Fertigation and Leaf Analysis Reduce Nitrogen Requirements of Pecans

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SUMMARY. Yield and quality of pecan nuts were as high when 50 pounds N/acre was applied through a drip-irrigation system as with 100 pounds/acre (112 kg·ha⁻¹) applied either all broadcast or half broadcast-half fertigated. All N treatments kept leaf N well above the 2.50% (dry weight) lower threshold recommended for pecans. The 50 pounds N/acre-all-fertigated treatment resulted in less soil pH reduction and less loss of K, Ca, and Mg from soil in the nonwetted zone underneath the tree canopy than broadcast treatments. Soil pH, K, and Mg were slightly lowered in the 6- to 12-inch (15 to 30 cm) soil layer when all of the N was fertigated. Higher leaf Ca and Mg from the low rate of N fertigated reflected the higher concentrations of these elements in the soil in the nonwetted zone rather than the lower concentrations in the wetted zone. There was no evidence of a detrimental effect on the tree from lowering the N application to only 50 pounds/acre and applying it in four monthly applications through the drip irrigation system beginning 1 Apr.

Recently, we reported the results of a study comparing broadcast vs. fertigation of N for pecan [*Carya illinoensis* (Wangenh) C. Koch] trees (Worley et al., 1995).

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Over 10 years, there was no detrimental effect on yield or nut quality from reducing the N application from 200 to 100 pounds/acre (224 to 112 kg·ha⁻¹) and applying all of it through the drip-irrigation system. Nitrogen rates were reduced the last 6 years by one-half in an effort to measure treatment differences. This report is of the last 6 years of the study. A similar N fertigation study on peaches in Fort Valley, Ga. (Edwards et al., 1982), reported a substantial soil pH reduction in the wetted zone from fertigated N. Lowering of the pH around emitters did not occur during the first 10 years, but calcium hydroxide had been applied to neutralize the acid-forming effect of the N. We wanted to verify that low pH would not be a problem over time with fertigation when no additional corrective measures were taken to prevent reduction of soil pH and to determine the long-term effects of fertigation on pecan tree yield, nut quality, and leaf analysis. Georgia growers usually apply >100 pounds N/acre (112 kg·ha⁻¹) annually for pecans. If this could be halved, it would save more than \$2 million in a year in material costs in Georgia and reduce application costs, soil compaction, and pollution of surface and ground water.

Materials and methods

This study is a continuation of the study reported previously (Worley et al., 1995) with the N application rates halved from that of the first 10 years. Trees were 'Stuart' and 'Schley' estimated to be >50 years old growing on Red Bay and Greenville soil. This location is within the area and on soil types that produce about one-third of the world's pecans. Tree size, cultivars, and orchard history are typical of many older pecan orchards.

Treatments were 1) no irrigation, 100 pounds N/acre (112 kg·ha⁻¹) with all the N surface-broadcast, half of the N was applied ≈1 Apr. and the remainder ≈1 June [broadcast not irrigated (BNI)]; 2)

drip irrigation with 100 pounds N/acre broadcast as for treatment 1 [broadcast irrigated (BI)]; 3) drip irrigation with 50 pounds N/acre (56 kg·ha⁻¹) broadcast 1 Apr. as for treatment 1 plus 12.5 pounds N/acre (14 kg·ha⁻¹) injected into the irrigation water (fertigated) ≈1 Apr., 1 May, 1 June, and 1 July, for a total of 50 pounds N/acre fertigated [broadcast-fertigated (BF)]; 4) no broadcast N with 50 pounds N/acre fertigated as for treatment 3 [half the rate of N all fertigated (1/2 F)]. Liquid Uran (16% N from urea and 16% N from ammonium nitrate) was the N source for fertigation. The injection rate was 25 gallons/h (95 L·h⁻¹) of the concentrated solution. Additional nutrients and lime were added uniformly to all trees each spring if leaf or soil analysis indicated need. These included 1 ton lime/acre (2240 kg·ha⁻¹) in 1991 and 70 pounds K/acre (78 kg·ha⁻¹) in 1993. All the broadcast N was from ammonium nitrate.

The statistical design was a split plot in a randomized complete block with three replications. Main plots consisted of eight insect control and cover crop treatments, and subplots consisted of the four irrigation-fertilizer treatments; therefore, each fertilizer-irrigation treatment was replicated 24 times. Each irrigation-fertilizer subplot consisted of up to five trees and contained one or more 'Stuart' and 'Schley' trees each. A separate analysis was done for each cultivar for yield and nut quality data, but leaf and soil analyses were a composite from all trees within a plot. This paper concerns only the results of the irrigation-fertilizer

Table 1. Number of nuts to produce 1 pound (0.454 kg) of 'Stuart' and 'Schley' pecans from broadcast and fertigated N applications.

N application (pounds/acre)		Irrigation	Nuts/pound ²
Broadcast	Fertigated		
<i>Stuart</i>			
100	0	No	76 b
100	0	Yes	66 a
50	50	Yes	67 a
0	50	Yes	66 a
<i>Schley</i>			
100	0	No	103 c
100	0	Yes	82 a
50	50	Yes	85 b
0	50	Yes	82 a

²Mean separation within each cultivar by general linear models with PDIFF option (t test) at P = 0.05.

subplot treatments. Statistical analysis was by general linear models analysis of variance with mean separation by the PDIFF option (*t* test) (SAS Institute, Cary, N.C.).

A line of emitters was placed within the herbicide strip on two sides of each

tree and two 2-gallon/h (7.6 L·h⁻¹) emitters were spaced ≈4 feet (1.2 m) apart on each side of each tree on each line, for a total of eight emitters per tree. This recommended procedure places emitters on all sides of the tree with little overlap of the wetted zone

and within the weed-free herbicide strip where they can be seen and serviced easily. When fertigating, the valves for the irrigation lines for BI were turned off and the specified volume of Uran was pumped through the system onto the BF and 1/2F treatment trees. All irrigated trees received the same amount of irrigation water except for the four times each year when fertigation occurred. The irrigation system was operated ≥1 h (usually overnight) after each fertigation to flush the system and distribute the N through the wetted zone. Additional irrigation was applied 12 h·d⁻¹ beginning ≈3 d after each 1-inch (2.5 cm) rain during the growing season or if there was visual indication of need. This method approximates recommended irrigation practices for growers in the area.

Yield and quality data were taken for each tree annually. A 50-nut sample was taken from each tree at harvest, sized by categories separated by 1/16 inch (0.16 cm) of diameter, and then cracked. Kernels were graded into fancy, standard, and amber grades, and percentage of each size, kernel grade, and total percentage edible kernel was calculated. Fancy kernels were plump, well-filled kernels of the brightest color. Standard kernels were similar but darker. Amber kernels were darker than standard kernels or had edible kernels with defects.

Leaf samples were taken from each plot between the second week in July and the first week of August (Plank, 1989), and soil samples were taken in winter each year. The samples were analyzed using an atomic absorption spectrophotometer for cations, colorimetric procedures for P (Gaines and Mitchell, 1979) and Kjeldahl (Helrich, 1990) for N. Additional soil samples were taken within 1 to 2 feet (30 to 60 cm) of each emitter to determine the effect of fertigation on soil in the wetted zone.

Results and discussion

Irregular bearing, common to pecan trees, was well in evidence over the 6 years. Yield of 'Schley' was very low [<10 pounds per tree (4.5 kg/tree)] in 1990 and 1991 and was essentially zero in 1995. Yield was fair [>65 pounds per tree (30 kg/tree)] in 1994. 'Stuart' yield was good [>80 pounds per tree (36 kg/tree)] in 1991, 1993, and 1994 and <30 pounds per

Fig. 1. Leaf N, Ca, and Mg for pecan trees from broadcast (BC) and fertigated applications of N. Mean separation by general linear models PDIFF option (*t* test) at *P* = 0.05. The horizontal line is the lower threshold of the normal range for each nutrient.

tree (14 kg/tree) in other years. The response from irrigation was not significant. The year 1994 was the year of the great flood in that county when >21 inches (53 cm) of rain fell within 24 h; however, the orchard was not flooded. Yield was as high for 1/2F as for any of the other treatments (data not shown). Kernel quality grades and total percent kernel were similar for all treatments (data not shown). Larger nuts were produced by both cultivars when irrigation was provided than when not irrigated. With irrigation, nuts were as large or larger for 1/2F as for any of the other treatments (Table 1).

Other experiments have indicated that a leaf N concentration of 2.75% is sufficient for optimum tree growth, nut yield, and nut quality (O'Barr, 1985; Worley, 1985, 1990). The lower threshold used by the pecan leaf analysis program is 2.50% (Plank, 1989). The mean leaf N concentration for

1/2F was 2.70%, well above the threshold for the normal range (Fig. 1). Although this value was statistically less than that for the other treatments, the difference was 0.06 percentage points or less and suggests greater efficiency for fertigation; however, the test does not confirm this because there were no broadcast treatments at the low rate. Percentage of leaf dry matter was not measured. All treatments supplied abundant N (Fig. 1). Differences in leaf mineral concentration between treatments, although sometimes statistically significant, were small. Leaf Ca and Mg were higher for 1/2F than for other treatments (Fig. 1), but again, leaf Ca and Mg were abundant for all treatments. High leaf Ca and Mg concentrations for the 1/2F treatment reflect higher concentrations of these elements in the nonwetted soil away from the emitter rather than the lower concentrations

of these elements in the wetted zone around the emitter, and suggests that the soils of the nonwetted zone are relatively important in leaf nutrition.

The acid-forming effect of N on soil was in effect, although of low magnitude. Nitrogen applications usually lower pH and soil cations K, Ca, and Mg in the locations applied. When all N was fertigated, the nonwetted soil in the area away from the emitters received no N, resulting in soil pH, K, Ca, and Mg being highest for 1/2F and lowest for the all-broadcast plots (Fig. 2). Conversely, when all the N was fertigated, the N was concentrated in the wetted zone, resulting in a lowering of pH and soil K and Mg in the 6- to 12-inch (15 to 30 cm) layer. The differences were not as apparent in the 0- to 6-inch layer (Fig. 3) and were not significant for Ca in either layer. Soil characteristics all were lower in the wetted zone than in the nonwetted

Fig. 2. Soil pH, K, Ca, and Mg in the nonwetted area outside the wetted zone of the drip-irrigation emitter when N was broadcast (BC) and fertigated. Mean separation within each depth by general linear models PDIFF option (t

zone (Table 2), which is opposite to that revealed in the first 10 years. The reason could be due to cultivation of the nonwetted area between trees during the last 6 years. The cultivation may have mixed surface-applied lime and fertilizers to make them more detectable by soil sampling. The wetted area could not be cultivated because of the drip-irrigation lines. No cultivation was done the first 10 years.

There was no evidence of a progressive lowering of the soil pH in the wetted zone over time; in fact, the opposite trend was occurring (Fig. 4). The significant year $\times$ treatment interaction was caused by the relative increases in pH of BI over years compared with BF and 1/2F. All treatments increased with time, but BI started with a lower pH than 1/2F in 1990 and increased at a faster rate than the other

treatments causing a crossover interaction. The high concentration of basic cations in the irrigation water probably neutralized much of the acid formed by the N. An analysis of the irrigation water revealed Ca, Mg, and Na at 0.95, 1.81, 4.11 $\mu\text{g}\cdot\text{g}^{-1}$, respectively.

The data from this study indicate that a N application of only 50 pounds/acre (56 $\text{kg}\cdot\text{ha}^{-1}$), if fertigated in four monthly applications, can supply pecan trees with an adequate supply of N without causing a serious reduction of pH or loss of other nutrients in the wetted zone of the drip emitter. The reduction in pH and lowering of soil K and Mg in the 6- to 12-inch layer of the wetted zone was not reflected in pecan leaves. The leaf analyses do not indicate any nutritional problems from supplying all of the N by drip irrigation. The lowering of pH and loss of K and Mg in the 6- to 12-inch soil layer does indicate that a correction might be needed if irrigation water does not contain sufficient basic cations to neutralize the acidity produced by the N. This correction could be accomplished with calcium nitrate or other soluble sources of basic cations. Early results from studies at another location indicate that using calcium nitrate as a N source is effective in maintaining pH and soil nutrients.

Literature Cited

Edwards, J.H., R.R. Bruce, B.D. Horton, J.L. Chesness, and E.J. Wehnt. 1982. Soil cation and water distribution as affected by NH_4NO_3 .

Table 2. A comparison of soil characteristics inside and outside the wetted zone of the drip-irrigation emitter.

Variable	Nonwetted zone	Wetted zone ²
0 to 6 inches		
pH	5.90	5.49
P (pound/acre)	96	59
K (pound/acre)	182	147
Ca (pound/acre)	1793	1084
Mg (pound/acre)	518	328
6 to 12 inches		
pH	5.51	5.03
P (pound/acre)	41	26
K (pound/acre)	116	67
Ca (pound/acre)	739	524
Mg (pound/acre)	262	141

²All variables were significantly lower in the wetted zone than the nonwetted zone.

Fig. 3. Soil pH, K, and Mg within and away from the wetted zone of the drip-irrigation emitters when N was broadcast (BC) and fertigated. Mean separation within each zone by general linear models PDIFF option (t test) at $P = 0.05$.

Fig. 4. Soil pH in the wetted zone of the emitters in the 0- to 6 and 6- to 12-inch layer over years and method and rate of N application. The year $\times$ fertilization interaction was significant. BC = broadcast, Fert. = fertigated.

applied through a drip irrigation system. *J. Amer. Soc. Hort. Sci.* 107:1142-1148.

Gaines, T.P. and G.A. Mitchell. 1979. Chemical methods for soil and plant analysis. UGA CPES Agron. Hdbk. no. 1.

Helrich, K. (ed.). 1990. Official methods of analysis of the Association of Agricultural Chemists. 15th ed. vol. 1, p. 74, Section 984.13. Assn. of Official Agricultural Chemists, Washington, D.C.

O'Barr, R.D. 1985. LSU pecan nutritional research. *Proc. Southeastern Pecan Growers Assn.* 78:93-100.

Plank, C.O. 1989. Plant analysis handbook for Georgia (un-numbered special publication).

Worley, R.E. 1985. Use of leaf analysis for basing N applications for Stuart pecans. *Proc. Southeastern Pecan Growers Assn.* 78:79-83.

Worley, R.E. 1990. Long-term performance of pecan trees when nitrogen application is based on prescribed threshold concentrations in leaf tissue. *J. Amer. Soc. Hort. Sci.* 115:745-749.

Worley, R.E., J.W. Daniel, J.D. Dutcher, K.A. Harrison, and B.G. Mullinix. 1995. A long-term comparison of broadcast application vs. drip fertigation of nitrogen for mature pecan trees. *HortTechnology* 5:43-47.

Assessing Vascularization Response of Three Tomato (*Lycopersicon esculentum* Mill.) Cultivars to Soil Type, Nutrient Stress, and Water Stress

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ADDITIONAL INDEX WORDS. fruit quality

SUMMARY. Amount of vascular development (veininess) is an important quality factor for processing whole-pack tomatoes. The influences of nutrient and soil moisture stress on the amount of vascular development in 'Chico III', 'Dorchester', and 'Roma' tomato fruit were studied. Fruit subjected to nutrient stress showed the highest amount of veininess. Fruit exposed to moisture stress after initial fruit set did not differ from controls in amount of veininess. Amount of vascularization did not differ among cultivars. A method for quantifying veininess was developed and compared with a traditional subjective rating scale. There was a high correlation ($r^2 = 0.77$) between the subjective rating and quantitative measurement of veininess.

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