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Response of Young 'Topred Delicious' Apple Trees to Orchard Floor Management and Fertilization

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Abstract. **Growth of 'Topred Delicious' (*Malus domestica* Borkh)/Malling Merton (MM) 111 apple trees during the first 5 years in the orchard was significantly affected by the orchard floor management system. Trees grown in a mowed sod were smaller and had a significantly lower yield efficiency (kg/cm^2) than those grown under cultivation or a herbicide strip system. N source or rate did not influence growth or average yield/tree; fruit size and bitter pit development were significantly greater where a complete fertilizer (10N–4P–8K) was applied. N increased tree growth under sod but not under a cultivated or herbicide strip managment system. Growth response in the first year was increased when larger-sized trees were planted under a weed-free management system and trees were headed to 76 cm.**

Today's high cost of developing an orchard requires greater attention to cultural management in order to obtain early returns on the investment. One of the primary objectives after planting is to quickly fill the allotted space with bearing wood. Applications of fertilizers can increase growth and yield of fruit trees (1, 5, 13, 23, 29). Management of the orchard ground cover can also influence growth and yield of deciduous fruit trees (2, 6, 7, 17, 20, 24, 28). Research dealing with the interaction of fertilization and ground cover management is limited, particularly with trees on clonal rootstocks in the United States.

The height at which trees are headed or the severity of pruning at planting affects growth and shoot development (11, 21). Oskamp (21) found a slight, nonsignificant reduction in trunk circumference when trees were severely pruned at planting, but ground cover condition was not specified. Ferree (11) found no difference in average or total shoot length on 9 apple cultivars when they were headed at 61, 68, or 76 cm. In the same study,

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spur 'Delicious' headed at 35 cm produced significantly more central leader growth than did heading to 40, 51, or 61 cm.

The purpose of the present study was to evaluate the effect of 5 N sources, each applied at 4 levels adjusted annually based on tree age, on newly planted 'Delicious' apple trees grown under 3 systems of orchard floor management.

Materials and Methods

The research plot was established in 1974 on a Lloyd clay soil. The area planted had an initial pH of 6.7 and was considered of medium- to high-fertility (corn and sorghum had been cropped on the site since 1969 with 672 kg/ha of 4N–5P–10K applied annually). The site was subsoiled to a depth of 50 cm, plowed and harrowed, and sowed to Kentucky 31 tall fescue (*Festuca arundinacea*) in October 1974. In April 1975, one-year whips (some had lateral shoots) of 'Topred Delicious'/MM 111 (caliper 0.9 to 1.3 cm) were planted at a spacing of 4.9×7.3 m (16×24 ft) with a 60-cm auger. All trees were headed at 76 ± 2 cm above the graft union at planting. Any laterals which developed in the nursery were also removed at this time.

Central leader training was followed throughout the study. A limited amount of summer pruning was employed and consisted of removing shoots competing with the terminal, the central leader, or the primary scaffold limbs. The experimental design was a split plot with orchard floor managment system as the main plot. Main plots were replicated twice. N sources and rates made up the subplots with 3 tree replicates of each of the 20 treatment combinations. All N source/rate combinations were fully randomized within a single row. Therefore, main plots consisted of 3 adjacent rows with 20 trees/row. Five N sources were used: NH_4NO_3, $Ca(NO_3)_2$, $NaNO_3$, urea, and 10N–4P–8K. Each N source was applied at 4 individual rates: 22.7 g ($0.5\times$), 45.4 g ($1\times$), 68.1 g ($1.5\times$), or 90.8 g ($2\times$) of actual N per year of tree age. Fertilizer treatments were applied by hand 6 weeks after planting and about 4 weeks before budbreak each year thereafter in a band at the dripline of the tree (about 61 cm from the base of the tree in 1975).

The following orchard floor management systems were initiated in 1975 and continued through 1979:

1) *Cultivation*. This treatment consisted of shallow cultivation initiated each spring as soon as weed growth began to appear and continued as often as needed through the growing season to maintain vegetation control. Tillage was confined to strips about 1.8 m (6 ft) wide on each side of the tree. A Howard rotovator set at a depth of 7.5 cm was used in 1975 and 1976. A Smitty tree hoe was utilized for the remainder of the study. Generally, 3 cultivations were required per year to maintain a weed-free surface.

2) *Herbicide*. A combination of residual and nonresidual herbicide was used for weed control. Paraquat (1,1-dimethyl-4,4-bipyridiniumion) at 1.1 kg/ha was used alone in 1975. Three applications were required. A combination of paraquat and simazine [2-chloro-4, 6-bis-(ethylamino)-s-triazine], 4.5 kg/ha, was applied beginning in 1976 through 1979. Glyphosate [N-(phosphonomethylglycine] was used as a spot treatment in 1978 and 1979 to control Johnsongrass [*Sorghum halepense* (L.) Persoon] at 3.4 kg/ha. Except for spot treatments, herbicides were applied as a directed spray with a tractor-mounted boom sprayer to a 1.5-m strip on each side of the tree row. A nonionic surfactant (X77) at 0.125% (v/v) was added to all paraquat sprays.

3) *Mowed sod*. The orchard floor was established in Kentucky 31 tall fescue sod, as previously described. Vegetation was maintained by mowing with a rotary mower when it reached a height of 10 to 15 cm. An average of 4 mowings was required per year.

Recommendations of the Middle Georgia Apple Spray Guide were followed for pest control. Trunk circumference, tree height, canopy width, terminal growth, and weight of prunings (1976–1978) were determined annually. Number of fruit and total weight (kg per tree) were obtained in 1978 and 1979. In 1979, a random fruit sample (40 fruit) was collected from each treatment and average fruit size and the number of cork spots per fruit were determined. Samples were held for 90 days in conventional refrigerated storage (0.5°C) prior to recording the number of bitter pit spots appearing on individual fruits. The amount of wood (total length in cm) removed when trees were planted was used as a covariant to adjust growth response measurements at the end of the first growing season to determine the influence of initial pruning on growth.

Results and Discussion

Influence of initial pruning. Total length of prunings at planting ranged from 24.1 to 277.6 cm with an average of 65.8 cm per tree for all trees. Total shoot growth and tree height were not significantly affected by the amount of wood removed at planting (data not presented). Trunk circumference ($r = .38$), average terminal shoot growth ($r = .24$), and central leader growth ($r = .47$) were, however, significantly related to the total length of shoot growth removed (analysis of covariance, $P = 5\%$). Therefore, larger tree size at planting resulted in more growth under a herbicide strip or cultivation system but less growth under sod when all trees were headed back to the same height at planting. These findings suggest that a growth advantage might be acheived by the grower in the first year if he purchased the largest-sized one-year-old whips, headed them near 76 cm, and eliminated all ground cover competition.

Influence on growth. Neither N source nor rate had a significant influence on growth (data not presented). Lord et al. (16) found no influence of 3 N sources on growth of newly planted 'Sturdeespur Delicious' apple trees through the 8th growing season. Results of this study with a standard strain of 'Delicious' concur and support the suggestion that price per unit of N should be one of the major determining factors when choosing an N fertilizer source for young apple trees (15, 22).

Growth of apple trees generally has been increased with increasing rates of N fertilization (1, 4, 5, 29), but exceptions have been reported (10, 13, 19, 20). Failure to obtain a growth response has often been attributed to: 1) competition of the grass cover for the additional N (7, 17, 19); 2) a nonlimiting N leaf status (13); or 3) low moisture availability (13). In the present study, trees grown in sod plots made significantly less growth in the 2nd and 3rd growing seasons than trees grown under either of the weed-free cultural systems (Table 1). In the first growing season, there was no significant response regardless of the orchard floor management system. This indicates that vigor and built-up N-reserves of the nursery tree play a major roll in the initial tree growth. After 5 growing seasons, trees in the cultivated and herbicide plots had filled 57% of their allotted space, based on canopy width, compared to 45% for trees in the mowed sod. Other reports have shown that trees grown in a permanent grass sod produce less growth than similar trees grown under mulch or in the absence of weed competition (2, 7, 17, 18, 24). Trees were trained to a central leader system with extensive heading of main scaffold and laterals during dormant pruning. Significantly more prunings were removed from herbicide and cultivated trees in 1976–1978 than from those trees in the mowed

Table 1. Effect of orchard floor management system on the mean growth of 'Topred Delicious' apple trees on MM 111 rootstock during the first 5 years in the orchard.

Year	System	Terminal growth (cm)	Trunk circumf (cm)	Tree height (m)	Canopy width (m)	Weight of prunings (kg)
		5-year means[z]				
1975	Mowed sod	70.5	6.0	1.62	---	---
	Herbicide	66.7	6.1	1.60	---	---
	Cultivated	79.4	6.6	1.66	---	---
	LSD 5%	NS	NS	NS		
1976	Mowed sod	59.8	9.7	2.08	---	0.3
	Herbicide	72.5	11.5	2.23	---	0.6
	Cultivated	88.1	13.1	2.40	---	1.0
	LSD 5%	11.2	3.1	NS	---	0.3
1977	Mowed sod	56.1	12.7	2.45	1.10	0.4
	Herbicide	84.2	16.8	2.76	1.54	1.3
	Cultivated	79.7	18.0	2.88	1.64	1.5
	LSD 5%	12.4	3.5	0.15	0.32	0.5
1978	Mowed sod	49.9	16.0	2.74	1.79	0.8
	Herbicide	59.1	21.0	3.20	2.28	2.3
	Cultivated	62.1	22.7	3.35	2.39	2.7
	LSD 5%	NS	5.3	0.39	0.31	1.3
1979	Mowed sod	55.3	19.4	3.11	2.25	---
	Herbicide	56.9	25.0	3.55	2.84	---
	Cultivated	51.7	25.7	3.65	2.82	---
	LSD 5%	NS	3.3	0.44	0.28	---

[z]Means pooled over sources and rates.

sod (Table 1). Pruning can be expected to influence terminal growth (1) and may have influenced canopy size; however, there was a trend of less difference in terminal growth between soil management systems after the 3rd growing season, and no significant difference by the 5th year (Table 1). While it appeared that pruning did not significantly affect tree growth in the present study, this response may have been masked by the orchard floor management system.

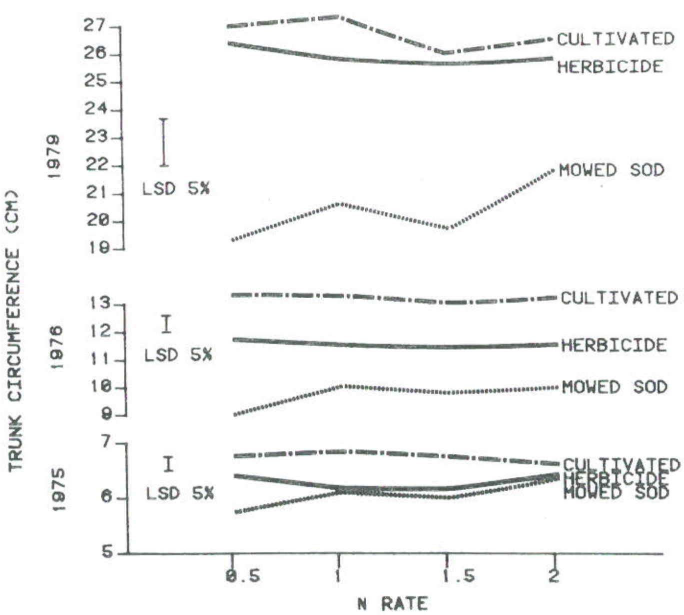

Fig. 1. Interaction of orchard floor management system and N rate on trunk circumference in 1975, 1976, and 1979 of 'Topred Delicious' apple trees on MM 111 rootstock planted in 1975. N = 45.4 g actual nitrogen per year tree age.

A significant interaction did occur between N rate and management system for the 2nd through the 5th growing season. Additional N resulted in growth increases for trees growing in sod while trees in cultivated or herbicide-treated plots did not respond to additional N (Fig. 1). Control of grass competition may not be as important during the first year of planting if moisture supplies are adequate and the sod is frequently mowed. However, the growth response was significantly improved by cultivation at the lower N levels (Fig. 1). This may suggest that shallow cultivation releases additional N or improves water penetration sufficiently to result in better growth. Rainfall was above normal during the first and 5th growing seasons and below normal for the 2nd, 3rd, and 4th growing seasons (Table 2). The precipitation data show that rainfall was generally below average during the months of April, June, and August. Much of the rain which falls in the summer months occurs as heavy thundershowers and thus is run-off, rather than available moisture. Terminal buds are usually "set" by mid-June in this growing region; therefore, any moisture deficit in the early part of the growing season could have an adverse effect on terminal growth, which in turn could be reflected in reduced tree height and canopy size. Undoubtedly, competition for moisture was involved in the reduced tree growth associated with the sod culture in this study. It has been shown that trees growing under grass cover have deeper root systems than under herbicide systems (24). Under these conditions, moisture deficits could develop, especially when rains are infrequent or percolation is poor. Recent studies have shown the significant effect of water stress on dry matter production in apple (12) and on the growth of peach trees (8). Lord and Vlach (17) found that frequent mowing did not overcome the moisture deficit caused by grass competition in peaches. When trees were irrigated, Crabtree and Westwood (9) could find no significant differences in growth of apple trees on 6 rootstocks under 4 orchard floor management systems and therefore concluded that apples could be grown successfully under a wide range of management systems.

Influence on yield and quality. Studies dealing with the effect of orchard floor management and N fertilization on early yield of apples on clonal rootstocks are limited. In general, increased rates of N fertilization have been associated with increased yields in deciduous fruits (3, 4, 5, 20, 25). The present study revealed no yield response in the 4th and 5th growing seasons due to N source or rate (Table 3). A trend was indicated in the 4th growing season; the first-season yield was measured. In the 5th season, trees in the cultivated and herbicide-treated

Table 2. Rainfall during the 1975 through 1979 growing season at the Georgia Experiment Station, Experiment, Ga.

Month	1975	1976	1977	1978	1979	51-year mean
	Total precipitation (mm)					
April	202	36	46	83	268	116
May	186	156	106	165	73	95
June	77	102	19	24	29	118
July	165	52	144	138	171	130
August	92	61	155	93	62	101
September	58	110	60	17	126	87
Total	780	517	530	520	729	647

plots had significantly higher per tree yields than trees in mowed sod.

One might suspect that higher yields were directly correlated with tree size as has been shown in previous studies (1, 4). However, correlation between yield efficiency and either canopy width, trunk circumference, or tree height resulted in r values of 0.30 or less. Individual tree yields were found to be more closely correlated with the above tree size parameters ($r = 0.51$, $r = 0.51$, and $r = 0.48$, respectively). Yields per tree are influence by many factors such as bloom density, fruit set, final fruit size, and tree size (27). Adequate pollinators were present in this study (one for every 3 'Delicious'); however, bee populations and weather conditions during pollination were considered marginal. Under less than optimum pollination conditions, considerable tree-to-tree variation may exist. A previous study (9) found that mowed sod trees were significantly less efficient than trees in cultivation or herbicides, but there were no differences between the latter 2 systems. Results of the present study illustrate the growth and yield advantages obtained when competition is reduced or eliminated; yield efficiency was significantly greater for berbicide-and cultivated-managed trees (Table 3).

Fruit from herbicide-treated trees had the largest diameter, probably due to reduced competition for moisture and available nutrients (Table 4). Fertilizing at twice the recommended rate did not affect fruit size. The percentage of fruit which developed bitter pit was not significantly affected by the orchard floor management system. High tree vigor is associated with increased incidence of bitter pit (26). Significantly more bitter pit was found on fruit from trees receiving the complete fertilizer (10N–4P–8K) compared to the other N sources. This may be due to an increase in the potassium levels which are known to decrease Ca levels. The explanation for the significantly greater percentage of fruit showing cork spot grown on trees in mowed sod is not readily apparent. Research has generally shown that cork-

Table 3. Main effects of orchard floor management system, N sources, and rates on initial yield and efficiency of 'Topred Delicious' apple trees on MM 111 rootstock planted in 1975.

Main treatment	Yield (kg) 1978	Yield (kg) 1979	Yield efficiency[z] 1979
Management system			
Mowed sod	2.0	6.1	0.19
Herbicide	3.4	13.0	0.27
Cultivated	5.8	17.5	0.34
LSD 5%	NS	4.9	0.03
N source			
NH_4NO_3	3.1	11.8	0.26
$Ca(NO_3)_2$	4.2	12.2	0.28
$NaNO_3$	3.7	11.8	0.25
Urea	4.0	13.1	0.28
10N–4P–8K	3.5	12.2	0.27
LSD 5%	NS	NS	NS
N rate[y]			
0.5 N	3.5	12.5	0.28
1.0 N	3.9	12.0	0.25
1.5 N	4.0	12.8	0.30
2.0 N	3.3	11.6	0.25
LSD 5%	NS	NS	NS

[z]Yield (kg)/cm^2 trunk cross-sectional area.
[y]N = 45.4 g actual nitrogen per year tree age.
[NS]Nonsignificant.

Table 4. Main effects of orchard floor management system, N sources, and rates on fruit size and the incidence of bitter pit and cork spot on 'Topred Delicious' apples harvested in the 5th growing season.

Main effect	Fruit diam (cm)	Bitter pit %	Bitter pit No. spots/fruit	Cork spot %	Cork spot No. spots/fruit
Management system					
Mowed sod	7.68	39	2.7	47	1.3
Herbicide	8.04	40	2.2	31	0.7
Cultivated	7.84	42	3.1	25	0.5
LSD 5%	0.07	NS	0.6	6	0.2
N source					
NH_4NO_3	7.87	38	2.4	32	0.8
$CA(NO_3)_2$	7.74	39	2.4	35	0.7
$NaNO_3$	7.84	39	2.5	38	0.9
Urea	7.86	39	2.5	33	1.0
10N–4P–8K	7.97	48	3.4	31	0.8
LSD 5%	0.09	8	0.6	NS	NS
N rate[z]					
0.5N	7.83	43	2.9	35	0.8
1.0N	7.89	39	2.7	34	0.8
1.5N	7.84	40	2.5	33	0.7
2.0N	7.87	39	2.4	36	0.9
LSD 5%	NS	NS	NS	NS	NS

[z]N = 45.3 g actual nitrogen per year tree age.
[NS]Nonsignificant.

ing is more severe on vigorous trees where competition for Ca is greater. Leaf calcium levels were below levels associated with reduced cork spot (14). I have observed erratic development, which appeared to be moisture-related, of cork in 'Delicious' orchards in the same geographic region over the years. Both bitter pit and cork spot were considered severe on the fruit harvested from this study. In recent years, $Ca(NO_3)_2$ has been promoted as a readily available source fo Ca which may reduce the incidence of Ca-related fruit disorders. Results of the present study would not support this contention (Table 4). It should also be pointed out that $Ca(NO_3)_2$ was the most costly N source used in this study.

The present study illustrates the significant growth and yield advantages which can be achieved when competition is reduced or eliminated during the first 5 years after planting. Unlike previous reported studies on fertilization in which N was applied at a fixed rate not based on tree age, this study involves multiples of a fixed rate based on tree age. Under these conditions a significant interaction occurs between soil management systems and rate of N applied; therefore, growers should base their fertilization program on the type of orchard floor management system and the growth response desired. Highest yields and maximum tree growth can be expected for standard 'Delicious' where a system of clean cultivation or herbicides is employed. Rapid tree growth and possible competition for available Ca may require additional cultural practices to control nutrient-related fruit disorders.

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