

Nineteen Years of Ammonium Nitrate Applications to Limited Areas Is Not Detrimental to Pecans

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Abstract. Nitrogen was applied at 112 kg·ha⁻¹ to mature 'Stuart' pecan [*Carya illinoensis* (Wangenh.) C. Koch] trees, but the radii of the application were limited to 4.6, 6.1, 7.6, or 9.1 m. Yield, nut size, percentage of kernel, tree growth, and appearance were not affected by concentrating the N application. Leaf N was highest for the largest N application radius, but all treatments supplied abundant N. Concentrating N reduced soil pH and occasionally P, K, and Ca in the 0–15 or 15–30 cm soil layers, but all three soil nutrients and Mg were medium to high after 19 years of treatments.

The cost of producing pecans is continually increasing without compensating price increases received by growers. To survive economically, pecan growers must reduce the cost of growing pecans. Soil compaction and weed competition are major production problems that reduce yield and profits. Application of N through the drip or microsprinkler irrigation system would prevent soil compaction by the fertilizer applicator truck, reduce weed competition by not fertilizing weeds in row middles, and reduce application cost. Fertilizer application through a low-volume irrigation system would be limited to the small area wetted by the emitter or sprinkler. Apple (*Malus domestica* Borkh.) tree performance was the same when fertilizer was applied uniformly over the area in the orchard and when applied only to the herbicide strip (Kulesza and Szafranek, 1990), and no difference in apple leaf N was obtained when N was broadcast or applied only along the dripline (Michaelson et al., 1969). Other research has indicated that recycling of nutrients through the leaves and soil helps redistribute them throughout the soil underneath the tree canopy (Adams and Attiwill, 1986; Worley, 1990).

I report on a long-term study on pecan tree performance to determine the feasibility of applying the recommended rate of N to a limited area of the tree canopy, which would cause part of the root system to be in an area well supplied with N and subject to soil changes brought on by N concentration and the remainder of the root system with limited N. If N application within a small radius is not detrimental to tree yield, tree growth, and nut quality, then application of N to only a part of

the root system or fertigation by drip or trickle irrigation should be acceptable alternatives. If the recommended rate of N can be concentrated, then additional studies can be conducted to refine the rate for optimum fertilizer efficiency. Shorter-term studies have shown feasibility of fertigation (Aitkin, 1986; Smith et al., 1979; Worley et al., 1995).

Materials and Methods

Trees were mature 'Stuart' (>50 years old) and 'Farley' (>30 years old) spaced 21 × 21 m apart at Tifton, Ga. Since limbs of adjacent trees were not touching, trees were not considered to be crowded. The soil was a Tifton loamy sand, which is an Ultisol Fine, loamy, silicious, thermic, Plintic Kandiodults located at ≈31.3°N lat. and 83.6°W long. A root distribution study in the orchard revealed that most roots were limited to the 15 to 45 cm depth due to a compact plintite subsoil (Worley et al., 1974). Trees grow well in this humid area of the southeast, and roots explore the total area underneath the tree canopy without irrigation, but yield and quality are usually improved by supplemental irrigation during fall and perhaps spring. A subsoil furrow at 45-cm depth was made midway between trees each year to reduce feeding of one tree underneath another. Area of application treatments were initiated in 1976 and continued annually through 1994. Ammonium nitrate was applied manually in a single annual application in mid-March with N at 112 kg·ha⁻¹ (5.1 kg N/tree) for all treatments, but the amount for each tree was applied to radii of 4.6, 6.1, 7.6, or 9.1 m. This rate has proven to be adequate and near optimum from other studies (Worley, 1990). Other nutrients and lime were added if soil or leaf analysis indicated need.

Leaf elemental concentrations were determined from 50 middle leaflet pairs from middle leaves from terminals in the area of maximum limbspread (≈6 to 9 m high) of each tree between the second week of July and the first week of August each year (Plank, 1988). Leaves were visually clean, had not been sprayed with

mineral elements, and were not washed (Plank, 1988; Worley, 1993). Leaves were dried and ground to pass a 1-mm-pore sieve. Duplicate 1-g samples were analyzed for N by an AOAC macro-Kjeldahl procedure (Horwitz, 1980). Leaf P was determined colorimetrically and the cations K, Ca, and Mg were determined by atomic absorption spectroscopy as described by Worley (1990). Residual soil nutrients were determined from a composite of 12 soil plugs taken in early winter underneath each tree canopy at 0–15 and 15–30 cm depths. Beginning in 1989, soil was sampled within and outside the fertilized area. Soil was dried, and analyzed for pH (water) (5 g soil to 10 mL water) and P, K, Ca, and Mg (double-acid extractant) by the procedures of Cahoon (1974). A soil density of 2,240,000 kg·ha⁻¹ was assumed.

Twenty-five adjacent terminal shoots were measured for shoot length in each quadrant of the tree in the same area of the tree canopy. At this time, leaf samples were collected and the number of fruit present on 100 terminals was counted. Tree trunk circumference was measured annually in the area of minimum circumference between the root flange and the first limb and circumference increase was calculated. Vigor and leaf color ratings (1 = poor vigor or light green, 9 = excellent vigor or dark green) were made visually for each tree in fall.

Nuts from each tree were harvested, weighed, and a 50-nut (≈0.5 kg) sample was removed for quality analysis. The in-shell nut sample was weighed and graded into commercial size categories by 1.6-mm increments of diameter. The sample was then cracked and edible kernels were graded into fancy, standard, and amber color grades. Percentages of in-shell nut of each grade, total percentage of kernel, and mass/nut were calculated. Edible kernels with defects and dark kernels were graded as amber; the brightest kernels were graded fancy.

Trees were sprayed uniformly to control insects and diseases using Univ. of Georgia Cooperative Extension Service recommendations. Insecticides were applied only when scouting indicated need. Trees had no irrigation before 1981. After 1980, drip supplemental irrigation was provided uniformly to all trees through 12, 8 L·h⁻¹ emitters/tree. Irrigation was provided when soil matric potential was less than about -300 kPa in the wetted zone. Mean rainfall (mm) for the area is: January, 108; February, 110; March, 119; April, 96; May, 87; June, 116; July, 145; August, 127; September, 91; October, 58; November, 59; and December, 91. Periods of water stress frequently occur during May and June and August and September. The critical period for water use is during the August to September nut sizing and filling period. Orchard floor management was a close-mowed native sod with a weed-free ≈3-m herbicide strip in the tree row. The statistical design was a randomized complete block with six replications of 'Stuart' and two replications of 'Farley' trees with single-tree plots. Mean separation was by the SAS GLM procedure with the PDIF option (*t* test) (SAS Institute, 1989).

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Results and Discussion

Yield, nut size, and kernel quality. Yields varied greatly from year to year due to the irregular bearing nature of pecan trees (data not presented). Yearly tree yields averaged 45 kg (range 44 to 49 kg/tree) and were not affected by treatments. Kernel quality, measured by percentage in three grades; total percentage of kernel; and nut size grades were not affected by treatments (data not shown).

Tree growth, appearance, and cropping density. Trunk circumference was affected little by the treatments (data not presented). Trunk circumference at the end of 19 years averaged 199 cm, and circumference increase (1994 circumference minus initial circumference) averaged 49 cm. Terminal shoot growth averaged 9.1 cm-year⁻¹ (range 8.9 to 9.4 cm) and cropping density averaged 1.02 nuts per terminal (data not shown). Treatments did not affect any of these growth and yield characteristics or tree vigor and foliage color. Vigor and color were good for all treatments.

Leaf elemental concentration. Differences in elemental concentration were small and were all within the sufficiency range suggested for pecans (Plank, 1988). Overall, only leaf N and Mn were affected by treatments. Leaf N was not affected by treatments in most years, but in some years (1980, 1981, 1983, 1984, 1987) the N concentration was higher in leaves receiving N in the largest radius than in leaves from trees receiving N in one or more of the smaller radii. Over all years leaf N was higher for the 9.1-m radius than for the 4.6- and 7.6-m radii (Table 1). Although statistically significant, this difference averaged no more than 0.08 percentage points and was of no practical significance. All treatments supplied abundant N with leaf N well above the 2.50% lower threshold of the sufficiency range (Plank, 1988). Greater N stress might have caused greater treatment differences. Fertigation with N at 56 kg·ha⁻¹ provided abundant N in another study (Worley, 1996).

The year × treatment interaction was significant only for leaf P and Mn. Leaf P was only 0.12% to 0.13% even though soil P was very high for all samples. The leaf P interaction was caused by inconsistent treatment differences in 1979, 1984, and 1991, with no significant treatment differences in other years (data not shown). Leaf Mn was increased with reduction in area of application (Table 1), probably resulting from the decreased pH caused by concentrating the N. The year × leaf Mn interaction was one of degree. Leaf Mn

Table 1. Leaf N and Mn and soil pH 0–15 cm depth when N application is limited to various radii of the tree trunk over 19 years.

Radius of application (m)	Leaf		Soil pH
	N (%)	Mn (μg·g ⁻¹)	
4.6	2.72 a ²	287 b	5.8 a
6.1	2.74 ab	257 b	5.8 a
7.6	2.70 a	237 ab	5.9 b
9.1	2.78 b	196 a	6.0 c

²Mean separation by GLM Pdiff (*t* test) at *P* ≤ 0.05.

Table 2. Soil analysis within the fertilized radii after 19 years of application.

Radius of application (m)	Treated area/tree (ha)	Rate within circle (kg·ha ⁻¹)	Soil composition							
			pH		Mineral (kg·ha ⁻¹)					
					P		K		Ca	
			0–15	15–30	Depth of sampling (cm)				0–15	15–30
4.6	0.0065	785	5.6 a ²	5.1 a	157 a	144 a	151 a	94 a	470 a	276 a
6.1	0.0117	436	5.7 a	5.2 a	222 ab	204 a	144 a	87 a	925 ab	477 a
7.6	0.0182	281	6.2 ab	5.2 a	222 ab	162 a	131 a	90 a	982 b	487 a
9.1	0.0262	195	6.6 b	6.1 b	286 b	194 a	149 a	122 b	1326 b	653 a

²Mean separation by GLM Pdiff (*t* test) at *P* ≤ 0.05.

was higher for the smallest than for the largest radius each year, but differences were not significant in the first 3 and last 2 years of the study (data not shown). There was no indication of a change in treatment effects caused by the initiation of drip irrigation in 1981.

Soil analysis. Mean soil pH in the treated area was lower in the 0–15 cm depth when the N application radius was <7.6 m (Table 1). Results were similar, but pH was lower at the 15–30 cm depth (data not shown). A significant year × treatment interaction was caused by the slow reaction of the soil to the acid forming conditions caused by concentrating the N. No significant treatment differences in pH at the 0–15 cm depth were detected until 1981, and significant differences between the smallest and largest radii were not detected until 1989 (data not shown). The slow reaction to soil Ca was also similar, with significant differences between the smallest and largest radii being first significant in 1990 (data not shown). The 1994 soil test data (Table 2) were the culmination of 19 years of the treatments. Soil pH at the end of 19 years was higher for the largest radius than for the two smallest radii at the 0–15 cm depth and higher for the largest radius than all others at the 15–30 cm depth. Soil P was higher for the largest than the smallest radii in the topsoil but did not differ with radii at the 15–30 cm depth (Table 2). Soil K was not influenced significantly by N application radii in the topsoil, but was higher for the largest radii than all others in the 15–30 cm depth (Table 2). Calcium was higher in the two largest radii than in the smallest radius in the topsoil, but differences were not significant in the 15–30 cm depth. Radii of N application did not influence soil Mg significantly at either depth. (The values for pH differ in Tables 1 and 2 because those in Table 1 are the means for the 19 years and those in Table 2 represent the pH at the end of 19 years.) Apparently, the acid forming N causes a loss of some of the P and cations when concentrated. Soil K was medium (68 to 168 kg·ha⁻¹) for all treatments, which, according to other studies, is adequate for good yield (Worley, 1974; Worley et al., 1974). The high levels of soil P and low levels of leaf P indicate the difficulty of getting high levels of P into pecan leaves. Sparks (1988) was able to raise leaf P by only 0.02 to 0.04 percentage points by massive applications of P each year (15,028 kg·ha⁻¹) for 2 years.

During the last 5 years of the study, a comparison was made for soil test results within and outside the fertilized area. No differences were significant for treatments outside the treated circle, except for an unex-

plained higher soil P in the 15–30 cm zone for the 6.1-m radius than for the two larger radii. This area was not fertilized for any of the treatments; thus, any differences would have come from the residual effects of the decaying leaves and shucks that moved nutrients from the fertilized to the nonfertilized area.

This study shows little detrimental effect from reducing the area of application of N to a 4.6-m radius of the tree trunk of pecan trees on pecan tree production, growth, and nut quality and suggests that application of N to a small area will be satisfactory if soil and leaf nutrients are maintained in the recommended ranges. This conclusion has been indicated experimentally for drip irrigated pecans by other studies in progress at our station, by Aitken (1986), and for fruit trees by Smith et al. (1979). Over time, however, there will be a reduction in pH and resulting loss of soil cations and increase in leaf Mn in the fertilized part of the root zone when N is concentrated, which may result in the need of pH adjustments and added nutrients in the area where N application is concentrated. Neilsen et al. (1995) concluded that restricting the soil volume, as with drip fertigation, intensifies the effects of beneficial or detrimental soil chemical changes. My results and those of Edwards et al. (1982) tend to confirm that conclusion. The extent of compensation by roots outside the fertilized area is yet to be determined where roots are not restricted to the wetted zone. This study and another (Worley, 1996) indicate that these roots may be important in maintaining tree nutrition when conditions within part of the root system are less than optimum. Redistribution of nutrients by decay of fallen leaves and shucks in mature orchards likely helps prevent uneven distribution of nutrients when applied through drip irrigation in the herbicide strip. The lack of similar soil response on the inside and outside of the fertilized area of this study indicates redistribution, if present, was not restricted to the area underneath each individual tree. Additional measures may need to be taken on small trees to ensure that all sides of the tree have roots that feed in a fertilized area.

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