments are needed to explore applications of plug transplant production for tomatoes.

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Tree and Fruit Growth of 'Napoleon' Cherry in Response to Rootstock and Planting Method

Anita N. Miller[1], Porter B. Lombard[2], Melvin N. Westwood[3], and Robert L. Stebbins[4]

Department of Horticulture, Oregon State University, Corvallis, OR 97331

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Abstract. **'Napoleon' grafted onto Colt, F/12-1, and MxM60 rootstock were planted into three types of tree holes: augered; backhoed, and backhoed plus fumigation. The auger treatment resulted in lower yields, smaller trunk cross-sectional area (TSCA), and smaller canopy volume when compared to backhoed holes. Fumigation had no significant effect. Trees on Colt rootstock were more precocious, had a smaller TCSA and canopy volume, greater cumulative yield efficiency, and, in 1987, the smallest fruit weight. The yield efficiency of Colt was the highest until 1988, when it was surpassed by MxM60, but was still similar to F/12-l. Yields were highest on trees of MxM60 in 1987 and 1988.**

Sweet cherries in western Oregon are sometimes grafted onto the *Prunus avium* L. clone F/12-l. This rootstock has good resistance to bacterial canker disease caused by *Pseudomonas syringae* pv. *syringae* Van Hall. Highly susceptible to bacterial canker, yet horticulturally desirable, genotypes such as 'Napoleon' are high-budded or grafted onto limbs of F/12-l to decrease tree losses (Cameron, 1971). However, F/12-l produces vigorous trees that are often slow to begin bearing (Stebbins et al., 1978).

Clones of hybrids between mahaleb *(Prunus mahaleb)* and mazzard *(P. avium)* were selected by L. Brooks, an Oregon nurseryman. Growth control and canker resistance on several of these rootstock have been reported (Stebbins et al., 1978; Westwood, 1978; Stebbins and Cameron, 1984; Perry, 1987). However, because of undesirable characteristics, such as excessive suckering (MxM2), weak understock (MxM97), drooping growth habit (MxM39), and excessive dwarfing (MxM14), only MxM60 remains as a promising rootstock. Previous research by Stebbins and Cameron (1984) determined that trees on this rootstock suckered more than F/12-1, but were only two-thirds as large. MxM60 is also resistant to *Phytophthora cambivora* (Petri) Buisman and *P. megasperma* Dreshler (Cummins et al., 1986).

A hybrid of *Prunus avium* x *P. pseudocerasus,* named Colt, was released by East Mailing Research Station, U.K. This rootstock is easy to propagate, *Phytophthora-tolerant*, precocious, and resistant to the bacterial canker-causing organism *Pseudomonas syringae* pv. *morsprunorum* (Mircetich and Matherton, 1981; Webster, 1984). Undesirable characteristics of Colt reported are poor drought tolerance, lack of winter hardiness, and lack of size control (Cummins et al., 1986; Oosten, 1979; Zahn, 1980).

New cherry orchards are often planted into

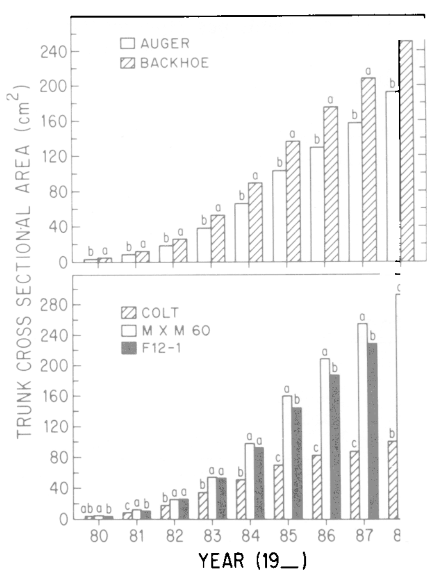

Fig. 1. Effect of preplant treatment and rootstock on trunk cross-sectional area of 'Napoleon' cherry trees from 1980 to 1988. Means separation by Wailer-Duncan k-ratio t test, k-ratio = 100. Means were obtained from 10 replicate trees.

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[1]Assistant Professor.
[2]Fu11 Professor.
[3]Emeritus Professor.
[4]Extension Specialist.

Table 1. Cherry rootstock and preplant treatment effects on flowering density of 'Napoleon' over 3 years and canopy volume (m^3) in 1988.[z]

Variable	Flowering density (%)[y] Year 1985	1986	1987	Canopy volume (m^3)[x] 1988
Rootstock				
F/12-1	19 b	44 c	47 c	62.6 a
M × M60	21 b	56 b	67 b	56.0 a
Colt	65 a	77 a	90 a	26.8 b
Significance	**	**	**	**
Hole preparation				
Auger	30 b	54 b	65	34.9 a
Backhoe	40 a	63 a	66	50.0 b
Backhoe + fumigation	35 ab	61 ab	71	60.4 c
Significance	*	*	NS	**
Preplant treatment × rootstock				
Significance	NS	NS	NS	NS

[z]Means separation by Wailer–Duncan k-ratio *t* test, k-ratio = 100. Means were obtained from 10 replicate trees.

[y]Percentage of tree covered with flowers.

[x]Canopy volume was calculated as a spheroid: $4/3\ \pi\ a \cdot b^2$, where a = 1/2 of the major axis and b = 1/2 of the minor axis.

*,**,[NS]Significant at $P = 0.05$ and 0.001 or nonsignificant, respectively.

old orchard sites. Potential replanting problems, such as increased tree mortality, low tree vigor, increased disease incidence, and lower yields, have been encountered. Frequently, the soils are heavily compacted. Vigor above a minimum level is required for trees to produce consistent annual yields.' Cultural practices used in the planting year can affect vigor over years. The size of the tree hole and soil fumigation may have significant effects on shoot growth (Auxt et al., 1980). A conventional auger hole often creates a compact hole wall that remains evident over time and restricts root growth. Therefore, a study was established to evaluate the influence of three rootstock and the effect of three preplant treatments — augered, backhoed, or backhoed plus methyl bromide fumigation—on early tree growth and yields.

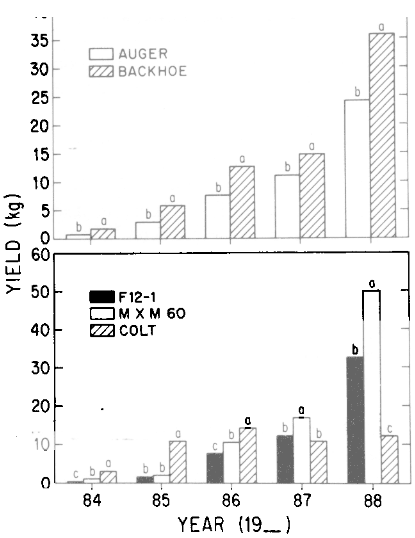

Fig. 2. Effect of preplant treatment and rootstock on yield of 5- to 9-year-old 'Napoleon' cherry trees planted in 1980. Means separation by Wailer-Duncan k-ratio *t* test, k-ratio = 100. Means were obtained from 10 replicate trees.

The planting was established on a 5.5 × 6.7-m spacing in Feb. 1980 on an unirrigated replant hill site in the Willamette Valley of Oregon, where an old cherry orchard had been pulled in 1979. The soil series is Nekia-Jory and the texture is a silty clay loam. About 750 to 1000 mm of rain falls during winter and spring, with little in July, August, and early September. Before planting the understocks, lime was applied at a rate of 5.6 $t \cdot ha^{-1}$ and disked in to a depth of 10 to 15 cm before planting to bring the pH to 6.0. The backhoed tree holes were dug 3 weeks before planting and were $\approx 1.8\ m^3$. Methyl bromide (340 g) was released in a set of backhoed holes and then quickly backfilled. Another set of tree holes was dug with a 45-cm auger to a depth of 61 cm. The experiment was arranged in a completely randomized split plot design. The preplant treatment was the whole plot; these were randomized within the planting and replicated 10 times. The rootstock were randomized within each whole plot. Ammonium nitrate (226 g of NH_4NO_3 as actual N) was placed in a ring around all trees. The understocks were grafted in Spring 1981 and 1982 with 'Napoleon' scion wood at about a 90- to 100-cm height onto three to four major understock scaffolds.

Trunk diameters were measured annually after each growing season. Flowering density was determined by rating the percentage of the tree covered with flowers. Yields were estimated in 1984-1987 by counting the number of fruit and multiplying by a mean fruit weight. In 1988, actual yields were measured when trees were harvested mechanically by a hand-operated inertia shaker. An estimate of unharvested fruit remaining on the tree was also made. Mean fruit weight was determined on a 50-fruit sample from each tree in 1986-1988. Soluble-solids concentration (SSC;°Brix) was measured with a hand-held refractometer from free run fruit juice from the 50-fruit sample. Canopy volume was calculated in 1988 using the equation for a spheroid.

Trunk cross-sectional (TCSA) area was affected by both the preplant treatment and rootstock,. with no significant interaction (Fig. 1). Within each year, the TCSA of trees in augered holes was consistently smaller than either backhoe treatment. Results for fumigation in conjunction with the backhoe treatment were similar to those for the backhoe-only treatment. Root development and expansion have been reported to be restricted by the compact interface that is formed by auger drills (Auxt et al., 1980). The smaller tree growth observed in this study of trees planted in augered holes may have been a result of early root restriction.

The MxM60 trees had a larger TCSA than F/12-l after one growing season in 1980. In the second year and all the subsequent years, Colt had a smaller TCSA than the other two rootstock. F/12-l and MxM60 began to differ in size in 1985, where MxM60 had the larger TCSA. However, in 1988, TCSA for MxM60 and F/12-l was similar.

Colt is not drought-tolerant, but it is often similar in tree size to commercially grown rootstock (Zahn, 1980; Stebbins, unpublished data). Because the months of July and August are usually dry in the Willamette Valley, the relatively small TCSA may be indicative of water stress in Colt.

Yield of 'Napoleon' was highest in the backhoe treatments when compared to the auger treatment (Fig. 2), but fumigation provided no additional benefit. The growth of the aboveground portion of the tree is directly related to the growth of the roots (Chalmers, 1982). If the roots have a greater area to explore early in orchard establishment, with less restriction, shoot growth could be greater, thereby, creating more potential fruiting sites.

Trees on the Colt rootstock were precocious and yielded more than the other two rootstock through the 6th year. MxM60 outyielded both Colt and F/12-l in the 7th and 8th years (Fig. 2). Yields on Colt have reached an apparent plateau, while the yields of F/12-l and MxM60 continue to increase proportional to tree size.

The percentage of tree covered with bloom was greater on Colt rootstock than on MxM60 or F/12-l (Table 1). This indirect measure of flowering density also confirms the precocious nature imparted by Colt (Webster, 1984). Method of hole preparation also had an effect in 1985 and 1986, but it was not as great as that of rootstock. The trees in augered holes had less bloom than those planted in backhoe-dug holes. Tree canopy volume was greatest for the backhoe + fumigation treatment, followed by the backhoe and auger treatments (Table 1). Trees on F/12-1 and MxM60 rootstock had equally large canopies and larger than those of Colt (Table 1).

The method of hole preparation only affected fruit weight in 1986, where the backhoe + fumigation treatment had larger fruit than the auger treatment (Table 2). Rootstock had a much greater effect on fruit

Table 2. The mean fruit weight, soluble solids concentration (SSC), cumulative yields, and yield efficiencies (1980-1988) of 'Napoleon' cherries at harvest after three preplant treatments on three rootstocks.[z]

Variable	Fruit wt (g)			SSC (°Brix)		Unharvested fruit (kg)	Cumulative yield efficiency (kg·cm^{-2} TCSA)	Cumulative yield (kg)
Year	1986	1987	1988	1987	1988	1988		
Hole preparation								
Auger	7.4 b	6.3	7.0	19.0	19.0	0.34	0.288 a	46.7 b[z]
Backhoe	7.7 ab	5.8	6.8	18.6	18.5	0.46	0.335 ab	70.1 a
Backhoe + fumigation	7.8 a	6.2	6.9	18.6	18.1	0.58	0.340 b	71.6 a
Significance	*	NS	NS	NS	NS	NS	*	**
Rootstock								
F/12-1	7.6	7.0 a	7.5 a	18.8	18.1 b	0.49 b	0.179 a	54.8 b
M×M60	7.8	6.2 b	6.4 b	18.9	16.6 c	0.79 a	0.275 b	81.2 a
Colt	7.5	5.2 c	6.7 b	18.4	20.9 a	0.10 c	0.503 c	52.0 b
Significance	NS	**	**	NS	**	**	**	**
Preplant treatment × rootstock Significance	NS	NS	NS	NS	NS	NS	NS	NS

[z]Means separation by the Wailer–Duncan k-ratio *t* test, k-ratio = 100. Means were of 50-fruit subsamples from each of 10 replicate trees for fruit weight and soluble solids and 10 replicate trees for cumulative yield efficiencies and cumulative yields.

*,**,[NS]Significant at $P = 0.05$ and 0.01 or nonsignificant, respectively.

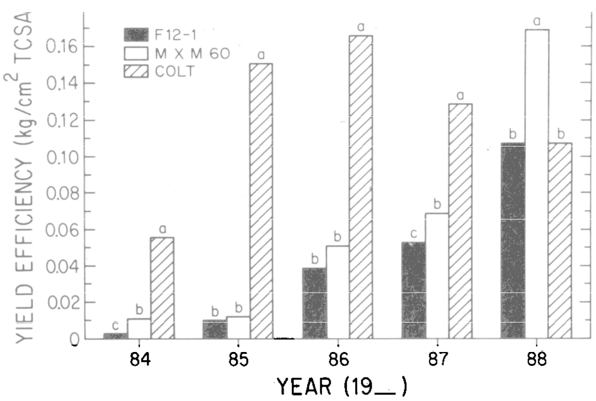

Fig. 3. Effect of rootstock on yield efficiency for 5- to 9-year-old cherry trees planted in 1980. Means separation by Wailer–Duncan k-ratio *t* test, k-ratio = 100. Means were obtained from 30 replicate trees.

weight. The fruit size on F/12-1 was generally larger than MxM60 and Colt. Fruit from trees on MxM60 were larger than on Colt trees in 1987, but did not differ in 1988. Higher crop loads on MxM60 could explain the decrease in fruit size (Fig. 2). Another possible explanation for the small fruit size on MxM60 in 1988 could be that the fruit were less-mature than those on Colt. The SSC was much lower and the amount of unharvested fruit on MxM60 trees was greater than on Colt trees (Table 2).

The yield efficiency of 'Napoleon' on Colt was greater than on F/12-1 and MxM60, except in 1988 (Fig. 3). MxM60 had the highest yield efficiency in 1988, while those for Colt and F/12-l were not different. Cumulative yields were greatest for MxM60 (Table 2). Yields were ≈35% greater for the trees planted in backhoe-dug holes, whether fumigated or not, than in augered holes (Table 2). Trees on F/12-l and Colt did not differ in cumulative yield for the first 9 years of growth.

The backhoe preplant treatment increased tree size, annual and cumulative yields, and yield efficiency. This report of increased tree growth, as measured by TCSA and canopy volume with the backhoe treatment, is similar to the increased shoot growth reported by Auxt (1980). This type of hole probably allowed for better root development and expansion, or the backhoe could have broken through the compacted plow sole. An augered hole in clayey soils often has a compact interface that seems to inhibit root penetration (Auxt, 1980), which may also have accounted for the decrease in tree growth of the augered holes relative to the backhoe-dug holes.

MxM60 appears to be a promising rootstock. The potential advantages are higher yields and efficiency and its probable *Pseudomonas* syringae-tolerance (Westwood, 1978). The disadvantages may include large tree size and relatively small fruit size. Although Colt was precocious and efficient in the early years of production, several concerns are evident. In a nonirrigated site, tree vigor on Colt rootstock is low, fruit size is small, and trees defoliate early and are not winter-hardy. Further research is needed to determine how trees on Colt rootstock would respond to irrigation.

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