THE MANAGEMENT OF GLYPHOSATE-RESISTANT PALMER AMARANTH IN COTTON USING DEEP-TILLAGE, COVER CROPS, AND HERBICIDES

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Introduction

The production and profitability of cotton has been greatly improved by the development and release of genetically-modified, herbicide-tolerant cultivars, particularly those resistant to glyphosate (http://www.agbioforum.org/v8n23/v8n23a15-brookes.pdf, http://www.pgeconomics.co.uk/index.php). Since its commercial introduction in 1996, glyphosate-resistant (GR) cotton has been grown on an increasing number of acres worldwide; recent data indicates that approximately 70% of the global cotton crop is planted with GR cultivars. The proposed benefits of GR crop technology include: improved weed control (including difficult-to-control flora, such as perennials and volunteer crop plants) and reduced crop injury, which can lead to higher crop productivity. The adoption of GR cultivars has also allowed US cotton growers to engage in conservation tillage (CT). This transition has been especially beneficial for farmers in the SE Coastal Plain, where the soils are sandy, compacted, nutrient-poor, and have low moisture-holding capacities.

Unfortunately, the widespread use of glyphosate across space and time has resulted in the development of GR weeds. In 2004, the existence of GR Palmer amaranth was confirmed at a 250 ha field site in Macon County, Georgia; production at this site had been a monoculture of GR cotton where glyphosate, often applied at reduced rates, was used, singly, for at least seven years. Within three years of its discovery, GR Palmer amaranth became the single greatest threat to the economic sustainability of cotton production. Currently, GR Palmer amaranth infests more than 2 million ha in 10 states (Alabama, Arkansas, Georgia, Louisiana, Missouri, Mississippi, North Carolina, New Mexico, South Carolina and Tennessee).

When acceptable control is not realized and Palmer amaranth is allowed to set seed, population densities can become quite high in infested fields. Current University of Georgia recommendations recommend that growers prevent Palmer amaranth from reaching reproductive maturity as a means of reducing the size of weed seedbank on their farms. A reduction in the total number of germinable seeds reduces the number of individuals that will, subsequently, be subjected to chemical weed management, as well as the potential number of weed management survivors that can then replenish the seedbank. In order to maximize herbicide efficacy and prevent the development of further resistances, cotton growers must consider using additional mechanical (i.e. tillage) and cultural (i.e. cover crops) weed management strategies to limit Palmer amaranth infestations.

Results from a recent (2008-2010) study in Georgia showed that the majority of Palmer amaranth seedlings emerged from depths shallower that 2.5 cm; less than 2% emergence was observed for Palmer amaranth seeds buried at depths greater than 10 cm. Deep soil inversion, or deep tillage, can be used to bury a significant proportion of surface/near surface Palmer amaranth seeds to depths below their optimal germination and emergence zone. Results from a study conducted in 2008 showed that deep tillage, to a depth of 30 cm, reduced GR Palmer amaranth seedbank densities and emerged seedling densities by 40 to 60%, as compared to undisturbed soil. Cover crops can suppress weeds by serving as a physical barrier to emergence, by inhibiting germination via reduced light transmittance and allelopathic effects, and by preventing herbicide loss through runoff and leaching. Results from small-plot experiments (2008-2010) integrating winter rye residue into standard cotton herbicide systems showed that control of GR Palmer amaranth exceeded 90% in row-middles when cover crops were employed. The use of rye, when paired with a Roundup-based, residual herbicide system, significantly increased cotton yields by 43% when compared to cotton strip-tilled into winter weeds.

The objective of this study was to evaluate the use of heavy-residue cover crops, herbicides, and a single deep soil inversion event for control GR Palmer amaranth in large scale, grower-managed, on-farm trials.

Materials and Methods

Three fields managed by grower-cooperators were selected to evaluate the effectiveness and adoptability of deep tillage and rye cover crop for managing glyphosate-resistant Palmer amaranth in cotton (2010-2011). Demonstration sites were located in Worth (31° 38'01.65"N, 83° 45'35.36"W), Seminole (30° 57’40.59”N, 84° 53’19.78”W) and Screven (32° 34'59.87"N, 81° 29'39.73"W) Counties. All fields were approximately 10 A (4 Ha) in size and were planted to cotton the previous year (2010). Grower-cooperators and county extension agents described the local Palmer amaranth infestations as moderate to severe; participants also indicated that the pigweed present at each of the study sites was glyphosate-resistant. In 2010, the Worth County site received glyphosate and flumioxazin preplant; fomesafen, diuron, and pendimethalin at planting; and glyphosate plus pyrithiobac and glufosinate at the first and second postemergence (POST1 and POST2) application timings, respectively. In Seminole county, trifluralin was applied preplant; fomesafen was applied at planting; glyphosate was applied POST; and diuron plus glyphosate were applied at layby. At the Screven county site, trifluralin was applied preplant; fomesafen was applied preemergence (PRE); glufosinate plus *S*-metolachlor were applied three times POST; and glyphosate, prometryn, and MSMA were applied at layby.

Three treatments, which included: 1) cotton planted into winter weed residue [bare ground], 2) cotton planted into a winter rye cover crop [no deep-tillage + rye], and 3) cotton planted into a winter rye cover crop on deep-tilled (moldboard plowed) soil [deep-tillage + rye] were established at each site during the 2010-2011 season. At Worth County, deep tillage operations were undertaken and rye planted on November 15, 2010. Rye was fertilized with 20-25 units of nitrogen on February 18, 2011. The cover crop was terminated on April 19, 2011 and subsequently rolled. At Seminole County, rye was planted in the non-tilled treatment on November 2, 2010. The deep-tillage treatment was initiated on December 10, 2010, although rye was not planted until January 11, 2011 because of rain. Rye was fertilized with 20-25 units of nitrogen on February 21, 2011. The cover crop was terminated on May 17, 2011 and subsequently rolled. At Screven County, deep tillage operations were undertaken on January 14, 2011. Rye was planted on January 15, 2011. Rye was fertilized with 20-25 units of nitrogen on February 24, 2011; the cover crop was killed and rolled four to six weeks before cotton planting. Twenty replicated samples (0.5 m by 0.5 m) of rye were harvested from each study site in May of 2011, dried in a greenhouse, and weighed to determine cover crop biomass.

Cotton was planted at all locations by June 1, 2011. Phytogen 565 was planted at the Worth and Screven County sites, FiberMax 1845 was planted in Seminole county. Paraquat, fomesafen, and pendimethalin were applied at all three sites preplant for burndown/residual weed control. An additional preplant/PRE application of diuron was made at the Worth County site; glyphosate and flumioxazin were applied at Screven County preplant/PRE. Glyphosate plus acetochlor (in Worth County), glufosinate followed by pyrithiobac (in Seminole County), and glyphosate (in Screven County) were applied postemergence (POST) on June 16, June 20, and July 1, 2011, respectively. In Seminole County, gramoxone plus diuron was applied at layby (July 11, 2011) using a hooded sprayer. Worth County received diuron plus MSMA, also at layby (July 16, 2011). The Screven County site received a second POST application of glyphosate on August 1, 2011. All herbicides were applied at labeled rates and according to the recommendations of the local county extension agent. Weed counts were conducted at each site multiple (four to six) times during the growing season; observation timings were selected so as to capture Palmer amaranth densities following significant crop production/weed management practices (i.e. preplant/PRE herbicide applications, POST, and layby/POST herbicide applications). Weed densities were obtained by counting all of the weeds present in 25% of the crop production rows assigned to each treatment and then converting the numbers to plants/ha for analysis and presentation.

Results and Discussion

Rye biomass production: For both Screven and Worth Counties, mean dry rye biomass was greater when the cover crop was planted on deep-tilled soil (5700 and 6800 kg/ha, respectively), as compared to the non-tilled soil (2600 and 5400 kg/ha, respectively). Conversely, cover crop biomass production in the deep-tilled treatment (3,000 kg/ha) at the Seminole county site was approximately 80% lower than biomass produced on non-tilled soil. This was due to the fact that the rye planting in the deep-tilled treatment was delayed by more than two months, relative to the non-disturbed treatment, because of rain and cold soil temperatures. The increased rye biomass production in the non-tilled Seminole County treatment, relative to the other sites, was likely due to its longer growing season (beginning on November 2, 2010) and to the fact that the site received almost two times the amount of rainfall (54 cm) throughout the entire production period as did Worth (35 cm) and Screven (29 cm) counties.

Weed densities: At the Worth County site, mean Palmer amaranth densities following preplant/PRE herbicide applications were greater in the no deep-tillage + rye treatment (190 plants/ha) as compared to the bare ground and deep-tillage + rye (0 plants/ha) treatments because of an error in the application of residual herbicides at planting (Figure 1). In Seminole County, the mean number of Palmer amaranth plants/ha observed following preplant/PRE applications were 20, 0, and 10 plants/ha in the bare ground, no deep-tillage + rye and deep-tillage + rye plots, respectively. Most of the plants encountered in the bare ground and the deep-tillage + rye treatments were larger than 50 cm in height and were likely plants that escaped the preplant herbicide burndown, rather than newly germinated seedlings (Figure 2). Mean Palmer amaranth densities were extremely high in both the bare ground (2940 plants/ha) and no deep-tillage + rye (1230 plants/ha) treatments in Screven county; no Palmer amaranth plants were observed in the deep-tillage + rye treatment following preplant/PRE herbicide applications (Figure 3). When averaged over all three sites, mean Palmer amaranth densities following preplant/PRE herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments were 990, 470, and <10 plants/ha, respectively (Figure 4).

Similar trends in Palmer amaranth density were observed following POST herbicide applications. At Worth County, mean Palmer amaranth densities were greater in the no deep-tillage + rye treatment (260 plants/ha) as compared to the bare ground (30 plants/ha) and deep-tillage + rye (10 plants/ha) treatments. As was suggested previously, mean Palmer amaranth densities were greater in the no deep-tillage + rye treatment as compared to the bare ground and deep-tillage + rye treatments because of an error in the application of residual herbicides at planting, as well as ineffectual control of glyphosate-resistant Palmer amaranth with glyphosate POST (Figure 1). In Seminole County, mean Palmer amaranth densities were higher in the bare ground (520 plants/ha) plot as compared to the no deep-tillage + rye (300 plants/ha) and deep-tillage + rye treatments (90 plants/ha). Glufosinate failed to control glyphosate-resistant Palmer amaranth at the Seminole county site because weeds were overly large (> 25 cm) at the time of application; current University of Georgia recommendations indicate that Palmer amaranth should be no more than 7.5 cm in height when glufosinate is applied in order to maximize control (Figure 2). Similarly, Palmer amaranth densities at the Screven County site were also higher in the bare ground (3490 plants/ha) treatment as compared to no deep-tillage + rye (2560 plants/ha) and deep-tillage + rye (140 plants/ha) (Figure 3). When averaged over sites, mean Palmer amaranth densities following POST herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments were 1340, 1040, and 80 plants/ha, respectively (Figure 4).

Following layby/POST applications, mean densities of 130, 30, and 20 Palmer amaranth plants/ha were observed in the bare ground, no deep tillage + rye, and deep-tillage + rye plots, respectively, in Seminole County (Figure 2). At Worth County, mean Palmer amaranth densities were highest in the no deep-tillage + rye (120 plants/ha) treatment, followed by the bare ground (20 plants/ha) plot; no Palmer amaranth plants were observed in the deep-tillage + rye treatment following layby/POST herbicide applications (Figure 1). In Screven County mean densities of 1140, 1300, and 80 plants/ha were observed in the bare-ground, no deep-tillage + rye, and deep-tillage + rye treatments, respectively (Figure 3). When averaged across sites, mean Palmer amaranth densities were numerically greatest in the no deep-tillage + rye (480 plants/ha) treatment, followed by the bare ground (430 plants/ha) and deep-tillage + rye (30 plants/ha) plots (Figure 4).

Summary

In 2010-2011, three on-farm field trials (Seminole, Screven, and Worth Counties in Georgia) were established with the assistance of farmer-cooperators and County extension agents. The purpose of the study was to evaluate the effectiveness of an integrated weed management program for controlling GR Palmer amaranth populations. Previous research, conducted at multiple institutions throughout the SE US, have demonstrated the merits of both deep soil inversion and heavy residue cover crops for suppressing/reducing in-field Palmer amaranth populations. Results from large-scale on-farm trials in Georgia showed that the use of deep-tillage plus a rye cover, in combination with herbicides, (deep-tillage + rye) reduced Palmer amaranth densities relative to the rye plus herbicide (no deep-tillage + rye) and herbicide only (bare ground) treatments at every observation period (i.e. followingpreplant/PRE, POST, and layby applications). Participating farmer-cooperators and extension agents indicated that GR Palmer amaranth populations were severe at each of the field sites; results suggest that aggressive tillage/rye/herbicide programs are effective at controlling GR Palmer amaranth in cotton, including GR cotton (Worth and Screven counties).

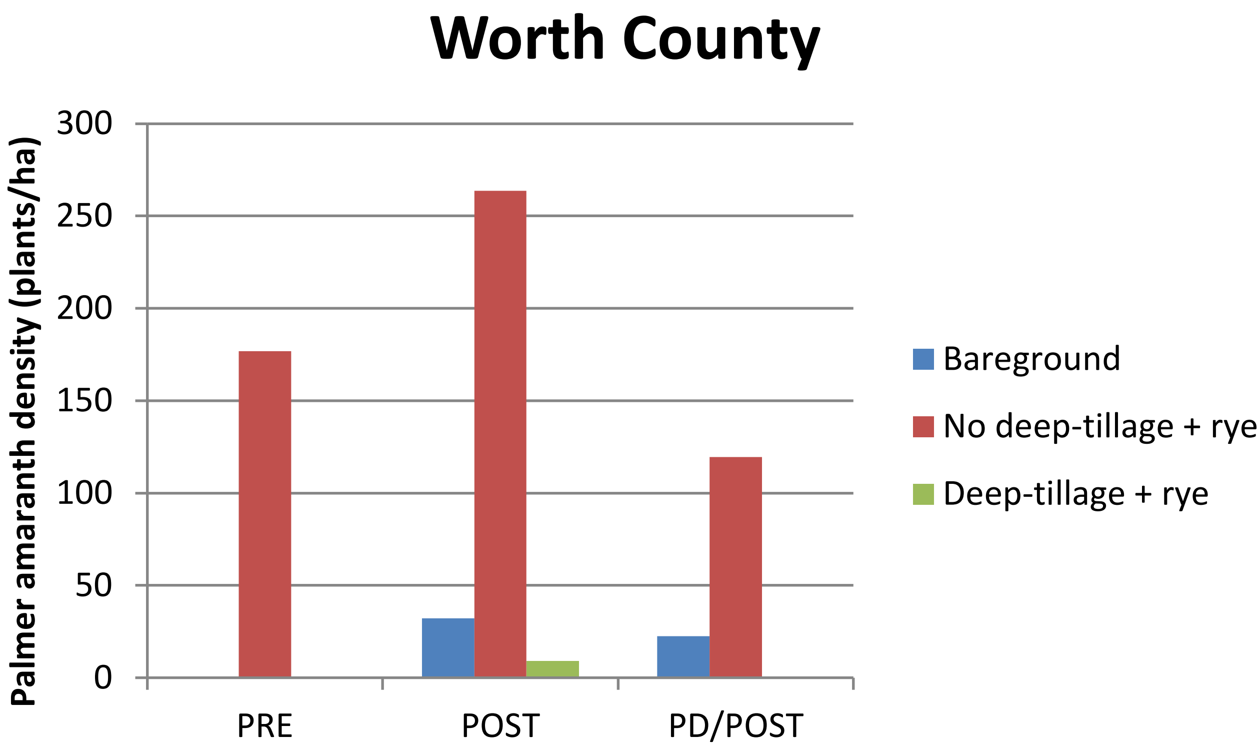

Figure 1. Mean Palmer amaranth densities (plants/ha) in Worth County following preplant/PRE [PRE], postemergence [POST], and layby/POST [PD/POST] herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments.

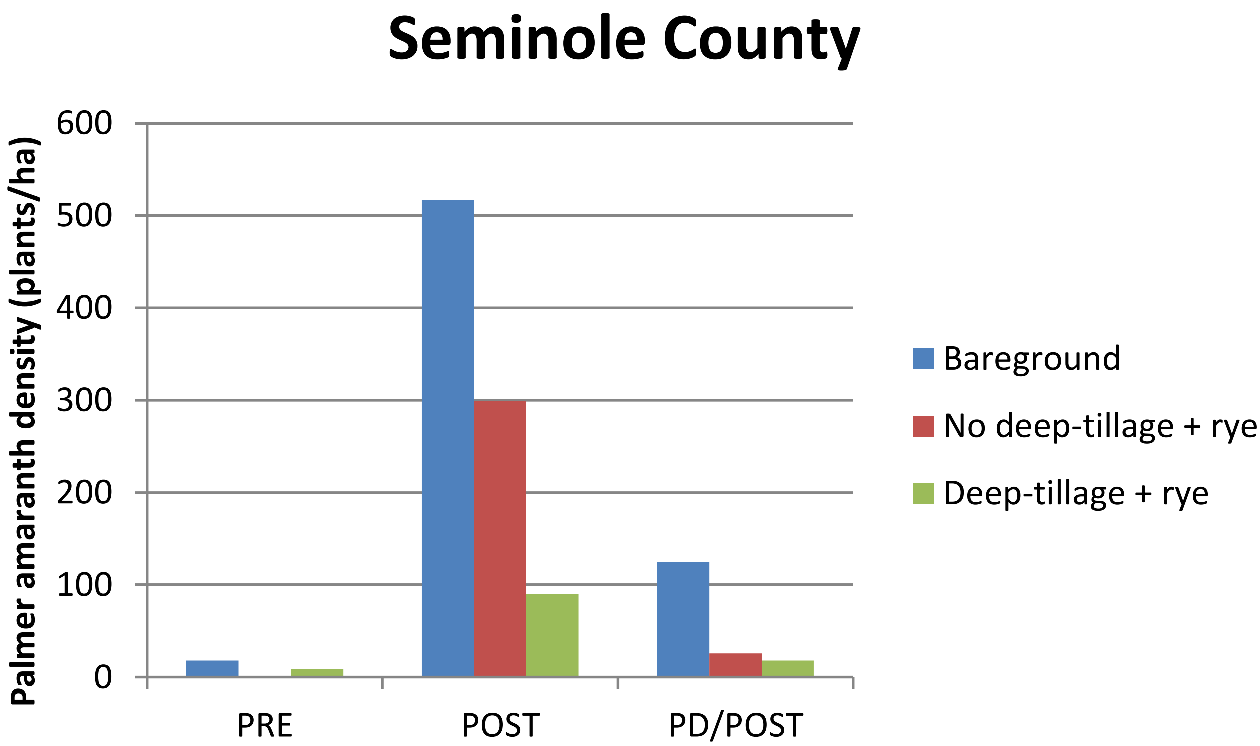

Figure 2. Mean Palmer amaranth densities (plants/ha) in Seminole following preplant/PRE [PRE], postemergence [POST], and layby/POST [PD/POST] herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments.

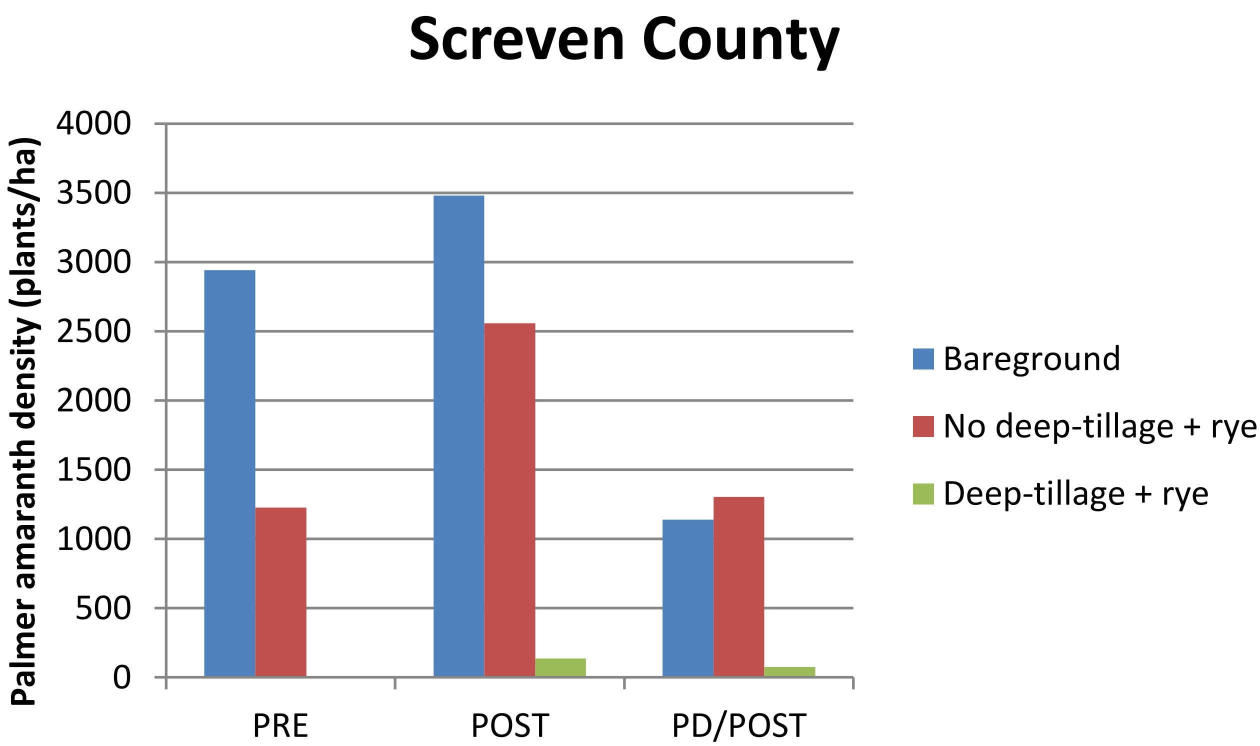

Figure 3. Mean Palmer amaranth densities (plants/ha) in Screven County following preplant/PRE [PRE], postemergence [POST], and layby/POST [PD/POST] herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments.

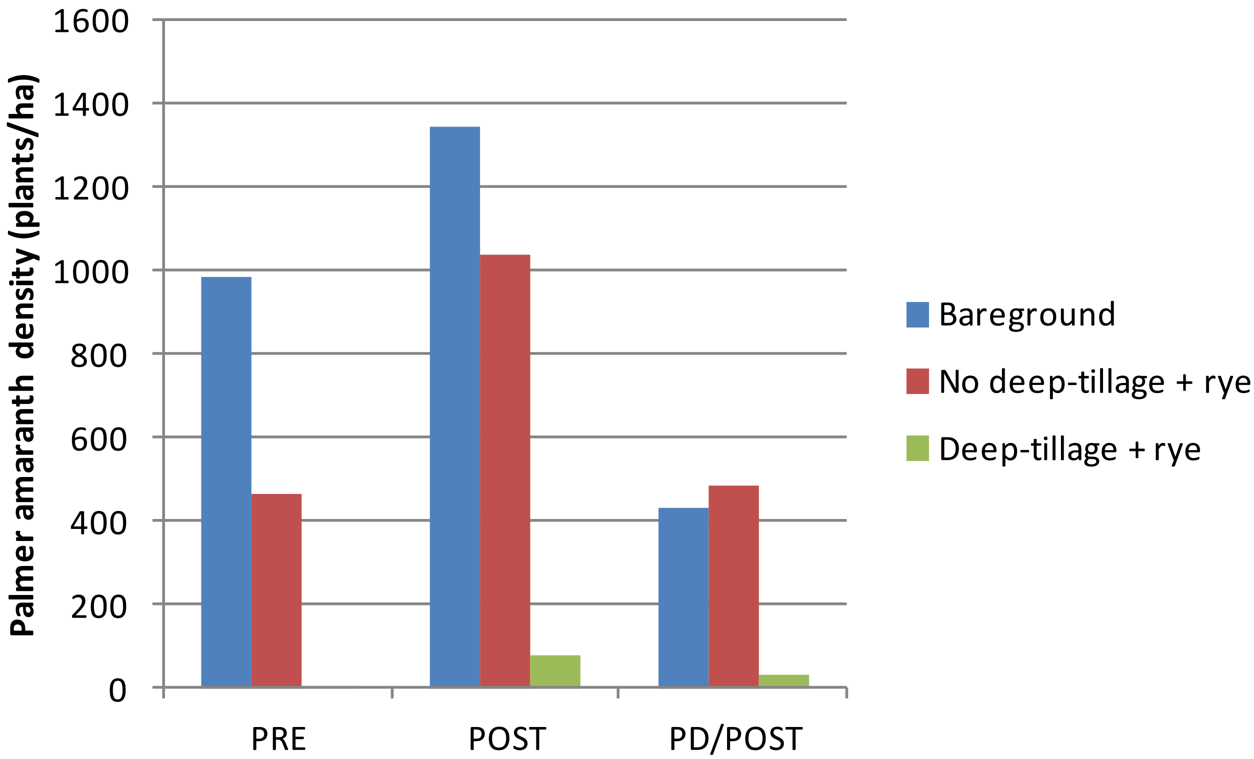

Figure 4. Mean Palmer amaranth densities (plants/ha) averaged across all three experimental following preplant/PRE [PRE], postemergence [POST], and layby/POST [PD/POST] herbicide applications in the bare ground, no deep-tillage + rye, and deep-tillage + rye treatments.