Response of Pecan to Annual Soil Band Applications of Phosphorus and Potassium

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Abstract. Phosphorus (P) and potassium (K) deficiencies were identified in a ‘Pawnee’ pecan [*Carya illinoensis* (Wangenh.) C. Koch] orchard. Deficiencies of P and K have traditionally been difficult to correct in pecan. Broadcast application of P rarely results in a positive response. Broadcast applications of K frequently require 3 or more years before a positive response was noted, particularly in soils with high clay content. A 4-year study was initiated on 10-year-old trees using soil band-applied P, K, blended P plus K, and a non-treated control. Rates were based on trunk cross-sectional area adjusted annually for tree growth. Phosphorus application alleviated leaf deficiency symptoms, increased leaf P concentration, and improved flowering. However, P application resulted in darker kernels than the control or K-treated trees. Band-applied K was not associated with observed leaf symptoms but increased leaf K above the recommended minimum level and increased the percentage of number-1 kernels. Band-applied P or blended P plus K suppressed leaf K concentrations. Blended P plus K applied as a band appeared to improve return bloom 2 of 3 years, although no improvement in leaf K concentration was noted.

Pecan alternate bearing is typified by high production 1 year followed by 1 year or more of low production (Sparks, 1986). All segments of the pecan industry consider alternate bearing as the greatest factor limiting expansion (Smith and Weckler, 2010). Low crop years are normally associated with a lack of return bloom rather than flower abortion (Rohla et al., 2007).

Alternate bearing trees show distinct differences in leaf K and P accumulation and depletion between large and small crops (Krezdorn, 1955; Smith, 2009). During large crop years, trees had higher concentrations of leaf K and P shortly after budbreak, perhaps resulting from greater stored reserves after a small crop (Krezdorn, 1955), or greater absorption from soil triggered by a signal from a large number of developing flowers (Smith, 2009). Shortly after the fruit begins rapid volume increase, phloem-mobile K (Marschner et al., 1996) in leaves drops and shuck K accumulates rapidly (Diver et al., 1984; Kim and Wetzstein, 2005; Pe’er and Kessler, 1984; Smith, 2009) presumably associated with carbohydrate transport (Haeder, 1977; Mengel,

1980; Mengel and Haeder, 1977; Vreugdenhil, 1985) to the developing cotyledons supporting lipid accumulation (Pe’er and Kessler, 1984). Accumulated shuck K acts to increase shuck hydration assisting in shuck opening (Pallardy, 2008; Thor and Smith, 1935). Potassium shortages have been associated with leaf margin chlorosis/necrosis and partial defoliation (Smith, 2010; Sparks, 1977), reduced kernel oil content (Hunter and Hammar, 1956), poor kernel development (Smith, 2010), greater fruit abortion (Wood et al., 2010), lower tree yield (Blackmon and Ruprecht, 1934; Smith et al., 1985), and reduced return bloom (Smith, 2010).

Pecan tree yield was unresponsive to applied K in many studies (Alben and Hammar, 1963, 1964; Gammon and Sharpe, 1959; Hunter, 1956; Hunter and Hammar, 1947; Sharpe et al., 1950, 1952; Worley, 1974). However, four studies reported a yield increase with applied K (Smith et al., 1985; Wells and Wood, 2007; Wood et al., 2010; Worley, 1994). Inconsistent response to applied K was largely the result of native K availability or lack of plant uptake indicated by leaf K concentration. Frequently, multiple years of annual K application were required to elicit a response (Smith et al., 1985; Worley, 1994). Typically, applied K was more readily available in soils with a sandy texture than those with high clay content. Wood et al. (2010) demonstrated that banding K within the root zone near a drip irrigation source resulted in substantial K uptake by trees.

Worley (1994) conducted a 20-year study to establish the minimum pecan leaf K concentration to achieve maximum production.

He concluded that 0.75% was adequate for non-irrigated, old ‘Stuart’ trees. However, other work reported fruit drop of ‘Desirable’ could be reduced if fruit K was $\approx 1.25\%$ during Stage II fruit drop and suggested minimum leaf K concentrations as high as 1.5% might be needed for irrigated ‘Desirable’ (Wood et al., 2010). Another study suggested that K concentrations should be adjusted based on nitrogen (N) management to yield a leaf N:K ratio of 2:1 for maximum pecan yield (Wells and Wood, 2007).

Phloem-mobile P in leaves decreased rapidly as it was transported to developing cotyledons during the latter part of the growing season (Diver et al., 1984; Kim and Wetzstein, 2005; Krezdorn, 1955; Smith, 2009). Rapid P transport was later than K to developing fruit. Phosphorus accumulation was primarily in the cotyledons in the form of phospholipids used as a substrate for unsaturated fatty acid synthesis and stored as inositol hexaphosphate (Chesworth et al., 1998). The rapid accumulation of P in the fruit and concurrent depletion from the leaves resulted in leaf necrosis and partial defoliation when P was limiting (Smith, 2010; Sparks, 1977).

Smith (2010) reported that leaf, kernel, and shuck P concentrations were positively correlated with weight/nut and the percentage of number-1 kernels and recommended a minimum leaf P concentration of 0.14% in July. Sparks (1988) suggested that a leaf P concentration of 0.16% may be required for pecan. However, correcting a P shortage using traditional broadcast application was frequently unsuccessful (Alben and Hammar, 1964; Hunter and Hammar, 1948, 1952, 1957; Smith et al., 1960; Worley, 1974). Sparks (1988) increased P absorption of pecan by broadcasting massive quantities of P (2.2 kg/6 m²/tree P; equivalent to broadcasting 7491 lb/a P₂O₅). Such large amounts of P are not economically practical to correct a shortage.

This study was conducted in a pecan orchard with documented shortages of P and K (Smith, 2010). The objective of this study was to correct these deficiencies using banded fertilizer applications and to determine tree response. Because broadcast applications were usually ineffective unless exceptionally large quantities of P were applied and K shortages are difficult to correct in soils with high clay content, banding the fertilizer at the edge of the vegetation-free area surrounding the tree seemed a reasonable approach.

Materials and Methods

The study was conducted in a 10-year-old ‘Pawnee’ pecan orchard located near Cleveland, OK (36°15’43” N lat., –96°30’3” W long.). The Dennis silt loam soil (fine, mixed, active, thermic Aquic Argiudolls) had a pH at the start of the experiment of 4.6 at 0- to 15-cm level and 4.8 at 15- to 30-cm. Agricultural limestone was applied at 3.6 t·ha⁻¹ effective calcium carbonate equivalent. When the experiment was ended after 4 years, soil pH was 6.4 and 5.9 at 0- to 15-cm and 15- to 30-cm

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levels. Cation exchange capacity (sum of exchangeable cations plus extractable acidity) was 11.7 meq/100 g and 9.6 meq/100 g at the 0- to 15-cm and 15- to 30-cm depths, respectively. Soil organic matter in the top 15 cm was 2.5%. Trees received commercial management for pests. Irrigation was provided with a subsurface drip irrigation system located ≈ 1.8 m from the trunk running the length of the row with 3.8-L-h⁻¹ emitters spaced 0.3 m apart. The water source for irrigation was a pond (small lake) at the lower edge of the orchard. A vegetation-free area centered on the trees was maintained 3.6 m wide and 6 m long with selected herbicides. The remainder of the orchard floor was sod that was mowed as needed. Weather records were obtained from a nearby Mesonet station operated by the Oklahoma Climatological Survey.

Treatments were a control (no P or K), application of P and K alone, or a blend of P plus K. Fertilizer rates were adjusted annually based on trunk diameter measured 1.4 m above the ground. Treatments were arranged in a randomized complete block design with blocking based on trunk diameter; replicated six times using single tree plots with border trees. In 2009, rates were 4.5 g·cm⁻² cross-sectional trunk area P or K, 9 g·cm⁻² cross-sectional trunk area P or K in 2010 and 2011, and 4.5 g·cm⁻² cross-sectional trunk area P or K in 2012. The fertilizer sources were 46N-0P-0K (urea), 18N-20P-0K (diammonium phosphate), 0N-0P-49.8K (potassium chloride), and a 28% N solution (mixture of urea and ammonium nitrate). Phosphorus, K, and N were applied in March each year as a band ≈ 15 cm wide and 4.5 m long, 1.8 m from the trunk on each side of the tree. Urea was added such that all trees received the same N rate, including the control. March N rates were 4 g·cm⁻² cross-sectional trunk area in 2009 and 2012 and 8 g·cm⁻² cross-sectional trunk area in 2010 and 2011. An additional 0.9 kg/tree N from urea was hand-broadcast under the canopy in May 2009 and in 2012, 1.5 kg/tree N (0.375 kg/tree N each application) from a N solution was injected through the

drip system in four equal amounts in May and June.

Trunk diameter was measured 1.4 m above the ground annually during dormancy. Leaf samples, collected annually in July, were 30 middle leaflet pairs per tree from the middle leaf on the current season's growth. Leaves were washed using the following sequence: tap water, 0.1 N HCl, P-free detergent, and two deionized water rinses. Total washing and rinsing time was less than 1 min per sample. Washed leaves were dried in a forced-air oven at 70 °C, ground to pass an 850- μ m screen, and stored for later analysis. Leaf elemental concentrations of N were determined after additional grinding of samples in a Cyclotec mill followed by analysis with a Leco N analyzer (Leco, St. Joseph, MI) (Yoemans and Bremner, 1991). Samples were ashed in a muffle furnace at 500 °C, dissolved in 20% hydrochloric acid, filtered through Whatman 41 filter paper, and brought to the appropriate dilution with a 2% lanthanum solution. Extracted leaf P was determined colorimetrically (Olsen and Sommers, 1982). Potassium, calcium (Ca), magnesium (Mg), copper, iron (Fe), zinc (Zn), and manganese (Mn) were analyzed using atomic absorption spectroscopy (Perkin Elmer model 2380, Waltham, MA) (David, 1958).

Flowers on current season's growth were counted annually in late May. In 2011, 30 each vegetative- or fruit-bearing (in 2010) 1-year-old branches per tree were counted. During 2012, flower counts were on 30 1-year-old branches per tree that were vegetative in 2011. In 2013, flower counts were on 30 1-year-old branches per tree that had fruited in 2012.

Ratings of leaves with necrosis and partial defoliation were conducted in 2009, 2010, and 2012. On 29 Aug. 2009, individual trees were ranked as having or not having any necrotic leaf symptoms (Fig. 1). These data were analyzed using Fisher's exact test for equal cell frequency (no difference among treatments). A grading system was devised for rating trees in 2010 and 2012 (Fig. 2). A ranking of 1 indicated no necrotic leaves or

defoliation, 2: 1% to 19% of the leaves with necrosis, 3: 20% to 39% necrotic leaves, 4: 40% to 59% necrotic leaves with some defoliation, and 5: 60% or greater necrotic leaves combined with partial defoliation. Trees were rated on 4 Oct. 2010 and 31 Aug. 2012.

Twenty-nut samples per tree were collected in 2010 and 2012 (trees were damaged by a 2009 spring freeze and fruit aborted in 2011 from drought stress) and analyzed for weight per nut, kernel percentage, and kernel grade. Commercial standards were used to grade kernels. Briefly, grade number-1 is a bright yellow kernel that is well-filled; number-2 is bright yellow but the kernel lacks plumpness; number-3 is off-color that may be well-filled or lightweight; and a grade of number-4 is a reject.

Data were analyzed using a mixed model procedure by year, except where a Fisher's exact test was indicated. Means were compared using a least significant difference test at the 5% level if the F-test indicated a probability of 5% or less that treatment means were equal.

Results and Discussion

Application of P resulted in leaf P concentrations greater than the control each year of the study (Table 1). Control trees had 0.08% to 0.09% leaf P throughout the study within the range where P-deficiency symptoms are

Fig. 1. Characteristic leaf symptoms observed. These included mottling and necrotic leaf margins progressing to individual leaflets dropping.

Fig. 2. Representative trees used for rating symptoms. The tree on the left had no symptoms and was rated 1. On the center tree, most of the leaves on shoots bearing fruit had mottling or necrotic areas but no defoliation and was rated 3. The tree on the right had extensive mottling and necrosis on leaves of fruit-bearing shoots combined with some defoliation and was rated 5.

expected (Sparks, 1978). Target leaf P concentrations (0.14%) (Smith et al., 2012) were achieved during the second year of the study with application of P alone or the P and K blend. However, leaf P concentrations measured the third and fourth years were lower than in the second year, but remained higher than the control. During the third and fourth years of the study (2011 and 2012), Oklahoma experienced a drought of historic proportions combined with an uncharacteristic number of days exceeding 38 °C. In fact, the drought began in 2010 although rainfall had been above normal until June; the rest of 2010 was abnormally dry. Average rainfall for this area is 1016 mm annually. Rainfall during the rain year (1 Oct. to 30 Sept.) was 1044, 561, and 667 mm and for the growing season (1 Apr. to 30 Sept.) 685, 382, and 281 mm in 2010, 2011, and 2012, respectively. Supplemental irrigation was normal in 2009 and 2010, ranging from 182 L/day/tree to 302 L/day/tree depending on evapotranspiration. In 2011 and 2012, inadequate water runoff into the pond limited the amount of water available for irrigation. In 2011, trees received 91 L/day/tree in July and August until water depleted, and in 2012 182 L/day/tree in June to August when water was depleted. Data suggest that the abnormally dry conditions

combined with the inability to supply adequate supplemental irrigation depressed P uptake in 2011 and 2012. Drought stress can reduce the fine root mass of European beech (*Fagus sylvatica* L.) (Meier and Leuschner, 2008), suppress P uptake of tall fescue (*Festuca arundinacea* Schreb.) (Huang, 2001), and reduce uptake and suppress translocation of P in soybean [*Glycine max* (L.) Merr.] (Jin et al., 2006). Their results support the conclusion that drought depressed leaf P concentrations in 2011 and 2012.

Addition of P reduced the percentage of trees with necrotic symptoms in 2009 (Table 2). In 2010 and 2012, trees receiving P had a substantially lower symptom rating than the control and exhibited few signs of P deficiency. In 2012, leaf P (0.11% P) concentration of P-treated trees was at a level where deficiency symptoms are expected (Sparks, 1978), but they failed to materialize. Leaf P deficiency symptoms also did not occur as fruit reached shuck split, although the large crop increased P demand. This suggests that leaf P concentrations during drought may not be representative of the available labile P in the tree to meet fruit demand. High temperatures and water stress reduce transpiration which in turn depress the amount of P transported to leaves in the xylem. Huang (2001)

reported that drought reduced P in shoots and increased the amount available in the roots of tall fescue. We speculate that fruit demand of P-fertilized trees was met by phloem-mobile P supplied primarily from root accumulations of drought-stressed trees, whereas leaves were the primary source of labile P in non-drought-stressed pecan trees (Smith, 2009).

Potassium application did not affect leaf K concentrations compared with the control for the first 2 years of the study (Table 1). Phosphorus application appeared to suppress leaf K compared with K applied alone in 2009 and 2010. Leaf K resulting from application of blended P and K was similar to all treatments for the first year, but the second year had lower leaf K than applying K alone. During the third and fourth years, leaf K was greater than the control when K was applied without P, but when blended with P, leaf K was similar to the control. The response to K applied alone but not when blended with P was unexpected because their soil retention mechanisms differ. Soil P is mostly bound by ligand exchange reactions on the surface of variable charged minerals, whereas soil K is typically held onto permanently charged cation exchange sites where it is highly labile. As a result of these differences, K is prone to leaching losses, whereas P is not.

Increased P uptake is known to improve root growth. In fact, applied P in a deficient situation increased root growth, but K did not (Anghinoni and Barber, 1980; Borkert and Barber, 1985; Yao and Barber, 1986); hence, blending P with K was expected to increase K uptake. Phosphorus and K transport to the root is primarily met by diffusion through water-filled pores and the water film surrounding soil particles (Marschner and Rengel, 2012). Soil solution P is normally substantially lower and plant demand less than for K. The exact mechanism for decreased K uptake among blended P and K compared with K applied alone is unknown. Sorption of P to variable charged minerals results in an increase in the soil cation exchange capacity that will increase the affinity of K for the surface. Perhaps this increase in cation exchange capacity was enough to shift the equilibrium between soil-bound K and solution K toward soil-bound K. Drought conditions reduce the soil water, which could increase the potential for new, less soluble K minerals to precipitate. For example, another possibility is the precipitation of potassium taranakites [$H_2K_3Al_5(PO_4)_8 \cdot H_2O$] (Foth and Ellis, 1997) that would reduce the solubility of both P and K compared with each applied alone with an ultimately greater net effect on K because more is required to meet plant demand. However, taranakites are unstable (more soluble) compared with other phosphate minerals such as variscite and strengite; therefore, reduced K solubility resulting from taranakite formation should be temporary.

Leaf elemental concentrations of Ca, Mg, Zn, Fe, and Mn were rarely affected by treatment (Table 1). In those few instances when treatment did affect their concentration, it was not of physiological significance

Table 1. The influence of soil band-applied P and K on the July leaf elemental concentration of pecan.

Element applied	Elemental concn (% DW)					Elemental concn ($\mu\text{g}\cdot\text{g}^{-1}$ DW)		
	N	P	K	Ca	Mg	Zn	Fe	Mn
<i>Sample collected 15 July 2009</i>								
None	2.33 a	0.09 b ²	0.78 ab	1.29 a	0.32 a	50 b	40 a	617 a
P	2.41 a	0.11 a	0.71 b	1.35 a	0.36 a	71 a	43 a	810 a
K	2.33 a	0.09 b	0.82 a	1.33 a	0.35 a	72 a	42 a	860 a
P + K	2.34 a	0.11 a	0.77 ab	1.38 a	0.35 a	65 ab	43 a	752 a
<i>Sample collected 16 July 2010</i>								
None	2.58 b	0.09 b	0.73 ab	1.68 a	0.38 a	125 a	56 a	919 a
P	2.70 a	0.14 a	0.67 b	1.69 a	0.42 a	125 a	57 a	925 a
K	2.52 b	0.09 b	0.79 a	1.79 a	0.40 a	123 a	58 a	1147 a
P + K	2.62 ab	0.14 a	0.69 b	1.82 a	0.40 a	118 a	53 a	937 a
<i>Sample collected 14 July 2011</i>								
None	2.22 ab	0.09 b	0.81 b	1.34 b	0.36 a	80 ab	61 a	723 a
P	2.23 ab	0.12 a	0.61 c	1.57 ab	0.43 a	69 b	66 a	704 a
K	2.10 b	0.09 b	1.07 a	1.41 ab	0.36 a	105 a	69 a	1009 a
P + K	2.29 a	0.11 a	0.81 b	1.59 a	0.37 a	74 b	67 a	856 a
<i>Sample collected 12 July 2012</i>								
None	2.41 a	0.08 b	0.86 b	1.38 b	0.32 ab	64 b	56 a	684 a
P	2.43 a	0.11 a	0.50 c	1.57 b	0.43 a	48 b	55 a	663 a
K	2.39 a	0.08 a	1.11 a	1.45 b	0.30 b	92 a	59 a	931 a
P + K	2.44 a	0.11 b	0.82 b	1.82 a	0.37 ab	57 b	62 a	1003 a

²Means within the same year and column followed by the same letter are not significantly different by the protected least significant difference, 5% level.

P = phosphorus; K = potassium; DW = dry weight; N = nitrogen; Ca = calcium; Mg = magnesium; Zn = zinc; Fe = iron; Mn = manganese.

Table 2. The influence of soil band-applied P and K treatment on ratings of leaf necrosis and partial defoliation of pecan trees.

Element applied	Trees with any necrotic leaf symptoms 29 Aug. 2009 (%)	Tree necrosis rating 4 Oct. 2010	Tree necrosis ratings 31 Aug. 2012
None	66 ²	3.7 a ^{3,x}	4.0 a
P	33	1.5 b	1.7 b
K	100	3.3 a	4.3 a
P + K	17	1.3 b	1.5 b

²Significantly different from equal cell frequencies by Fisher's exact test, 5% level.

³Means within the same column followed by the same letter are not significantly different by the protected least significant difference, 5% level.

^xRating system: 1 = none, 5 = severe leaf necrosis and partial defoliation.

P = phosphorus; K = potassium.

because concentrations remained within the recommended range (Smith et al., 2012).

In 2011, P application substantially increased return bloom of shoots that were vegetative- or fruit-bearing the previous year (Table 3). Although K did not affect return bloom compared with the control in 2011, when combined with P, return bloom exceeded either element applied alone. This indicates that the shortage of P was more acute than K, but inadequate K also limited return bloom. Return bloom was also greater on fruit-bearing terminal shoots than terminal vegetative shoots, a result reported in another study using ‘Pawnee’ (Rohla et al., 2007). In 2012, flowering was only determined on shoots that were vegetative the previous year (2011) because the control and K alone treatment did not produce sufficient pistillate flowers in 2011. All treatments had substantial return bloom in 2012, but treatments that received P application had a significantly greater return bloom. Fruit were not thinned in 2012, although trees that received P were overloaded and all trees were drought-stressed. Return bloom in 2013 was low with no significant difference among treatments at the 5% level, but at the 10% significance level, trees receiving blended P and K had a larger return bloom than the control.

Neither weight per nut nor kernel percentage was affected by treatment in 2010 (Table 4). In 2012, weight/nut was smaller and kernel percentage less when trees received P, probably reflecting the larger cropload

compared with control trees or those receiving only K. Smaller nuts in 2012 compared with 2010 reflected the drought stress experienced in 2012. Potassium application increased the percentage of number-1 kernels compared with the control in 2012. Kernels were darker (greater percentage of number-3 kernels) when trees received P. This was alarming; however, a similar study being conducted in Georgia indicated no negative effects of banded P on kernel color (data not published). Sparks (1988) did not report any negative effects on kernel color of ‘Mahan’ and ‘GraBohls’ pecans when massive amounts of P were applied to the soil. Also, a review of literature found no negative effects of P on pecan kernel color or cotyledon color of other species. This anomaly may be associated with larger croploads on trees receiving P and the tendency of ‘Pawnee’ kernels to have dark spots and streaks when stressed (cropload, high temperature, and drought) or harvest is delayed. Otherwise, we have no explanation for this result but are concerned because it occurred in 2010 (drought stress late in the growing season) and 2012 (drought stress throughout the growing season).

Conclusions

Band applications of N with P or K at rates used in this study were effective in correcting P and K shortages (Table 1). Deficiency symptoms, including marginal necrosis on leaves and partial defoliation, were resolved

by addition of P (Table 2). The suppression of leaf K concentration by P applied alone or blended with K was unexpected and not well understood (Table 1). Drought may have aggravated this response or may have been the primary cause. Sparks (1988) using massive soil P applications to increase P uptake reported P application reduced leaf K concentration in ‘GraBohls’ but not ‘Mahan’ pecan. Additional work is merited concerning effect of P on K concentrations, especially because blended applications would be common when both elements are deficient.

Drought conditions appeared to suppress leaf P concentrations to levels where leaf deficiency symptoms would be expected, especially when P is mobilized from leaves to maturing fruit. However, applied P virtually eliminated leaf symptoms (Table 2), suggesting that P was being mobilized from other areas. Others reported drought suppressed P translocation to aerial portions while P accumulated in roots, probably the result of reduced xylem transport (Huang, 2001; Jin et al., 2006). However, fruit P demand is primarily met by phloem transport, and the lack of leaf symptoms indicates root P accumulations, rather than labile P in leaves, was the primary source.

Band-applied P substantially increased flowering (Table 3). Blended application of P with K appeared to increase flowering compared with P alone (2011 at $P = 5\%$ and 2013 at $P = 10\%$) (Table 3), but leaf elemental concentrations of K do not support this conclusion because P suppressed leaf K below the critical level (Table 1) (Smith et al., 2012). The dilemma of P negatively affecting K absorption or translocation, yet obtaining a positive response when applied together, is unresolved.

Potassium applied alone improved kernel grade (percent number-1 kernels) (Table 4), probably as a result of its association with phloem loading of carbohydrates, speed of phloem transport, and unloading (Haeder, 1977; Mengel, 1980; Mengel and Haeder, 1977; Vreugdenhil, 1985). When K was applied with P, the benefits of K application on kernel grade were eliminated. An unexpected and perplexing effect of applied P on kernel grade was the substantial increase in off color (number-3) kernels. No reports of discolored cotyledons associated with P application were located as the result of a thorough literature search. ‘Pawnee’ has a tendency to develop dark spots and streaks on the kernel, becoming progressively more intense if harvest is delayed. The cause of this characteristic is unknown, but it is common knowledge among scientists, producers and processors. We have observed that stress such as abnormally high temperature, drought, or excessive cropload results in some darkened ‘Pawnee’ kernels and a greater prevalence of spots and streaks on the kernel. Plant stress was obvious in this study and correcting the P shortage may have allowed greater discoloration of kernels in response to perceived stresses.

In summary, band application of P or K was effective in alleviating shortages of each

Table 3. The influence of soil band-applied K and P on the percentage of 1-year-old branches producing fruit in current-season shoots the next year.

Element applied	1-year-old branches producing fruiting shoots (%)			
	Yr			
	2011	2012	2013	
	Vegetative shoot in the previous year	Fruiting shoot in the previous year	Vegetative shoot in the previous year	Fruiting shoot in the previous year
None	1 a ^z	0 a	65 a	6 a
P	26 b	39 b ^y	92 b	10 a
K	1 a	0 a	65 a	7 a
K + P	42 c	55 c ^y	90 b	22 a

^zMeans within columns followed by the same letter are not significantly different by the protected least significant difference, 5% level.

^yShoot type means within the same fertilizer treatment in 2011 significantly different by the protected LSD, 5% level.

K = potassium; P = phosphorus.

Table 4. The influence of soil band-applied P and K treatment on selected pecan nut quality parameters.

Element applied	Wt/nut (g)	Kernel (%)	Kernel grade (% by category)			
			Number-1	Number-2	Number-3	Number-4
			bright-colored, full-bodied, solid	bright-colored, but lightweight	amber color, either full-bodied or lightweight	reject
2010						
None	6.6 a	54.55 a	81 ab	9 a	9 b	0
P	7.2 a	52.44 a	64 bc	0 b	36 a	0
K	6.9 a	54.65 a	87 a	2 ab	11 b	0
P + K	6.9 a	52.44 a	59 c	1 b	40 a	0
2012						
None	4.7 a	53.58 a	31 b	45 a	23 b	1 a
P	3.9 b	49.06 b	0 c	9 a	90 a	0 a
K	4.6 a	55.18 a	72 a	8 a	19 b	1 a
P + K	3.7 b	49.35 b	1 c	23 a	75 a	0 a

^zMeans within the same tissue and column followed by the same letter are not significantly different by the protected least significant difference, 5% level.

P = phosphorus; K = potassium.

element. Phosphorus application improved flowering, and K application improved kernel grade. However, certain issues were identified in this study that require clarification. First, does a blend application of P and K applied in a band negate absorption or translocation of K, and if so, by what means? Second, does elevating P by band application negatively affect kernel color of 'Pawnee' only in stress conditions? Will elevated P by band application negatively affect kernel color of other cultivars? Commercial orchards that were early adopters of band-applied P and/or K have not reported any negative results but have seen a positive impact on cropping consistency.

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