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Kernel Necrosis of 'Pawnee' Pecan: Expanded Distribution and Relation to Yield, Tree Size, and Canopy Location

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Abstract. **Pecan [*Carya illinoinensis* (Wangenh.) K. Koch.] kernel necrosis is a malady characterized by development of a dark necrotic area at the basal end of the kernel. This problem is particularly severe on 'Pawnee' at some locations during certain years. Currently, the cause of kernel necrosis is not known. Initially, this problem appeared confined to certain cultivars in a north Texas orchard in the Red River Basin and 'Oklahoma' in a central Oklahoma orchard adjacent to the Deep Fork River. After El Paso, TX, producer reports of an unknown problem on 'Pawnee', mature nuts from orchards near El Paso, north Texas, and southern, central and northeastern Oklahoma were evaluated for kernel necrosis. Kernel necrosis was abundant on 'Pawnee' nuts from El Paso and southern Oklahoma, moderate at the north Texas site, and at low levels in one northeastern Oklahoma orchard. None was found in two 'Pawnee' orchards, one in central Oklahoma and the other in northeastern Oklahoma. In another study, yield was monitored on hedge-pruned 'Pawnee' pecan trees over a 5-year period to determine the relationship with kernel necrosis. The incidence of kernel necrosis was greater when yield was less. A third study sampled nuts from the lower and upper one-third of canopies from randomly selected trees varying in trunk size. Kernel necrosis frequency was similar in the upper canopy among different trunk sizes, but the incidence in the lower tree canopy decreased as trunk size increased.**

Kernel necrosis is a malady characterized by necrotic tissue at the basal end (stem end) of the kernel (Fig. 1) (Smith et al., 2007). It was first reported in an orchard near Charlie, TX, and has since been identified in several orchards with 'Pawnee' trees located in the Red River Basin located along the Oklahoma and Texas border (unpublished observations). No symptoms of kernel necrosis were visible on the shuck (involucre), although the intact fruit appeared slightly larger than normal fruit. Kernel necrosis was more prominent on 'Pawnee', 'Choctaw', and 'Oklahoma' and rarely, if ever, occurred on other observed cultivars (Smith et al., 2007). At maturity, nuts (pericarp and cotyledons) with kernel necrosis had a larger shell volume than nuts with normal kernels. The orchard near Charlie, TX, received unusually large amounts of nitrogen (N) from a combination of the producer's applications (112 kg·ha^{-1} N in March and June plus 84 kg·ha^{-1} N in September) and nitrate (NO_3) -contaminated irrigation water (≈160 kg·ha^{-1} N annually). Accumulated NO_3-N in the upper 45 cm of soil was 197 kg·ha^{-1} N in 2006 with a July leaf N value of ≈2.8%. During a 5-year study, the average percentage of kernel necrosis ranged from ≈1.4% to 22.2% of the crop, but individual trees sometimes had a much larger percentage of kernel necrosis. It was hypothesized that excess N was involved in kernel necrosis; however, a 5-year N rate study found no relationship between N application and kernel necrosis (Smith et al., 2007). Supplemental foliar applications of copper and nickel also failed to affect the incidence of kernel necrosis (Wagle et al., 2011).

Producers in the Rio Grande Basin near El Paso, TX, reported an unidentified problem on 'Pawnee' kernels in 2011. Samples from selected orchards near El Paso were evaluated for kernel necrosis along with samples from northeastern, southern, and central Oklahoma and northern Texas orchards. Occurrence of kernel necrosis from additional orchards is reported here. Results of studies of the relationship of kernel necrosis with crop load, tree size, and its distribution in the tree canopy are reported.

Materials and Methods

Kernel necrosis occurrence. After reports of 'Pawnee' pecan kernels with symptoms similar to those reported earlier (Smith et al., 2007) from producers near El Paso, TX, nut samples were collected from selected orchards at fruit maturity in 2011. Orchards included two near El Paso, one from north Texas, one from southern Oklahoma, two from northeastern Oklahoma, and one from central Oklahoma (Table 1). The orchards in northeastern Oklahoma near Cleveland and central Oklahoma near Perkins had no history of kernel necrosis after several years of sampling (Smith, personal observations). Orchards in north Texas near Charlie and southern Oklahoma near Madill had a history of kernel necrosis varying in quantity among years. The orchards near El Paso and northeastern Oklahoma near Sapulpa had not been previously evaluated for kernel necrosis. Soil types among orchards ranged from a sandy loam to silty clay loam (Table 1). Rootstocks varied among orchards. All orchards were irrigated, except at Cleveland, but irrigation delivery systems were variable. Drought characterized the 2010 and 2011 growing seasons and although orchards were irrigated, both the quantity and quality of available water for irrigation varied among orchards. In most cases, less irrigation water than optimum was available to supplement rainfall. Nut samples were collected during commercial harvesting procedures, i.e., nuts

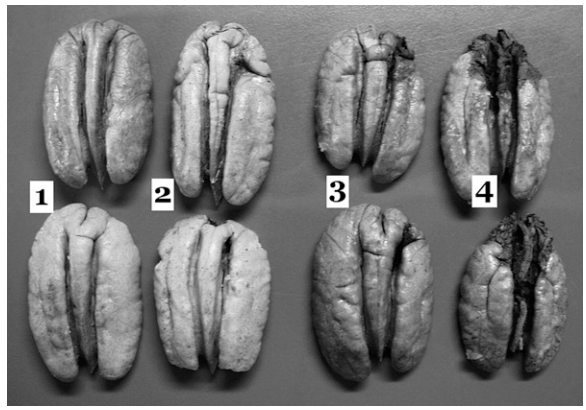

Fig. 1. Kernel necrosis grades of 'Pawnee' pecan. From left to right: Grade 1 = normal kernels; Grade 2 = darkening of testa in the dorsal grove at the basal (stem) end of the kernel; Grade 3 = necrotic tissue progressing outside of the dorsal grove at the basal end; and Grade 4 = encompasses the entire basal section of the kernel.

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Table 1. The percentage of 'Pawnee' pecan kernels with any necrosis (Grades 2–4) or severe necrosis (Grades 3 and 4).[z]

Location, soil type, rootstock, irrigation	Any kernel necrosis (%) Mean ± SD	Severe kernel necrosis (%) Mean ± SD
Cedar Creek Pecan Farms, Cleveland, OK, northeast Oklahoma on tributary to Arkansas River, Dennis silty clay loam, Giles rootstock, not irrigated	0 ± 0	0 ± 0
Cimarron Valley Research Station, Perkins, OK, central Oklahoma, Cimarron River Basin, Teller sandy loam, Peruque rootstock, solid set sprinkler	0 ± 0	0 ± 0
Knight Creek Farm, Sapulpa, OK, northeast Oklahoma on tributary of the Arkansas River, Verdigris silty clay loam, unknown rootstock, microsprinkler	1.7 ± 0.8	0.6 ± 1.0
Montz Pecan Orchard, Charlie, TX, north Texas, Red River Basin, Teller sandy loam, Apache rootstock, microsprinkler	15.9 ± 5.1	6.6 ± 3.5
Hauani Creek Ranch, Madill, OK, southern Oklahoma, tributary of the Red River, Madill sandy loam, Apache rootstock, microsprinkler	45.1 ± 45.1	29.6 ± 26.6
Schuster Farms, El Paso, TX, Rio Grande Basin, Harkey loam, Elliott rootstock, flood	55.1 ± 14.8	50.1 ± 14.5
5 R Enterprises, El Paso, TX, Rio Grande Basin, Gila loam, Elliott rootstock, flood	57.5 ± 45.3	46.4 ± 2.2

[z]Three replications of 60 nuts (360 kernels total) were analyzed from each location in 2011. Kernel necrosis grades are 1 = none, 2 = discoloration in the dorsal grove at the basal end, 3 = discoloration extending beyond the dorsal grove, and 4 = the lower one-third or more of the kernel tissue is necrotic.

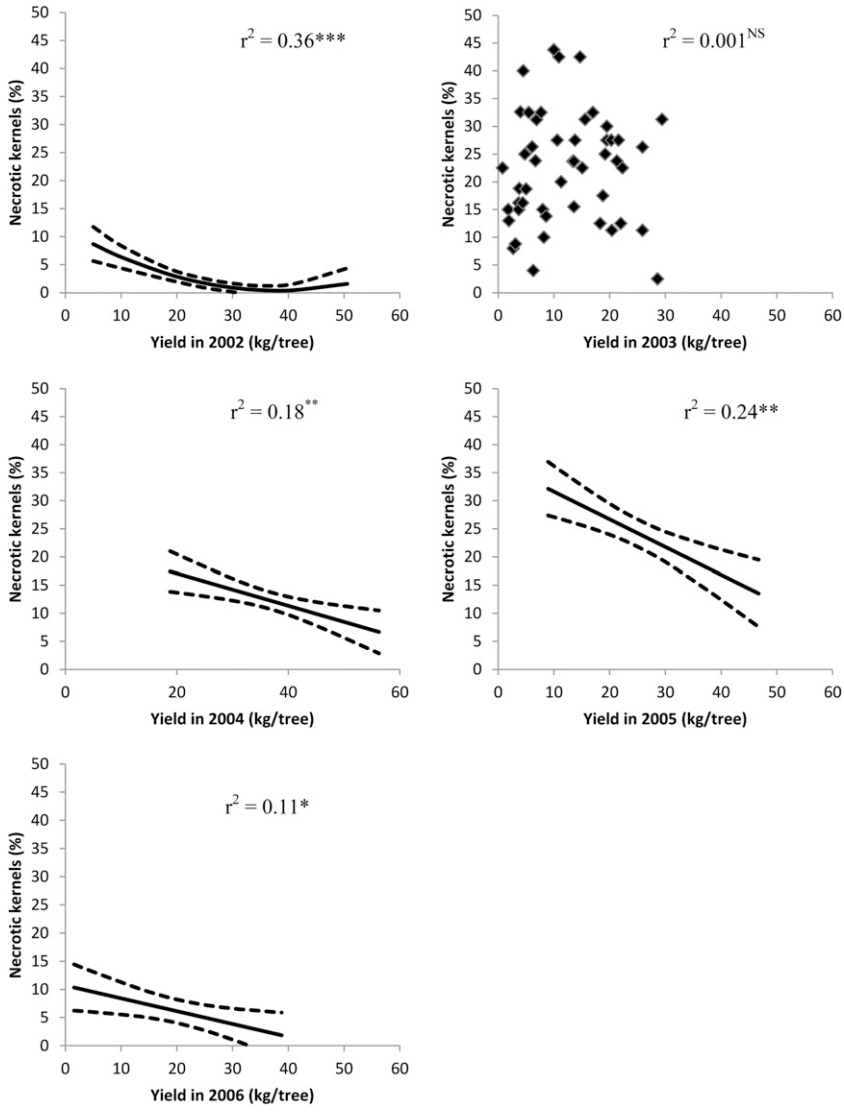

Fig. 2. Correlations between yield and the percentage of necrotic kernels from of 49 'Pawnee' pecan trees evaluated annually from 2002–2006. Coefficients of determination were nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***). Dotted lines represent 95% confidence bands.

dislodged with a shaker, harvested mechanically, and processed through a cleaner, except at Cleveland, OK, and Charlie, TX, where samples were hand- harvested. Samples consisted of 60 nuts (120 kernel halves) per replication with three replications per orchard. Nuts were cracked and kernels rated on a 1 to 4 scale (Fig. 1). The percentage of kernels with any necrosis (rating 2–4) and severe necrosis (rating 3–4) were calculated for each orchard along with the SD.

Kernel necrosis and yield. Two studies were conducted at a site near Charlie, TX, using adjacent pecan orchards where kernel necrosis had been characterized (Smith et al., 2007). The orchards were spaced 12.2 m × 12.2 m, irrigated by a microsprinkler, and were planted on a Teller sandy loam soil (fine-loamy, mixed, thermic, Udic Argiustoll). The orchard floor was maintained vegetation-free throughout the growing season with multiple applications of glyphosate [N-(phosphonomethyl) glycine]. No winter cover crops were used. The soil pH was 7.9 in the upper 15 cm and 7.2 in the 15–30 cm level. Trees received ≈160 kg·ha^{-1} N annually from nitrate-contaminated irrigation water and had not received supplemental N application since 2002. Foliar applications of zinc sulfate (36%; 6.7 kg·ha^{-1} material) were applied annually beginning when the first leaf began to unfurl and then at ≈2-week intervals until applied five times during each growing season.

Trees were 14 years old grown on a seedling 'Elliott' rootstock when the study was initiated. Rows were oriented north–south and were hedge-pruned annually on the east and west sides and the top.

In one of the two orchards, 49 trees were monitored annually for 5 years. Trees were harvested, yield measured, and a random 40-nut sample was collected from each tree. Nut samples were collected from field-run nuts (before cleaning to remove light weight nuts) and kernels (cotyledon) rated for necrosis symptoms using a 1–4 scale (Fig. 1) on each kernel half (80 halves/tree). Trunk diameter was measured annually at 1.4 m height while trees were dormant.

Linear or quadratic equations were fitted to data using least squares techniques with 95% confidence bands calculated (Draper and Smith, 1966). Current-season yield/tree was correlated with the percentage of kernels showing any necrosis (Grades 2–4; Fig. 1) for each year of the study.

Kernel necrosis with canopy location and tree size. In the adjacent orchard, nut samples were collected at shuck split from 40 'Pawnee' trees ranging in age from 14 to 20 years old in 2008. One nut from each of 20 fruit clusters selected at random was collected from the top one-third and another sample from the bottom one-third of the tree canopy periphery. Kernel halves (40/tree from the top and 40/tree from the bottom one-third) were rated for kernel necrosis using a 1–4 scale (Fig. 1). Tree diameter was measured at 1.4 m above the ground at the time samples were collected. The effect of canopy position and trunk cross-sectional trunk area was regressed (linear and

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quadratic models) against the percentage of necrotic kernels in the lower and upper one-third of the tree canopy.

Results

Kernel necrosis occurrence. Originally it appeared that kernel necrosis was prominent in the Red River Basin on 'Pawnee' and a few other cultivars. In the initial report, kernel necrosis was also reported on 'Oklahoma' trees near Luther in central Oklahoma (Smith et al., 2007). These data indicate that kernel necrosis was extensive in the Rio Grande Basin on 'Pawnee' and occurred at a low incidence but with classic symptoms in a northeastern Oklahoma 'Pawnee' orchard located on a tributary of the Arkansas River (Table 1). These data expand the known distribution of kernel necrosis.

Kernel necrosis and yield. Kernel necrosis was significantly related to yield/tree 4 of 5 years (Fig. 2). As yield/tree increased, the incidence of kernel necrosis decreased. In 2003, when the relationship between yield/tree with kernel necrosis was not significant, yields (mean = 12.3 kg/tree) were lower than normal and kernel necrosis (mean = 22.5%) was copious. Individual trees had up to 45% of the kernels displaying symptoms in 2003. Necrotic kernels varied substantially among years with the rate in 2003 and 2005 being particularly severe.

Kernel necrosis with canopy location and tree size. A significant interaction existed between canopy location and tree size affecting necrotic kernels (Fig. 3). In the lower canopy, incidence of necrotic kernels decreased as tree size increased, but in the upper canopy, tree size was not related to necrotic kernels.

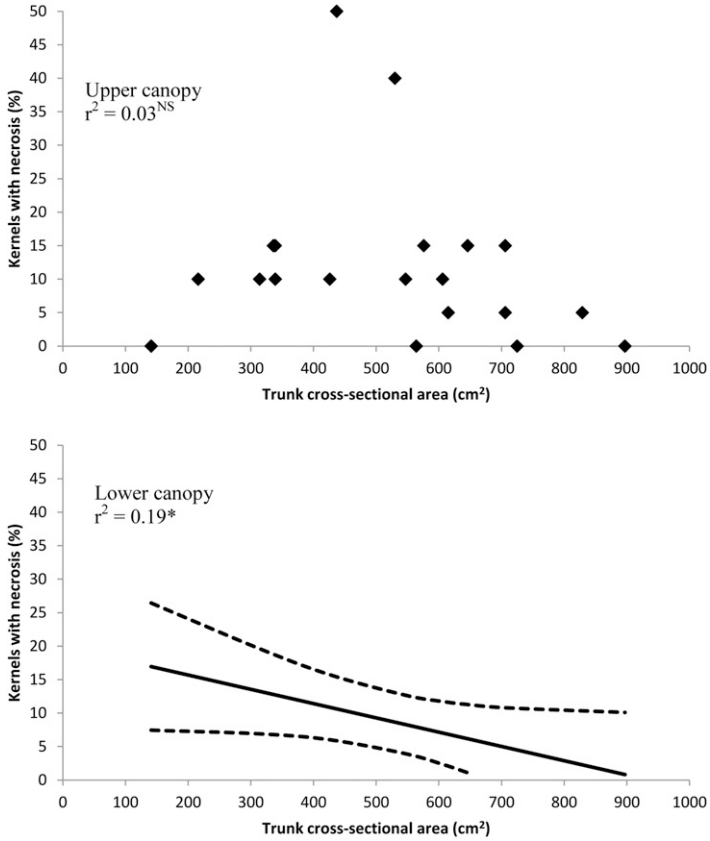

Fig. 3. Correlations between trunk cross-sectional area and necrotic kernels in the upper and lower one-third of canopies from 40 'Pawnee' pecan trees in 2008. Coefficients of determination were nonsignificant (NS) or significant at 5% (*). Dotted lines represent 95% confidence bands.

Discussion

Kernel necrosis on 'Pawnee' grown in the Red River Basin, Rio Grande Basin, and Arkansas River Basin has been identified, expanding the known distribution of this problem (Table 1). None was found from two orchards sampled in this study, one in the Arkansas River Basin and the other in the Cimarron River Basin. Kernel necrosis has not been detected in samples collected from these two orchards over several years (personal observations). 'Pawnee' appears to be the most susceptible cultivar to this malady, but it has been documented on other cultivars (Smith et al., 2007). Pecan producers and scientists working on pecan from various states have been consulted to ascertain the extent of this problem. Apparently, 'Pawnee' in most areas is not plagued with this trouble. However, experience suggests that this problem may go unnoticed until a year when it is abundant; thus, the problem may be more extensive than reported here.

Soil types and textures were variable among orchards and not clearly related to kernel necrosis (Table 1). Rootstock recommendations vary by location, and orchards sampled in this study were grown on the appropriate rootstock for that location. There were no indications that rootstock was involved in the incidence of kernel necrosis.

Yield/tree was negatively related to the frequency of kernel necrosis (Fig. 2). It is unclear why the percentage of necrotic kernels decreased with greater yield. Substantial variation in the amount of kernel necrosis was observed among years.

Kernel necrosis was less in the lower one-third of the tree canopy as tree size increased but was unaffected by tree size in the upper one-third (Fig. 3). A higher incidence on younger (smaller) trees was noted by a producer (Tim Montz) and the author.

The cause of kernel necrosis remains elusive. Kernel necrosis was greater on trees with less production (Fig. 2), variable among years, and more frequent on smaller trees (Fig. 3). Nuts with kernel necrosis had a larger shell volume (Smith et al., 2007), and shucks were sometimes noticeably larger (T. Montz and M. Smith, personal observations). Kernel necrosis on 'Pawnee' was prevalent on trees grown in the Red River Basin and Rio Grande Basin and was confirmed at low levels from an orchard in the Arkansas River Basin. Research has eliminated the possibilities of excess N or inadequate copper or nickel related to the development of kernel necrosis. Additional research is required to determine the cause of this problem on a popular cultivar grown from the east to west coast.

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