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Emergence pattern of horseweed (*Erigeron canadensis* L.) accessions across Nebraska

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Research Article

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Abstract

Horseweed is a North American indigenous plant species commonly found in Nebraska cropping systems. Horseweed management is challenging because of horseweed's prolific seed production, long-distance seed dispersal via wind, competitiveness, and rapid evolution of herbicide resistance. Understanding the horseweed emergence pattern across Nebraska can contribute to implementing effective and more sustainable tactics to minimize its impact on cropping systems. Field studies were conducted during fall and spring from 2016 to 2018 in Lincoln (corn and soybean), North Platte (wheat stubble and soybean), and Scottsbluff (corn and fallow) to investigate the emergence pattern of horseweed accessions from Lincoln, North Platte, and Scottsbluff, NE. Results show that most horseweed seedling emergence occurred in fall (99%) and only a few seedlings emerged in spring across locations, except in the wheat stubble experiment at North Platte, where higher spring emergence was detected (3% to 22%). In four out of six experiments, the density of total emerged seedlings of each accession was greatest when established in their site of origin. Our results suggest that late fall and/or early spring is likely the best timing for horseweed management across Nebraska.

Introduction

Horseweed is a native North American plant species in the Asteraceae family that causes major economic losses to worldwide agricultural systems (Bajwa et al. 2016). Horseweed can directly impact crop growth and development (Bajwa et al. 2016; Chahal and Jhala 2019), reduce mechanical harvest efficiency (Leroux et al. 1996), and serve as an alternate host of several pests and diseases (Al-Ghamdi et al. 1993; Bajwa et al. 2016). In North America, horseweed is found in field crops, pastures, and orchards and on roadsides (Miller and Miller 1999). Horseweed is well adapted to conservation agriculture, and in Nebraska, it is the most common weed in no-till soybean production (Chahal and Jhala 2019). In conservation agriculture systems, herbicides constitute the main weed management option (Bajwa et al. 2016; Marble 2015; Nandula et al. 2006). The reliance on herbicides as the primary tool for horseweed management has resulted in the evolution of several herbicide-resistant horseweed biotypes, including resistance to acetolactate synthase (HRAC Group 2), enolpyruvyl shikimate phosphate synthase (HRAC Group 9), photosystem I (electron diversion, HRAC Group 22), and photosystem II (serine 264 binders, HRAC Group 5) inhibitors (Heap 2022). There are more than 30 unique cases of horseweed biotypes with either single or multiple herbicide resistance reported in the United States (Heap 2022).

Uncontrolled horseweed has been reported to reduce soybean and corn yields up to 98% and 69%, respectively (Bruce and Kells 1990; Ford et al. 2014). Crop yield losses are influenced by weed emergence time, density, and interference duration (Estorninos et al. 2005; Hussain et al. 2015; Lindström and Kokko 2002). Time of weed emergence plays an important role in weed growth and fecundity (Davis et al. 2010; Mobli et al. 2020b). Knowledge of weed emergence patterns provides primary information for management decisions and for understanding the interference potential of weed species (Ogg and Dawson 1984). Davis et al. (2010) suggests that the poor efficacy of herbicide management to control horseweed could be due to lack of emergence pattern understanding leading to incorrect herbicide application timing.

Predicting the emergence time of horseweed is challenging due to lack of seed dormancy and the ability of this species to germinate under a broad range of environmental conditions (Main et al. 2006; Shrestha et al. 2008). The environmental conditions and historical site-specific weed management strategies can affect horseweed emergence patterns, for example, repeated fall

Figure 1. Locations of horseweed seed collection and research sites across Nebraska.

burndown herbicide applications likely selected for spring-emerging horseweed biotypes in Indiana and Illinois (Davis et al. 2010). Schramski et al. (2021) reported that shifts from fall to spring-emerging biotypes expedited glyphosate resistance evolution. Moreover, horseweed is self-pollinated and a prolific seed producer, producing up to 1 million seeds per plant, with effective wind seed dispersal infesting areas up to 550 km away from the source (Bhowmik and Bekech 1993; Shields et al. 2006; Tozzi and Van Acker 2014). Therefore horseweed seeds can be easily transferred to neighboring cropping systems, and newly introduced horseweed biotopes with genetic diversity and differential response to management strategies make predicting its emergence pattern and control more difficult. Horseweed exhibits different fall- and spring-emerging phenotypes. The fall-emerging seedlings overwinter as rosettes, and a flowering stem starts to elongate in the spring. In contrast, spring-emerging cohorts grow in the upright form, skipping the overwintering rosette stage (Main et al. 2006; Schramski et al. 2021). The differential horseweed growth due to its emergence pattern could increase management complexity, thus warranting studies evaluating horseweed emergence across a range of environmental conditions throughout Nebraska.

A comprehensive investigation of horseweed emergence patterns across Nebraska has not been conducted and can support implementation of more effective and sustainable practices for managing this troublesome weed species. We hypothesized that Nebraska horseweed emerges primarily in the fall. The objective of this study was to evaluate the emergence pattern of three horseweed accessions from Nebraska across multiple locations and cropping systems throughout the state.

Materials and Methods

Plant Material

Horseweed accessions were collected from Lincoln (Lin), North Platte (Npl), and Scottsbluff (Scb), NE, in late August 2016 and again in late August 2017 (Figure 1). Mature horseweed seeds were harvested from 20 arbitrarily selected plants from soybean fields in 2016 and soybean (Npl, Lin) and corn (Scb) fields in 2017. Each accession was collected from a single field. Horseweed seeds were cleaned and briefly stored at 25 C until the onset of experiments in 2016 and 2017. Fresh seeds from all accessions were collected and used for each experimental year.

Field Experiments

The experiments were conducted across Nebraska over two horseweed emergence years (2016 to 2017 and 2017 to 2018) at Lincoln and Scottsbluff and over one horseweed emergence year (2016 to 2017) at North Platte (Figure 1; Table 1). At each location, two experiments were established, representing regional cropping systems. In Lincoln, experiments were established in rainfed corn and rainfed soybean fields; rainfed wheat stubble and irrigated soybean in North Platte; and irrigated corn and rainfed fallow in Scottsbluff (Table 1). Experiments were arranged in a randomized complete block design with 3 horseweed accessions and 6 replications (totaling 18 experimental units). Polyvinyl chloride (PVC) rings with a 30-cm diameter and 10-cm height, with a 2.5-cm lip remaining above the soil surface, were used to delineate the experimental units. For experiments conducted within row-crop systems (i.e., corn and soybean; 76-cm row spacing), PVC rings were buried between crop rows (10 cm from the adjacent ring within the crop row) or arranged in a block for wheat stubble and fallow experiments with 10-cm spacing between rings (Figure 2). A 5-ml aliquot of horseweed seeds from a single accession was spread in each PVC ring, and seeds were lightly incorporated onto the soil surface (0 to 5 mm deep) to provide seed-to-soil contact while simulating seed-rain from naturally occurring horseweed plants. A 5-ml aliquot of horseweed seeds of Lin, Npl, and Scb contained an average of 6,600 (±550) seeds. In Lincoln, an extra treatment was included to monitor the natural horseweed population (“Natural” accession; total of 24 experimental units in each experiment). The study locations at North Platte and Scottsbluff were not naturally infested with horseweed.

Emerged seedlings were counted weekly and gently removed by hand from the experimental units with minimum soil disturbance.

Table 1. Field information and soil conditions during horseweed emergence experiments at Lincoln, North Platte, and Scottsbluff, NE, in 2016 to 2018.[a]

Site and year	Previous crop	Current crop	Crop planting	Crop harvest	Horseweed planting	Soil type	Soil pH	Organic matter
								%
Lin, 2016–2017	Soybean	Corn	26 Apr 2016	3 Oct 2016	9 Sep 2016	Crete silty clay loam	5.0	3.6
Lin, 2016–2017	Corn	Soybean	13 May 2016	11 Oct 2016	9 Sep 2016	Crete silty clay loam	5.2	3.2
Lin, 2017–2018	Soybean	Corn	8 May 2017	13 Oct 2017	15 Sep 2017	Crete silty clay loam	5.3	3.1
Npl, 2016–2017	Wheat	Wheat stubble	28 Sep 2015	7 Jul 2016	22 Aug 2016	Hall silt loam	6.2	1.6
Npl, 2016–2017	Corn	Soybean	13 May 2016	11 Oct 2016	22 Aug 2016	Cozad silt loam	7.4	1.7
Scb, 2016–2017	Fallow		——		30 Aug 2016	Glenberg sandy loam	7.4	1.5
Scb, 2016–2017	Corn	Corn	20 May 2016	31 Oct 2016	30 Aug 2016	Glenberg sandy loam	7.5	1.3
Scb, 2017–2018	Fallow		——		18 Sep 2017	Glenberg sandy loam	7.4	1.5
Scb, 2017–2018	Corn	Corn	8 May 2017	1 Nov 2017	18 Sep 2017	Glenberg sandy loam	7.5	1.3

[a]Abbreviations: Lin, Lincoln, NE; Npl, North Platte, NE; Scb, Scottsbluff, NE.

Emergence counts were conducted from time of fall establishment until late spring, when emergence ceased. The total density of emerged seedlings during the fall and spring (seedlings per experimental unit) was recorded. Emergence data from each observation were converted to cumulative emergence (%) for each accession as follows:

$$\text{Cumulative emergence } (\%) = \frac{\text{Number of emerged seedlings} \times 100}{\text{Total seedling emergence}} \quad [1]$$

Daily mean air temperature and precipitation for each location were obtained from the nearest High Plains Regional Climate Center automated station (https://hprcc.unl.edu/; Figure 3). Temperature data were converted to growing degree days (GDDs) accumulation from horseweed planting ($i = 1$) to each data collection time (n = days after i); 5 C was considered as the base temperature for horseweed emergence (Nandula et al. 2006; Ottavini et al. 2019):

$$\text{GDD}_5 = \sum_{i=1}^{n} \left\{ \left[\frac{(\text{Maximum daily temperature} + \text{Minimum daily temperature})}{2} \right] - 5 \right\}. \quad [2]$$

Statistical Analyses

The statistical analyses were performed separately for each cropping system within each location. The data from the two experimental years were pooled, and the year effect was treated as random throughout the statistical analyses. The statistical analyses were performed using R statistical software version 4.1.1 (R Development Core Team 2022). Horseweed cumulative emergence was described using the asymmetrical three-parameter Weibull model (W1.3) of the DRC package (Ritz et al. 2015):

$$Y = d \exp\{-\exp[b(\log(x) - e)]\} \quad [3]$$

where Y is the horseweed cumulative emergence, d is the upper limit (set to 100), e is the inflection point, b is slope, and x is the GDDs.

The required GDDs for 10%, 50%, and 90% horseweed cumulative emergence were estimated using the ED function of the DRC package. The 10%, 50%, and 90% horseweed cumulative emergences were compared among horseweed accessions using the EDcomp function of the DRC package. The EDcomp function compares the 10%, 50%, and 90% cumulative emergences using t-statistics with a $P = 0.05$. The root mean square error (RMSE) was calculated as an indicator of goodness of fit for each model according to Roman et al. (2000):

$$\text{RMSE} = \left[1/n \sum_{i=1}^{n} (\text{P}i - \text{O}i)^2 \right]^{1/2} \quad [4]$$

where n is the total number of comparisons and Pi and Oi is the predicted and observed value, respectively. The smaller the RMSE is, the closer are the observed values to the predicted values.

The total horseweed seedling emergence data for each cropping system at each location were analyzed with generalized linear mixed models using the template model builder with the glmmTMB function from the GLMMTMB package (Brooks et al. 2017). In the model, accession and emergence timing ("fall" [September to November] vs. "spring" [March to May]) were the fixed effects and block nested within year as the random effects. Analysis of variance (ANOVA) was performed with the Anova.glmmTMB function from the GLMMTMB package at $\alpha = 0.05$. Marginal means and compact letter display were estimated with *emmeans* and *cld* from package EMMEANS (Lenth et al. 2021) and MULTCOMP (Hothorn et al. 2008), respectively, using a least square difference at $P = 0.05$.

Results

Horseweed Emergence in Lincoln, NE

In the rainfed corn experiment, the required GDDs for 50% cumulative emergence and density of emerged seedlings varied across horseweed accessions (Figure 4; Table 2; $P < 0.05$). The Lin and Natural accessions required 100 and 161 GDDs for 50% emergence, respectively, which was the least and greatest among the accessions (Table 2). No differences ($P = 0.18$) were observed between required GDDs for 50% emergence of Npl (108 total emerged seedlings experimental unit^{-1}) and Scb (123) accessions. In addition, more than 99% of total horseweed seedlings across accessions emerged in the fall, whereas only a few seedlings

Figure 2. General scheme of experiment in different seed accessions. Experimental unit established in soybean (A). Experimental unit established in wheat stubble (B). Experiment established in wheat stubble (C). Photographs taken from the experiment established in wheat stubble and soybean, North Platte, NE, in fall 2016.

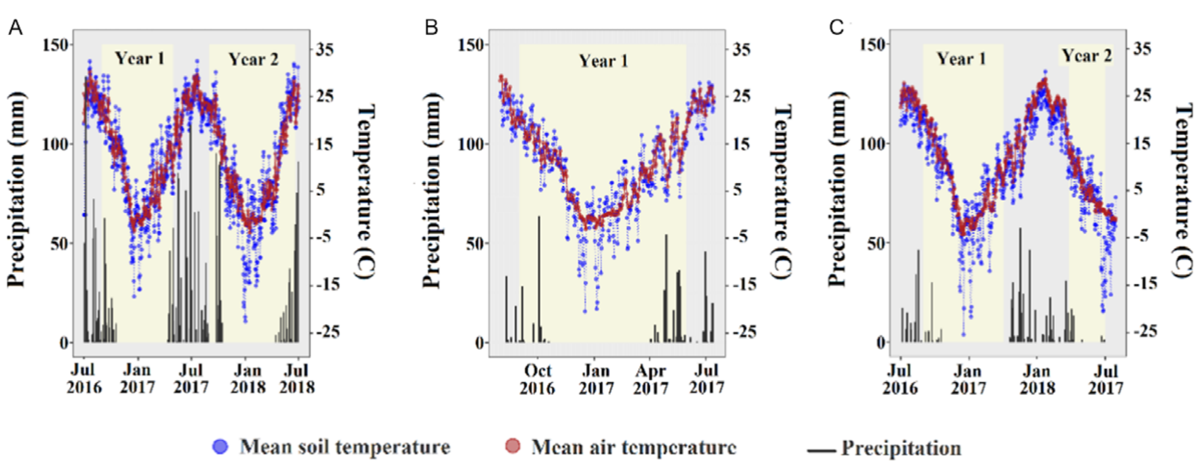

Figure 3. Daily mean air temperature, mean soil temperature, and precipitation of Lincoln, NE (A), North Platte, NE (B), and Scottsbluff, NE (C) research sites during the study in 2016 to 2018. Data were adopted from the High Plains Regional Climate Center website, https://hprcc.unl.edu/.

(<1%) emerged in the subsequent spring (Table 3). The greatest fall emergence density was observed for Lin (average of 852), followed by Npl (770), Scb (670), and Natural (280).

In the rainfed soybean experiment, no difference ($P \geq 0.23$) was observed for 50% (184 to 194 GDDs) cumulative emergence among the horseweed accessions (Figure 4; Table 2). In the fall, the average horseweed density varied from 127 (Natural) to 322 (Npl) seedlings experimental unit^{-1} (Table 3). More than 99% of horseweed seedlings from all accessions emerged in the fall.

Horseweed Emergence in North Platte, NE

In the rainfed wheat stubble experiment, the Scb (165 total emerged seedlings experimental unit^{-1}) required fewer GDDs for 50% emergence compared to the Lin accession, and there was no difference ($P = 0.21$) between Lin (245) and Npl (211) (Figure 4; Table 2). The density of emerged seedlings of the Npl (337) in fall was greatest compared to the other accessions (Table 3). More than 78% of horseweed seedlings from all accessions emerged in the fall.

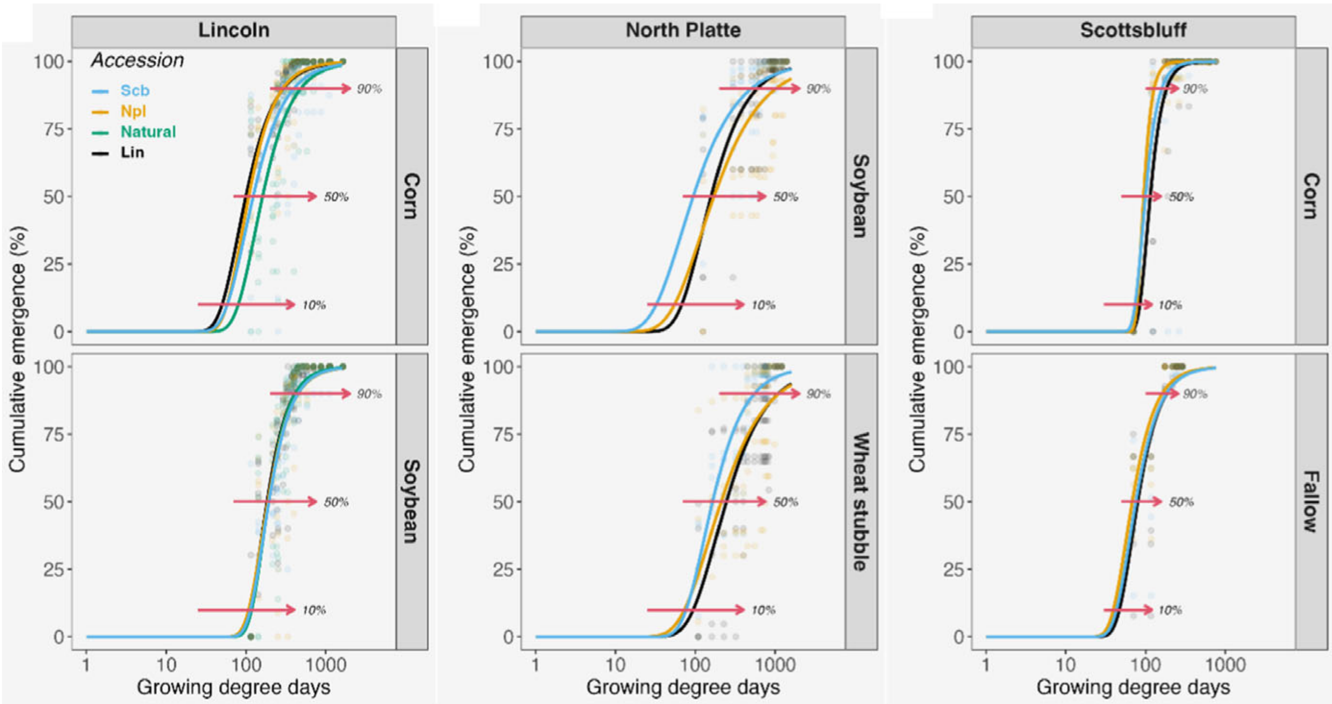

Figure 4. Cumulative emergence (%) of horseweed accessions collected in Lincoln, NE (Lin), North Platte, NE (Npl), and Scottsbluff, NE (Scb), at Lincoln (A), North Platte (B), and Scottsbluff (C) research locations. Model parameters are described in Table 2.

In the irrigated soybean experiment, the Npl accession required more GDDs for 50% emergence compared to the Scb (94 total emerged seedlings experimental unit^{-1}) accession; no difference ($P = 0.43$) was detected between Lin (158) and Npl (172) for the required GDDs for 50% emergence. Most seedlings emerged in the fall (>99%; Table 2). The greatest fall emergence density was observed for Npl (174), followed by Scb (107) and Lin (46) (Table 3).

Horseweed Emergence in Scottsbluff, NE

In the irrigated corn experiment, the Npl (94 total emerged seedlings experimental unit^{-1}) and Scb (100) accessions required fewer GDDs for 50% than the Lin (114) accession (Figure 4; Table 2). Seedling emergence occurred only in fall (100%; Table 3). In the corn experiment, the seedling emergence density of the Scb (792) was greatest, and the seedling emergence density of the Lin (14) was lowest.

In the rainfed fallow experiment, no difference ($P \geq 0.09$) was observed for 50% (68 to 80 GDDs) cumulative emergence among horseweed accessions. No seedling emergence occurred in spring (100% fall emergence; Table 3), and the density of emerged seedlings in the fall was similar across accessions ($P > 0.05$; 17 to 21 seedlings experimental unit^{-1}).

Discussion

Horseweed has a high ability to adapt to new environments (Bajwa et al. 2016; Nandula et al. 2006). Horseweed is reported as a semi–water stress–tolerant species (Bajwa et al. 2016; Nandula et al. 2006). In laboratory conditions, horseweed maintained its emergence at water potential −0.8 Mpa and NaCl concentration of 200 Mm; however, emergence was reduced under these stressful conditions (Nandula et al. 2006). The Scottsbluff location received periodic rainfall during the growing season (Figure 1); the supplementary irrigation in the corn experiment exhibits the potential emergence fitness of the Scb compared to other accessions in more favorable moisture conditions (Table 2). In the Lincoln location, the Natural accession required greater GDDs for 50% emergence than the other introduced accessions (only at the rainfed corn experiment); however, all introduced accessions responded similarly. It is well understood that genetic diversity and different maternal conditions during seed production among populations of a species may cause differences in seedling emergence (Geng et al. 2016; Gioria and Pyšek 2017). In the current study, differences among accessions across environmental conditions were observed. However, except for two out of six experiments (fallow experiment at Scottsbluff and soybean experiment at Lincoln), the greatest density of emerged seedlings of each accession was observed in their location of origin. This showcases the effect of local environmental conditions during seed production (aka maternal effect) as the same seed source was used during the study. The unique ecophysiological features of horseweed, such as prolific seed production, long-distance seed dispersal via wind, and competitiveness, make it able to invade and establish in a broad range of environments (Bajwa et al. 2016; Ottavini et al. 2019; Yan et al. 2020). Therefore special attention should be paid to implementing tactics that can reduce its introduction and establishment into neighboring areas.

Microsite conditions are critical for horseweed emergence, as seed dormancy is not reported for this species (Regehr and Bazzaz 1979; Weaver 2001). Crop residue and crop canopy act as physical barriers and can affect the microsite soil hydrothermal conditions and light transmission to topsoil (Grundy and Bond 2007; Teasdale 1996). Crop residue on the soil surface may increase water availability to trigger seed germination; however, low crop

Table 2. GDD requirement for 10%, 50%, and 90% cumulative emergence for accessions collected in Lincoln, North Platte, and Scottsbluff, NE, at Lincoln, North Platte, and Scottsbluff research locations.[a,b]

Research location	Crop	Horseweed accession	GDD requirement for emergence			Model parameters[c]		
			10%	50%	90%	e	b	RMSE
Lincoln	Rainfed corn	Lin	50 [34, 66]	100 [82, 118]	293 [242, 344]	80.76 (±9.04)	−1.74 (±0.21)	0.556
		Natural[d]	80 [65, 95]	161 [145, 177]	487 [420, 554]	130.27 (±8.05)	−1.71 (±0.13)	
		Npl	58 [42, 74]	108 [92, 124]	290 [240, 341]	89.35 (±8.28)	−1.91 (±0.24)	
		Scb	58 [43, 73]	123 [106, 140]	399 [330, 467]	97.85 (±8.36)	−1.60 (±0.16)	
	Rainfed soybean	Lin	110 [98, 122]	184 [172, 196]	412 [369, 456]	158.86 (±6.14)	−2.34 (±0.16)	0.554
		Natural	118 [105, 130]	192 [180, 204]	414 [373, 455]	157.35 (±5.98)	−2.45 (±0.17)	
		Npl	108 [96, 120]	188 [176, 201]	451 [401, 500]	165.23 (±6.07)	−2.16 (±0.14)	
		Scb	113 [100, 127]	194 [180, 207]	448 [401, 495]	164.43 (±6.77)	−2.24 (±0.16)	
North Platte	Rainfed wheat stubble	Lin	94 [69, 120]	245 [210, 279]	1,093 [808, 1,377]	182.99 (±15.78)	−1.26 (±0.12)	0.975
		Npl	73 [50, 96]	211 [177, 245]	1,114 [790, 1,438]	152.72 (±15.52)	−1.13 (±0.11)	
		Scb	77 [58, 96]	165 [142, 188]	548 [408, 689]	130.76 (±10.77)	−1.57 (±0.17)	
	Irrigated soybean	Lin	68 [44, 88]	158 [130, 186]	599 [457, 740]	121.99 (±12.74)	−1.41 (±0.14)	0.789
		Npl	55 [33, 77]	172 [135, 208]	1,027 [756, 1,299]	121.15 (±16.20)	−1.12 (±0.16)	
		Scb	32 [12, 53]	94 [60, 129]	505 [347, 664]	68.10 (±15.14)	−1.05 (±0.10)	
Scottsbluff	Irrigated corn	Lin	84 [77, 92]	114 [109, 119]	183 [168, 199]	104.14 (±2.98)	−3.97 (±0.41)	0.391
		Npl	78 [67, 89]	94 [87, 102]	128 [118, 138]	88.93 (±4.50)	−6.18 (±1.15)	
		Scb	74 [68, 79]	100 [95, 104]	160 [145, 175]	90.78 (±2.36)	−3.99 (±0.38)	
	Rainfed fallow	Lin	47 [39, 55]	80 [71, 88]	184 [155, 212]	67.66 (±4.06)	−2.25 (±0.22)	0.856
		Npl	39 [30, 48]	68 [59, 77]	161 [132, 190]	57.51 (±4.48)	−2.19 (±0.27)	
		Scb	43 [31, 51]	75 [67, 84]	182 [151, 212]	63.55 (±4.29)	−2.14 (±0.22)	

[a]In brackets are the 95% confidence interval upper and lower limits.
[b]Abbreviations: GDD, growing degree day; Lin, Lincoln, NE; Npl, North Platte, NE; RMSE; root mean square error; Scb, Scottsbluff, NE.
[c]$Y = d\ \exp\{-\exp[b(\log(x) - e)]\}$, where Y is the horseweed cumulative emergence, d is the upper limit (set to 100), e is the inflection point, b is slope, and x is the GDDs. In parentheses is standard error.
[d]In Lincoln, an extra treatment was included to monitor the natural horseweed population (Natural).

Table 3. Total emergence of horseweed seedlings for accessions collected in Lincoln, North Platte, and Scottsbluff, NE, at Lincoln, North Platte, and Scottsbluff research locations.[a,b]

Research location	Crop	Horseweed accession	Horseweed density	
			Fall	Spring
			emerged seedlings experimental unit^{-1}	
Lincoln	Rainfed corn	Lin	852 a	1 ef
		Natural[c]	280 d	2 e
		Npl	770 b	2 e
		Scb	670 c	0 f
	Rainfed soybean	Lin	165 b	1 e
		Natural	127 d	1 e
		Npl	322 a	1 e
		Scb	140 c	0 e
North Platte	Rainfed wheat stubble	Lin	29 c	8 d
		Npl	337 a	10 d
		Scb	203 b	8 d
	Irrigated soybean	Lin	46 c	1 d
		Npl	174 a	3 d
		Scb	107 b	3 d
Scottsbluff	Irrigated corn	Lin	14 c	0 d
		Npl	48 b	0 d
		Scb	792 a	0 d
	Rainfed fallow	Lin	20 a	0 b
		Npl	21 a	0 b
		Scb	17 a	0 b

[a]Letters show grouping differences between means for fall and spring emergence cohorts within each experiment at each research site.
[b]Abbreviations: Lin, Lincoln, NE; Npl, North Platte, NE; Scb, Scottsbluff, NE.
[c]In Lincoln, an extra treatment was included to monitor the natural horseweed population (Natural).

residue levels (e.g., absence of a physical barrier on the soil surface) may result in higher weed emergence and establishment (Chauhan and Johnson 2011; Mobli and Chauhan 2020a). Daily temperature fluctuation has been reported not to influence the emergence of horseweed, and light exposure is not a mandatory factor for its germination (Nandula et al. 2006; Ottavini et al. 2019). In the current study, the effect of cropping systems on horseweed emergence suppression was not directly compared; therefore further studies are required to fully understand the effects of cropping systems on horseweed emergence.

In the selected research sites in Nebraska, fresh horseweed seeds could emerge from late summer to late spring (September to June). However, most seedling emergence occurred in the fall (>99%), and only a few seedlings (except for the rainfed wheat stubble experiment at North Platte, where higher spring emergence was detected [3% to 22%]) emerged in the spring. The present study demonstrates that the horseweed accessions from Nebraska have a predominant fall emergence window that may reflect common agronomic practices across the state (widespread adoption of no-till soil conservation practices and fall burndown herbicide applications not as a standard practice). In contrast, in previous studies in Indiana and Illinois, most horseweed emerged in the spring (Davis et al. 2010). Spring emergence has also been reported in Michigan (Schramski et al. 2021). Bhowmik and Bekech (1993) hypothesized that shifted horseweed emergence from fall to spring could be a mechanism to escape from fall management (e.g., fall herbicide burndown, fall tillage). Therefore management strategies should be designed based on the emergence pattern in each location and weed management history. In Nebraska corn–soybean rotations, horseweed management after crop harvest can be beneficial. However, the environmental conditions following crop harvest in the fall are not always favorable for management strategies, and under unfavorable conditions, growers would have to wait until conditions become suitable early in the spring.

The results from this study provide primary input for decision-making models and could contribute to developing effective horseweed management practices across Nebraska cropping systems. Late fall or early spring management with effective burndown herbicide(s) or shallow tillage could be an option for management of fall-emerging cohorts. Alternatively, cover crops are considered as one of the most compatible nonchemical horseweed management strategies in no-till corn–soybean rotations. Fall cover crops can reduce horseweed density and the evolution of herbicide-resistant biotypes (DeSimini et al. 2020; Wallace et al. 2019; Werle et al. 2017). Although most seedlings emerged in the fall, management of spring cohorts should not be neglected, as horseweed is a prolific seed producer, and continuous development of fall horseweed management strategies may increase the selection pressure on spring-emerging biotypes, as has been observed in other states.

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