Long-term Response to Phosphorus Banding in Irrigated and Nonirrigated Pecan Production

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Abstract. An experiment was conducted to determine the effects of banded phosphorus (P) applications at differing rates in irrigated and nonirrigated pecan (Carya illinoinensis) plots on P movement within the soil, P uptake and movement within pecan trees, and the yield and quality of nuts. On 20 Mar. 2015, P applications of 0 kg·ha⁻¹ (0×), 19.6 kg·ha⁻¹ (1×), 39.2 kg·ha⁻¹ (2×), and 78.5 kg·ha⁻¹ (4×) were administered to bands of triple superphosphate to randomly selected trees in nonirrigated and irrigated plots of a ‘Desirable’ orchard bordered by ‘Elliot’ trees. When P was applied at the 2× and 4× rates, the total soil test P decreased linearly by 35% and 54%, respectively, in nonirrigated plots and by 41% and 59%, respectively, in irrigated plots over the course of the experiment. There was no change in soil test P over time at the 0× rate for either irrigation regimen; however, at the 1× rate, soil test P decreased 44% in the irrigated plot but did not change in the nonirrigated plot. The largest linear decrease of the soil test P from the start of the experiment to the end of the experiment occurred in the top 0 to 7.6 cm. In contrast, soil test P at a depth of 15.2 to 22.9 cm decreased linearly by 23% in the nonirrigated plot, but it did not decrease over time in the irrigated plot. Increasing the P application rate increased foliar P quadratically in the nonirrigated plot, but only the 4× application rate increased foliar P compared with the 0× control. In the irrigated plot, foliar P concentrations decreased linearly from 2015 to 2017, and foliar P concentrations were not influenced by the P application rate. No differences in pecan yield or quality were observed in either irrigated or nonirrigated plots. Overall, P banding may not be the most sustainable way to increase foliar concentrations of P quickly or to maintain concentrations of the nutrient in the long term.

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Phosphorus banding has yet to be replicated in an irrigated or nonirrigated environment like that present in the southern portion of Alabama. Additionally, the effects of a one-time band application have not been observed, nor have those of lesser, more sustainable application rates. An experiment was designed to determine the efficacy of a single P band at selected rates on soil test P and P uptake by plants over multiple years in a typical nonirrigated and irrigated Alabama pecan orchard.

Materials and Methods

The experiment was conducted at the Gulf Coast Research and Extension Center in Fairhope, AL. The soil type of the orchard was a mixture of a Greenville loam and an Orangeburg fine sandy loam. The mature orchard comprised ‘Desirable’ trees planted with 12 × 12-m (40 × 40-ft) spacing or ≈66 trees/ha (27 trees/ac). Six 49-m (160-ft) rows of ‘Desirable’ trees were bordered on all sides by a row of ‘Elliot’ trees. All trees in the orchard were originally grafted to open-pollinated ‘Elliot’ seedling rootstocks. The orchard had a recorded history of difficulty maintaining adequate foliar P concentrations that, along with the reduced alternate bearing of ‘Desirable’, made it ideal for the research conducted. The orchard was scouted frequently for pests and pathogens and treated as necessary. This was especially important because ‘Desirable’ is susceptible to pecan scab (Fusarium oxysporum), which is endemic in the region.

For irrigation, the orchard was split into equal halves, with each half (plot) being treated as a separate experiment. A border row of ‘Desirable’ trees separated the plots to prevent water from the irrigated plot from crossing over into the nonirrigated plot. The existing sub-surface drip irrigation system in the orchard was turned off in the nonirrigated plot, so the trees only received natural rainfall (Table 1). Trees in the irrigated plot received supplemental irrigation to meet the requirements outlined by Wells (2007) (Table 1). The irrigation regime was suspended for a 3-d period if rainfall of 2.54 cm (1 inch) or more occurred. The irrigation system was a sub-surface drip system with five emitters per row of ‘Desirable’ trees separated the plots to prevent water from the irrigated plot from crossing over into the nonirrigated plot.

Soil samples were collected within the application strip from three experimental unit trees at each treatment level starting 2 months after initiation on 20 May 2015, and continuing at 2-month intervals until 20 July 2017. Three 22.5-cm (9-inch) core samples were collected within each band (tree) and were pooled in three 7.5-cm (3-inch) increments, hereafter referred to as top, middle, or bottom. Soil samples were not collected on 20 Sept. 2016 for nonirrigated trees due to moderate drought conditions. Standard soil analysis was performed to determine pH (McLean, 1982), organic matter (Schulte and Hopkins, 1996), estimated nitrogen release (Schulte and Hopkins, 1996), Bray I P (Bray and Kurtz, 1945), exchange capacity (Gavlak et al., 2003), percent base saturation of cations (Gavlak et al., 2003), and Mehlich III extractable P, manganese (Mn), Zn, boron (B), Cu, Fe, aluminum (Al), sulfur (S), calcium (Ca), magnesium (Mg), K, and sodium (Na) (Mehlich, 1984) (Brookside Laboratories, New Bremen, OH).

Foliar samples were collected from all experimental trees once per year on 20 July 2015, 2016, and 2017, which falls within the standard recommended time for the collection of foliar samples (Smith et al., 2012; Wells, 2007). Samples were collected from both the south (treated) and north (untreated) sides of the canopy. Each sample contained 20 middle leaflet pairs of the current season’s growth. After drying, 1 g was used for analysis. Samples were digested according to procedures for wet acid digestion using nitric and perchloric acids described by Mills and Jones (1996). Concentrated samples were diluted in 20 mL deionized water and analyzed for elemental concentrations using inductively coupled plasma optical emission spectroscopy (Brookside Laboratories, New Bremen, OH).

Nut yield data were collected at the 50% shuck date, which for ‘Desirable’ occurred during the first week of Nov. 2015 and the first week of Nov. 2016. Yield data from 2017 were omitted due to a tropical weather system that caused the crop to fall early and mix on the orchard floor. The wedge method was used to determine total yield (Worley and Smith 1984). Quality data were collected from 40 nut samples taken in conjunction with those collected for yield in 2015 and 2016. Pecans were graded according to USDA guidelines (Goff et al., 1989; USDA, 1976).

An analysis of variance was performed for soil and foliar responses using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Cary, NC). Nonirrigated and irrigated data were analyzed as separate experiments. Soils and foliar data were analyzed as a split-split plot where the P rate in the main plot, sampling depth in the sub-plot, and sampling period in the sub-sub plot. Foliar data were analyzed as a split plot, with year in the main plot and application rate and side of application in the sub-plot. When residual plots and a significant covariance test indicated heterogeneous variance among treatments, a RANDOM statement with the GROUP option was used to correct heterogeneity. Least squares means are presented. Linear and quadratic trends regarding the P rate, sampling depth, and sampling period were tested using model regressions. All significance levels were set as $\alpha = 0.05$.

Results

The soil depth–P rate, P rate–sample date, and soil depth–sample date interactions were significant for soil test P in irrigated and nonirrigated plots. Over the course of the experiment, soil test P decreased linearly with increasing soil depth by 31% and 42% with the 1x and 2x application rates, respectively, and decreased quadratically by 40% with the 4x rate (Table 2). In contrast, there was no significant change in soil test P in the depth with the 0x application rate. Soil test P increased quadratically as the application rate increased at each soil depth. Similar trends were observed in the irrigated plot (Table 2).

Soil test P increased linearly or quadratically as the P application rate increased for all sampling periods (Table 3). During the first collection period (20 May 2015), soil test P increased linearly by 1624% from the 0x rate to the 4x rate. By the last collection period (20 July 2017), this trend had changed to a quadratic increase of 727% from the 0x rate to the 4x rate. Soil test P decreased linearly over time by 35% and 54% when P was applied at the 2x rate and 4x rate, respectively, but there was no change in the 0x rate or the 1x rate. Similar trends were observed in soil P according to the P application rate and sampling date of the irrigated plot, with two notable exceptions (Table 4). In the irrigated plot, soil test P increased quadratically with the increasing P rate, but the increase was lower (402%) compared with the increase in the nonirrigated plot (727%). Soil test P did not change over the course of the experiment at the 1x application rate in the nonirrigated plot, but it decreased quadratically by 44% in the irrigated plot.

### Table 1. Rainfall totals and supplemental irrigation in nonirrigated and irrigated ‘Desirable’ orchards from 2015 to 2017.

| Month | 2015 | 2016 | 2017 |
|-------|------|------|------|
| Apr.  | 26.6 | 26.6 | 17.1 | 17.1 | 8.5 | 8.5 |
| May   | 6.7  | 6.7  | 7.5  | 7.5  | 27.5 | 27.5 |
| June  | 12.8 | 15.3 | 11.2 | 13.8 | 31.5 | 32.5 |
| July  | 17.1 | 19.0 | 13.0 | 15.0 | 19.8 | 21.8 |
| Aug.  | 13.6 | 24.8 | 21.7 | 25.6 | 34.7 | 35.9 |
| Sept. | 9.1  | 23.4 | 16.1 | 25.2 | 2.2  | 20.5 |
| Oct.  | 13.1 | 19.7 | 0.4  | 7.5  | 35.1 | 35.1 |
| Nov.  | 16.7 | 16.7 | 1.6  | 3.6  | 0.4  | 4.2  |

Rainfall totals are presented in centimeters. I = irrigated; N = nonirrigated.

| Year | 2015 | 2016 | 2017 |
|------|------|------|------|
| Apr. | 26.6 | 26.6 | 17.1 | 17.1 | 8.5 | 8.5 |
| May  | 6.7  | 6.7  | 7.5  | 7.5  | 27.5 | 27.5 |
| June | 12.8 | 15.3 | 11.2 | 13.8 | 31.5 | 32.5 |
| July | 17.1 | 19.0 | 13.0 | 15.0 | 19.8 | 21.8 |
| Aug. | 13.6 | 24.8 | 21.7 | 25.6 | 34.7 | 35.9 |
| Sept.| 9.1  | 23.4 | 16.1 | 25.2 | 2.2  | 20.5 |
| Oct. | 13.1 | 19.7 | 0.4  | 7.5  | 35.1 | 35.1 |
| Nov. | 16.7 | 16.7 | 1.6  | 3.6  | 0.4  | 4.2  |

Rainfall totals are presented in centimeters. I = irrigated; N = nonirrigated.
Table 2. Soil phosphorus as affected by soil depth and application rate from 2015 to 2017 after a one-time application of triple superphosphate fertilizer for nonirrigated and irrigated ‘Desirable’ pecans.a

| Rate | Depth | Sign. | 0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm |
|------|-------|-------|----------|-------------|-------------|
| 0x   |       |       | 67.5     | 41.9        | 35.3        |
| 1x   |       |       | 277.6    | 234.5       | 192.0       |
| 2x   |       |       | 526.7    | 373.7       | 307.3       |
| 4x   |       |       | 702.0    | 485.9       | 420.5       |
| Sign. |       |       | Q***     | Q***        | Q***        |

Irrigated

| Rate | Depth | Sign. | 0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm |
|------|-------|-------|----------|-------------|-------------|
| 0x   |       |       | 63.2     | 46.0        | 52.4        |
| 1x   |       |       | 274.1    | 234.4       | 175.7       |
| 2x   |       |       | 547.9    | 404.4       | 294.0       |
| 4x   |       |       | 885.8    | 594.7       | 485.7       |
| Sign. |       |       | Q***     | Q***        | Q***        |

aThe core depth–phosphorus rate interaction was significant at P < 0.05.

The phosphorus rate–sample period interaction was significant at

1The core depth–phosphorus rate interaction was significant at P < 0.05.

2Soil core samples measuring 22.5 cm (9 inches) in depth were collected within the application band and divided into 7.5-cm (3-inch) increments.

3Rates are the equivalent of 0 kg·ha⁻¹ (0 lb/ac), 19.6 kg·ha⁻¹ (17.5 lb/ac), 39.2 kg·ha⁻¹ (35 lb/ac), and 78.5 kg·ha⁻¹ (70 lb/ac) P and are referred to as 0x, 1x, 2x, and 4x, respectively.

4Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.01 (***) or 0.01 (**), ns = not significant.

Melich III extractable phosphorus values are reported in milligrams per kilogram.

Table 3. Soil phosphorus as affected by the application rate and collection period from 2015 to 2017 after a one-time application of triple superphosphate fertilizer for nonirrigated ‘Desirable’ pecans.a

| Date | Rate | Sign. | 0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm |
|------|------|-------|----------|-------------|-------------|
| 20 May 2015 | 47.1 |       | 287.2    | 528.6       | 811.9       |
| 20 July 2015 | 41.7 |       | 219.1    | 527.0       | 615.1       |
| 20 Sept. 2015 | 60.2 |       | 258.7    | 541.7       | 685.9       |
| 20 Nov. 2015 | 41.4 |       | 188.3    | 423.6       | 585.3       |
| 20 Jan. 2016 | 49.7 |       | 260.4    | 484.7       | 577.7       |
| 20 Mar. 2016 | 47.2 |       | 272.2    | 403.1       | 655.6       |
| 20 May 2016 | 51.2 |       | 293.7    | 433.7       | 596.4       |
| 20 July 2016 | 42.9 |       | 256.1    | 378.7       | 602.4       |
| 20 Sept. 2016 | .    |       | .        | .           | .           |
| 20 Nov. 2016 | 47.9 |       | 83.7     | 178.0       | 430.2       |
| 20 Jan. 2017 | 82.2 |       | 206.4    | 318.1       | 338.0       |
| 20 Mar. 2017 | 36.6 |       | 210.2    | 361.8       | 351.0       |
| 20 July 2017 | 33.7 |       | 219.2    | 309.2       | 346.2       |
| 20 July 2017 | 45.2 |       | 299.5    | 345.2       | 373.7       |
| Sign. |       |       | ns       | ns          | L***        |

Discussion

The irrigated and nonirrigated plots had linear decreases in soil test P of the soil depth at rates of 1x and 2x, followed by a quadratic decrease at the 4x rate. This confirmed that the majority of P applied remained in the top depth but was moving steadily down to lower depths. As the P application rate increased, the soil test P increased at each depth.

In the nonirrigated plot, soil test P concentrations remained higher for the 2x and 4x rates at the end of the experimental period than for the 1x rate at the start of the experimental period. This was significant because there was no change in the concentration of soil test P present over time at the 1x rate in the nonirrigated plot. It is likely that because soil test P concentrations were nearly constant for the experimental period with the 1x application rate, the 1x rate introduced what is or is close to the P-holding capacity of the organic soil, and the soil simply maintained P concentrations at or near the maximum equilibrium concentration. Changes in the concentrations of soil test P throughout the soil profile at higher application rates would further support this reasoning. However, data collected during this experiment...
were insufficient to confirm or deny this explanation. With further observations, soil test P concentrations would likely level-off over time for the 2× and 4× rates and approach those present at the 1× rate.

In the irrigated plot, soil test P was higher with the 4× rate at the end of the experimental period than it was with the 1× rate at the start of the experimental period. The same was not true for the 2× rate. A quadratic decrease of soil test P over time was observed at the 1× rate in the irrigated plot, which was different from what was observed for the nonirrigated plot. Diffusion is the primary way that P moves within the soil (Lewis and Quirk, 1967), but these data suggested that irrigation played a significant role in moving P within the soil profile. Previous research supports our observation that the residual effectiveness of superphosphate decreases as soil water content increases (Bolland and Baker, 1987). This residual effectiveness may be due to the reduced diffusion of P that occurs in dry soils, although it has been reported that reduced soil moisture does not reduce bioavailability of P (McBeath et al., 2012). Our data did not reveal the extent to which P movement occurred laterally over the course of the experiment or how potential lateral movement was influenced by irrigation. Previous research of the diffusion of P at rates of 10 and 20 kg·ha⁻¹ showed that concentrations of P in bands decreased logarithmically from the band center and varied substantially along the direction of band application (Stecker et al., 2001).

During the irrigated and nonirrigated experiments, most foliar plant nutrients remained within the sufficiency ranges published for pecan (Smith et al., 2012), except for P, K, S, and Fe. Sulfur and Fe levels were just below the sufficiency range; therefore, application of the nutrients was not necessary. High concentrations of soil test P can reduce Fe uptake in pecan (Sparks, 1988). The small decrease in foliar Fe observed in the irrigated plot as the P application rate increased could have been caused by the high concentrations of soil test P in the banded area, but the expected increase in foliar P was not observed. Potassium concentrations were corrected by separate fertilization over the course of the study. The increase in foliar concentrations of N during the study was also attributed to fertilization. Foliar P concentrations were quadratic over the years in the nonirrigated plot, with higher concentrations in 2015 and 2017 than in 2016. In contrast, foliar P concentrations decreased linearly in the irrigated plot from 2015 to 2017. Trends similar to those observed in the nonirrigated orchard were reported by other studies and have been attributed to the alternate bearing phenomenon observed for pecan (Krezdorn, 1955; Smith, 2009). In those studies, higher foliar P concentrations were observed during higher yielding years than during lower yielding years. The trend in the irrigated plot differed from what was reported in those studies.

The differing trends observed between the experiments are notable because ‘Desirable’ is known for reduced alternating bearing characteristics (Wells, 2007), and there was no difference in yield between 2015 and 2016 in either setting. ‘Desirable’ trees self-thin flowers each year, which reduces yield variance between years (Wells, 2007). Our data may indicate that P partitioning within the plant still follows an alternate bearing pattern regardless of self-thinning in a nonirrigated orchard. Furthermore, irrigation might ameliorate the tendency of P in ‘Desirable’, but that comes with the tradeoff of steady use of the nutrient. The 4× application rate was required in the nonirrigated orchard to increase foliar P concentrations to more than that of the 0× rate. Foliar P concentrations at the 4× rate would still be considered deficient for a high-input orchard (0.14%), but they would be considered sufficient for a low-input orchard (0.12%) (Smith et al., 2012). In contrast, none of the P rates increased foliar P concentrations to more than the 0× rate in the irrigated orchard, and all foliar P concentrations were less than those needed in a high-input orchard. This indicates either that a higher rate of application would be necessary to increase foliar concentrations to those recommended for a high-input commercial orchard in both

Table 4. Soil phosphorus as affected by application rate and collection period from 2015 to 2017 after a one-time application of triple superphosphate fertilizer for irrigated ‘Desirable’ pecans.\(^*\)

| Date | 0x | 1x | 2x | 4x | Sign. |
|------|----|----|----|----|-------|
| 20 May 2015 | 64.1 | 387.0 | 498.9 | 1114.9 | L*** |
| 20 July 2015 | 50.3 | 217.2 | 413.4 | 674.0 | L*** |
| 20 Sept. 2015 | 47.9 | 352.7 | 454.4 | 747.4 | L*** |
| 20 Nov. 2015 | 44.4 | 177.0 | 395.4 | 667.7 | L*** |
| 20 Jan. 2016 | 59.8 | 237.3 | 385.4 | 707.2 | L*** |
| 20 Mar. 2016 | 53.2 | 264.0 | 509.6 | 862.2 | L*** |
| 20 May 2016 | 62.4 | 177.4 | 514.0 | 702.6 | L*** |
| 20 July 2016 | 50.3 | 191.3 | 427.8 | 616.6 | L*** |
| 20 Sept. 2016 | 50.0 | 182.2 | 486.7 | 606.4 | L*** |
| 20 Nov. 2016 | 54.3 | 128.9 | 244.7 | 572.1 | L*** |
| 20 Jan. 2017 | 43.4 | 228.8 | 399.9 | 450.3 | L*** |
| 20 Mar. 2017 | 37.3 | 130.8 | 364.2 | 466.6 | L*** |
| 20 May 2017 | 44.4 | 266.8 | 427.3 | 525.7 | L*** |
| 20 July 2017 | 20.1 | 215.2 | 294.3 | 461.8 | L*** |

The phosphorus rate–sample period interaction was significant at P < 0.05. Rates are the equivalent of 0 kg·ha⁻¹ (0 lb/ac), 19.6 kg·ha⁻¹ (17.5 lb/ac), 39.2 kg·ha⁻¹ (35 lb/ac), and 78.5 kg·ha⁻¹ (70 lb/ac) P and are referred to as 0x, 1x, 2x, and 4x, respectively.

Soil samples were collected from three trees at each treatment level 2 mo. after initiation starting on 20 May 2015, and collection continued at 2-mo. intervals until 20 Sept. 2017. The ninth collection period (20 Sept. 2016) was omitted because collection was prevented by drought conditions.

Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*) or 0.001 (**), ns = not significant.

Melich III extractable phosphorus values are reported in milligrams per kilogram.

Table 5. Soil phosphorus as affected by soil depth and collection period from 2015 to 2017 after a one-time application of triple superphosphate fertilizer at various rates for nonirrigated ‘Desirable’ pecans.\(^*\)

| Date | 0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm | Sign. |
|------|----------|-------------|-------------|-------|
| 20 May 2015 | 627.4 | 341.6 | 287.1 | L*** |
| 20 July 2015 | 472.3 | 322.1 | 257.8 | Q* |
| 20 Sept. 2015 | 517.5 | 333.9 | 308.4 | Q* |
| 20 Nov. 2015 | 392.4 | 286.8 | 249.8 | Q** |
| 20 Jan. 2016 | 442.6 | 329.2 | 257.6 | Q*** |
| 20 Mar. 2016 | 456.3 | 318.5 | 258.8 | Q* |
| 20 May 2016 | 423.7 | 331.9 | 275.7 | Q*** |
| 20 July 2016 | 409.2 | 292.0 | 258.9 | Q* |
| 20 Sept. 2016 | . | . | . | . |
| 20 Nov. 2016 | 246.5 | 173.0 | 135.3 | Q*** |
| 20 Jan. 2017 | 297.6 | 220.2 | 190.8 | Q*** |
| 20 Mar. 2017 | 277.8 | 239.3 | 202.6 | Q*** |
| 20 May 2017 | 259.3 | 221.5 | 200.5 | Q*** |
| 20 July 2017 | 292.2 | 285.0 | 220.5 | Q*** |

The sample depth–sample period interaction was significant at P < 0.05.

Soil core samples measuring 22.5 cm (9 inches) in depth were collected within the application band and were divided into 7.5-cm (3-inch) increments.

Soil samples were collected from three trees at each treatment level 2 mo. after initiation starting on 20 May 2015, and collection continued at 2-mo. intervals until 20 July 2017. The ninth collection period (20 Sept. 2016) was omitted because collection was prevented by drought conditions.

Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*), 0.001 (**), or 0.001 (**), ns = not significant.

Melich III extractable phosphorus values are reported in milligrams per kilogram.
Table 6. Soil phosphorus as affected by soil depth and collection period from 2015 to 2017 after a one-time application of triple superphosphate fertilizer at various rates for irrigated ‘Desirable’ pecans.†

| Date† | Rate0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm | Sign.† |
|-------|--------------|-------------|--------------|--------|
| 20 May 2015 | 801.8† | 429.8 | 317.1 | L*** |
| 20 July 2015 | 488.8 | 293.8 | 229.2 | Q*** |
| 20 Sept. 2015 | 547.0 | 370.7 | 284.2 | Q*** |
| 20 Nov. 2015 | 423.0 | 306.2 | 234.3 | L** |
| 20 Jan. 2016 | 459.7 | 337.8 | 272.1 | Q*** |
| 20 Mar. 2016 | 547.4 | 396.7 | 322.7 | Q*** |
| 20 May 2016 | 491.6 | 363.0 | 264.8 | Q*** |
| 20 July 2016 | 420.4 | 294.8 | 249.4 | Q*** |
| 20 Sept. 2016 | 419.9 | 322.0 | 252.0 | Q*** |
| 20 Nov. 2016 | 266.9 | 279.1 | 204.0 | Q*** |
| 20 Jan. 2017 | 344.8 | 276.4 | 220.6 | Q*** |
| 20 Mar. 2017 | 301.8 | 245.8 | 201.7 | Q*** |
| 20 May 2017 | 373.8 | 335.0 | 239.4 | Q*** |
| 20 July 2017 | 311.5 | 250.1 | 235.8 | Q*** |
| Sign.† | L*** | L** | NS |

†The table reports the depth–sample period interaction was significant at P < 0.05.
‡Soil core samples measuring 22.5 cm (9 inches) in depth were collected within the application band and were divided into 7.5-cm (3-inch) increments.
§Soil samples were collected from three trees at each treatment level 2 mo. after initiation starting on 20 May 2015, and collection continued at 2-mo. intervals until 20 July 2017. The ninth collection period (20 Sept. 2016) was omitted because collection was prevented by drought conditions.
∥Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*), 0.01 (**), or 0.001 (**). NS = not significant.
∗Data are reported as parts per million of the foliar dry weight.
†Melich III extractable phosphorus values are reported in milligrams per kilogram.

Table 7. Foliar phosphorus concentrations from 2015 to 2017 as affected by application of a one-time band of triple superphosphate for nonirrigated ‘Desirable’ pecans.‡

| Rate0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm | Sign.† |
|--------------|-------------|--------------|--------|
| 0 | 0.125 | 0.122 | 0.124 | Q* |
| 1x | 1.5 | 1.3 | 1.2 | Q* |
| 2x | 2 | 1.7 | 1.5 | Q* |
| 4x | 4 | 3 | 2.5 | Q* |

†The table reports the phosphorus rate main effect was significant at P < 0.05.‡RATES ARE THE EQUIVALENT OF 0 kg·ha–1 (0 lb/ac), 19.6 kg·ha–1 (70 lb/ac), 39.2 kg·ha–1 (140 lb/ac), and 78.5 kg·ha–1 (70 lb/ac) P and are referred to as 0x, 1x, 2x, and 4x, respectively.
§Significant (Sign.) quadratic (Q) trend using model regressions at P < 0.05 (*).

Table 8. Foliar nutrient concentrations as affected by year after application of a one-time band of triple superphosphate for nonirrigated ‘Desirable’ pecans.‡

| Yr | Element | 2015 | 2016 | 2017 | Sign.† |
|----|---------|------|------|------|--------|
| Nitrogen | 2.44† | 2.47 | 2.63 | L*** |
| Phosphorus | 0.128 | 0.120 | 0.127 | Q*** |
| Potassium | 0.913 | 0.990 | 1.080 | L*** |
| Magnesium | 0.445 | 0.462 | 0.378 | Q*** |
| Calcium | 1.587 | 1.611 | 1.475 | NS |
| Sulfur | 0.187 | 0.189 | 0.181 | L* |
| Boron | 48.33† | 41.84 | 40.50 | Q* |
| Iron | 47.19 | 48.05 | 49.50 | NS |
| Manganese | 624.58 | 620.21 | 542.22 | NS |
| Copper | 7.58 | 6.53 | 6.90 | Q* |
| Zinc | 96.30 | 84.20 | 85.20 | NS |

†The table reports the phosphorus rate main effect was significant at P < 0.05.‡Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*), 0.01 (**), or 0.001 (**). NS = not significant.
§Data are reported as parts per million of the foliar dry weight.

Table 9. Foliar nutrient concentrations as affected by year after application of a one-time band of triple superphosphate for irrigated ‘Desirable’ pecans.‡

| Yr | Element | 2015 | 2016 | 2017 | Sign.† |
|----|---------|------|------|------|--------|
| Nitrogen | 2.56† | 2.45 | 2.67 | Q** |
| Phosphorus | 0.133 | 0.125 | 0.121 | L*** |
| Potassium | 0.845 | 0.879 | 1.017 | L*** |
| Magnesium | 0.435 | 0.426 | 0.374 | L* |
| Calcium | 1.64 | 1.55 | 1.36 | L** |
| Sulfur | 0.190 | 0.183 | 0.181 | L* |
| Boron | 49.74† | 42.00 | 41.41 | Q* |
| Iron | 48.11 | 42.79 | 46.89 | Q** |
| Manganese | 811.25 | 744.92 | 711.71 | NS |
| Copper | 7.74 | 7.84 | 6.94 | Q* |
| Zinc | 89.70 | 95.66 | 102.23 | NS |

†The table reports the phosphorus rate main effect was significant at P < 0.05.‡Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*), 0.01 (**), or 0.001 (**). NS = not significant.
§Data are reported as parts per million of the foliar dry weight.

Table 10. Foliar iron, copper, and boron concentrations from 2015 to 2017 as affected by the application of a one-time band of triple superphosphate for irrigated ‘Desirable’ pecans.‡

| Rate0–7.5 cm | 7.5–15.0 cm | 15.0–22.5 cm | Sign.† |
|--------------|-------------|--------------|--------|
| 0 | 420.4 | 294.8 | 249.4 | Q*** |
| 1x | 419.9 | 322.0 | 252.0 | Q*** |
| 2x | 266.9 | 279.1 | 204.0 | Q*** |
| 4x | 344.8 | 276.4 | 220.6 | Q*** |

†The table reports the phosphorus rate main effect was significant at P < 0.05.‡Rates are the equivalent of 0 kg·ha–1 (0 lb/ac), 19.6 kg·ha–1 (70 lb/ac), 39.2 kg·ha–1 (140 lb/ac), and 78.5 kg·ha–1 (70 lb/ac) P and referred to as 0x, 1x, 2x, and 4x, respectively.
§Significant (Sign.) linear (L) or quadratic (Q) trends using model regressions at P < 0.05 (*) or 0.01 (**).
combination with foliar application of P. This approach is not unprecedented for pecan and has been used as a more long-term solution for correcting Zn deficiency. Foliar sprays of Zn are commonly used to correct short-term deficiency of the element, but band application of the nutrient has been shown to have long-term efficacy (Wood, 2007). The adoption of this two-pronged approach has been proven advantageous for pecan growers in areas where foliar applications of Zn paired with a banded application can make future foliar applications unnecessary. Research should be performed to create a similar protocol involving P for pecan.

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