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Influence of Various Rates of $Ca(NO_3)_2$ Fertilizer and Soil Management on Young Apple Trees

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Abstract. **Calcium nitrate applied annually at rates ranging from 22.5 g actual N per tree (0.5 N, one-half the recommended rate) to 363 g/tree (8 N) and adjusted according to tree age did not influence the growth of 4 apple (*Malus domestica* Borkh) cultivars ('Golden Delicious', 'Triple Red Delicious', 'Red Yorking', and 'Stayman 201') on EM 7a rootstock. There was a significant soil management (herbicide, clean cultivation, or mowed sod) × rate interaction; trees in mowed sod responded to additional N with growth and leaf N levels comparable to the vegetation-free management systems at 4 times (4 N) the recommended rate (45 g N/tree/year age). Soil management and rate of fertilization influenced leaf N levels but not leaf Ca. Leaf N and Ca differed significantly among the 4 cultivars. Cumulative yield after 4 growing seasons was influenced by tree size and soil management, but not rate of fertilization. Soil pH was significantly higher under sod than under cultivated or herbicide strip culture. Soil Ca levels were not affected in the 0 to 30 cm profile. Residual soil NO_3-N did not accumulate in the surface 30 cm for any of the management systems except at the highest rate (8 N) under the cultivated and herbicide systems. Data for residual NO_3-N in the 0 to 120 cm soil profile indicated that the tree demand and leaching potential for NO_3-N was met at the 0.5 N rate when competition was eliminated and between the 2 N and 4 N level in mowed sod.**

Of the essential elements, N is the most important, and it must be added annually for adequate performance of deciduous fruit trees. A considerable amount of research has been focused on application and utilization of N fertilizers in apple orchards (8). Much of this work relates to low density orchards with established cultivars on seedling rootstocks under sod management. Recent studies (2, 14, 21, 26) have provided information on the use of N fertilizers with high density plantings on clonal rootstocks. Miller (26) has shown that a significant interaction exists between rate of fertilization (up to twice the recommended rate) and the soil management system; N source or rate alone did not influence growth. Increasing N generally will result in increased growth (3, 5, 6, 14), but not always (10, 15, 16, 25, 26).

In the east and particularly in Appalachia, the most common cultivars suffer from low Ca disorders. Calcium nitrate has been recommended for fruit trees as a readily available source of Ca and N (11, 22). In a recent study, however, Lord et al. (21) reported no increase in soil Ca levels with 8 annual applications of $Ca(NO_3)_2$. In their study, trees received 114 g of N in the 4th year and 136 g N in the 8th year. Hogue et al. (20) increased leaf and fruit Ca on apples grown in nutrient solution with increasing Ca levels in the nutrient solution. They concluded that if higher levels of Ca are made available to apple trees, leaf and fruit Ca would be increased significantly. Apple cultivars differ in their ability to accumulate Ca (12).

Haynes' (18) recent review of the influence of soil management practices on the orchard agro-ecosystem illustrates the variation in response obtained under different climatic and soil conditions. Research on the interaction of fertilizers and soil management for trees on clonal rootstocks in the United States is still limited despite recent work by Lord et al. (21), Crabtree and Westwood (9), and Miller (26).

The present study was designed to evaluate long-term effects of $Ca(NO_3)_2$ as a broadcast fertilizer source, applied at 5 levels adjusted annually to tree age, under 3 soil management systems on 4 apple cultivars. Soil and climatic conditions differed from those in previous experiments. This report describes the influence on growth, yields, and tree and soil nutrient levels, including residual nitrate during the 1st 4 years.

Materials and Methods

The research plot was established in 1979 on a Hagerstown/Frederick cherty silt loam soil (fine, mixed, mesic Typic Hapludalf). This soil is considered to be deep, well drained, with a high moisture holding capacity and high natural fertility. Soil pH ranged from 6.1 to 6.7 in the top 30 cm. One-year-old whips of 'Triple Red Delicious', 'Golden Delicious', 'Stayman-201', and 'Red Yorking' on EM 7a rootstock were planted in May with a mechanical tree planter at a spacing of 5.5 × 5.5 m. All trees were headed at 72 ± 2 cm at planting and subsequently trained to the central leader system. A permanent cover crop of 'Kentucky 31' tall fescue was established in the orchard drive middles. In the 1st year weeds were controlled in a 1.5 m strip on each side of the tree planting with a Smitty tree hoe. Permanent soil management systems were established later.

The experimental design was a split-split plot with soil management system as the main plot. Main plots were in 2 replicates, subdivided into 10 fertilizer subplots. Each cultivar was planted within a subplot with 1 tree/sub-subplot. Fertilizer grade $Ca(NO_3)_2$ was applied annually in March to all trees within a subplot at 5 rates beginning in 1980: 22.5 g (0.5 N), 45 g (1 N), 91 g (2 N), 182 g (4 N), or 363 g (8 N) of actual N per tree per year of tree age. Fertilizer treatments were broadcast under the dripline of the tree. The fertilized area was extended each year with the growth of the tree. During the 3-year period, N was applied to an average area of 5.31×10^4 cm^2 around the tree. For a soil sampling depth of 120 cm and a soil bulk density of 1.4 g/cm^3, this rate results in a total soil application of 22.5, 45, 91, 182, 363 ppm NO_3-N in the fertilizer subplots.

Three soil management systems (clean cultivation, herbicide,

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and mowed sod), previously described by Miller (26), were established in 1980. All cultivation was done with a Smitty tree hoe to a depth of 5 cm. Generally, 3 cultivations were required per year to maintain a weed-free surface. 'Kentucky 31' tall fescue was established as a monoculture in mowed sod treatments to cover the entire orchard floor. A combination of paraquat, 1, 1'-dimethyl-4-4'-bipyridiniumion salts, at 1.1 kg/ha and simazine, 6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine 4.5 kg/ha, was applied annually in April beginning in 1980. Glyphosate, N-(phosphonomethyl) glycine, was used as a spot treatment to control persistent weed species 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 leaving a 2.5 m wide strip of sod in the drive middles. A nonionic surfactant (X77) at 0.125% (v/v) was added to all paraquat sprays. A 2.5 m wide strip of 'Kentucky 31' tall fescue was maintained in all drive middles.

A commercial spray schedule was followed for pest control. Trunk circumference, canopy width, terminal growth, and yield (kg/tree) were determined annually. Leaf samples for analysis were taken annually in July from the mid-portion of current season's shoots. Following drying at 70°C and grinding in a stainless steel mill to pass a 40 mesh screen, samples were analyzed for N by micro-Kjeldahl. Total P, K, Ca, and Mg were determined by inductively coupled RF plasma emission spectrophotometry. Soil under the trees was sampled with an auger at 0 to 30 cm to determine pH and nutrient levels. Soil was extracted with 1 N NH_4OAC (pH = 7.0), and K, Ca and Mg in the extract were measured by atomic absorption spectrophotometry. Soil pH was measured in a 1 soil:1 water mix. Available P was determined using the Bray's extraction procedure. Base saturation was calculated as the meq of Ca + Mg + K/C.E.C. × 100. Main treatment effects were separated using analysis of variance for split-split plot design. Dependent variables were regressed against fertilizer rate and residual NO_3-N.

Soil cores 4.1 cm in diameter were collected in March of 1983 to a 120 cm depth to determine residual NO_3-N levels. One core was taken from a 30 cm band inside the drip line from each sub-subplot of the 'Delicious' and 'Golden Delicious' cultivars. Soil cores were divided into depth increments of 0–15, 15–30, 30–60, 60–90, and 90–120 cm. Each increment was air dried and ground to pass a 0.2 cm screen. Soil NO_3-N was extracted by shaking 20 g soil in 100 ml of 0.02 N KC1 for 30 min. The solution was filtered through a coarse qualitative filter paper and analyzed the same day for NO_3-N using a nitrate selective ion electrode. The reference electrode was a saturated calomel electrode with an outer reference solution of 0.04 M $(NH_4)_2SO_4$. The reference blank was 0.02 N KC1, and the dilutant served for the reference standards. Measured recovery efficiency for this system was 100.3% ± 2.8% for additions of 0, 20, and 40 ppm NO_3-N in 6 soils ranging in native NO_3-N content from 6–67 ppm.

Results

Influence on soil. Application of $Ca(NO_3)_2$ for 3 years did not affect soil pH, available P, or exchangeable K, Ca, or Mg at the 0 to 30 cm depth (data not presented). Soil pH was significantly lower under cultivation and herbicide management systems than where trees were grown in sod (Table 1). Exchangeable K was reduced significantly by sod culture. Sod management tended to increase available P and exchangeable Ca and Mg.

Table 1. Effect of ground cover management on soil pH and nutrient levels for apple trees fertilized with $Ca(NO_3)_2$.[z]

Management system	pH	P kg/ha	meq/100 g K	Ca	Mg
Cultivated	6.1 b[y]	161 a	0.47 a	5.82 c	0.39 b
Herbicide	6.2 b	129 b	0.46 ab	6.60 b	0.48 a
Mowed sod	6.6 a	170 a	0.42 b	7.13 a	0.48 a

[z]Means pooled over 5 fertilizer rates and 4 cultivars; values are averages of 80 cores.
[y]Mean separation, Duncan's multiple range test, 5% level.

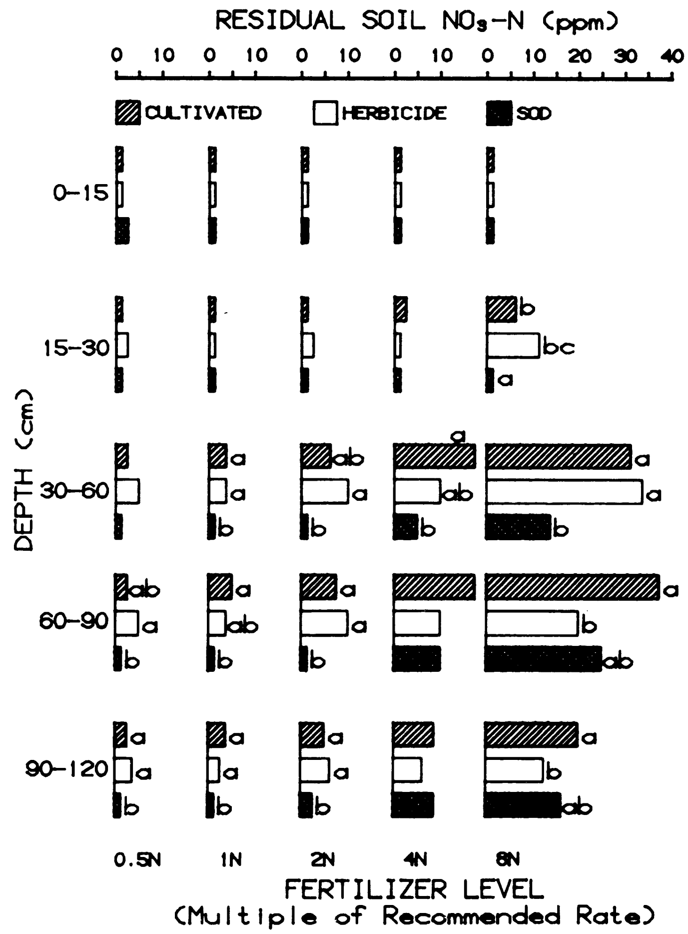

Fig. 1. The effect of floor management systems and $Ca(NO_3)_2$ fertilizer level on residual soil NO_3-N at 5 depths in a 120 cm profile. Values represent an average of 8 cores from 'Red Delicious' and 'Golden Delicious' sub-subplots. Probability level equals 0.05 for Duncan's multiple range values.

NO_3-N did not accumulate in the surface 30 cm except at the highest rate of $Ca(NO_3)_2$ (8 N) (Fig. 1). Even at the 8 N rate, NO_3-N did not accumulate in the top 30 cm in the sod treatment. As the rate of fertilization increased, the amount of residual NO_3-N generally increased throughout the 0–120 cm soil profile (Fig. 2). The least amount of residual NO_3-N was determined under sod (Fig. 3). The most dramatic initial increase in soil NO_3-N occurred at the 2 N fertilizer rate for the cultivated and herbicide systems, and at the 4 N level for the mowed sod system.

Influence on growth and yield. There were no interactions between cultivars and system or N rate with regard to tree growth. $Ca(NO_3)_2$ had no appreciable influence on trunk circumference

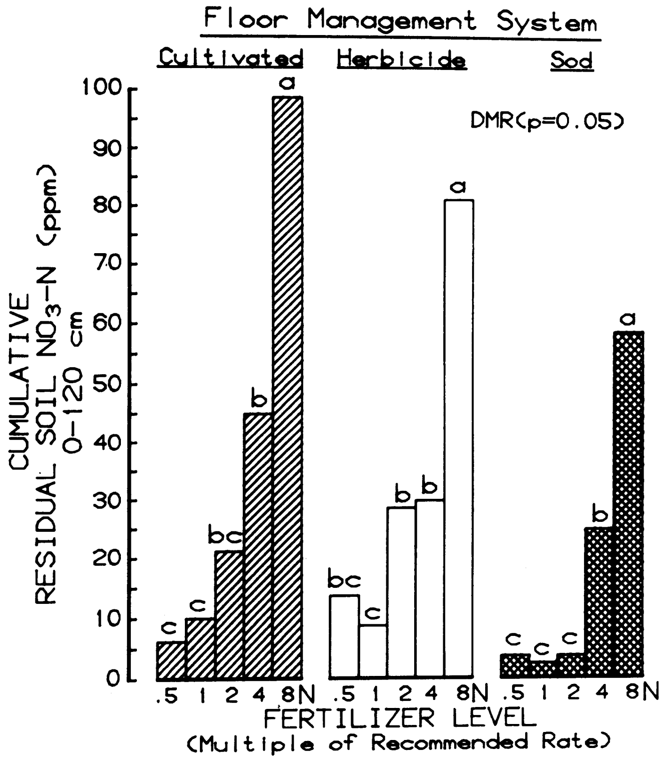

Fig. 2. The effect of $Ca(NO_3)_2$ fertilizer levels on residual NO_3-N in 3 floor management systems. Values represent an average of 8 cores from 'Red Delicious' and 'Golden Delicious' sub-subplots.

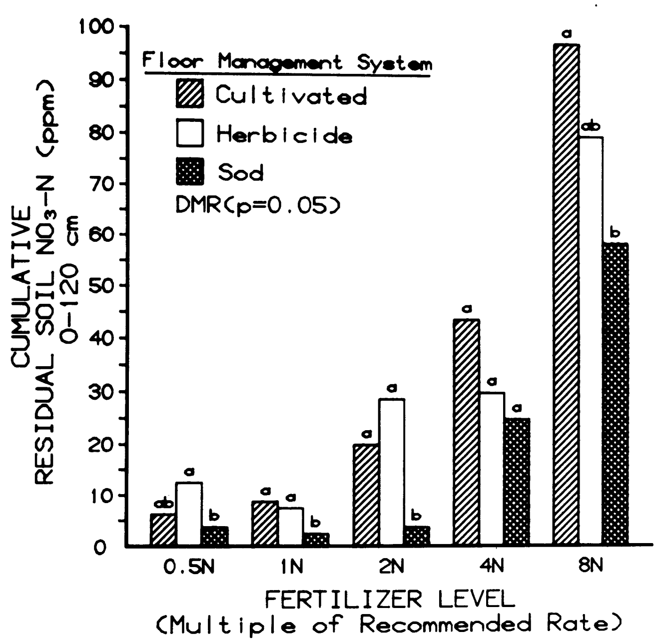

Fig. 3. The effect of floor management systems on residual NO_3-N for 5 levels of $Ca(NO_3)_2$ application. Values represent an average of 8 cores from 'Red Delicious' and 'Golden Delicious' sub-sub-plots.

or canopy spread after 3 annual treatments (r = 0.04 and 0.10, respectively; data not presented). Average terminal growth was less for 'Golden Delicious' than for the other cultivars (Table 2). After 4 growing seasons, trees in the weed-free plots had filled 42% to 45% of their allotted space based on canopy width compared to 35% for trees in mowed sod. Differences in mean

Table 2. Influence of ground cover management system on the mean growth of 4 apple cultivars on EM 7a rootstock fertilized with $Ca(NO_3)_2$ during the 1st 4 years in the orchard.[z]

	Trunk circum (cm)	Terminal growth (cm)		Canopy width (m)
Main treatment	1982	1980	1982	1982
Management system				
Cultivated	20.4 a[y]	61 a	68 a	2.31 b
Herbicide	20.5 a	60 a	64 b	2.47 a
Mowed sod	16.9 b	42 b	64 b	1.91 c
Cultivar				
Triple Red Delicious	19.4 a	63 a	68 a	2.20 b
Golden Delicious	19.5 a	54 b	60 b	2.15 b
Red Yorking	18.8 a	47 c	68 a	2.14 b
Stayman – 201	19.4 a	58 b	66 a	2.44 a

[z]Means pooled over rates and main effect. Trees planted May 1979.
[y]Mean separation for main effect, Duncan's multiple range test, 5% level.

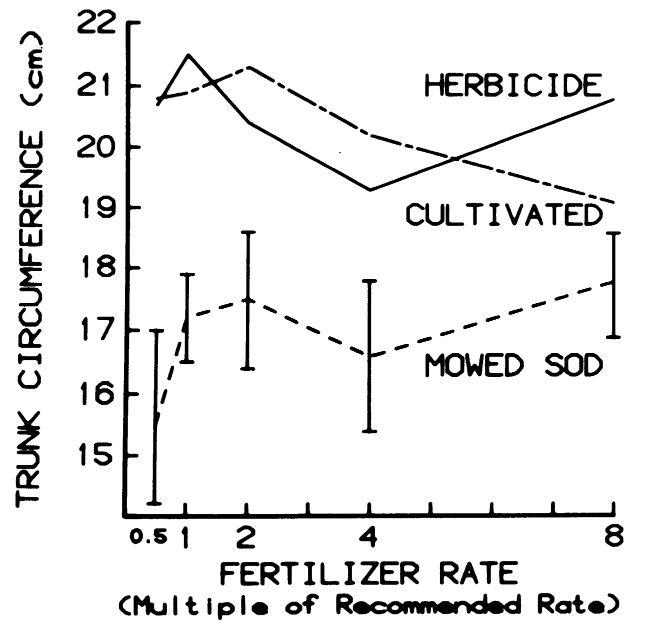

Fig. 4. Interaction of ground cover management system and rate of $CA(NO_3)_2$ on trunk circumference of apple (4 cultivars pooled) trees on EM 7a rootstock after 4 growing seasons. N = 45 g actual nitrogen per year tree age. Vertical bars represent the SE of the mean; absence of bars indicate nonsignificant differences.

terminal growth were less pronounced in 1982 than in 1980, the initial year of treatment. Trunk circumference decreased as N rate increased in clean cultivated and herbicide strip but increased with sod (Fig. 4).

Yield and yield efficiency were not influenced by fertilizer rates (r = 0.14 and 0.12, respectively) (Table 3). Cumulative yields for 1981 and 1982 were significantly increased with the herbicide strip system; clean cultivation was more than mowed sod. Herbicide treated trees were the most efficient among the 3 soil management systems, based on 1982 yield and the calculated trunk cross sectional area. 'Stayman-201' was the most precocious of the cultivars tested. There was a signficant interaction of soil management system × cultivar for yield/tree in 1982. Yields were equal for 'Delicious' regardless of management system; 'Golden Delicious', 'Red Yorking', and 'Stay-

Table 3. Cumulative yield and yield efficiency of 4-year-old apple trees fertilized with $Ca(NO_3)_2$ and maintained under 3 orchard floor management systems.

Main treatment	Cumulative yield (kg/tree) 1981–1982	Yield efficiency[z] (kg cm^{-2} TCSA^2) 1982
Management system		
Cultivated	5.56 b[x]	0.037 b
Herbicide	7.04 a	0.049 a
Mowed sod	2.97 c	0.034 b
Cultivar		
Triple Red Delicious	4.52 bc	0.042 ab
Golden Delicious	4.18 c	0.029 b
Red Yorking	5.70 ab	0.042 ab
Stayman-201	6.95 a	0.047 a
N rate[y]		
0.5 N	4.83	0.037
1.0 N	5.82	0.041
2.0 N	5.75	0.040
4.0 N	5.01	0.042
8.0 N	5.20	0.040
Corr. coeff. (r)	0.14	0.12

[z]TCSA trunk cross sectional area.
[y]N = 45 g actual nitrogen per year tree age; trees planted May 1979.
[x]Mean separation, Duncan's multiple range test, 5% level.

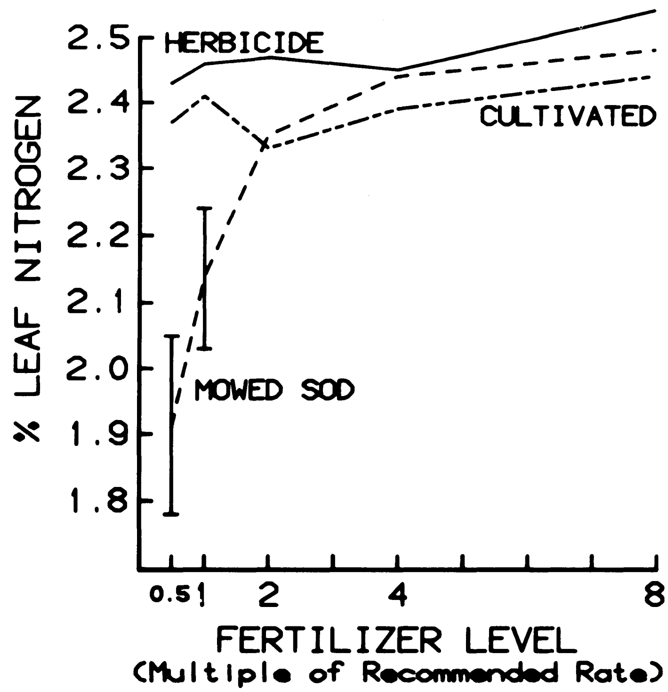

Fig. 5. Interaction of ground cover management system and rate of $Ca(NO_3)_2$ fertilizer on the percentage of leaf N in apple (4 cultivars pooled) on EM 7a rootstock in the 4th growing season. N = 45 g actual N per year tree age. Vertical bars represent the SE of the mean; absence of bars indicate nonsignificant differences.

man-201' had reduced yields under sod and higher yields with herbicide stip management. 'Delicious' bore no fruit until 1982, the 4th growing season.

Influence on leaf nutrient levels. Trees growing in weed-free plots accumulated a maximum amount of leaf N at the 1 N rate (45 g actual N/tree/year age), whereas trees in mowed sod required at least 4 N (181 g actual N/tree year age) to reach an equal leaf N content (Fig. 5).

Trees growing in cultivated or herbicide strip had significantly higher N and Mn levels and lower P than those in sod. Leaf Ca was not affected by soil management (Table 4). Leaf N levels in the mowed sod were correlated with the level of residual soil NO_3-N for both 'Delicious' and 'Golden Delicious' (r = 0.84 and r = 0.71, respectively) (Fig. 6 and 7). No relationship was evident between leaf N level and residual soil NO_3-N for the cultivated and herbicide management systems. Rate of fertilization had a significant effect on leaf nutrient level (Table 4). Phosphorus, Mg, and B decreased as the rate of $Ca(NO_3)_2$ was increased. Leaf Mn, Cu, and Zn were not affected by rate. Leaf Ca levels were not affected by ground applications of $Ca(NO_3)_2$ even when 2.3 kg of actual Ca [9.3 kg actual $Ca(NO_3)_2$] was applied in the 4th growing season. Leaf N increased linearly with increasing N rate when data was pooled over main effects. Cultivars differed in leaf nutrient levels, but no one cultivar was consistently higher or lower than another for those elements measured (Table 4). Among cultivars pooled over rate and soil management systems, 'Delicious' and 'Golden Delicious' had significantly increased levels of leaf N. Ca levels were significantly reduced in 'Delicious' and 'Red Yorking' leaves.

Discussion

Positive responses in growth and yield from increased N fertilization in tree fruit, particularly apple, are documented (3, 5, 6, 8, 13). Such a response can be expected when leaf N is a limiting factor, competition from cover crops is great, or moisture levels are adequate (16).

Soil moisture and leaf water potential/stomatal resistance measurements were not determined in this study. Observations, coupled with local rainfall, temperature, and relative humidity data, suggest that moisture stress may have occurred twice during the months April through July of the 1st 4 growing seasons—June 1980 and May 1982. Only the latter was probably severe enough to affect growth (3.0 cm measured precipitation vs. 9.5. cm mean normal, average noon day temperature = 22°C, 49% RH). Traditionally the months of August and September are the driest in this area. Except for the year of planting, precipitation for these months was below the recorded 50-year mean in each year. Rainfall measured during the 6-week period after fertilizer was applied each year was considered sufficient to dissolve and carry the material to feeder roots. Broadcast placement of the $Ca(NO_3)_2$ was considered optimum for maximum uptake (2).

In the present study, leaf N levels were considered adequate (2.24% mean, pooled over all systems) even at the lowest rate of fertilization (0.5 N), except for trees grown in sod. Those trees had only 1.91% leaf N. Trees fertilized at the 2 N or above rate had adequate leaf N levels regardless of the soil management system. However, since growth was not increased by increasing rates of N fertilization, the main effect of N rate was not considered to be a limiting factor. The data, however, suggest that cover crop is a limiting factor when trees are grown in sod and fertilized at the normal recommended rate (1 N = 45 g actual N/tree/year age) and this limitation can be overcome partially with additional N application. Sod competition for limited water continues to restrict growth. Crabtree and Westwood (9) recently reported that apple trees grown under irrigation could perform normally under various soil management sys-

Table 4. Main effects of ground applied $Ca(NO_3)_2$ fertilizer under 3 orchard floor management systems on leaf nutrient levels in 4 apple cultivars on EM7a rootstock in the 4th growing season.[z]

	Dry wt (%)					ppm	
Main treatment	N	P	K	Ca	Mg	Mn	B
Management system							
Cultivated	2.39	0.17 b[y]	1.79 a	1.43 a	0.25 c	102 a	21.0 a
Herbicide	2.46	0.18 b	1.70 b	1.43 a	0.27 a	101 a	20.0 a
Mowed sod	2.26	0.26 a	1.80 a	1.38 a	0.26 b	88 b	20.0 a
Cultivar							
Triple Red Delicious	2.47 a	0.22 a	1.79 b	1.27 b	0.26 bc	93 b	21.5 a
Golden Delicious	2.42 a	0.21 ab	1.94 a	1.53 a	0.25 c	109 a	20.8 ab
Red Yorking	2.33 b	0.20 bc	1.55 c	1.35 b	0.28 a	82 c	19.8 b
Stayman-201	2.26 c	0.19 c	1.76 b	1.52 a	0.27 ab	104 a	19.6 b
N rate							
0.5 N[x]	2.24	0.28	1.80	1.41	0.27	97	22.1
1.0 N	2.34	0.20	1.77	1.40	0.27	95	21.0
2.0 N	2.38	0.19	1.72	1.40	0.26	93	20.8
4.0 N	2.43	0.18	1.70	1.42	0.26	99	19.4
8.0 N	2.47	0.17	1.82	1.45	0.25	100	18.8
Corr. coeff. (*r*)	0.31	0.44	0.18	0.08	0.22	0.08	0.33

[z]Trees planted May 1979; fertilized annually beginning 1980.
[y]Mean separation, Duncan's multiple range test, 5% level. Absence of letters indicates significant interaction between main effects (management system × N rate for leaf N level).
[x]N = 45 g actual N per year tree age (1982 = 4-years-old).

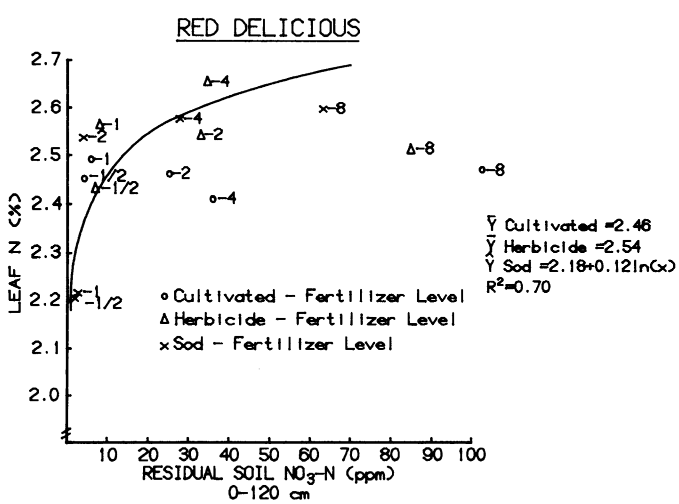

Fig. 6. The effect of residual NO_3-N and floor management system on leaf N levels for 'Triple Red Delicious'.

tems, although yield efficiency was significantly reduced for trees growing in sod.

The present results support earlier findings (26) regarding soil management for apples on dwarfing rootstocks: competition for available moisture, not N fertilizer rate, is the principle limiting factor in the growth and initial yields of young apple trees. The presence of a rate × management system interaction indicates that any fertilizer program must consider the soil management system as well as the needs of the tree. Application of $Ca(NO_3)_2$ at a rate above that required by the tree and crop in a weed-free management system is not justified. Further studies are needed to answer the questions of moisture as a limiting factor in eastern production areas.

Limited information (19) is available concerning the effect of fertilizer rates on leaf nutrient levels of apple on clonal rootstocks. However, rootstocks influence leaf nutrient levels (29).

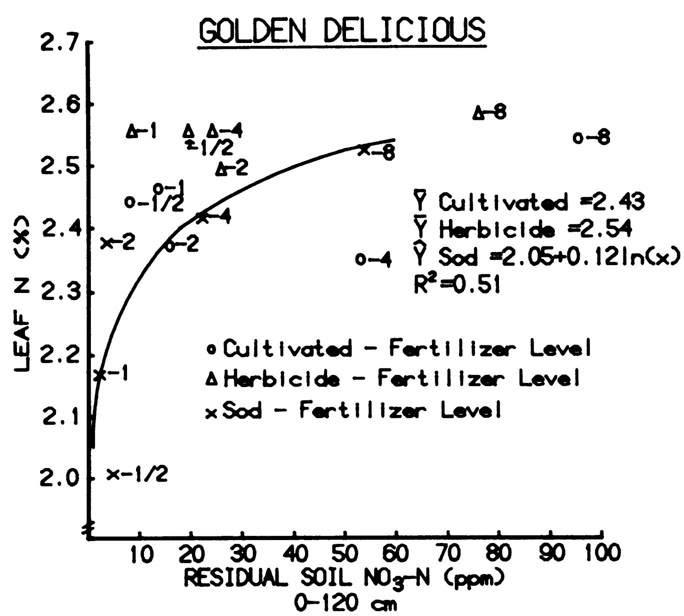

Fig. 7. The effect of residual NO_3-N and floor management system on leaf N levels for 'Golden Delicious'.

Except for K and Mg (5, 7, 16, 33), changes in leaf nutrient levels generally were consistent with other published reports when N fertilizers were applied (5, 6, 7, 8, 14, 25), i.e., leaf N increased while P and B decreased. Failure to detect a consistent decrease in K may be due to a high availability of soil K. The slight but significant decrease in Mg may be the result of excess Ca from high rates of $Ca(NO_3)_2$ (475 kg/ha actual at the 8 N rate in 1982). Increasing the rate of $Ca(NO_3)_2$ maintained or increased leaf N but did not affect leaf Ca. On sandy soils, applications of $Ca(NO_3)_2$ increased leaf Ca significantly (28). Lord et al. (21) found no consistent effect on a sandy loam from 8 annual applications of $Ca(NO_3)_2$ on leaf N, K, Ca, or Mg.

Our results would support and strenghthen the contention that $Ca(NO_3)_2$ is a satisfactory source of N but unsatisfactory for Ca. Lack of a leaf Ca response may be related to the high N rates which increased growth and consequent demand on the Ca pool, or to a lack of movement of Ca in the soil (32). Our field studies do not support a recent nutrient solution study (20) which indicated that leaf Ca will be increased significantly if high levels of Ca are made available to apple trees. In the field many factors influence nutrient uptake, unlike nutrient culture studies as reported by Hogue et al. (20).

The influence of soil management system on leaf nutrient levels can be attributed to the effect of competition for N, changes in the organic matter under vegetation free culture, and the change in soil pH. In this study, an additional 45 to 135 g of N/tree/year age was necessary to overcome the effect of grass competition (Fig. 5). These results support findings from other fruit growing regions with regard to the influence of various soil management systems (4, 17, 24). Herbicide treated plots had significantly increased leaf N levels. Simazine has been reported to increase N levels in fruit trees, possibly through an effect on N metabolism (23, 30, 31). Leaf Ca levels were not influenced by vegetation free management, even though these trees made significantly more growth than those grown in sod. Such growth often leads to reduced Ca levels (31).

It is not readily apparent why fertilizer rates failed to influence soil P, K, Ca, or Mg. The soil type in this study is considered to be well drained. Soil moisture generally is near field capacity after spring fertilizer applications in this area. Leaching may account for the failure to elicit a Ca response. However, the soil in this study had a relatively low C.E.C. (mean of 10.3 meq/100 g) and a high precentage of base saturation (mean of 75%); about 65% of the latter was attributed to Ca. Under these conditions added Ca may not increase soil Ca levels.

Soil management system clearly influenced soil nutrient levels, pH and percentage of base saturation in the surface 30 cm. These results are consistent with previous reports where grass was the cover crop (19).

Nitrogen fertilizer applied in excess of crop needs and leaching potential, will accumulate in the soil profile (1, 27). The standard N rate (1 N) for the cultivated and herbicide floor management systems demonstrated no significant increase in residual NO_3-N over the 0.5 N level after 3 years (Fig. 2, 3). Doubling this rate (2 N) did result in an increase in residual NO_3-N in the 120 cm soil profile, suggesting that at the 2 N or greater levels the application rate was greater than the tree's demand and the leaching potential. The sod management system demonstrated no appreciable accumulation of NO_3-N until the 4 N rate of $Ca(NO_3)_2$ was applied. Young trees growing in a mowed sod culture require additional N to meet the demand of both the tree and the sod (17). These results also suggest that a soil N survey of orchards in Appalachia would show whether previous N applications have been excessive, resulting in an accumulation of soil N.

Our results indicate that competition from a grass sod may be a significant limiting factor in the growth of young apple trees on EM7a rootstocks. The N demand of these trees and the leaching potential of a well drained silt clay loam soil may be met with 22.5 g of actual N per tree/year age (at least in the 1st 4 growing seasons) when competition is eliminated by cultivation or with herbicides. Four to 8 times this rate is needed to achieve comparable growth and leaf N levels when trees are grown in sod. $Ca(NO_3)_2$ is a satisfactory source of available N, but even at high rates (2.32 kg actual $Ca(NO_3)_2$/tree) leaf Ca levels are not affected. Excess rates of $Ca(NO_3)_2$ may increase the N:Ca ratio which could lead to severe Ca related physiological disorders. Cultivars can be expected to respond similarly to the various rates of $Ca(NO_3)_2$ fertilizer and soil management, except for yields, where elimination of the grass cover may not improve early yields for some cultivars like 'Delicious'.

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Composition and Color of Fruit and Juice of Thornless Blackberry Cultivars

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Abstract. **Ripe fruit of 40 thornless blackberry cultivars and selections, and juice samples obtained therefrom, were compared to determine differences in color and composition after freezing, thawing, and heating. Color changes (reddening) during frozen storage were associated with within-sample variability in ripeness. Red subsamples of frozen blackberries were lower than black subsamples in soluble solids and total anthocyanin contents and higher in titratable acidity and anthocyanin recovery in the pressed juice. When juice samples were standardized to compensate for differences in pH and anthocyanin concentration, ripeness and cultivar effects on juice tristimulus parameters were small. Rapid thawing of frozen fruit resulted in less anthocyanin loss than did slow thawing. Heating darkened blackberry juice samples and increased values of A_{440}/A_{513}.**

Considerable interest has been shown in the breeding, production, and utilization of thornless blackberries (2, 6, 20). Information on composition, quality, and processability is needed to guide breeders and to expedite the commercialization of this crop. Limited data are available on the sugars, nonvolatile acids, phenolics, and anthocyanins of thornless blackberry cultivars (12, 13, 21, 23, 24). Jennings and Carmichael (7) described the tendency of frozen blackberries to turn red, a phenomenon they attributed to cellular disruption and intracellular pH changes in fruit that were not fully ripe. Crivelli and Rosati (1) studied the suitability of 'Smoothstem' and 'Thornfree' blackberries for freezing but did not report a color change during frozen storage. Comprehensive evaluations such as those performed with the fruit of thorny cultivars, 'Cherokee', 'Comanche', and 'Cheyenne' (10, 11, 17) have not been reported for thornless cultivars.

Our objective in this study was to investigate the composition of fruit and juice of thornless blackberry cultivars and selections

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