

## Improving the Growth of Newly Planted Apple Trees

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**Abstract.** Increasing the N application rate (in the form  $\text{NH}_4\text{NO}_3$ ) to newly planted 'Marshall McIntosh'/M.9 apple (*Malus domestica*, Borkh.) trees beyond 76 g N per tree per year reduced growth in the first two growing seasons. Peat moss or composted manure mixed into the planting hole of 'Royal Gala'/M.26 increased growth in the first growing season after planting. The soil-active fungicides, fosetyl-Al and metalaxyl, increased trunk and shoot growth of 'Royal Gala'/M.26 in the first season after planting. Mulching enhanced growth of 'Gala'/M.26 only in the third season after planting, a season during which the region experienced a drought. Mulching significantly increased bloom on 'Gala'/M.26 2 years after planting. The growth of 'Royal Gala'/M.26, 'Marshall McIntosh'/M.26, and 'Ace Delicious'/M.26 was not affected by planting technique planting by hand in 61-cm augered holes vs. planting with a mechanical tree planter. Chemical names used N-(2,6-dimethyl-phenyl)-N-(methoxyacetyl)alanine methyl ester (metalaxyl); aluminum tris (O-ethyl phosphonate) (fosetyl-Al); 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat); isopropylamine salt of N-(phosphonomethyl) glycine (glyphosate).

Apple orchardists in the United States are facing a complex and increasing set of difficulties when producing a crop. The availability of labor is decreasing, while the cost of land, labor, capital, and other inputs of production is increasing. Clearly, apple growers must become more efficient in pro-

ducing apples if they are to remain in business. Early production is a critical factor in obtaining early returns from newly planted trees. To obtain earlier returns, these trees must grow well and produce a framework suitable for production early in their lives (Forshey, 1988). This study was initiated to assess several techniques that may affect the growth and early fruiting potential of newly planted apple trees.

*Nitrogen fertilization (Expt. 1).* Ninety-six 'Marshall McIntosh'/M.9 trees were planted on 25 Apr. 1986 in a Scituate fine sandy loam at the Univ. of Massachusetts Horticultural Research Center (UMHRC), Belchertown, Mass. The site was grassed and had not previously been planted to orchard. Eight months before planting, rows were located and 1-m-wide strips were treated with

glyphosate to kill the sod. Planting holes were dug with a tractor-mounted, 61-cm soil auger to a depth of 60 cm. Tree spacing was  $2.4 \times 4.9$  m. Trees were partitioned into 16 blocks of six trees each. In 1986-88, each tree in each block received a total of 227, 454, or 680 g  $\text{NH}_4\text{NO}_3$  (76, 152, or 228 g actual N, respectively) per year as a split application, one in early May and a second application 1 month later. Two trees were treated similarly within each block. Therefore, the experimental design was a randomized complete block with 16 replications and two experimental units per treatment per replication. This experiment was terminated at the end of the 1988 growing season.

*Planting technique and soil amendments (Expt. 2).* On 2 May 1986, 80 'Royal Gala'/M.26 trees were planted in a Ridgebury fine sandy loam at the UMHRC. Apple trees previously on the site were removed 2 weeks before planting this experiment. After tree removal, new tree rows were located 1 to 3 m offset from the previous tree rows but in the same orientation. Rows were rototilled, leaving existing vegetation between rows. The field was partitioned into 16 blocks, each including five trees. One tree in each block was planted with a mechanical tree planter, which made a 50-cm-deep vertical slice into the soil, separated the soil to allow tree placement, and returned the soil to fill around the root system. The four remaining trees in each block were planted by hand in 61-cm holes dug to a depth of 60 cm with a tractor-mounted soil auger. The holes were filled with either the soil that had been removed from the hole, a non-orchard loam (from land not previously planted to orchard), a 1 peat moss : 1 soil (v/v) mixture, or a 2 composted cow manure : 1 soil (v/v) mixture. Tree spacing was  $3.7 \times 6.1$  m. The experimental design was a randomized complete block with 16 replications and a single experimental unit per treatment per replication. This experiment was terminated at the end of the 1988 growing season.

*Fungicide applications (Expt. 3).* A third planting was established at the UMHRC on 2 May 1986 in the same block described in Expt. 2. The planting included 72 'Royal Gala'/M.26 trees partitioned into 16 blocks of four trees each. All trees were planted with a mechanical tree planter as described in Expt. 2. Tree spacing was  $3.7 \times 6.1$  m. In 1986 and 1987, one tree per block was sprayed to the drip point on 15 Apr., 2 June,

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Table 1. Effects of levels of N fertilization on the growth of 'Marshall McIntosh'/M.9 apple trees planted in 1986 (Expt. 1).<sup>2</sup>

NH <sub>4</sub> NO <sub>3</sub> (g)	Initial TCSA (cm <sup>2</sup> )	Annual TCSA increment (cm <sup>2</sup> )			Final TCSA (cm <sup>2</sup> )	Tree ht (cm)			Tree spread (cm)			Shoot growth/tree (cm)		
		1986	1987	1988		1986	1987	1988	1986	1987	1988	1986	1987	1988
227	0.82	0.23	2.18	4.12	7.46	114	196	243	26	104	182	110	634	1800
454	0.85	0.12	1.70	4.59	7.22	107	186	247	24	90	163	93	530	1840
680	0.82	0.08	1.18	3.79	5.90	105	165	238	23	78	149	78	326	1360
Significance <sup>y</sup>	NS	L***	L***	NS	L*	L**	L***	NS	L*	L***	L**	L***	L***	L*

<sup>2</sup>Means are of 31 observations for the 227-g treatment (one tree died) and 30 observations for the 454- and 680-g treatments (two trees died in each treatment).

<sup>y</sup>L = significant linear relationship.

NS,\*\*\*,\*\*\*Nonsignificant or significant at  $P = 0.05, 0.01, \text{ or } 0.001$ , respectively.

Table 2. Effects of planting treatments on the growth and early bloom of 'Royal Gala'/M.26 apple trees planted in 1986 (Expt. 2).<sup>2,3</sup>

Treatment	Initial TCSA (cm <sup>2</sup> )	Annual TCSA increment (cm <sup>2</sup> )			Final TCSA (cm <sup>2</sup> )	Bloom density (1988, clusters/ cm <sup>2</sup> )	Tree ht (cm)			Tree spread (cm)			Shoot growth/tree (cm)		
		1986	1987	1988			1986	1987	1988	1986	1987	1988	1986	1987	1988
Control	1.17 a	0.73 c	3.76 ab	6.83 b	12.5 b	18.5 a	148 b	222 ab	289 ab	56 a	128 b	218 ab	317 c	1020 c	1960 b
Non-orchard soil	1.15 a	0.78 bc	4.51 a	8.63 a	15.1 a	9.6 b	142 b	234 a	305 a	60 a	147 ab	234 a	319 c	1480 a	3100 a
Peat moss	1.15 a	1.14 a	4.66 a	7.77 ab	14.7 a	21.7 a	158 a	230 ab	291 ab	66 a	148 a	235 a	494 a	1330 ab	2110 b
Manure	1.11 a	0.93 b	4.31 ab	7.49 ab	13.8 ab	21.8 a	146 b	213 b	278 b	56 a	134 ab	217 ab	391 b	1170 bc	2270 b
Tree planter	1.20 a	0.61 c	3.38 b	6.73 b	11.9 b	11.3 b	149 b	221 ab	286 ab	56 a	128 b	207 b	260 c	1020 c	2090 b

<sup>2</sup>Means are of 16 observations, except for the control where one tree died and for bloom density where  $n = 20$ .

<sup>3</sup>Mean separation within columns by Duncan's new multiple range test ( $P = 0.05$ ).

and again 20 Aug. with a solution of 2.4 g Aliette 80% WP (fosetyl-Al)/liter, and another tree was sprayed at the same time with a solution of 4.8 g Aliette 80% WP/liter. The third tree in each block was treated on 15 Apr., 2 June, and again on 20 Aug. with a soil drench (distributed evenly within the drip line) of 1 liter of a solution of 2.4 ml Ridomil 2E (metalaxyl)/liter. The fourth tree was left untreated as a control. The experimental design was a randomized complete block with 16 replications and a single experimental unit per treatment per replication. This experiment was terminated at the end of the 1988 growing season.

**Mulching (Expt. 4).** A planting of 40 'Gala'/M.26 trees was established on 28 Apr. 1986 at the UMHRC in a Ridgebury fine sandy loam. Apple trees previously on the site were removed 1 year before the establishment of this planting. New tree rows were in the same location as the previous rows. Trees were planted at a spacing of 3.7 × 6.1 m in 61-cm planting holes dug with a tractor-mounted soil auger to a depth of 60 cm. Trees were partitioned into 10 blocks of four trees each. Two trees in each block were mulched with hay to a depth of 20 cm in a circle 1.5 m in diameter around each tree. The experimental design was a randomized complete block with two experimental units per treatment per replication. This experiment was terminated after bloom in 1989.

**Soil amendments only (Expt. 5).** On 5 May 1988, 24 'Morspur McIntosh'/M.7 EMLA trees were planted in a Paxton-Charlton fine sandy loam at the Univ. of Maine Highmoor Farm, Monmouth, Maine. This site was grassed and had not previously been planted to orchard. The site was partitioned into eight blocks of three trees each. Trees in each block were planted by hand in 61-cm holes dug to a depth of 60 cm with a tractor-mounted soil

auger. The holes were filled with either the soil that had been removed from the hole, a 1 peat moss : 1 soil (v/v) mixture, or a 2 composted horse manure : 1 soil (v/v) mixture. Trees were spaced 3 × 5.5 m. The experimental design was a randomized complete block with eight replications and one experimental unit per treatment per replication. This experiment was terminated after bloom in 1990.

**Mechanical vs. hand planting only (Expt. 6).** A block of 14 'Marshall McIntosh'/M.26 and a block of 14 'Ace Delicious'/M.26 trees were planted on 5 May 1988 in a Montauk fine sandy loam at the UMHRC. The site had previously been planted to apple trees that were removed 6 months before planting. After removal of old trees, new rows were located and 1-m strips were treated with glyphosate to kill existing vegetation. New rows were oriented in the same direction and in some cases may have been established in the same location as previous rows. Trees were either planted by hand in holes dug with a tractor-mounted 61-cm soil auger to a depth of 60 cm or planted with a mechanical tree planter as described in Expt. 2. Each of these plantings was a randomized complete block with seven replications and one experimental unit per treatment per replication. This experiment was terminated at the end of the 1989 growing season.

**Tree care.** All trees were headed at ≈90 cm immediately after planting and were trained to a central leader using a conduit pipe stake protruding 2.2 m above the soil surface. Weed control was maintained by treating 0.5-m-wide strips on either side of tree rows two to four times between May and July with paraquat. Grassed strips were maintained in the alleys. Trees received minimal pruning, and unless otherwise stated, pest control and nutrient management were

performed per local recommendations.

**Data collection and analysis.** For all experiments, trunk circumference was measured at 50 cm above the soil surface after planting and each October thereafter. These data were transformed to trunk cross-sectional area (TCSA) before analysis. When seasonal growth was complete, the length of shoot growth produced per tree in each season was measured, and tree height and spread were measured. In 1988 for Expts. 2 and 3 and in 1988 and 1989 for Expt. 4, blossom density was assessed in 10 replications by counting all the blossom clusters on two representative limbs per tree. In Expt. 5, blossom clusters were counted on entire trees in 1990.

Data were subjected to analysis of variance and covariance using the GLM procedure of the SAS PC 6.04 software package (SAS Institute, Cary, N.C.). Mean separation was by Duncan's new multiple range test, single-degree-of-freedom linear comparisons, or orthogonal polynomial comparisons.

**Nitrogen fertilization (Expt. 1).** Increasing N fertilization clearly can increase the growth of established apple trees (Cain, 1953), and before the beginning of this experiment we believed that our standard recommendation of 76 g N per tree applied soon after planting might have been too low for optimal growth. However, increasing N beyond 76 g per tree clearly had a negative linear effect on the incremental increase in TCSA, shoot growth per tree, tree height, and tree spread for the first two seasons (Table 1). Similar results have been obtained with tung plantings (Sitton, 1949), where high levels of N reduced growth of newly planted trees on some sites, possibly by injuring the root system. In our planting, TCSA increase and shoot growth in the third season were not affected by lev-

Table 3. Effects of soil-active fungicide treatments in 1986 and 1987 on the trunk growth of 'Royal Gala'/M.26 apple trees planted in 1986 (Expt. 3).<sup>z</sup>

Fungicide	Initial TCSA (cm <sup>2</sup> )	Annual TCSA increment (cm <sup>2</sup> )			Final TCSA (cm <sup>2</sup> )	Shoot growth/tree (cm)		
		1986	1987	1988		1986	1987	1988
None	1.20	0.61	3.38	6.73	11.9	249	1020	2090
Aliette (2.4 g·liter <sup>-1</sup> )	1.13	0.80	3.71	7.62	13.3	302	1130	2040
(4.8 g·liter <sup>-1</sup> )	1.08	0.95	3.82	7.78	13.6	324	1270	2050
Ridomil (2.4 ml·liter <sup>-1</sup> )	1.11	0.82	3.76	7.06	12.8	323	1090	2220
Significance								
Aliette concn <sup>y</sup>	NS	L***	NS	NS	NS	L*	NS	NS
Ridomil	NS	**	NS	NS	NS	**	NS	NS

<sup>z</sup>Means are of 16 observations except the 2.4-g Aliette/liter treatment where one tree died.

<sup>y</sup>L = significant linear relationship.

<sup>NS,\*,\*\*</sup> Nonsignificant or significant at  $P = 0.05, 0.01, \text{ or } 0.001$ , respectively.

Table 4. Effects of mulching on shoot growth and early bloom of 'Gala'/M.26 apple trees planted in 1986 (Expt. 4).

Treatment	Shoot growth/tree (cm) <sup>z</sup>			Bloom density (clusters/cm <sup>2</sup> ) <sup>y</sup>	
	1986	1987	1988	1988	1989
Control	284	907	2330	8.4	27.9
Mulch	307	947	2760	20.4	22.9
Significance	NS	NS	*	**	NS

<sup>z</sup>Means of 16 observations for the mulch treatment and 14 for the control (two trees died).

<sup>y</sup>Means of 20 observations.

<sup>NS,\*,\*\*</sup> Nonsignificant or significant at  $P = 0.05 \text{ or } 0.01$ , respectively.

els of N. Presumably, the larger trees, with a more developed root system, were more capable of using the higher N levels without injury. These data suggest that our recommended rates of N must be re-evaluated.

**Planting technique (Expts. 2, 6).** The increasing costs and declining availability of agricultural labor have made apple growers look very seriously at the use of mechanical tree planting equipment, which speeds planting and reduces labor requirements. A secondary benefit of the use of this equipment is that it usually results in growers planting trees earlier in the growing season than they would otherwise (Forshey, 1988). Expts. 2 (Table 2) and 6 (data not shown) show that under the soil conditions used in this study the mechanical tree planter resulted in similar TCSA increase, shoot growth, tree height, and spread to planting in augered holes. These results are contrary to those obtained by Auxt et al. (1980). They found that trees planted with a tree planter or backhoe grew more than those planted in an augered hole. The reduced growth rate with the augered hole was explained by a high resistance to root penetration at the hole wall. Augering the soil in our study may not have produced enough resistance to cause reduced growth, differing from the soil used by Auxt et al. (1980) because of a lower clay content. A second, puzzling result occurred in Expt. 2 (Table 2), where 'Royal Gala' trees planted in an augered hole produced significantly more flower clusters in 1988 than trees planted with a tree planter. Root restriction can have a positive impact on flowering (Proebsting et al., 1977); however, we did not find the reduced growth that should have accompanied the root restriction.

**Planting hole amendments (Expts. 2, 5).**

A non-orchard soil was used as a planting hole treatment. This treatment was not different from the control in the first season, but it resulted in a significantly greater increase in TCSA in the third season and more shoot growth in the second and third seasons. Even when tree size at the beginning of the season was accounted for by analysis of covariance (i.e., covarying the growth measurement with TCSA measured at the end of the previous growing season), the non-orchard soil resulted in significantly more trunk and shoot growth. The delay in response to this treatment is difficult to explain. Some characteristic of the soil may have allowed better root development in the first season after shoot growth had stopped. Therefore, the trees may have had a root system more developed than the controls when they began growth in the second season. The decrease in blossom density caused by this treatment was unexpected. It may have been related to the higher vigor of these trees in 1987 when they would have been initiating flower buds for the 1988 season; however, accounting for the vigor in 1987 using analysis of covariance (incremental TCSA increase or shoot growth) did not eliminate the effect.

The peatmoss and composted manure treatments resulted in significantly greater increases in TCSA and shoot growth than controls during the first season in Expt. 2 (Table 2). The effect dissipated, so that neither was significantly different from the controls in the third season. Peat moss appeared to enhance growth in the second season; however, when TCSA at the beginning of the season was accounted for by analysis of covariance the effect of peat moss became nonsignificant. The initial enhancement of

growth may be explained by the enhanced nutrient availability, improved aeration, or increased water-holding capacity in the root zone of these trees caused by the high organic matter content. When the roots moved beyond the planting hole the response disappeared. Additionally, the organic matter content may have reduced the detrimental effects of apple replant disorder (ARD), as suggested by the studies of Havis (1962) and Peryea and Covey (1989). Unfortunately, the severity of ARD, the nutritional status of the soil, and the nutritional status of the trees were not assessed; therefore, specific reasons for these results cannot be given. Studies are underway to assess the specific nature of this response.

In Expt. 5 (data not shown), peat moss resulted in significantly taller trees than the control (202 vs. 177 cm) at the end of the second growing season; however, incremental trunk growth and shoot growth were not affected. Composted horse manure had no effect on tree growth. Neither treatment affected bloom density in 1990.

**Fungicide applications (Expt. 3).** This experiment was conducted within the same block as Expt. 2, and therefore was planted only 2 weeks after the removal of old apple trees. Even though a specific assessment of their presence was not made, root-colonizing fungi may have been present in the soil at this site. The use of the systemic fungicide Aliette had a significant positive, linear impact on the increase in trunk and shoot growth in the first season (Table 3). Additionally, the soil-applied fungicide Ridomil significantly increased trunk and shoot growth in the first growing season. These results suggest that pathogens, such as *Phytophthora*, may have played a role in reducing the growth and development of control trees. Ferree and Ellis (1984) obtained similar results with Ridomil application on *Phytophthora*-inoculated apple trees. In our experiment, the effects of the fungicides were not apparent in the second or third growing seasons. In situations where there is a potential for infection by fungi, the type of fungicide treatment described here may be beneficial.

**Mulching (Expt. 4).** Mulching newly planted trees did not have a dramatic effect on growth except in 1988 (Table 4), a year with below-normal rainfall. In 1988, mulching significantly increased shoot growth. Mulching is well known to improve the moisture status of soil by reducing evaporation and improving infiltration rates (Skroch and Shribbs, 1986). Shribbs and Skroch (1986) found a much more pronounced effect of mulching on growth of 'Golden Delicious' apple trees than we did. However, Lord et al. (1968) obtained similar results to ours when comparing shoot and trunk growth of 'McIntosh' apple trees with and without hay mulch. An interesting response found in this study was that mulched trees bloomed significantly more in 1988 than nonmulched trees. This response may be related to the higher soil moisture levels under mulch or other effects of mulch, such as a higher organic matter content, lower temperature, and

higher nutrient levels (Haynes, 1980).

The specific reasons for the effects observed in this study are unclear because of the lack of initial data, such as an assessment of ARD and the soil nutritional status, and the measurement of the nutritional conditions throughout the study; however, we have defined some cultural techniques that may improve the growth and possibly early fruiting of newly planted apple trees. The use of increased organic matter levels in the planting soil may be of benefit in the early years. Mulching may provide benefit in nonirrigated soils, and the use of fungicides directed at root pathogens may be beneficial.

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Table 3. Effects of soil-active fungicide treatments in 1986 and 1987 on the trunk growth of 'Royal Gala'/M.26 apple trees planted in 1986 (Expt. 3).<sup>z</sup>

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Significance								
Aliette concn <sup>y</sup>	NS	L***	NS	NS	NS	L*	NS	NS
Ridomil	NS	**	NS	NS	NS	**	NS	NS

<sup>z</sup>Means are of 16 observations except the 2.4-g Aliette/liter treatment where one tree died.

<sup>y</sup>L = significant linear relationship.

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Significance	NS	NS	*	**	NS

<sup>z</sup>Means of 16 observations for the mulch treatment and 14 for the control (two trees died).

<sup>y</sup>Means of 20 observations.

<sup>NS,\*,\*\*</sup> Nonsignificant or significant at  $P = 0.05 \text{ or } 0.01$ , respectively.

els of N. Presumably, the larger trees, with a more developed root system, were more capable of using the higher N levels without injury. These data suggest that our recommended rates of N must be re-evaluated.

**Planting technique (Expts. 2, 6).** The increasing costs and declining availability of agricultural labor have made apple growers look very seriously at the use of mechanical tree planting equipment, which speeds planting and reduces labor requirements. A secondary benefit of the use of this equipment is that it usually results in growers planting trees earlier in the growing season than they would otherwise (Forshey, 1988). Expts. 2 (Table 2) and 6 (data not shown) show that under the soil conditions used in this study the mechanical tree planter resulted in similar TCSA increase, shoot growth, tree height, and spread to planting in augered holes. These results are contrary to those obtained by Auxt et al. (1980). They found that trees planted with a tree planter or backhoe grew more than those planted in an augered hole. The reduced growth rate with the augered hole was explained by a high resistance to root penetration at the hole wall. Augering the soil in our study may not have produced enough resistance to cause reduced growth, differing from the soil used by Auxt et al. (1980) because of a lower clay content. A second, puzzling result occurred in Expt. 2 (Table 2), where 'Royal Gala' trees planted in an augered hole produced significantly more flower clusters in 1988 than trees planted with a tree planter. Root restriction can have a positive impact on flowering (Proebsting et al., 1977); however, we did not find the reduced growth that should have accompanied the root restriction.

**Planting hole amendments (Expts. 2, 5).**

A non-orchard soil was used as a planting hole treatment. This treatment was not different from the control in the first season, but it resulted in a significantly greater increase in TCSA in the third season and more shoot growth in the second and third seasons. Even when tree size at the beginning of the season was accounted for by analysis of covariance (i.e., covarying the growth measurement with TCSA measured at the end of the previous growing season), the non-orchard soil resulted in significantly more trunk and shoot growth. The delay in response to this treatment is difficult to explain. Some characteristic of the soil may have allowed better root development in the first season after shoot growth had stopped. Therefore, the trees may have had a root system more developed than the controls when they began growth in the second season. The decrease in blossom density caused by this treatment was unexpected. It may have been related to the higher vigor of these trees in 1987 when they would have been initiating flower buds for the 1988 season; however, accounting for the vigor in 1987 using analysis of covariance (incremental TCSA increase or shoot growth) did not eliminate the effect.

The peatmoss and composted manure treatments resulted in significantly greater increases in TCSA and shoot growth than controls during the first season in Expt. 2 (Table 2). The effect dissipated, so that neither was significantly different from the controls in the third season. Peat moss appeared to enhance growth in the second season; however, when TCSA at the beginning of the season was accounted for by analysis of covariance the effect of peat moss became nonsignificant. The initial enhancement of

growth may be explained by the enhanced nutrient availability, improved aeration, or increased water-holding capacity in the root zone of these trees caused by the high organic matter content. When the roots moved beyond the planting hole the response disappeared. Additionally, the organic matter content may have reduced the detrimental effects of apple replant disorder (ARD), as suggested by the studies of Havis (1962) and Peryea and Covey (1989). Unfortunately, the severity of ARD, the nutritional status of the soil, and the nutritional status of the trees were not assessed; therefore, specific reasons for these results cannot be given. Studies are underway to assess the specific nature of this response.

In Expt. 5 (data not shown), peat moss resulted in significantly taller trees than the control (202 vs. 177 cm) at the end of the second growing season; however, incremental trunk growth and shoot growth were not affected. Composted horse manure had no effect on tree growth. Neither treatment affected bloom density in 1990.

**Fungicide applications (Expt. 3).** This experiment was conducted within the same block as Expt. 2, and therefore was planted only 2 weeks after the removal of old apple trees. Even though a specific assessment of their presence was not made, root-colonizing fungi may have been present in the soil at this site. The use of the systemic fungicide Aliette had a significant positive, linear impact on the increase in trunk and shoot growth in the first season (Table 3). Additionally, the soil-applied fungicide Ridomil significantly increased trunk and shoot growth in the first growing season. These results suggest that pathogens, such as *Phytophthora*, may have played a role in reducing the growth and development of control trees. Ferree and Ellis (1984) obtained similar results with Ridomil application on *Phytophthora*-inoculated apple trees. In our experiment, the effects of the fungicides were not apparent in the second or third growing seasons. In situations where there is a potential for infection by fungi, the type of fungicide treatment described here may be beneficial.

**Mulching (Expt. 4).** Mulching newly planted trees did not have a dramatic effect on growth except in 1988 (Table 4), a year with below-normal rainfall. In 1988, mulching significantly increased shoot growth. Mulching is well known to improve the moisture status of soil by reducing evaporation and improving infiltration rates (Skroch and Shribbs, 1986). Shribbs and Skroch (1986) found a much more pronounced effect of mulching on growth of 'Golden Delicious' apple trees than we did. However, Lord et al. (1968) obtained similar results to ours when comparing shoot and trunk growth of 'McIntosh' apple trees with and without hay mulch. An interesting response found in this study was that mulched trees bloomed significantly more in 1988 than nonmulched trees. This response may be related to the higher soil moisture levels under mulch or other effects of mulch, such as a higher organic matter content, lower temperature, and

Table 1. Effects of levels of N fertilization on the growth of 'Marshall McIntosh'/M.9 apple trees planted in 1986 (Expt. 1).<sup>2</sup>

NH <sub>4</sub> NO <sub>3</sub> (g)	Initial TCSA (cm <sup>2</sup> )	Annual TCSA increment (cm <sup>2</sup> )			Final TCSA (cm <sup>2</sup> )	Tree ht (cm)			Tree spread (cm)			Shoot growth/tree (cm)		
		1986	1987	1988		1986	1987	1988	1986	1987	1988	1986	1987	1988
227	0.82	0.23	2.18	4.12	7.46	114	196	243	26	104	182	110	634	1800
454	0.85	0.12	1.70	4.59	7.22	107	186	247	24	90	163	93	530	1840
680	0.82	0.08	1.18	3.79	5.90	105	165	238	23	78	149	78	326	1360
Significance <sup>y</sup>	NS	L***	L***	NS	L*	L**	L***	NS	L*	L***	L**	L***	L***	L*

<sup>2</sup>Means are of 31 observations for the 227-g treatment (one tree died) and 30 observations for the 454- and 680-g treatments (two trees died in each treatment).

<sup>y</sup>L = significant linear relationship.

NS,\*\*\*,\*\*\*Nonsignificant or significant at  $P = 0.05, 0.01, \text{ or } 0.001$ , respectively.

Table 2. Effects of planting treatments on the growth and early bloom of 'Royal Gala'/M.26 apple trees planted in 1986 (Expt. 2).<sup>2,3</sup>

Treatment	Initial TCSA (cm <sup>2</sup> )	Annual TCSA increment (cm <sup>2</sup> )			Final TCSA (cm <sup>2</sup> )	Bloom density (1988, clusters/ cm <sup>2</sup> )	Tree ht (cm)			Tree spread (cm)			Shoot growth/tree (cm)		
		1986	1987	1988			1986	1987	1988	1986	1987	1988	1986	1987	1988
Control	1.17 a	0.73 c	3.76 ab	6.83 b	12.5 b	18.5 a	148 b	222 ab	289 ab	56 a	128 b	218 ab	317 c	1020 c	1960 b
Non-orchard soil	1.15 a	0.78 bc	4.51 a	8.63 a	15.1 a	9.6 b	142 b	234 a	305 a	60 a	147 ab	234 a	319 c	1480 a	3100 a
Peat moss	1.15 a	1.14 a	4.66 a	7.77 ab	14.7 a	21.7 a	158 a	230 ab	291 ab	66 a	148 a	235 a	494 a	1330 ab	2110 b
Manure	1.11 a	0.93 b	4.31 ab	7.49 ab	13.8 ab	21.8 a	146 b	213 b	278 b	56 a	134 ab	217 ab	391 b	1170 bc	2270 b
Tree planter	1.20 a	0.61 c	3.38 b	6.73 b	11.9 b	11.3 b	149 b	221 ab	286 ab	56 a	128 b	207 b	260 c	1020 c	2090 b

<sup>2</sup>Means are of 16 observations, except for the control where one tree died and for bloom density where  $n = 20$ .

<sup>3</sup>Mean separation within columns by Duncan's new multiple range test ( $P = 0.05$ ).

and again 20 Aug. with a solution of 2.4 g Aliette 80% WP (fosetyl-Al)/liter, and another tree was sprayed at the same time with a solution of 4.8 g Aliette 80% WP/liter. The third tree in each block was treated on 15 Apr., 2 June, and again on 20 Aug. with a soil drench (distributed evenly within the drip line) of 1 liter of a solution of 2.4 ml Ridomil 2E (metalaxyl)/liter. The fourth tree was left untreated as a control. The experimental design was a randomized complete block with 16 replications and a single experimental unit per treatment per replication. This experiment was terminated at the end of the 1988 growing season.

**Mulching (Expt. 4).** A planting of 40 'Gala'/M.26 trees was established on 28 Apr. 1986 at the UMHRC in a Ridgebury fine sandy loam. Apple trees previously on the site were removed 1 year before the establishment of this planting. New tree rows were in the same location as the previous rows. Trees were planted at a spacing of 3.7 × 6.1 m in 61-cm planting holes dug with a tractor-mounted soil auger to a depth of 60 cm. Trees were partitioned into 10 blocks of four trees each. Two trees in each block were mulched with hay to a depth of 20 cm in a circle 1.5 m in diameter around each tree. The experimental design was a randomized complete block with two experimental units per treatment per replication. This experiment was terminated after bloom in 1989.

**Soil amendments only (Expt. 5).** On 5 May 1988, 24 'Morspur McIntosh'/M.7 EMLA trees were planted in a Paxton-Charlton fine sandy loam at the Univ. of Maine Highmoor Farm, Monmouth, Maine. This site was grassed and had not previously been planted to orchard. The site was partitioned into eight blocks of three trees each. Trees in each block were planted by hand in 61-cm holes dug to a depth of 60 cm with a tractor-mounted soil

auger. The holes were filled with either the soil that had been removed from the hole, a 1 peat moss : 1 soil (v/v) mixture, or a 2 composted horse manure : 1 soil (v/v) mixture. Trees were spaced 3 × 5.5 m. The experimental design was a randomized complete block with eight replications and one experimental unit per treatment per replication. This experiment was terminated after bloom in 1990.

**Mechanical vs. hand planting only (Expt. 6).** A block of 14 'Marshall McIntosh'/M.26 and a block of 14 'Ace Delicious'/M.26 trees were planted on 5 May 1988 in a Montauk fine sandy loam at the UMHRC. The site had previously been planted to apple trees that were removed 6 months before planting. After removal of old trees, new rows were located and 1-m strips were treated with glyphosate to kill existing vegetation. New rows were oriented in the same direction and in some cases may have been established in the same location as previous rows. Trees were either planted by hand in holes dug with a tractor-mounted 61-cm soil auger to a depth of 60 cm or planted with a mechanical tree planter as described in Expt. 2. Each of these plantings was a randomized complete block with seven replications and one experimental unit per treatment per replication. This experiment was terminated at the end of the 1989 growing season.

**Tree care.** All trees were headed at ≈90 cm immediately after planting and were trained to a central leader using a conduit pipe stake protruding 2.2 m above the soil surface. Weed control was maintained by treating 0.5-m-wide strips on either side of tree rows two to four times between May and July with paraquat. Grassed strips were maintained in the alleys. Trees received minimal pruning, and unless otherwise stated, pest control and nutrient management were

performed per local recommendations.

**Data collection and analysis.** For all experiments, trunk circumference was measured at 50 cm above the soil surface after planting and each October thereafter. These data were transformed to trunk cross-sectional area (TCSA) before analysis. When seasonal growth was complete, the length of shoot growth produced per tree in each season was measured, and tree height and spread were measured. In 1988 for Expts. 2 and 3 and in 1988 and 1989 for Expt. 4, blossom density was assessed in 10 replications by counting all the blossom clusters on two representative limbs per tree. In Expt. 5, blossom clusters were counted on entire trees in 1990.

Data were subjected to analysis of variance and covariance using the GLM procedure of the SAS PC 6.04 software package (SAS Institute, Cary, N.C.). Mean separation was by Duncan's new multiple range test, single-degree-of-freedom linear comparisons, or orthogonal polynomial comparisons.

**Nitrogen fertilization (Expt. 1).** Increasing N fertilization clearly can increase the growth of established apple trees (Cain, 1953), and before the beginning of this experiment we believed that our standard recommendation of 76 g N per tree applied soon after planting might have been too low for optimal growth. However, increasing N beyond 76 g per tree clearly had a negative linear effect on the incremental increase in TCSA, shoot growth per tree, tree height, and tree spread for the first two seasons (Table 1). Similar results have been obtained with tung plantings (Sitton, 1949), where high levels of N reduced growth of newly planted trees on some sites, possibly by injuring the root system. In our planting, TCSA increase and shoot growth in the third season were not affected by lev-