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SHORT COMMUNICATION

Spring-tillage has no effect on the emergence pattern of glyphosate-resistant giant ragweed (*Ambrosia trifida* L.) in Nebraska

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Abstract: The objective of this study was to investigate the effect of spring tillage on glyphosate-resistant giant ragweed emergence pattern. Giant ragweed emerged from late Mar. until early June and tillage had no effect on total seedling emergence and days required to reach 50% cumulative emergence (T_{50}); however, results differed between years.

Key words: emergence pattern, herbicide resistance, integrated weed management, physical elimination, seedling emergence.

Résumé : L'étude avait pour but d'examiner les effets d'un travail printanier du sol sur la levée de la grande herbe à poux résistante au glyphosate. Cette adventice lève de la fin de mars au début de juin et les labours n'ont aucune incidence sur le nombre total de plantules qui germent ni sur le nombre de jours nécessaires pour atteindre 50 % de levée cumulative (T_{50}). Les résultats diffèrent néanmoins d'une année à l'autre. [Traduit par la Rédaction]

Mots-clés : mode de levée, résistance aux herbicides, lutte intégrée contre les mauvaises herbes, extirpation, levée des plantules.

Introduction

Giant ragweed, a native of eastern North America, is an early emerging summer annual weed species and is considered one of the most troublesome weeds in agronomic crops in the Midwestern United States and the province of Ontario, Canada (Soltani et al. 2011). Due to its early emergence pattern, giant ragweed vigorously competes with crops for light, water, space, and nutrients. Moreover, giant ragweed has a high photosynthetic rate, making it a vigorous and rapidly growing weed, resulting in significant crop yield loss when not controlled early in the season.

Tillage is a commonly practiced mechanical weed management strategy. Tillage can reduce weed populations by eliminating emerged seedlings and (or) moving weed seeds into deeper layers of soil, which then fail to meet the optimum conditions for germination. Conversely, tillage may also stimulate the germination of some weed species by altering micro-environmental conditions such as light, nutrient availability, temperature, and soil porosity. Response to tillage has been reported to be species dependent, but the effect of tillage on the emergence pattern of giant ragweed is currently unknown.

Repeated applications of glyphosate for weed management in glyphosate-resistant crops across North America have led to the evolution of glyphosate-resistant weeds, including giant ragweed. To control glyphosate-resistant giant ragweed, growers are relying on mechanical and cultural practices as well as alternative herbicides prior to and (or) after crop establishment (Soltani et al. 2011; Jhala et al. 2014). Therefore, understanding the emergence pattern of giant ragweed and its response to alternative management practices such as tillage could be useful in prioritizing management approaches. Early emergence of giant ragweed can be exploited in a way that allows it to be controlled by tillage prior to crop establishment, thus reducing competition with the crop, especially during the initial growth stages. Limited information is available on the influence of tillage on the emergence pattern of giant ragweed; therefore, the objective of this study was to determine the influence

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of simulated spring tillage on the emergence pattern of a glyphosate-resistant giant ragweed population in Nebraska, USA. We hypothesized that spring tillage would not stimulate additional giant ragweed seedling emergence, and thus, has the potential to be used as an alternative tool to manage glyphosate-resistant giant ragweed.

Materials and Methods

Field experiments were conducted near David City, Butler County, Nebraska, USA (41.25°N, 97.13°W) in 2012 and 2013 in a field infested with a confirmed glyphosate-resistant giant ragweed population. During the previous 8 yr, glyphosate had been the primary herbicide used at this site, at least twice per growing season, for weed control in a glyphosate-resistant corn-soybean rotation under no-till and rain-fed conditions. The soil at the experimental site was silt loam with a pH of 5.4, 18% sand, 50% silt, 32% clay, and 2.1% organic matter.

The experiment was arranged in a randomized complete block design with five treatments and four replications. Early in the season (before the onset of giant ragweed emergence), 1.5 m × 4.5 m plots were established and three 0.25 m^2 quadrats were evenly placed in the center of each plot. Treatments included four tillage timings and an untreated control (no-till). Tillage was conducted using a rototiller at biweekly intervals starting 2 wk after the first giant ragweed seedlings were observed. Tillage depth was set to approximately 10 cm. In 2012, designated plots were tilled on 4 Apr., 19 Apr., 4 May, and 17 May. In 2013, plots were tilled on 18 Apr., 2 May, 16 May, and 30 May. Each year, the experiment was conducted in adjacent areas of the same field. Emerged plants at the cotyledon stage were counted and removed from each quadrat on a weekly basis. At the time of tillage, the quadrats were removed and immediately re-established in the same location. Data were collected until 30 June, when giant ragweed emergence had ceased in both years.

Statistical analysis

Giant ragweed emergence data were converted from weekly counts to total emergence (%) based on the total number of seedlings emerged per quadrat per year. A logistic function was fit to the data to describe emergence over time (Sahoo et al. 2010):

$$Y = a/[1 + \exp(b - c \times \mathrm{DOY})] \quad (1)$$

where Y is the total seedling emergence at a specific time (response variable), DOY is the day of the year (explanatory variable), a is the asymptote or maximum total emergence within a year (theoretical maximum for Y normalized to 100%), and b and c are shape parameters. The logistic function was fit to the data of each quadrat using PROC NLIN in SAS 9.2 (SAS Institute, Cary, NC), and the shape parameters b and c were used to estimate the number of days to 50% cumulative giant ragweed seedling emergence (T_{50}) (Sahoo et al. 2010):

$$T_{50} = b/c \quad (2)$$

The T_{50} and total seedling emergence data for the three quadrats within a plot were averaged prior to analysis of variance (ANOVA), with the average representing the response value for each plot. The total number of emerged giant ragweed seedlings was expressed in plants m^{-2}. The T_{50} (days to 50% seedling emergence) and total seedling emergence (plants m^{-2}) were subjected to ANOVA performed using PROC GLIMMIX in SAS 9.2 (SAS Institute, Cary, NC). Experimental treatments were treated as fixed factors, whereas replication blocks (nested within experimental runs) were treated as random factors in the model. Means were separated when the interaction or main effect was less than α = 0.05 based on Fisher's protected LSD test. The Gaussian assumptions of normality and homogeneity of variance were tested prior to analysis and no data transformation was necessary. Results presented were originated from the mixed model analysis.

Results and Discussion

There was no treatment by year interaction for the total giant ragweed seedling emergence (plants m^{-2}) and T_{50} ($P > 0.05$); thus, the main effects were evaluated. There was no difference between the different tillage times and no-till on total giant ragweed seedling emergence or T_{50} (P = 0.09 and 0.11, respectively; Table 1); however, results for these response variables differed between years (P = 0.003 and $P < 0.001$, respectively). In 2012, total giant ragweed seedling emergence was higher and occurred earlier compared with 2013 (Table 1). For instance, total seedling emergence in 2012 ranged from 1102 to 1759 m^{-2} compared with 346 to 658 m^{-2} in 2013. The difference in total seedling emergence between years was likely due to heavy seed production in the fall of 2011 as a result of complete failure of the commercial weed control program that resulted in a near-monoculture of giant ragweed in 2012 in the area where this research was conducted. Additional research evaluating alternative herbicide programs was conducted in the areas surrounding the emergence plots in 2012; thus, seed production in 2012 was significantly reduced, leading to reduced total seedling emergence in 2013. Moreover, besides occurring earlier in the season, the amount of time required for emergence was shorter in 2012 than in 2013 (Fig. 1). According to the best fit of eq. 1 to the combined data from each year, 10%, 50%, and 90% cumulative emergence were expected on DOY 80 (21 Mar.), 83 (24 Mar.), and 87 (28 Mar.) of 2012; and DOY 94 (4 Apr.), 104 (14 Apr.), and 115 (25 Apr.) of 2013, respectively (Fig. 1).

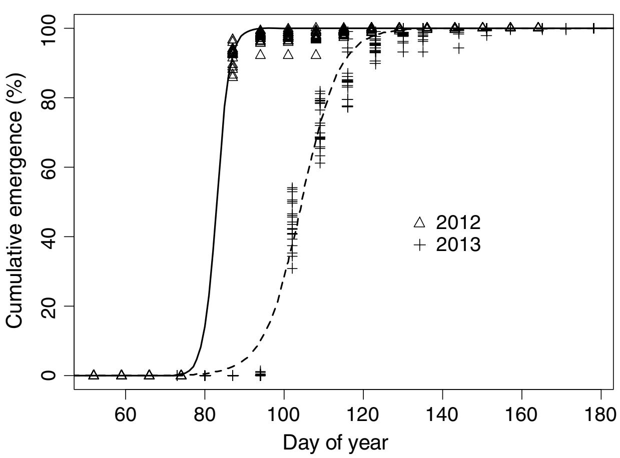
The differences in T_{50} between years can be explained by warmer temperatures during the early season in

Table 1. Influence of early spring tillage on giant ragweed total seedling emergence and time to 50% seedling emergence (T_{50}) in a field experiment conducted in 2012 and 2013 at David City, Nebraska, USA.

Year	Treatment	Total emergence (seedlings m^{-2})	T_{50} (day of year)
2012	No-till	1690a	83 (24 Mar.)a
	1st tillage (4 Apr.)	1598a	83 (24 Mar.)a
	2nd tillage (19 Apr.)	1759a	83 (24 Mar.)a
	3rd tillage (4 May)	1527a	83 (24 Mar.)a
	4th tillage (17 May)	1102a	83 (24 Mar.)a
2013	No-till	658b	105 (15 Apr.)b
	1st tillage (18 Apr.)	346b	103 (13 Apr.)b
	2nd tillage (2 May)	545b	104 (14 Apr.)b
	3rd tillage (16 May)	631b	105 (15 Apr.)b
	4th tillage (30 May)	533b	105 (15 Apr.)b
P-value	Treatment	0.088	0.107
	Year	0.003	<0.001

Note: Values with lowercased letters are not different at $P \leq 0.05$ according to Fisher's protected LSD test.

Fig. 1. Emergence pattern of a glyphosate-resistant giant ragweed population at David City, Nebraska, USA in a field experiment conducted in 2012 and 2013. As no differences were detected among tillage treatments, all data within an experimental year were combined. Solid and dashed lines represent the best fit of the logistic function to the data of 2012, $Y = 100 \times \{1/[1 + \exp(50.5447 - 0.6092 \times \text{DOY})]\}$, and 2013, $Y = 100 \times \{1/[1 + \exp(21.9265 - 0.2100 \times \text{DOY})]\}$, respectively. DOY, day of year.



2012 compared with 2013 and the 30 yr average (data not shown). Moreover, precipitation from March through October was 385, 1240, and 863 ± 46 mm for 2012, 2013, and the 30 yr average (1982 to 2011), respectively (High Plains Regional Climate Center; www.hprcc.unl.edu). Temperature and rainfall in March and April of 2012 and 2013 deviated significantly and in opposite directions from the 30 yr average (data not shown).

Compared with no-till, no additional seedlings were observed when tillage treatments were conducted after giant ragweed emergence had ceased (late March and late April in 2012 and 2013, respectively), indicating that besides not stimulating emergence, tillage could also mechanically eliminate young established plants. The soybean planting season begins, is most active, and ends on 5 May, 11 to 31 May, and 8 June, respectively, in Nebraska (USDA 2010). During both years, the majority of giant ragweed seedlings emerged prior to the time of soybean planting in Nebraska, indicating that management of giant ragweed could be accomplished prior to soybean planting using tillage and (or) other alternative practices. A twoyear study in Nebraska reported that pre-plant tillage provided >80% control of glyphosate-resistant giant ragweed; however, a follow-up application of PRE or POST herbicide was needed for season-long control in soybeans (Ganie et al. 2016). Despite the negative environmental effects of tillage (i.e., erosion, accelerated decomposition of soil organic matter, compaction, etc.), it still remains an important tool for weed management and, if wisely used, could assist with the management of herbicide-resistant weeds (Ganie et al. 2016).

Giant ragweed is a competitive weed that, if not controlled early, may lead to substantial yield loss. Complete soybean yield loss has been reported in a highly-infested (51 plants m^{-2}) glyphosate-resistant giant ragweed field when allowed to compete with soybean throughout the growing season (Kaur et al. 2014). Recent studies in Nebraska reported >90% control of glyphosate-resistant giant ragweed using pre-plant herbicides such as 2,4-D or saflufenacil applied alone or as a tank-mix partner in soybeans (Jhala et al. 2014; Kaur et al. 2014). Therefore, diversity in weed management is needed to combat herbicide-resistant weeds, with tillage and pre-plant herbicides as alternative tools for the early season management of giant ragweed.

The adaptation of the giant ragweed emergence pattern in response to intensive management has been reported. Schutte et al. (2012) reported giant ragweed in Ohio having an extended biphasic emergence pattern, which differed from the relatively short monophasic emergence pattern observed in Nebraska. Research conducted in Indiana and Iowa also reported a short monophasic emergence pattern of giant ragweed (Davis et al. 2013; Werle et al. 2014), corroborating the results of this study. Thus, results of this project could be translated to regions where giant ragweed populations have a monophasic, short emergence pattern during the early season. Though these results can be applied to giant ragweed, they may not translate to other weed species, such as common waterhemp (*Amaranthus tuberculatus* Moq. Sauer syn. *rudis*), which emerges throughout the growing season in the Midwestern United States (Werle et al. 2014).

For weeds with a short emergence window, knowledge of peak periods of emergence can help growers decide the best time for management and subsequently reduce crop-weed competition and seed-bank deposits. Established glyphosate-resistant giant ragweed plants growing within crops may be difficult to manage; therefore, controlling giant ragweed prior to soybean planting would be ideal (Ganie et al. 2016). Because of the monophasic emergence pattern, the results of this study suggest that spring tillage prior to corn/soybean planting can be an effective alternative to herbicides for an integrated management of glyphosate-resistant giant ragweed in Nebraska.

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