The Effect of Picloram Plus 2,4-Dichlorphenoxyacetic Acid on Peanut Growth and Yield

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ABSTRACT

Picloram (4-amino-3,5,6-trichloropicolinic acid) injury, in the form of leaf roll, is often observed in peanut fields due to short crop rotations, contaminated irrigation water, treated hay, and contaminated livestock waste. Limited data on peanut response to picloram is available. Field trials were conducted near Tifton, GA from 2015-2017 to determine the effects of picloram plus 2,4-D (2,4-dichlorophenoxyacetic acid) on peanut growth and yield. Picloram plus 2,4-D was applied to 'GA-06G' peanut at four different timings: preemergence (PRE), 30 d after planting (DAP), 60 DAP, and 90 DAP. At each timing, three rates of picloram plus 2,4-D were applied including the following: 1/10thX (0.18 + 0.67 kg ai/ha); 1/100thX (0.018 + 0.067 kg ai/ha); and 1/300thX (0.006 + 0.023 kg ai/ha). A non-treated control (NTC) or 0 rate was included for comparison. Peanut plant density was not influenced by any rate or timing of picloram plus 2,4-D. For peanut injury (leaf roll), a significant rate x timing interaction was observed (P=0.047). At 120 DAP, leaf roll was significant for the 1/10thX rate applied at 30, 60, and 90 DAP, the 1/100thX rate applied at 60 and 90 DAP, and for the 1/300thX rate applied at 90 DAP. When averaged over timing, peanut height at 120 DAP was significantly reduced by the 1/10thX and 1/100thX rates. When averaged over rate, peanut height reductions were greatest when picloram plus 2,4-D was applied at 60 DAP. When averaged over timing, only the 1/10thX rate caused significant yield reductions (11%). When averaged over rate, timing had no effect on yield (P=0.5403). Peanut fields unintentionally exposed to picloram plus 2,4-D rates $\leq$ 1/100thX can exhibit typical injury symptoms but most likely will not experience yield losses.

Key Words: *Arachis hypogaea* L., picloram, crop injury, herbicide carryover, crop rotation

Picloram (4-amino-3,5,6-trichloropicolinic acid) is an auxin-type herbicide that is a member of the pyridineocarboxylic acid family. Picloram controls plants by mimicking indoleacetic acid (IAA) in the new growth of the plant and inhibiting protein synthesis (Shaner, 2014). It was first introduced in 1963 for the control of broadleaf weed species and woody brush species (Hamaker *et al.,* 1963). Picloram is commonly mixed with 2,4-D (2,4-dichlorophenoxyacetic acid) to control broadleaf weeds because of the increased spectrum of weed control and the ability to lower use rates of these herbicides when used together (Agabakoba and Goodin, 1970). This mixture is currently formulated as Grazon® P+D (10.2% picloram and 39.6% 2,4-D, Corteva Agriscience, Wilmington, DE) and is labeled for use in grasslands, permanent pastures, and non-crop land (Anonymous, 2019). While picloram and 2,4-D have relatively low mammalian toxicity, picloram is a restricted use pesticide because of its long persistence, high water solubility with potential to contaminate surface and groundwater, and its high phytotoxicity to broadleaf plants (Lym and Messersmith, 1988; Ketchersid *et al.,* 1995). The soil half-life of picloram has been reported to be from 1 month to 4 yr depending on application rate, soil, and climate (Hunter and Strobbe, 1972; Shaner, 2014). However, phytotoxic levels of picloram residues can remain in the soil for up to five yr depending on soil type and dose (Lym and Messersmith, 1988). The high water solubility that allows picloram to move readily through the soil profile contaminating groundwater and surface water can lead to a contamination of irrigation water (Lym and Messersmith, 1988). The extreme sensitivity of broadleaf crops to picloram would allow for irrigation water to damage non-labeled crops. The combination of picloram plus 2,4-D is used on approximately 5% of all permanent pasture and grassland in Georgia (81,000 ha) (P. McCullough and D. Hancock, The University of Georgia, personal communication, 2019).

Peanut (*Arachis hypogaea* L.) is a self-pollinating, herbaceous legume, native to South America. Peanut is an extremely important agricultural crop for the southeastern United States and the state of Georgia. Georgia consistently contributes half of all peanut production in the US (USDA-NASS, 2019), with a value in 2015 of $684,000,000; which made up 31% of the total row and forage crop value for the state (Wolfe and Stubbs, 2016). In

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2019, peanut was planted on approximately 263,158 ha in Georgia (USDA-NASS, 2019).

Georgia peanut growers have consistently, for approximately 20 yr, reported injury due to picloram five to ten times per yr (author's observations). Previous research has been conducted to determine picloram's potential effects on peanut. In Texas, picloram at 1 ng/g caused visual injury, however, impact on yield was not documented (Ketchersid *et al.,* 1995). In Oklahoma, subsurface applied picloram at rates ranging from 0.56 to 1.12 kg ai/ha caused complete peanut death (Banks *et al.,* 1977). Consequently, field trials were conducted to determine the effect of several rates and timings of picloram plus 2,4-D on peanut growth and yield in Georgia.

Materials and Methods

Field trials were conducted in 2015, 2016, and 2017 at the Ponder Research Farm located near TyTy, Georgia (31.507654 N, -83.658395 W). Soil was a Fuquay sand with 96% sand, 0% silt, 4% clay, 0.57% organic matter, and a pH of 6.6. Conventional tillage practices were used and 'GA-06G' (Branch, 2007) peanut was planted using a vacuum planter calibrated to deliver 18 peanut seed/m at a depth of 5 cm (Monosem Precision Planters, 1001 Blake St., Edwardsville, KS). Peanut was planted in 2 twin rows (90 cm by 22 cm spacing) with a plot size of 7.6 m by 0.9 m. While there were no border rows between the plots, no injury was observed on adjacent plots or on non-treated checks.

Treatments were arranged in a randomized complete block design with four (application timings) by four (picloram + 2,4-D rates) in a factorial arrangement. Application timings were preemergence (PRE), 30, 60, and 90 d after planting (DAP) and rates of picloram plus 2,4-D were 0, 0.2 + 0.7, 0.02 + 0.07, and 0.006 + 0.02 kg ai/ha, which are equivalent to the $1/10^{th}$, $1/100^{th}$, and $1/300^{th}$ of the labeled use rate. It is important to note that previous research has shown that peanut exposure to 2,4-D at these low rates does negatively impact peanut growth and yield (Johnson *et al.,* 2012; Leon *et al.,* 2014; Merchant *et al.,* 2014). Treatments were replicated three or four times depending on field size for each yr. Treatments were applied using a CO_2–pressurized backpack sprayer calibrated to a pressure of 262 kPa to deliver 140 L/ha at 4.8 km/hr. Peanut plant height, width, and stage of growth at the time of application are presented in Table 1. Plots were maintained weed-free throughout the season using a combination of herbicides (pendimethalin, diclosulam, flumioxazin, imazapic, and 2,4-DB) and hand-weeding. Peanut yield data were obtained by mechanical harvesting at maturity.

Table 1. Peanut stage of growth[a] at the time of picloram plus 2,4-D applications in Georgia, 2015 to 2017.

	Time of Application		
	30 DAP[b]	60 DAP	90 DAP
Height	8 cm	28 cm	43 cm
Width	15 cm	43 cm	60 cm
Growth Stage	V6	R5	R6

[a]Peanut stages of growth as defined by Boote, K.J. 1982. Growth stages of peanut. Peanut Sci. 9:35-40.

[b]Abbreviations. d after planting, DAP

Data collected included plant density (14 and 30 DAP), visual injury (leaf roll) approximately every 14 d throughout season, plant height (120 DAP), and yield. Plant density was determined by counting plants present per m of row. Leaf roll ratings were based on a subjective visual scale of 1-4; with 1 = none and 4 = severe. Leaf roll symptoms were considered severe when greater than 75% of peanut leaves exhibited symptomology. Data were analyzed using the PROC GLM procedure in SAS 9.4 (SAS Institute, Cary, NC) considering the factorial treatment arrangement with injury and yield as random variables and application timing and rate as the fixed variables. Data were combined over yr due to no significant yr effect in the analysis. Data were combined over rate and timing when no significant interaction was present. Means were separated using Tukey's HSD (P=0.10).

Results and Discussion

Peanut density. All rates of picloram plus 2,4-D did not affect peanut plants/m at the PRE-application timing ($P > 0.5467$). Previously it was reported that peanut plant density was not negatively affected by PRE 2,4-D applications of up to 1066 g ai/ha (Blanchett *et al.,* 2017).

Peanut injury (leaf roll). Data presented in Table 2 show leaf roll ratings collected 14 d after each treatment was applied for each application timing. At 14 d after application, each treatment exhibited significantly more leaf roll than the non-treated control (NTC) (Table 2). Data are also presented from leaf roll ratings at 120 DAP, which reflects the peanut plant's ability to recover throughout the season (Table 3). Data are presented sperately over rate and timing due to a significant interaction. Thus, data are presented by rate for each application timing (Table 3). At

Table 2. Peanut visual injury ratings[a] at 14 DAT[b] from picloram plus 2,4-D in Georgia, 2015-2017[c].

Fraction of recommended use rate[d]	Time of Application			
	PRE	30 DAP	60 DAP	90 DAP
NTC	1.0d[e]	1.0d	1.0d	1.0b
1/300[th]	1.6c	1.2c	2.0c	1.6a
1/100[th]	2.1b	2.5b	2.7b	1.7a
1/10[th]	3.9a	3.7a	3.3a	2.0a

[a]Ratings are based on a visual scale of 1-4; with 1= no leaf roll and 4 = all peanut leaves exhibiting leaf roll.

[b]Abbreviations. Nontreated control, NTC; d after treatment, DAT; d after planting, DAP; preemergence at planting, PRE

[c]Data combined over 3 site-yr due to no yr effect.

[d]Picloram plus 2,4-D rates (kg ai/ha): 1/300[th] = 0.006 + 0.02; 1/100[th] = 0.02 + 0.07; 1/10[th] = 0.2 + 0.7.

[e]Means in the same column with the same letter are not significantly different according to Tukey's HSD (p=0.10).

the PRE application timing, rate had no effect on peanut leaf roll and injury was minor. At the 30 DAP timing, only the 1/10[th] labeled rate cause significant leaf roll. At the 60 DAP timing, both the 1/10[th] and 1/100[th] rates caused significant leaf roll rate. At the 90 DAP timing, all three rates of picloram + 2,4-D caused significantly more leaf roll injury when compared to the non-treated control (0 kg/ha rate). In earlier research, picloram at rates as low as 1 ppb caused visual injury (leaf roll) symptoms (Ketchersid *et al.,* 1995). Visual injury, such as leaf cupping and epinasty, from other auxin herbicides has been observed on peanut from dicamba at rates as low as 35 g ai/ha (Leon *et al.,* 2014). Generally, dicamba was more injurious than 2,4-D on peanut. Only 2,4-D rates >560 g ai/ha caused significant peanut injury (Leon *et al.,* 2014).

Table 3. Peanut visual injury ratings[a] at 120 DAP[b] from picloram plus 2,4-D in Georgia, 2015-2017[c].

Fraction of recommended use rate[d]	Time of Application			
	PRE	30 DAP	60 DAP	90 DAP
NTC	1.0a[e]	1.0b	1.0c	1.0c
1/300[th]	1.1a	1.1b	1.3c	1.5b
1/100[th]	1.1a	1.1b	2.6b	1.6ab
1/10[th]	1.1a	2.0a	3.5a	2.0a

[a]Ratings are based on a visual scale of 1-4; with 1= no leaf roll and 4 = all peanut leaves exhibiting leaf roll.

[b]Abbreviations. Nontreated control, NTC; d after planting, DA; preemergence at planting, PRE

[c]Data combined over 3 site-yr due to no yr effect.

[d]Picloram plus 2,4-D rates (kg ai/ha): 1/300[th] = 0.006 + 0.02; 1/100[th] = 0.02 + 0.07; 1/10[th] = 0.2 + 0.7.

[e]Means in the same column with the same letter are not significantly different according to Tukey's HSD (p=0.10).

Table 4. Peanut plant height at 120 DAP[a] and yield response to picloram plus 2,4-D rate in Georgia, 2015-2017[b].

Fraction of recommended use rate[c]	Height	Yield
	—cm—	-kg/ha-
NTC	40.4a[d]	5630a
1/300[th]	39.4ab	5520a
1/100[th]	38.9b	5335a
1/10[th]	37.3c	4996b

[a]Abbreviations. Nontreated control, NTC; d after planting, DAP

[b]No interaction was observed for application time x rate, therefore data combined over 4 timings and 3 site-yr due to no yr effect.

[c]Picloram plus 2,4-D rates as follows (kg ai/ha): 1/300[th] = 0.006 + 0.02; 1/100[th] = 0.02 + 0.07; 1/10[th] = 0.2 + 0.7.

[d]Means in the same column with the same letter are not significantly different according to Tukey's HSD (p=0.10).

Peanut height and yield. There was no interaction between rate and timing, therefore data were combined over the two factors and three yr (Tables 4 and 5). At 120 DAP, the 1/10[th] rate and the 1/100[th] reduced plant height by 9 and 4%, respectively. These two rates negatively impacted peanut growth. When data were combined over rates, only the 60 DAP timing had a negative effect on plant height. This timing effect is likely due to the peanut stage of growth at the time of application. The approximate growth stages of the peanut crop were V6 (last vegetative stage), R5 (beginning seed), and R6 (full seed) at 30, 60, and 90 DAP timings, respectively (Boote, 1982). Increased injury from herbicide applications at the R5 growth stage have been reported with applications of dicamba and lactofen (Prostko *et al.,* 2011; Dotray *et al.,* 2012).

For peanut yield there was no significant interaction between rate and timing (Table 4).

Table 5. Peanut plant height at 120 DAP[a] and yield response to picloram plus 2,4-D time of application in Georgia 2015-2017[b].

Time of Application	Height	Yield
	—cm—	-kg/ha-
PRE[a]	40.1a[c]	5398a
30 DAP	39.9a	5464a
60 DAP	37.3b	5196a
90 DAP	38.9a	5426a

[a]Abbreviations. preemergence after peanut planting, PRE; d after planting, DAP

[b]No interaction was observed for application time x rate, therefore data combined over 4 rates and 3 site-yr due to no yr effect.

[c]Means in the same column with the same letter are not significantly different according to Tukey's HSD (p=0.10).

When averaged over timing, the 1/10th rate (0.18 + 0.67 kg ai/ha) yielded significantly lower than all other treatments (Table 4). Yield loss with the 1/10th X rate was 11%. Previous research indicated that peanuts exposed to picloram at 0.56 to 1.12 kg ai/ha caused complete peanut death, thus no yield data was recorded (Banks *et al*., 1977). Yield losses up to 29% have been reported from dicamba at rates as low as 40 g ai/ha (0.14X of normal use rate) (Prostko *et al.,* 2011). When averaged over rates, timing had no effect on yield (Table 5). While the 60 DAP timing significantly reduced peanut plant height, it did not negatively impact yield.

Summary and Conclusions

Significant peanut yield loss was only observed for the highest rate of picloram plus 2,4-D (1/10th X rate). While peanuts appeared to be more sensitive to the 60 DAP timing, timing did not negatively impact yield. Peanut growers need to be aware of the fact that picloram is a persistent herbicide and injury can occur long after the initial application. Also, while injury symptoms may appear severe, injury does not always result in yield loss. If picloram injury occurs, peanut growers should continue to manage their peanut crop as planned with the goal of minimizing potential yield losses. Growers also need to be aware that currently no tolerance is set for picloram in peanut and should have their crop analyzed to determine if there is any residue in the harvested peanuts.

Literature Cited

Agbakoba, C.S.O. and J.R. Goodin. 1970. Picloram enhances 2,4-D movement in field bindweed. Weed Sci. 18:19–21.

Anonymous. 2019. Grazon® P+D product label. DowAgroSciences, Indianapolis, IN.

Banks, P.A., M.A. Kirby, P.W. Santelmann. 1977. Influence of postemergence and subsurface layered herbicides on horsenettle and peanuts. Weed Sci. 25:5–8.

Blanchett, B.H., T.L. Grey, E.P. Prostko, W.K. Vencill, and T.M. Webster. 2017. The effect of 2,4-Dichlorophenoxyacetic Acid (2,4-D) on peanut when applied during vegetative growth stages. Peanut Sci. 44:53–59.

Boote, K.J. 1982. Growth stages of peanut (*Arachis hypogaea* L.) Peanut Sci. 9:35–40.

Branch, W. 2007. Registration of 'Georgia-06G' Peanut. J. Plant Regist. 1:120.

Dotray, P.A., W.J. Grichar, T.A. Baughman, E.P. Prostko, T. L. Grey, and L. V. Gilbert. 2012. Peanut (*Arachis hypogaea* L.) response to lactofen at various postemergence timings. Peanut Sci. 39:9–14

Hamaker, J.W., H. Johnston, R.T. Martin, and C.T. Redeman. 1963. A picolinic acid derivative: a plant growth regulator. Science 141:363.

Hunter, J. H. and E. H. Stobbe. 1972. Movement and persistence of picloram in soil. Weed Sci 20:486–488.

Johnson V.A., L.R. Fisher, D.L. Jordan, K.E. Edmisten, A.M. Stewart, A.C. York. 2012. Cotton, peanut, and soybean response to sublethal rates of dicamba, glufosinate, and 2,4-D. Weed Technol. 26:195–206.

Ketchersid, M.L., O.D. Smith, and J.M. Chandler. 1995. Peanut sensitivity to environmental contamination by picloram. Abstr. Proc. Southern Weed Sci. Soc. 48:248.

Leon R.G., J.A. Ferrell, B.J. Brecke. 2014. Impact of exposure to 2,4-D and dicamba on peanut injury and yield. Weed Technol. 28:465–470.

Lym, R.G. and C.G. Messersmith. 1988. Survey for picloram in North Dakota groundwater. Weed Technol. 2:217–222.

Merchant R.M., E.P. Prostko, P.M. Eure, T.M. Webster. 2012. Peanut response to simulated drift rates of 2,4–D. Pages 36 APRES, American Peanut Res. Educ. Soc. Raleigh, NC.

Prostko, E.P., T.L. Grey, M.W. Marshall, J.A. Ferrell, P.A. Dotray, D.L. Jordan, W.J. Grichar, B.J. Brecke, and J.W. Davis. 2011. Peanut yield response to dicamba. Peanut Sci. 38:61–65.

Shaner, D.L. 2014. Herbicide Handbook. 10th Edition, Weed Sci. Soc. of America, Champaign, IL 513.

[USDA-NASS] U.S. Department of Agriculture- National Agriculture Statistics Service. 2019. Acreage. https://downloads.usda.library.cornell.edu/usda-esmis/files/ j098zb09z/ 0k225n39n/ jw827p632/ acrg0619.pdf. Date accessed: September 4, 2019.

Wolfe, K. and K. Stubbs. 2016. 2015 Georgia Farm Gate Value Report. University of Georgia Center for Agribusiness and Economic Development AR-15-01. Available online: http://caes2.caes.uga.edu/center/caed/documents/GAFGVR2015_DEC16.pdf. Accessed: March 4, 2018.