

Pecan Response to Nitrogen Fertilizer Placement

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Abstract. Application method and placement can improve the efficiency of applied nitrogen (N) per unit of yield, potentially minimizing N loss and increasing the profit margin for pecan producers. The following treatments were evaluated for their effect on pecan leaf N concentration, pecan yield, nut quality, agronomic N use efficiency (AE_N), and alternate bearing intensity (I); 1) emitter-adjacent application of liquid urea ammonium nitrate (UAN) (28N–0P–0K) with 5% sulfur (S); 2) broadcast application of dry ammonium nitrate (34N–0P–0K); 3) broadcast-band application of dry ammonium nitrate; 4) broadcast ground-spray application of liquid UAN; and 5) untreated control (2009–12). Leaf elemental tissue analysis, pecan yield, quality, and alternate bearing intensity indicate that pecans can be effectively fertilized with N using any of the application methods used in the current study. Based on AE_N , it appears that pecans can be effectively fertilized at a lower field rate of N than is currently recommended and that the volume of fertilizer applied to pecan orchards can be significantly reduced by minimizing the area in the orchard to which N fertilizer is applied and eliminating excessive applications to vegetated row middles, which apparently offer little additional benefit to pecan leaf N, pecan quality, or yield.

Nitrogen is the most commonly applied nutrient in orchard crops and is normally applied at higher rates than most other nutrients (Weinbaum et al., 1992). The effect of N on pecan yield and nut growth has been studied since 1918 (Skinner, 1922). Although N is a major component of pecan nutrient management, pecan tree response to N has been variable in multiple studies through the years (Hunter and Lewis, 1942; Smith et al., 1985; Storey et al., 1986; Worley, 1974, 1990).

Recently, rising energy costs have led to a dramatic increase in the price of synthetic fertilizer (Huang, 2009). Between 2002 and 2007 the cost of synthetic fertilizer N per acre rose by over 200% for pecan (Wells, 2009a). This sharp increase in the cost of a single input dramatically reduces the profit margin for pecan producers.

Overfertilization can be more common in orchard crops than in many other crop species as a result of the increased likelihood of fertilizer N application during the dormant period of perennial crops. Excess N increases vegetative growth, which promotes shading and reduces flower bud development, fruit set, quality, and survival. Excessive levels of applied N can also lead to nutritional imbalances

and increased susceptibility to insect and disease pests (Weinbaum et al., 1992). Historically, N fertilizer has been uniformly broadcast on the soil surface in single or split applications of ≈ 84 to $168 \text{ kg}\cdot\text{ha}^{-1}$ N in southeastern pecan orchards. Fertigation has been used effectively in southeastern pecan orchards as well (Worley et al., 1995; Worley and Mullinix, 1996). Most pecan orchards in the southeastern United States are managed with a 3.7- to 4.6-m vegetation-free strip centered on the trees, which run the length of the tree row. Middles between tree rows are covered with grass and or a grass/legume mix. Thus, much of the fertilizer N applied to vegetated row middles could potentially be used by the vegetation growing there and, as a result, would theoretically provide little immediate benefit for pecan trees. Kulesza and Szafrank (1990) observed no difference in apple (*Malus domestica* Borkh.) tree performance when fertilizer was applied only to the vegetation-free strip compared with uniform application over the entire orchard area. Worley (1997) observed that pecan yield, quality, and leaf N could be maintained with dry fertilizer applications when the full N rate was concentrated in a limited area, yet no studies have attempted to refine this practice by simply eliminating excessive fertilizer applied to vegetated row middles, allowing only the fertilizer N applied in the vegetation-free strip to meet the tree's N demand.

Application method and placement can improve the efficiency of applied N per unit of yield, potentially minimizing N loss and increasing the profit margin for pecan producers (Weinbaum et al., 1992). The objective of this study was to investigate the effects of N fertilizer application method and placement on pecan leaf tissue N concentration,

pecan yield, nut quality, and pecan tree yield efficiency.

Materials and Methods

Study site, experimental design, and soil sampling. The study was conducted in a 30-year-old drip-irrigated commercial 'Stuart' pecan orchard on a $15.2 \text{ m} \times 15.2\text{-m}$ spacing located in Crisp County, GA, from 2008 to 2012. All drip emitters were ported to the soil surface. Soil type was Lucy loam sand (loamy, siliceous, thermic Arenic Plinthic Paleudult). The orchard was managed under commercial conditions according to University of Georgia Cooperative Extension recommendations (Hudson et al., 2012). A 3.7-m wide vegetation-free strip was maintained with glyphosate along the tree row in all plots. Row middles consisted of bermudagrass (*Cynodon dactylon* L.) sod. The following treatments were evaluated: 1) emitter-adjacent application of liquid UAN (28N–0P–0K) with 5% S; 2) broadcast application of dry ammonium nitrate (34N–0P–0K); 3) broadcast-band application of dry ammonium nitrate; 4) broadcast ground-spray application of liquid UAN; and 5) untreated control (2009–12). Treatments were arranged in a randomized complete block design using five blocks with each treatment represented once per block. Each plot consisted of a $60.9 \text{ m} \times 15.2\text{-m}$ area centered on four pecan trees within a row. Data were taken from the two center trees in each plot. All plots were separated by untreated border plots on each side. Individual plots received the same treatments during each year of the study with the exception of the untreated control, which was not used in 2008. Trees used in untreated control plots from 2009 to 2012 had received a single broadcast application of N at a rate of $78 \text{ kg}\cdot\text{ha}^{-1}$ in 2008.

All plots except for the untreated control received the same per-ha rate of N ($78 \text{ kg}\cdot\text{ha}^{-1}$ from 2008 to 2011 and $140 \text{ kg}\cdot\text{ha}^{-1}$ in 2012) per treated area. The area treated with N fertilizer around each tree varied by treatment. In the emitter-adjacent application, the volume of UAN applied was determined by dividing $\text{kg}\cdot\text{ha}^{-1}$ N required by 42 trees per hectare. A total 5.07 L of liquid UAN per tree was poured by hand adjacent to the drip emitters from 2008 to 2011. UAN was distributed evenly among each of the six emitters per tree. The total volume of UAN applied was split into three applications separated by 10 to 14 d beginning in mid-April. In 2012, a total of 9 L of liquid UAN per tree was applied in five separate applications made every 10 to 14 d beginning on 12 Apr. 2012.

In the broadcast application, dry ammonium nitrate (34N–0P–0K) was applied uniformly over the entire 929-m^2 plot in mid-April at a rate of $78 \text{ kg}\cdot\text{ha}^{-1}$ from 2008 to 2011 and $140 \text{ kg}\cdot\text{ha}^{-1}$ in 2012. In the broadcast-band application, dry ammonium nitrate (34N–0P–0K) was applied to a 225.5-m^2 area within the 3.7-m wide vegetation-free strip along the tree rows at a rate of $78 \text{ kg}\cdot\text{ha}^{-1}$ from 2008 to 2011 and $140 \text{ kg}\cdot\text{ha}^{-1}$ in 2012. For the

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broadcast ground-spray application, UAN was applied to a 225.5-m² area within the 3.7-m wide vegetation-free strip along the tree rows with a tractor-mounted, pressurized herbicide sprayer calibrated to deliver 215 L·ha⁻¹ from 2008 to 2011 and 384 L·ha⁻¹ in 2012 using flood nozzles (TK5; TeeJet Technologies, Springfield, IL). The rate per hectare was figured only for the treated area in each treatment. Thus, the total N rate per field hectare was reduced by 76% in the emitter-adjacent, broadcast-band, and ground-spray treatments as compared with the broadcast treatment (Table 1). The untreated control received no N fertilizer inputs.

Dolomitic lime was applied at the following rates: 3360 kg·ha⁻¹ in 2008, 2240 kg·ha⁻¹ in 2009, 2016 kg·ha⁻¹ in 2011, and 1120 kg·ha⁻¹ in 2012. Phosphorous (P) was applied at 44.8 kg·ha⁻¹ in 2009, 2010, and 2012. Potassium (K) was applied at 56 kg·ha⁻¹ in 2008 and 2010, 61.6 kg·ha⁻¹ in 2011, and 89.6 kg·ha⁻¹ in 2009 and 2012. Rainfall amounts for the study site during the month of April were 10.3, 17.3, 5.0, 3.3, and 2.8 cm for 2008, 2009, 2010, 2011, and 2012, respectively.

Foliage was sampled in late July of each study year by collecting 30 leaflet pairs per tree. All leaflet samples were taken from the middle leaf of sun-exposed terminals. Leaflet samples were washed in a dilute phosphate-free detergent solution (0.1% detergent) followed by rinsing with deionized water. Leaves were then dried to a constant weight at 80 °C and ground in a Wiley Mill (Wiley, Philadelphia, PA) to pass a 1-mm screen. Leaves for N analysis were ground with a mortar and pestle. Samples were analyzed for N by combustion using a Leco FP528 protein/N determinator (Leco Corp., St. Joseph, MI).

Separate soil samples at 0-cm to 15.2-cm depth with the surface 2.54 cm removed were taken from the vegetated area under the dripline of each tree and from the vegetation-free strip adjacent to drip emitters in Dec. 2010 and 2012. At each location, four soil cores per tree were combined for an individual sample per plot. Samples from the vegetation-free strip and from the vegetated middles were kept separate. Soil was dried and analyzed for pH. Soil pH was determined in a 0.01 M calcium chloride (CaCl₂) solution using a LabFit AS-3000 (Labfit, Perth, Australia) dual pH analyzer. At harvest, yield was estimated by shaking trees and measuring the weight of nuts in a wedge-shaped grid consisting of 1/100 of the area beneath the tree (Conner and Worley, 2000). Four subsample grids were used per tree, the weight summed, and multiplied by 25 to obtain the total tree yield. Only non-germinated, marketable nuts were used to measure yield. A 50-nut sample was collected from each tree for analysis of individual nut weight and percent kernel. Nuts were shelled and percentage of edible kernel was calculated by dividing the kernel weight for the 50-nut sample by total nut weight.

Fluctuation in yield was expressed in terms of alternate bearing intensity (*I*), calculated as: $I = 1/(n-1) \times \{ |(Y_1 - Y_2)/(Y_1 + Y_2) + |(Y_2 - Y_3)/(Y_2 + Y_3) + \dots |(Y_{n-1} - Y_n)/(Y_{n-1} + Y_n)| \}$, where *n* = number of years and *Y* = tree yield for the corresponding year (Pearce and Dobersek-Urbanc, 1967). Agronomic N use efficiency, defined as pecan yield per unit of N applied, was determined by dividing yield (kg·ha⁻¹) by the total amount of fertilizer N applied (kg·ha⁻¹) per field hectare for each treatment.

Statistical analyses of data were performed with SAS (SAS Institute, Cary, NC). Analysis of variance was used to compare treatment effects. Means were separated using Tukey's honestly significant difference test ($P < 0.05$).

Results

Pecan leaf tissue. Leaf N was affected by treatment in 2008, 2010, 2011, and 2012 (Table 2). In 2008, leaf N concentration was higher in the emitter-adjacent treatment than in the broadcast and ground-spray treatments, whereas in 2010, the emitter-adjacent treatment had higher leaf N concentration than all other treatments. In 2011, leaf N concentration was higher in the emitter-adjacent treatment than in the ground-spray or control treatments. The emitter-adjacent, broadcast, and broadcast-band treatments resulted in higher leaf N concentration than the control in 2012. There were no differences in leaf N concentration between the broadcast and broadcast-band treatments throughout the study (Table 2).

Pecan orchard soil pH and elemental analysis. The ground spray treatment had a higher soil pH in 2010 than that of the remaining treatments. In 2012, there were no differences in soil pH among treatments. Although soil pH was lower in the vegetation-free strip than in the vegetated middles in 2010, there was no difference in soil pH relative to sampling location in 2012. In addition, there was no interaction between

fertilizer application and sample location for soil pH in either sampling year (Table 3).

Pecan yield, quality, and alternate bearing intensity. There was no treatment effect on percent kernel throughout the study. In the final year of study, nut weight was greater in the ground-spray treatment than in the control treatment (Table 4). Yield effects were observed for treatments in 2010, 2011, and 2012, although the results varied. Yields for the emitter-adjacent treatment were higher than those in the broadcast-band and control treatments in 2010. In 2011, broadcast treatment yields were higher than those of the emitter-adjacent, ground-spray, and control treatments. In 2012, yield for the control treatment was reduced compared with all other treatments (Table 4). There were no yield differences between the broadcast and broadcast-band treatments throughout the study. Agronomic N use efficiency was greater in the emitter-adjacent and broadcast band treatments than in the broadcast treatments in 2008, 2009, 2010, and 2012 (Table 4). In 2008, 2010, and 2012, the ground-spray treatment had higher AE_N than the broadcast treatment as well. In 2011, the broadcast-band treatment had higher AE_N than that of the emitter-adjacent and ground-spray treatments (Table 4).

Alternate bearing intensity (*I*) ranged from 0.0 to 0.95 for the emitter-adjacent treatment, from 0.24 to 0.69 for the broadcast treatment, from 0.15 to 0.88 for broadcast-band, from 0.14 to 0.97 for ground-spray, and from 0.28 to 1.0 for the control (Table 5). Alternate bearing intensity was higher for all treatments for the years 2010–11 and 2011–12. When all five years of study were included in the calculations, *I* was lower in the broadcast treatment than in the control treatment. There were no differences among all other treatments (Table 5).

Table 1. Comparison of nitrogen (N) rate used per field hectare versus nitrogen rate per treated area in emitter-adjacent, broadcast, broadcast-band, and ground-spray treatments from 2008 to 2012.

Treatment	2008–11		2012	
	N rate per field hectare (kg·ha ⁻¹)	N rate per treated area (kg·ha ⁻¹)	N rate per field hectare (kg·ha ⁻¹)	N rate per treated area (kg·ha ⁻¹)
Emitter-adjacent	19	78	34	140
Broadcast	78	78	140	140
Broadcast-band	19	78	34	140
Ground-spray	19	78	34	140
Control ²	0	0	0	0

²The untreated control treatment was added to the study in 2009.

Table 2. Effect of emitter-adjacent, broadcast, broadcast-band, and ground-spray fertilizer nitrogen application and control treatments on leaf nitrogen concentration of pecan from 2008 to 2012.

Treatment	Leaf nitrogen concn (%) ²				
	2008	2009	2010	2011	2012
Emitter-adjacent	2.98 a ^y	2.94 a	2.73 a	2.55 a	2.69 a
Broadcast	2.85 b	2.89 a	2.60 b	2.46 ab	2.64 a
Broadcast-band	2.89 ab	2.80 a	2.52 b	2.46 ab	2.57 a
Ground-spray	2.80 b	2.96 a	2.42 c	2.37 bc	2.52 ab
Control ²	—	2.84 a	2.42 c	2.34 c	2.37 b

²Recommended leaf sufficiency range for pecan in Georgia: N (%) = 2.5 to 3.0 (Wells, 2007).

^yMeans followed by the same letter within each year are not different at $P < 0.05$ by Tukey's honestly significant difference test.

²The untreated control treatment was added to the study in 2009.

Discussion

Multiple studies have shown that N fertigation supplies sufficient N to fruit and pecan trees, although N is applied to a small area in the orchard (Smith et al., 1979; Worley et al., 1995; Worley and Mullinix, 1996). Worley (1997) demonstrated no detrimental effects on pecan yield or nut quality from reducing the area of dry ammonium nitrate application around pecan trees by 50%. However, in the study by Worley (1997), the N rate per hectare increased as the treated area was reduced

Table 3. Effect of emitter-adjacent, broadcast, broadcast-band, and ground-spray fertilizer nitrogen application and control treatments on pecan orchard soil pH within and outside vegetation-free strips in 2010 and 2012.

Treatment	Soil pH	
	2010	2012
Fertilizer application (FA)		
Emitter-adjacent	6.19 b ²	7.08 a
Broadcast	6.07 b	6.92 a
Broadcast-band	6.08 b	6.98 a
Ground-spray	6.48 a	7.03 a
Control	6.10 b	7.02 a
Sample location (SL)		
Vegetated middles	6.51 a	7.08 a
Vegetation-free strip	5.90 b	6.93 a
<i>P</i>		
FA	0.071	0.855
SL	<0.001	0.275
FA × SL	0.131	0.835

²Means followed by the same letter within each year are not different at $P < 0.05$ by Tukey's honestly significant difference test.

Table 4. Effect of emitter-adjacent, broadcast, broadcast-band, and ground-spray fertilizer nitrogen application and control treatments on percent kernel, nut weight, pecan yield, and agronomic nitrogen use efficiency (AE_N) of pecan from 2008 to 2012.

Yr	Treatment	Percent kernel (%)	Nut wt (g)	Yield (kg per tree)	AE_N ² (kg·kg ⁻¹)
2008	Emitter-adjacent	48.3 a ³	8.7 a	58.8 a	132 a
	Broadcast	48.2 a	8.5 a	49.4 a	27 b
	Broadcast-band	48.1 a	8.3 a	49.4 a	111 a
	Ground-spray	48.8 a	8.6 a	70.3 a	158 a
	Control ⁴	—	—	—	—
2009	Emitter-adjacent	49.9 a	10.1 a	58.8 a	132 a
	Broadcast	50.9 a	10.0 a	80.9 a	44 b
	Broadcast-band	50.7 a	9.4 a	66.2 a	149 a
	Ground-spray	51.5 a	10.2 a	52.8 a	119 ab
	Control	50.8 a	9.4 a	69.8 a	—
2010	Emitter-adjacent	46.6 a	7.2 a	61.6 a	138 a
	Broadcast	46.8 a	7.5 a	48.2 ab	26 b
	Broadcast-band	47.1 a	7.3 a	45.0 b	101 a
	Ground-spray	48.0 a	7.4 a	57.0 ab	128 a
	Control	47.3 a	7.3 a	39.5 b	—
2011	Emitter-adjacent	49.3 a	8.0 a	2.28 b	5 c
	Broadcast	48.0 a	8.9 a	12.6 a	7 bc
	Broadcast-band	49.1 a	9.1 a	5.0 ab	11 ab
	Ground-spray	46.9 a	10.0 a	1.1 b	3 c
	Control	—	8.1 a	0 c	—
2012	Emitter-adjacent	45.6 a	8.2 ab	88.8 a	111 a
	Broadcast	45.7 a	8.3 ab	68.0 a	20 b
	Broadcast-band	45.2 a	8.4 ab	76.3 a	95 a
	Ground-spray	46.3 a	8.8 a	69.3 a	87 a
	Control	45.8 a	7.9 b	35.3 b	—

²Agronomic nitrogen use efficiency (AE_N) = pecan yield (kg·ha⁻¹)/total amount of fertilizer nitrogen applied (kg·ha⁻¹) per field hectare.

³Means followed by the same letter within each year are not different at $P < 0.05$ by Tukey's honestly significant difference test.

⁴The untreated control treatment was added to the study in 2009.

because the same amount of fertilizer material was applied to areas of varying size. In the current study, the total amount of fertilizer applied is reduced as the area of application is reduced. The emitter-adjacent, broadcast-band, and ground-spray treatments represent a 76% reduction in the amount of N fertilizer applied to the orchard (Table 1) with no effect on yield, quality, or leaf N. These treatments presumably concentrate fertilizer N near the highest concentration of feeder roots around drip emitters and also in the zone of least competition between the trees and competing vegetation while eliminating applications made to vegetated row middles where N is less likely to reach tree roots before being used by competing vegetation. It is likely that nutrients in mature pecan orchards are redistributed throughout the root zone of the tree by decay of fallen leaves and shucks as suggested by Worley (1997). This may help to buffer against uneven distribution of nutrients when fertilizers are applied to limited areas.

Leaf N concentration declined in all treatments from 2008 to 2011, falling below the minimum recommended leaf N concentration of 2.5% (Wells, 2007) in all treatments except the emitter-adjacent treatment in 2011 (Table 2). However, leaf N increased in all treatments during 2012 when the N rate was increased to 140 kg·ha⁻¹ in the treated area, indicating that N rates should be between 78 kg·ha⁻¹ and 140 kg·ha⁻¹ per treated area for intensively managed commercial pecan

orchards in the southeastern United States. Leaf N concentration was occasionally higher in the emitter-adjacent treatment than in the remaining treatments, supporting previous studies demonstrating the effectiveness of fertigation (Smith et al., 1979; Worley et al., 1995). Throughout the study, no reduction in leaf N concentration was observed in the broadcast-band treatment as compared with the broadcast treatment (Table 2). Michaelson et al. (1969) observed no difference in apple leaf N when N was broadcast or applied only along the dripline. The current study indicates that leaf N concentrations can be maintained within recommended levels by eliminating N application to vegetated row middles, resulting in as much as a 76% reduction in the amount of N applied. Smith et al. (1979) suggested that a 75% reduction in N with fertigation did not result in significantly reduced leaf N in most cases. The current study indicates the same results can be achieved with a similar reduction in dry fertilizer application as well.

After their transformation to nitrate-N, both ammonium and urea fertilizers have an acidifying effect on the soil to which they are applied (Havlin et al., 2005; Haynes, 1990; Singh et al., 1984). Worley (1997) demonstrated an occasional reduction in soil pH when N was concentrated in a reduced area of application in the orchard. Edwards et al. (1982) reported a lowering of pH around drip emitters under fertigation. In the current study, an increase in soil pH was observed with the ground-spray application in 2010; however, there was no difference in soil pH among the treatments in 2012. Soil pH was lower in vegetation-free strips than in vegetated middles in 2010, but no difference was observed in 2012. Because there was no interaction between fertilizer application and sample location regarding soil pH, it does not appear that elimination of fertilizer from vegetated row middles would require any change in orchard liming requirements.

Nut quality as measured by percent kernel and nut weight was unaffected by treatment, except in 2012 when nut size was higher in the ground-spray treatment than in the control (Table 4). Although yield was usually unaffected by treatment, there was some variation in the yield response during the study. Most of this variation occurred in 2011, the year in which yield was lowest in each of the treatments (Table 4). Much of this variation may be attributed to the alternate bearing cycle of pecans because I was highest for each treatment from 2010 to 2011 and from 2011 to 2012 (Table 5). Over the course of the study, I was reduced in the broadcast treatment as compared with the control; however, there were no differences among the remaining treatments. There were no differences in pecan yield or quality between the broadcast and broadcast-band treatments over the course of the study (Table 4), indicating that these parameters remain unaffected by a 76% reduction in N fertilizer application through elimination of fertilizer from vegetated middles within the orchard. As a result of the reduction in the total

Table 5. Alternate bearing intensity (I)² of 'Stuart' pecan trees for emitter-adjacent, broadcast, broadcast-band, ground-spray, and control treatments from 2008 to 2012.

Treatment	2008–09	2009–10	2010–11	2011–12	2008–12
Emitter-adjacent	0.0 c ³	0.02 c	0.92 a	0.95 a	0.47 ab
Broadcast	0.24 a	0.25 ab	0.58 b	0.69 a	0.44 b
Broadcast-band	0.15 b	0.19 b	0.8 a	0.88 a	0.51 ab
Ground-spray	0.14 b	0.51 a	0.96 a	0.97 a	0.53 ab
Control ⁴	—	0.28 ab	1.0 a	1.0 a	0.57 a

² $I = 1/(n-1) \times \{[(Y1 - Y2)/(Y1 + Y2) + (Y2 - Y3)/(Y2 + Y3) + \dots + (Y_{n-1} - Y_n)/(Y_{n-1} + Y_n)]\}$, where n = number of years and Y = tree yield for the corresponding year (Pearce and Dobersek-Urbanc, 1967).

³Means followed by the same letter are not different at $P < 0.05$ by Tukey's honestly significant difference test.

⁴The untreated control treatment was added to the study in 2009; therefore, I was only calculated from 2009 to 2012 for the untreated control.

amount of N applied, AE_N was consistently higher in the emitter-adjacent and broadcast-band treatments than in the broadcast treatment, except in 2011, when yields in all treatments were low. In addition, the ground-spray treatment resulted in a higher AE_N than the broadcast treatment in three of five years. These results suggest that the emitter-adjacent, broadcast-band, and to a lesser extent the ground-spray treatments result in more pecan production per unit of N applied than a broadcast application, increasing the profit margin for pecan producers.

Nearly half of all pecan orchards in Georgia use clover as an orchard floor cover (Wells, 2009b). Wells (2011) suggested that pecan producers using crimson clover as a ground-cover should continue to supply N in another form during early spring because much of the N produced by clover through N fixation will be unavailable until late in the growing season. These applications should be directed toward vegetation-free strips along the tree row to minimize the effect of reduced N fixation by clover when synthetic N is available. This could be accomplished through fertigation (as demonstrated by the emitter adjacent treatment), broadcast-band applications, or ground-spray applications as described in the current study.

Leaf elemental tissue analysis, pecan yield, quality, and alternate bearing intensity indicate that pecans can be effectively fertilized with N using any of the application methods used in the current study. Based on AE_N , it appears that pecans can be effectively fertilized at a lower field rate of N than is currently recommended and that the amount of fertilizer applied to pecan orchards can be significantly reduced by minimizing

the area in the orchard to which N fertilizer is applied and eliminating excessive applications to vegetated row middles, which apparently offer little additional benefit to pecan leaf N, pecan quality, or yield. This results in a reduction in the energy requirement for pecan production, an increased profit margin for pecan producers, and a potential reduction in N pollution of surface and groundwater.

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