Effect of common waterhemp (Amaranthus rudis) emergence date on growth and fecundity in soybean

Authors: Hartzler, Robert G., Battles, Bruce A., and Nordby, Dawn

Source: Weed Science, 52(2) : 242-245

Published By: Weed Science Society of America

URL: https://doi.org/10.1614/WS-03-004R

Weed Science, 52:242–245. 2004

Effect of common waterhemp (*Amaranthus rudis*) emergence date on growth and fecundity in soybean

Robert G. Hartzler
Corresponding author. Department of Agronomy, Iowa State University, Ames, IA 50011; hartzler@iastate.edu

Bruce A. Battles
Dawn Nordby
Department of Agronomy, Iowa State University, Ames, IA 50011

Field experiments were conducted in central Iowa to determine the growth of common waterhemp emerging after postemergence herbicide applications in soybean. Common waterhemp survival declined as emergence was delayed in relation to soybean. Ninety percent of plants emerging at approximately the same time as soybean survived, whereas only 13% of plants emerging approximately 50 d after planting (DAP) survived to maturity. Biomass accumulation declined rapidly as emergence was delayed in relation to soybean. Delaying emergence from 14 to 28 DAP resulted in a 50 to 80% reduction in shoot biomass. Common waterhemp emerging 50 DAP produced only 1 to 10% of the biomass of plants emerging at the same time as soybean. Plants emerging with soybean produced approximately 300,000 to 2.3 million seeds plant^{-1} depending on the location. Fecundity of common waterhemp plants was closely related to biomass accumulation and declined rapidly with delayed emergence. Although common waterhemp emerging after the V4 stage of soybean (40 DAP) are unlikely to affect crop yield because of high mortality levels and reduced growth, these plants may contribute significant seeds to the soil seed bank.

Nomenclature: Common waterhemp, *Amaranthus rudis* Sauer AMATA; soybean, *Glycine max* (L.) Merr.

Key words: AMATA, critical period, delayed emergence, fecundity.

Common waterhemp is native to the north-central region of the United States and since the 1980s has been one of the most problematic weeds of corn (*Zea mays* L.) and soybean production (Hager et al. 1997). Several factors have contributed to the increasing problems associated with this weed species. Unlike in the 1970s and earlier, less-intensive tillage systems are currently used in corn and soybean production, and these systems favor small-seeded weed species such as common waterhemp (Buhler 1992; Buhler and Oplinger 1990). Common waterhemp populations resistant to acetolactate synthase–inhibiting (Hinz and Owen 1997) and triazine herbicides (Foes et al. 1998; Horak and Peterson 1995) have been identified in Iowa and surrounding states. Finally, common waterhemp initiates emergence later, and emergence occurs during a longer time period than many summer annual weeds of the north-central United States (Hartzler et al. 1999). The delayed and prolonged emergence of common waterhemp is advantageous to survival under current weed management systems that rely less on residual herbicides and cultivation (Hager et al. 1997).

Although delayed emergence in relation to the crop may allow weeds to avoid control tactics, late emergence places the weed at a competitive disadvantage with the crop. The majority of research investigating time of weed emergence has focused on the effect of the weed on crop yield. In a review of weed interference in soybean, Stoller et al. (1987) concluded that the yield loss associated with interference declined rapidly as weed emergence was delayed at least 3 wk after soybean emergence. *Amaranthus* spp. emerging at the V2 to V3 soybean stages were approximately 25% as competitive as plants emerging with soybean (Cowan et al. 1998). Dielman et al. (1995) concluded that emergence time of *Amaranthus* spp. in soybean was more important in determining the yield effect of the weed than was weed density.

Although delays in emergence may diminish the yield effect of a weed infestation, seed production by these weeds may still be a concern. Shading by corn resulted in less branching of redroot pigweed (*Amaranthus retroflexus* L.) and an increase in the proportion of dry matter in the upper part of the plant canopy compared with plants grown in full sunlight (McLachlan et al. 1993). This plasticity can result in significant seed production from plants at a competitive disadvantage with the crop due to delayed emergence. Redroot pigweed emerging up to the four-leaf stage of corn produced 15,000 to 32,000 seeds plant^{-1} (Knezevic et al. 1994). When emergence was delayed until the four- to seven-leaf stage, seed production was reduced to 5,000 seeds or less.

The prolonged emergence pattern of common waterhemp creates management problems for farmers because significant numbers of plants may emerge after preemergence herbicides have dissipated or nonresidual postemergence herbicides have been applied. Farmers often must make decisions on whether to implement supplementary control tactics to eliminate common waterhemp that emerge after primary control tactics. The objective of this research was to determine the growth and fecundity of common waterhemp that emerges after postemergence herbicide applications. This information can be used by farmers to evaluate the need for implementing additional control tactics for weeds that emerge after primary tactics have been applied.

Materials and Methods

Four field experiments were conducted during 1998 and 1999 in central Iowa within 65 km of Ames. Similar pro-

Table 1. Site characteristic, dates of planting, and herbicide application dates for the four experiments.

	Ames	Collins	Iowa Falls	Stratford
Soil type	Spillville loam (mesic, Cumulic Hapludoll)	Webster silty clay loam (mesic, Typic Haplaquoll)	Webster-Nicollet clay loam (mesic, Typic Haplaquolls)	Marna silty clay loam (mesic, Typic Haplaquoll)
Organic matter (%)	3.2	5.4	4.0	4.0
Soybean variety	Asgrow 3002RR	Asgrow 3001RR	Asgrow 3002RR	Asgrow 3001RR
Date of planting	May 20, 1999	May 13, 1998	June 2, 1999	May 15, 1998
Glyphosate application (DAP)[a]				
V2	28	31	29	25
V4	42	39	41	38
V6	49	52	48	48

[a] Abbreviation: DAP, days after planting.

tocols were used in all experiments, and specific information for the individual experiments is provided in Table 1. All fields were planted to corn in the season before the experiment. The experimental area was chisel plowed in the fall and field cultivated immediately before planting. Glyphosate-resistant soybean was planted in 76-cm rows at a population of 342,000 seeds ha^{-1}. Individual plots were 3.0 m wide by 12.1 m long.

Four common waterhemp emergence cohorts were established in relation to the soybean stage of development (VE, V2, V4, and V6). The VE cohort comprised the first common waterhemp plants that emerged after soybean planting, approximately 14 to 20 d after planting (DAP) depending on the location. Soybean emerged within 6 to 12 DAP. The later cohorts were selected by applying 840 g ae ha^{-1} glyphosate at the V2, V4, and V6 soybean stages and selecting plants that emerged shortly after application. Common waterhemp plants typically emerged within 2 to 7 d after application. Application dates for the three glyphosate treatments are indicated in Table 1. The experiments at Collins, Iowa Falls, and Stratford had natural infestations of common waterhemp, whereas at Ames, common waterhemp seeds that had been soaked in water for 1 wk were planted immediately after planting of soybean or after the glyphosate application. Seeds were planted at a density of approximately 200 seeds m^{-1} of row. Common waterhemp plants emerging at the appropriate time were marked shortly after emergence using aluminum tags attached to a wire. Plants that were within a band 10 to 20 cm to the side of the center two soybean rows of a plot and separated by at least 0.5 m from other waterhemp plants were selected.

A randomized complete block design with three replications was used for all experiments. Twenty common waterhemp plants per plot were selected, resulting in a total of 60 plants per cohort. All weeds within the plots except the selected waterhemp plants were controlled with glyphosate applications and hand weeding. Tagged common waterhemp plants were covered with plastic cups when plots were sprayed. No plots received more than two glyphosate applications.

Height and survival of tagged common waterhemp plants were recorded throughout the growing season. At the initiation of senescence, common waterhemp plants were cut at the soil surface and placed in cloth bags. Plants were dried to constant weight in an oven for 5 d at 35 C. Dry weights were recorded, seeds were separated from female plants using a rotary seed cleaner and screens, and seeds were then weighed. Seeds per plant were determined by weighing 10 seed lots of 100 seeds to determine average seed weight and then calculating seed number on a weight basis. Soybean yields were not recorded because the densities studied were sufficiently low (< 0.5 plants m^{-2}) such that a significant yield effect was considered unlikely (Dielman et al. 1995). In addition, differential mortality of waterhemp plants occurred, resulting in different densities within treatments that would have confounded results.

Data were tested for homogeneity of variance before analysis of variance and regression procedures. There was not a significant location by treatment interaction in common waterhemp survival; thus, data from the four experiments were pooled. However, an interaction among height, biomass, and seed production among the experiments was observed. Further analysis indicated that the interaction was due to a differential response at the Collins experiment compared with the other three sites. Thus, data for common waterhemp height, biomass, and fecundity were combined for the Ames, Stratford, and Iowa Falls locations, whereas the Collins data are presented separately. For regression analysis, waterhemp emergence was set as the average DAP of the glyphosate applications in the four experiments. The rationale for this is that the objective of the project was to evaluate the productivity of plants emerging after postemergence herbicide applications. There were relatively small differences in the timing of the postemergence applications among the four experiments (Table 1).

Results and Discussion

Survival rates of common waterhemp declined with delayed emergence (Figure 1). Survival of the first cohort was 90%, and survival decreased by approximately 20 to 30% with each successive delay in emergence. Most studies investigating effects of delayed weed emergence on weed growth and competitiveness have not reported mortality rates associated with delayed emergence (Knezevic et al. 2001; Massinga et al. 2001; McLachlan et al. 1993). Mohler and Calloway (1992) reported that late-emerging weeds in sweet corn had higher survival rates than early-emerging cohorts because the late-emerging weeds were not exposed to mortality factors such as herbicides or interrow cultivation. Velvetleaf (*Abutilon theophrasti*) seedling survival was reduced in the presence of a soybean canopy, with mortality levels increasing with later emergence (Lindquist et al. 1995). Morality rates of 50 to 80% for wild oats (*Avena*

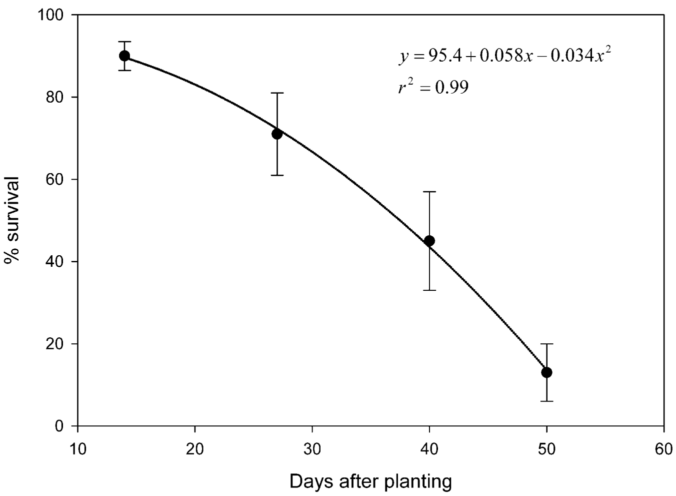

FIGURE 1. Survival rate of common waterhemp as affected by emergence delays in relation to soybean planting. Means and standard errors of means are pooled data from four experiments.

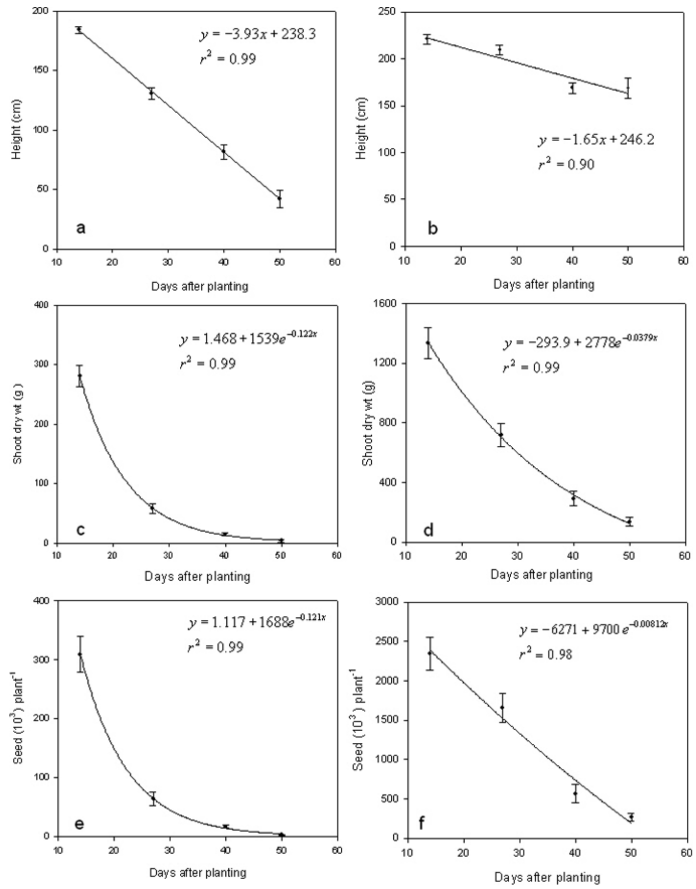

FIGURE 2. Height, shoot dry weight, and fecundity of common waterhemp as affected by emergence delays in relation to soybean planting. Pooled data from three experiments (a, c, and e), and data from the Collins location (b, d, and f). Bars represent standard errors of means.

fatua L.) that emerged late in wheat (*Triticum aestivum* L.) were attributed to competition with the established crop and earlier emerging weeds (Fernandez-Quintanilla et al. 1986).

The height of common waterhemp plants emerging with soybean at the three combined sites averaged 180 cm (Figure 2a). Emergence delays in relation to soybean resulted in a linear decrease in common waterhemp height, with each week of delay resulting in approximately a 30-cm reduction. The majority of common waterhemp emerging 40 or 50 DAP (V4 or V6 soybean stage) at these sites did not extend above the soybean canopy at the end of the growing season. The variability within emergence cohorts increased with delays in emergence. High levels of competition frequently result in an increase in size inequality (Weiner 1985; Weiner and Thomas 1986).

The earliest common waterhemp cohort at Collins averaged 221 cm, approximately 50 cm taller than corresponding plants at the other three sites (Figure 2b). A linear decline in height with emergence delays occurred, but the rate of decline was much less at Collins than at the other experiment sites. Each week delay in common waterhemp emergence resulted in only an 11-cm height reduction at Collins, compared with a 30-cm reduction at the combined locations (Figures 2a and 2b). The majority of the common waterhemp extended above the soybean canopy at the end of the growing season at Collins, regardless of emergence date.

The earliest emerging cohort at the combined locations averaged 280 g plant^{-1} (Figure 2c). Biomass accumulation by common waterhemp was more sensitive to emergence delays than plant height. Common waterhemp dry weight decreased by 80% when emergence was delayed from 14 to 27 DAP. Each successive delay in emergence resulted in approximately a 75% reduction in dry weight. Common waterhemp at Collins were much larger than those at the combined sites, with the early cohort accumulating more than 1,300 g plant^{-1} (Figure 2d). Each delay in emergence resulted in approximately a 50% reduction in dry weight compared with the previous cohort. Common waterhemp emerging 40 DAP (V4 application) at Collins accumulated biomass similar to that of common waterhemp that emerged with soybean at the other sites. The greater productivity of common waterhemp at Collins compared with the other sites may be due to the Collins experiment being positioned in a low, poorly drained area (Webster soil) of the field. Common waterhemp favors wet soils (Hager et al. 1997); thus, the Collins site may have provided an ideal environment for the weed. The other experiments were positioned in areas of fields with better drainage. Although no measurements of soybean canopy were taken, there was no visible evidence of suppressed soybean growth due to excessive soil moisture at Collins.

The vertical distribution of dry matter of redroot pigweed growing in corn (McLachlan et al. 1993) and sorghum [*Sorghum bicolor* (L.) Moench] (Knezevic et al. 2001) was altered compared with plants grown in the absence of competition. Delays in redroot pigweed emergence in relation to corn resulted in plants allocating a greater percentage of biomass to the main stem components and reducing allocation to branch components (McLachlan et al. 1993). Late-emerging redroot pigweed also allocated a higher proportion of dry matter in the upper portion of canopy than plants emerging with the crop. Although canopy architecture was not evaluated, the differential response of common waterhemp height and biomass to delayed emergence indicates that plants responded to crop shading by increasing allocation of resources to stem elongation as reported in other studies (Knezevic et al. 2001; McLachlan et al. 1993).

Female common waterhemp plants emerging with soybean averaged 309,000 seeds plant^{-1} at the combined sites, whereas at Collins common waterhemp produced more than 2.3 million seeds plant^{-1} (Figures 2e and 2f). The most productive plant at Collins produced more than 4.8 million seeds (data not shown). The decline in seed production due to late emergence was similar to the decline in dry weight. At Collins, plants emerging 27, 40, and 50 DAP produced 1,658,000, 566,000, and 265,000 seeds, respectively. At the combined locations, plants emerging 27, 40, and 50 DAP produced 64,000, 17,000, and 3,000 seeds plant^{-1}, respectively. The latest emerging common waterhemp at Collins produced approximately 85% of the seeds as the first waterhemp cohort at the combined sites.

Common waterhemp emerging with soybean planted in 0.76-cm rows produced 200,000 seeds plant^{-1} in Illinois, whereas in narrow rows production was reduced to 190,000 seeds plant^{-1} (Steckel and Sprague 2003). Redroot pigweed growing in monoculture at a density of 0.5 plant m^{-1} row produced up to 400,000 seeds plant^{-1}, whereas plants grown in competition with sorghum planted in 0.76-cm rows produced only 80,000 seeds (Knezevic and Horak 1998). Redroot pigweed grown in competition with corn in Ontario, Canada, had a maximum seed production of 30,000 seeds plant^{-1} (Knezevic et al. 1994). Palmer amaranth (*Amaranthus palmeri*) growing with corn produced more than 160,000 seeds plant^{-1} (Massinga et al. 2001).

The rapid reduction in common waterhemp biomass accumulation and high mortality rates associated with delayed emergence indicates that late-emerging plants would have much less effect on soybean yield than plants that emerge with the crop. In a review of weed competition in soybean, Stoller et al. (1987) concluded that the yield loss declined rapidly as weed emergence was delayed by at least 3 wk. Researchers in Ontario, Canada, reported that redroot pigweed emerging after the V2 stage of soybean was noncompetitive in terms of yield loss (Dielman et al. 1995). However, they reported that redroot pigweed emerging after the V2 stage did not exceed a height of 10 cm, whereas in our studies, common waterhemp reached at least 40 cm when emerging as late as the V6 soybean stage.

Moderate common waterhemp densities that emerge after the V4 soybean stage should not pose significant yield penalties under most situations because of the combination of reduced growth and relatively high mortality levels (> 50%). However, the prolific seed production capacity of common waterhemp allows late-emerging plants to contribute large quantities of seeds to the soil seed bank. A threshold value for velvetleaf that included an estimate for cost of weed seed production was 7.5-fold lower than a threshold based solely on effects of competition on soybean yields (Bauer and Mortensen 1992). Therefore, growers need to implement management practices that extend weed control beyond the period required to protect soybean yield in order to minimize common waterhemp seed production. Integrated management programs that combine control tactics and allow postermergence strategies to be delayed until at least the V4 stage are essential in maintaining effective long-term common waterhemp management.

Acknowledgment

This research was partially funded by a grant from the Iowa Soybean Promotion Board.

Literature Cited

Bauer, T. A. and D. A. Mortensen. 1992. A comparison of economic and economic optimum thresholds for two annual weeds in soybeans. Weed Technol. 6:228–235.
Buhler, D. D. 1992. Population dynamics and control of annual weeds in corn (*Zea mays*) as influenced by tillage systems. Weed Sci. 40:241–248.
Buhler, D. D. and E. S. Oplinger. 1990. Influence of tillage systems on annual weed densities and control in solid-seeded soybean (*Glycine max*). Weed Sci. 38:158–164.
Cowan, P., S. E. Weaver, and C. J. Swanton. 1998. Interference between pigweed (*Amaranthus* spp.), barnyardgrass (*Echinochloa crus-galli*), and soybean. Weed Sci. 46:533–539.
Dielman, A., A. S. Hammill, S. F. Weise, and C. J. Swanton. 1995. Empirical models of pigweed (*Amaranthus* spp.) interference in soybean (*Glycine max*). Weed Sci. 43:612–618.
Fernandez-Quintanilla, C., L. Navarette, J.L.G. Anduajar, A. Fernandez, and M. J. Sanchez. 1986. Seedling recruitment and age-specific survivorship and reproduction in populations of *Avena sterilis* L. ssp. *ludoviciana* (Durieu) Nyman. J. Appl. Ecol. 23:945–955.
Foes, M. J., L. Liu, P. J. Tranel, L. M. Wax, and E. W. Stoller. 1998. A biotype of common waterhemp (*Amaranthus rudis*) resistant to triazine and ALS herbicides. Weed Sci. 46:514–520.
Hager, A. G., L. M. Wax, R. W. Simmons, and E. W. Stoller. 1997. Waterhemp Management in Agronomic Crops. University of Illinois Bull. X855. 12 p.
Hartzler, R. G., D. D. Buhler, and D. E. Stoltenberg. 1999. Emergence characteristics of four annual weed species. Weed Sci. 47:578–584.
Hinz, J.R.R. and M.D.K. Owen. 1997. Acetolactate synthase resistance in a common waterhemp (*Amaranthus rudis*) population. Weed Technol. 11:13–18.
Horak, M. J. and D. E. Peterson. 1995. Biotypes of Palmer amaranth (*Amaranthus palmeri*) and common waterhemp (*Amaranthus rudis*) are resistant to imazethapyr and thifensulfuron. Weed Technol. 9:192–195.
Knezevic, S. Z. and M. J. Horak. 1998. Influence of emergence time and density on redroot pigweed (*Amaranthus retroflexus*). Weed Sci. 46: 665–672.
Knezevic, S. Z., R. L. Vanderlip, and M. J. Horak. 2001. Relative time of redroot pigweed emergence affects dry matter partitioning. Weed Sci. 49:617–621.
Knezevic, S. Z., S. F. Wiese, and C. J. Swanton. 1994. Interference of redroot pigweed (*Amaranthus retroflexus*) in corn (*Zea mays*). Weed Sci. 42:568–573.
Lindquist, J. L., B. D. Maxwell, D. D. Buhler, and J. L. Gunsolus. 1995. Velvetleaf recruitment, survival, seed production, and interference in soybean (*Glycine max*). Weed Sci. 43:226–232.
Massinga, R. A., R. S. Currie, M. J. Horak, and J. Boyer, Jr. 2001. Interference of Palmer amaranth in corn. Weed Sci. 49:202–208.
McLachlan, S. M., M. Tollenaar, C. J. Swanton, and S. F. Weise. 1993. Effect of corn-induced shading on dry matter accumulation, distribution, and architecture of redroot pigweed (*Amaranthus retroflexus*). Weed Sci. 41:568–573.
Mohler, C. L. and M. B. Calloway. 1992. Effects of tillage and mulch on the emergence and survival of weeds in sweet corn. J. Appl. Ecol. 29: 21–34.
Steckel, L. E. and C. L. Sprague. 2003. Late season common waterhemp (*Amaranthus rudis*) interference in soybean. Weed Sci. Soc. Am. Abstr. 43:18.
Stoller, E. W., S. K. Harrison, L. M. Wax, E. E. Regnier, and E. D. Nafziger. 1987. Weed interference in soybeans (*Glycine max*). Rev. Weed Sci. 3:155–181.
Weiner, J. 1985. Size hierarchies in experimental populations of annual plants. Ecology 66:743–752.
Weiner, J. and S. C. Thomas. 1986. Size variability and competition in plant monocultures. Oikos 47:211–222.

Received January 3, 2003, and approved August 15, 2003.