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Weed Management—Major Crops

Annual Grass Control in Strip-Tillage Peanut Production with Delayed Applications of Pendimethalin

W. Carroll Johnson, III, Eric P. Prostko, and Benjamin G. Mullinix, Jr.*

In strip-tillage peanut production, situations occur when dinitroaniline herbicides are not applied in a timely manner. In these cases, dinitroaniline herbicides would be applied days or weeks after seeding. However, there is no information that documents the effects of delayed applications on weed control. Trials were conducted in 2004, 2005, and 2007 in Georgia to determine the weed control efficacy of delayed applications of pendimethalin in strip-tillage peanut production. Treatments included seven timings of pendimethalin application and three pendimethalin-containing herbicide combinations. Timings of application were immediately after seeding (PRE), vegetative emergence of peanut (VE), 1 wk after VE (VE+1wk), VE+2wk, VE+3wk, VE+4wk, and a nontreated control. Pendimethalin containing herbicide programs included pendimethalin plus paraquat, pendimethalin plus imazapic, and pendimethalin alone. Among the possible treatment combinations was a current producer standard timing for nonpendimethalin weed control programs in peanut, which was either imazapic or paraquat alone applied VE+3wk. Pendimethalin alone did not effectively control Texas millet regardless of time of application (69 to 77%), whereas southern crabgrass was controlled by pendimethalin alone PRE (87%). Delayed applications of pendimethalin controlled Texas millet and southern crabgrass when combined with either paraquat or imazapic, with imazapic being the preferred combination due to better efficacy on southern crabgrass than paraquat at most delayed applications. Peanut yield was improved when any of the herbicide combinations were applied PRE compared to later applications. Across all times of application, pendimethalin plus imazapic effectively maximized peanut yield with interference from annual grasses.
Nomenclature: Imazapic; paraquat; pendimethalin; southern crabgrass, *Digitaria ciliaris* (Retz.) Koel.; Texas millet, *Urochloa texana* (Buckl.) R. Webster; peanut, *Arachis hypogaea* L., 'C99R'.
Key words: Conservation tillage, groundnut, southern crabgrass, Texas panicum.

En la producción de cacahuate o maní (Arachis hypogaea (strip-tillage peanut) ocurren situaciones diferentes cuando los herbicidas dinitroanilina no son aplicados de una manera escalonada. En estos casos, los herbicidas con dinitroanilina deberían ser aplicados días o semanas después de la siembra. Sin embargo no existe información que documente los efectos de la aplicación tardía en el control de malezas. Se llevaron a cabo diversos estudios en 2004, 2005 y 2007 en Georgia para determinar la eficacia del control de malezas en aplicaciones de pendimethalin en la producción mecanizada de cacahuate o maní (strip tilllage). Los tratamientos incluyeron siete etapas de aplicación de pendimethalin, tres aplicaciones del mismo producto conteniendo combinaciones de herbicidas. Las etapas de aplicación fueron inmediatamente después de la siembra (PRE), en emergencia vegetativa de cacahuate (VE), una semana después (VE+1wk), VE+2wk, VE+3wk, VE+4wk y un testigo no tratado. Los programas combinados conteniendo pendimethalin y otros herbicidas incluyeron pendimethalin más paraquat, pendimethalin más imazapic y solo pendimethalin. Entre las combinaciones de tratamientos posibles estuvo una etapa estandar la cual tuvo en forma alternada, imazapic o paraquat solos, aplicados en VE+3wks. El pendimethalin solo no controló con eficiencia el Texas Mollet (mijo de Texas) (69 al 77%), independientemente de su tiempo de aplicación mientras el southern crabgrass fue controlado por la pre aplicación de pendimethalin sin ninguna mezcla (87%). Las malezas Texas millet y southern crabgrass fueron controladas con aplicaciones tardías de combinaciones de paraquat e imazapic siendo la combinación de imazapic la preferida debido a la mejor eficacia sobre el southern crabgrass que el paraquat en la mayoría de las aplicaciones tardías. El rendimiento de cacahuate se incrementó cuando cualquiera de las combinaciones de herbicida se aplicó en (pre-siembra) en comparación con las aplicaciones tardías. Entre todas las etapas de aplicación, la combinación de pendimethalin mas imazapic fue la más efectiva para maximizar el rendimiento de cacahuate con presencia de estas malezas anuales.

Historically, annual grasses have been considered to be among the most troublesome weeds of peanut in the United States (Hauser et al. 1973). Annual grasses reduce peanut yield primarily through interference and excessive harvest losses. Fall panicum [*Panicum dichotomiflorum* (L.) Michx.] was found to be highly competitive with peanut, reducing yield by 25% with a density of one weed per 4.9 m (York and Coble 1977). They also reported that peanut was a poor competitor with fall panicum and particularly vulnerable to interference from early season through pod fill. Chamblee et al. (1982) investigated the interference of broadleaf signalgrass [*Urochloa platyphylla* (Nash) R.D. Webster] in North Carolina peanut and found that a density of 1.6 plants/m reduced peanut yield by 28%. McCarty (1983) found that goosegrass [*Eleusine indica* (L.) Gaertn.] at a density of 3.2 plants/m reduced peanut yield by 20%. Similarly, research in Georgia found that Texas millet at 2.0 plants/m reduced peanut yield by 25% and caused harvest losses of 840 kg/ha (Johnson and Mullinix 2005).

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* Research Agronomist USDA-ARS, Associate Professor, and Agricultural Research Statistician (retired), Coastal Plain Experiment Station, P.O. Box 748, Tifton, GA 31793-0748. Current address of third author: Texas A&M University, 5810 96th Street, Unit A, Lubbock, TX 79424. Corresponding author's E-mail: Carroll.Johnson@ars.usda.gov

Peanuts grown in the United States are increasingly being produced using conservation tillage practices (Sholar et al. 1995). Conservation tillage is attractive because conventional tillage requires multiple tillage operations in rapid succession which can be complicated by weather delays, shortages in skilled agricultural labor, and increasing fuel costs. Furthermore, conservation tillage is one of the critical factors that lessens incidence and severity of spotted wilt (tomato spotted wilt tospovirus), a viral disease of peanut (Brown et al. 1999; Johnson et al. 2001).

There are numerous conservation tillage variants used in the southeastern United States peanut producing region, with strip-tillage being the most common. Cereal cover crops are seeded the previous autumn and killed with a nonselective POST herbicide in early spring. Seedbeds are prepared using an implement with in-row subsoil shanks, multiple gangs of fluted coulters to cut cover-crop debris, and ground-driven crumblers that till a band approximately 30 cm wide. Crops are seeded with planter units either tandem mounted on the strip-tillage implement or as a separate operation.

Annual grass control in strip-tillage peanut typically includes either pendimethalin or ethalfluralin combined with a second application of a nonselective herbicide applied immediately after seeding peanut. This system has been shown to be an effective component in an integrated system to manage annual grasses (Grichar 2005; Johnson et al. 2002). However, in these trials, full-season control required a POST application of either clethodim or sethoxydim to control escapes. Dinitroaniline herbicides are potentially adsorbed by cover crop debris (Weber 1990), and it was speculated that this phenomenon was the primary reason for reduced efficacy in strip-tillage peanut production (Johnson et al. 2002).

Current surveys show that annual grasses continue to be among the most common and troublesome weeds of peanut (Webster 2005), with Texas millet and several species of crabgrass commonly found throughout the region. Despite the regular incidence of annual grasses in peanut, well documented potential yield losses, and the need for an aggressive control strategy (Johnson et al. 2002; Prostko et al. 2001), dinitroaniline herbicides are often applied long after planting in strip-tillage production systems with little knowledge on how the delayed applications affect weed control and peanut yield. Therefore, trials were initiated in 2004 to evaluate the effect of delayed applications of pendimethalin on weed control and peanut yield in strip-tillage peanut production.

Materials and Methods

Irrigated field trials were conducted at the Coastal Plain Experiment Station Ponder Farm near Tifton, GA in 2004, 2005, and 2007. Trials were not conducted in 2006 due to poor stand of the rye (*Secale cereale* L.) cover crop. Soil was a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) with 90% sand, 6% silt, 4% clay, and 0.9% organic matter. Soil at this location is representative of soils in the southeastern United States peanut production region with natural infestations of Texas millet (10 plants/m^2) and southern crabgrass (5 plants/m^2).

The experimental design was a randomized complete block with a factorial arrangement of treatments replicated four times. Treatments included seven timings of pendimethalin application and three pendimethalin-containing herbicide combinations. Timings of pendimethalin application were immediately after seeding (PRE), vegetative emergence of peanut (VE), one week after VE (VE+1wk), VE+2wk, VE+3wk, VE+4wk, and a nontreated control. Pendimethalin containing herbicide programs included pendimethalin[1] (1,120 g ai/ha) plus paraquat[2] (140 g ai/ha), pendimethalin plus imazapic[3] (71 g ai/ha), and pendimethalin alone. Among the possible treatment combinations was a current producer standard timing for nonpendimethalin weed control programs in peanut, which was either imazapic or paraquat alone applied VE+3wk (Grey et al. 2003). A nonionic surfactant[4] was included with all treatments that contained paraquat (0.13% by vol) and imazapic (0.25% by vol).

Plots were seeded with rye at 63 kg/ha using a grain drill (18-cm spacing) the preceding autumn. In late March, the rye cover crop was killed with glyphosate[5] at 1.1 kg ai/ha. Seedbeds were formed with a two-row–strip-tillage implement[6] that prepared a 30-cm seedbed and immediately planted to peanut with a vacuum planter[7] in a separate operation. 'C99R' peanut was seeded in rows 91 cm apart in early May each year at a rate of 112 kg/ha. Plots were two rows wide (1.8 m) and 6.1 m long. The entire experiment was maintained free of dicot weeds throughout the season with one application of chlorimuron[8] (8.8 g ai/ha) plus 2,4-DB[9] (0.28 kg ai/ha) applied 60 d after emergence. Other than weed control, pest and crop management practices were based on Georgia Cooperative Extension Service recommendations (Beasley et al. 1997).

Visual estimates of percent annual grass control were made midseason using a scale of 0 (no control) to 100 (complete control). Peanut yield was measured by digging, inverting, air-curing, and combining peanut using commercial two-row equipment. All yield samples were cleaned to remove foreign material. Final yield is reported as cleaned farmer stock peanut.

Data for annual grass control and peanut yield were subjected to ANOVA with partitioning appropriate for the factorial treatment arrangement. Means for significant main effects and interactions were separated using Fisher's Protected LSD test at $P \leq 0.10$. Arcsine transformations of weed control ratings did not change the results of the ANOVA; therefore, non-transformed data were used for analysis and presentation.

Results and Discussion

Preliminary ANOVA showed nonsignificant differences among years for visual estimates of Texas millet and southern crabgrass control and peanut yield. Therefore, all data are pooled across years. ANOVA also showed a significant interaction between timings of herbicide application and herbicide combinations with pendimethalin for Texas millet and southern crabgrass control. Peanut yield was affected only by main effects of timing of herbicide application and herbicide programs with pendimethalin.

Table 1. Interactive effects of pendimethalin tank-mix combinations and times of application on midseason annual grass control at Tifton, GA: 2004, 2005, and 2007.

Pendimethalin tank-mix combination	Time of application[a]	Texas millet control	Southern crabgrass control
		%	
Pendimethalin[b] plus paraquat[c]	PRE	70	82
Pendimethalin plus paraquat	VE	80	86
Pendimethalin plus paraquat	VE+1wk	89	90
Pendimethalin plus paraquat	VE+2wk	87	76
Pendimethalin plus paraquat	VE+3wk	87	66
Pendimethalin plus paraquat	VE+4wk	85	68
Pendimethalin plus imazapic[d]	PRE	84	91
Pendimethalin plus imazapic	VE	92	93
Pendimethalin plus imazapic	VE+1wk	85	90
Pendimethalin plus imazapic	VE+2wk	87	87
Pendimethalin plus imazapic	VE+3wk	93	91
Pendimethalin plus imazapic	VE+4wk	87	78
Pendimethalin alone	PRE	77	87
Pendimethalin alone	VE	75	76
Pendimethalin alone	VE+1wk	72	66
Pendimethalin alone	VE+2wk	69	56
Pendimethalin alone	VE+3wk	77	55
Pendimethalin alone	VE+4wk	70	51
Paraquat alone	VE+3wk	74	63
Imazapic alone	VE+3wk	78	85
LSD (0.10)		16	14

[a] Abbreviations: PRE, preemergence immediately after seeding peanut; VE, vegetative emergence of peanut; VE+1wk, 1 wk after vegetative emergence; VE+2wk, 2 wk after vegetative emergence; VE+3wk, 3 wk after vegetative emergence; VE+4wk, 4 wk after vegetative emergence.

[b] Pendimethalin applied at 1,120 g ai/ha.

[c] Paraquat applied at 140 g ai/ha. A nonionic surfactant was included with all paraquat applications at 0.13% by vol.

[d] Imazapic applied at 71 g ai/ha. A nonionic surfactant was included with all imazapic applications at 0.25% by vol.

Texas Millet Control. Pendimethalin alone provided similar Texas millet control ranging from 69 to 77%, regardless of timing of application (Table 1). At the VE+1wk (89%) and VE+2wk (87%) timings, paraquat combined with pendimethalin improved Texas millet control over pendimethalin alone. At this time of application, Texas millet was at the two to three-leaf stage of growth. Applied at the PRE (70%) or VE (80%) timings, paraquat plus pendimethalin applied did not improve Texas millet control over pendimethalin alone, likely due to little emergence of Texas millet at the time of application. Texas millet control with paraquat plus pendimethalin applied later than VE+2wk was 87 and 85% and did not differ from pendimethalin alone. This was attributed to larger Texas millet (three to four-leaf stage) that the paraquat component could not consistently control at similar timings. These data show that paraquat plus pendimethalin is potentially an effective combination for delayed applications in strip-tillage peanut, with Texas millet control dependent on presence of emerged Texas millet at a size consistently controlled by paraquat. These results agree with Wehtje et al. (1986), who reported that the overall effectiveness of paraquat alone for Texas panicum control was dependent on the presence and size of Texas millet; applications occurring too early were not effective due to nonemerged Texas millet, and applications occurring too late were not effective due to weeds being too large (6 cm tall).

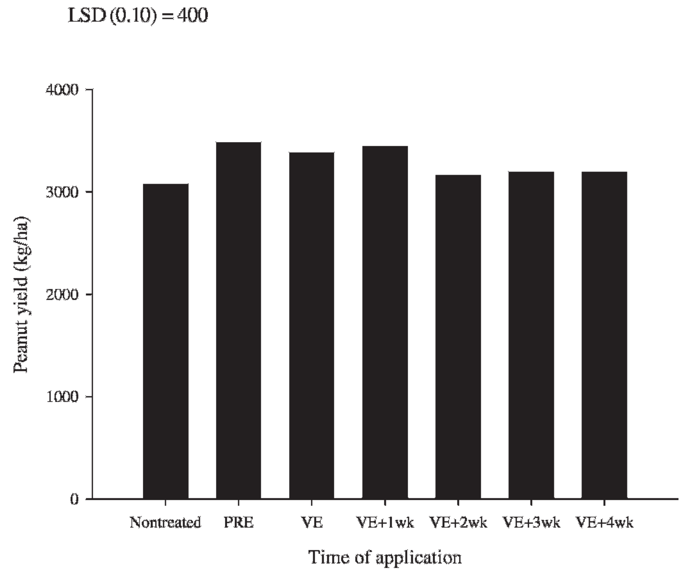

Figure 1. Main effect of herbicide application timing on peanut yield in Tifton, GA: 2004, 2005, and 2007.

Delayed application of imazapic plus pendimethalin effectively controlled Texas millet when applied from PRE through VE+4wk (84 to 93%), with no difference among timings of application (Table 1). When compared to pendimethalin alone, imazapic plus pendimethalin applied VE (92 vs. 75%), VE+3wk (93 vs. 77%), or VE+4wk (87 vs. 70%) was more effective controlling Texas millet. These results show the benefits of residual and POST control of Texas millet by imazapic plus pendimethalin. Imazapic alone applied at VE+3wk controlled Texas millet 78% in strip-tillage peanut, which is equivalent to combinations with pendimethalin at all application timings. However, these data suggest that imazapic alone does not provide sufficient residual control of Texas millet compared to combinations with pendimethalin (84 to 93%).

Southern Crabgrass Control. Pendimethalin alone applied VE or later controlled southern crabgrass 51 to 76% (Table 1). Paraquat plus pendimethalin applied PRE (82%) did not improve southern crabgrass control over pendimethalin alone applied PRE (87%) due to no emerged southern crabgrass at the time of application. Paraquat plus pendimethalin applied VE or VE+1wk resulted in 86 and 90% southern crabgrass control, respectively. When paraquat was combined with pendimethalin, application at VE+2wk or later did not adequately control southern crabgrass (66 to 76%) since the annual grass was too large (> three-leaf stage) to be consistently controlled by paraquat.

Imazapic combined with pendimethalin effectively controlled southern crabgrass from PRE to VE+3wk application timings (87 to 93%), and this level of control was generally equivalent to control from paraquat plus pendimethalin at similar timings. Imazapic alone applied VE+3wk controlled southern crabgrass 85%, demonstrating the benefits of imazapic in controlling emerged and nonemerged southern crabgrass. Furthermore, in cases where southern crabgrass is

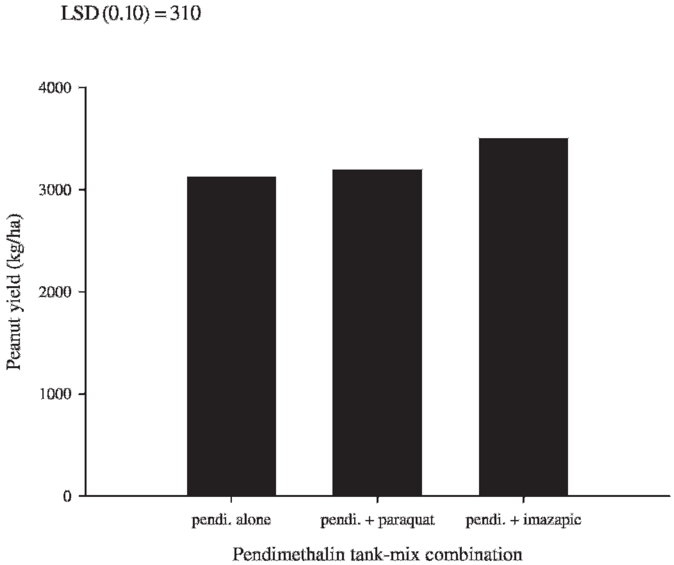

Figure 2. Main effect of pendimethalin tank-mix combinations on peanut yield in Tifton, GA: 2004, 2005, and 2007.

the predominant annual grass, imazapic alone will effectively control the weed, and pendimethalin is not needed.

Peanut Yield. Across all pendimethalin herbicide programs, peanut yield increased when pendimethalin was applied PRE compared to the current producer standard timing for nonpendimethalin weed control programs (3,480 vs. 3,070 kg/ha) (Figure 1). Peanut yield was maximized if pendimethalin was applied PRE or later. Based on peanut yield response, PRE application was early enough to minimize annual grass interference and protect peanut yields.

Across all possible timings of application, imazapic plus pendimethalin was the only combination that had the versatility to consistently control emerged and nonemerged annual grasses (Table 1) and maximize peanut yield (Figure 2). These results agree with Tubbs and Gallaher (2005) who reported better control of a nondifferentiated annual grass complex composed of Texas millet and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] using a weed management system that included imazapic compared to a system that used paraquat. Pendimethalin alone cannot control emerged annual grasses if applications are delayed (Appleby and Valverde 1989) and peanut yield is correspondingly reduced. Southern crabgrass is less susceptible to paraquat plus pendimethalin when applied later than VE+1wk, and peanut yields were reduced by weeds escaping control. Phytotoxicity of treatments was not a likely factor for any of the peanut yield responses to timings of pendimethalin application and herbicide combinations, due to lack of midseason injury symptoms and results from companion weed-free injury trials (W. C. Johnson, III, unpublished data).

Pendimethalin, paraquat, or imazapic alone did not effectively control both Texas millet and southern crabgrass in strip-tillage peanut. Previous research showed that effective season-long control of Texas millet is necessary for maximum peanut yield and required sequential applications of either pendimethalin or ethalfluralin followed by either sethoxydim or clethodim (Johnson et al. 2002). Our results are in agreement that a single herbicide treatment is not sufficient to consistently control annual grasses in strip-tillage peanut. Furthermore, these data indicate that if situations arise that require pendimethalin be applied after peanut emergence, Texas millet and southern crabgrass can be effectively controlled by including imazapic. Imazapic offers greater flexibility than paraquat when combined with delayed applications of pendimethalin by controlling emerged and nonemerged annual grasses that maximize peanut yield.

Sources of Materials

[1] Prowl 3.3EC®, BASF Corp., 26 Davis Drive, Research Triangle Park, NC 27709.

[2] Gramoxone Max®, Syngenta Crop Prot., Inc., P.O. Box 18300, Greensboro, NC 27709.

[3] Cadre®, BASF Corp., 26 Davis Drive, Research Triangle Park, NC 27709.

[4] Chem Nut 80-20 nonionic surfactant-adjuvant, Chem Nut Inc., 1918 Ledo Road, Albany, GA 31707.

[5] Roundup WeatherMAX®, Monsanto Company, St. Louis, MO 63167.

[6] Two-row–strip-tillage implement, Kelley Manufacturing Company, 80 Vernon Drive, Tifton, GA 31793.

[7] Vacuum planter, ATI., Inc., 17135 West 116th St., Lenexa, KS 66219.

[8] Classic®, E. I. Du Pont de Nemours and Co., Wilmington, DE 19898.

[9] Butyrac® 175, Albaugh, Inc., 1525 NE 36th Street, Ankeny, IA 50021.

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