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Decline of Weed Seeds and Seedling Emergence Over Five Years as Affected by Soil Disturbances[1]

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Abstract. **Weed emergence and viable weed seed numbers were determined in field plots during a 5-yr period where reseeding was prevented. Known numbers of seeds of seven weed species were added to the native seed population at the beginning of the study. Plots were nontilled or tilled to depths of 0, 5, 10, and 15 cm early in the spring of each year. Velvetleaf, spurred anoda, hemp sesbania, morningglory species, and pigweed species emergence was significantly greater from the nontilled plots during the first year after seeds were added to the native seed population. Tillage, regardless of depth, reduced weed emergence during the first year where seeds were added to the plots but had no effect on emergence from plots where no seeds were added. Tillage during the second through the fifth year did not affect emergence regardless of the addition of seeds. Of the 5-yr emergence totals, 61 to 88% of all weeds in all plots emerged during the first year and 9 to 23% emerged during the second year. The 5-yr decline rate for emergence of all weeds was exponential. Viable seeds of prickly sida, spurges, and pigweeds in the nontilled plots declined from 590, 1531, and 4346 m^{-2}, respectively, to zero by the third year. Tillage did not affect the decline. However, weed emergence in the field indicated that a few (1.0 to 5.6 m^{-2}) seeds of those weeds were still viable after 3 yr. In nontilled plots, many recently added seeds were on or near the soil surface and germinated during the first year. Tillage moved many seeds to sites that were unfavorable for germination and emergence during the first year. Nomenclature: Glyphosate, N-(phosphonomethyl)glycine; hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. ex A. W. Hill #[3] SEBEX]; morningglory (*Ipomoea* spp.); pigweed (*Amaranthus* spp.); prickly sida (*Sida spinosa* L.) # SIDSP; spurge (*Euphorbia* spp.); spurred anoda [*Anoda cristata* (L.) Schlecht. # ANVCR]; velvetleaf (*Abutilon theophrasti* Medik.) # ABUTH.**
Additional index words. **Tillage, weed seed longevity, weed seed viability, weed seed germination, ABUTH, ANVCR, POROL, SEBEX, SIDSP.**

INTRODUCTION

Agricultural soils contain many weed seeds (2, 14, 19). Some seeds are nondormant and germinate quickly while other seeds may persist for many months or years before germinating (6, 13). Conventional herbicidal and cultural procedures control weeds after germination but normally have little to no effect on dormant and other nongerminated seeds (8). Thus, nongerminated seeds pose potential weed problems. Even if 100% weed control is achieved, the soil reservoir (weed seed bank) of nongerminated, dormant seeds may persist to intermittently germinate and cause problems. Information on decline rates of viable weed seeds in soil is important to the development of proper weed management strategies during the period of seed persistence.

Germination of many seeds is promoted by soil disturbance (3, 5, 7, 14, 17, 19). The bases for the promotion are not precisely known, but exposure to light, improved soil aeration, increased loss of volatile inhibitors from soil, and movement of seeds to more favorable germination sites are possibilities (7, 8). However, germination of some seeds is not enhanced by soil disturbance (12). Some reasons for poor germination include exposure of negatively photosensitive seeds to light, movement of seeds to the surface where moisture may be inadequate for germination, or movement of seeds from near the surface to greater depths (10). Thus, the type, depth, and frequency of soil disturbance are important to the fate of weed seeds.

When fresh seed production was prevented, weed seed banks were reduced by as much as 90% within 4 to 6 yr (4, 15, 18, 21, 22). However, the seed bank was replenished within a few years when intensive weed control efforts were relaxed (4, 16). This recovery was due to reinfestation from seeds produced by plants arising from the few seeds that survived the period of intensive weed control. It was concluded that weed eradication was economically impractical with the current technology because 100% weed control is required as long as some viable seeds persisted in the soil (24). Replenishment of the seed bank can rapidly occur because many weeds produce several thousand seeds per plant (5).

In the present 5-yr field study, the decline of weed seeds and seedling emergence of several summer annuals were determined when production of new seeds was prevented. The effects of different depths of soil disturbance upon the decline was also determined. This information is important to a better understanding of how tillage can influence the period of viable weed seed survival in soil of the warm, humid midsouthern U.S.

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

MATERIALS AND METHODS

Field plot preparation. The study was conducted at Stoneville, MS, on an approximately 1-ha field that had been in cotton production from 1971 through 1975. The field remained idle during 1976 and weeds were allowed to mature and produce seeds to increase the weed seed population. In October 1976, the field was mowed to reduce standing vegetation and the soil was disced to a depth of 20 cm. It was then smoothed with a light spring-toothed cultivator. A shallow trench was dug around the periphery of the field to prevent runoff water from adjacent areas from crossing the field. The areas immediately surrounding the field were disced or mowed periodically to minimize weed seed production. The soil was a Rustin silty clay loam (fine-loamy, siliceous, thermic Typic). The texture ranged from 6 to 38% sand, 17 to 43% clay, and 42 to 54% silt. Organic matter ranged from 0.1 to 1.0% and soil pH ranged from 6.8 to 7.5. Forty 6.1- by 12.2-m plots with 6.1-m borders were marked within the field. In September and October of 1976, newly matured seeds of seven weed species were collected from a weed nursery established at Stoneville, MS. The weed species were velvetleaf, redroot pigweed, spurred anoda, pitted morningglory, hemp sesbania, prickly sida, and johnsongrass. Tests for germination and for viable embryos (response to 2,3,6-triphenyltetrazolium chloride) (9) indicated that seeds of all species were >98% viable. On November 17, the soil surface was smoothed to produce a fine seed bed and 2000 seeds of each species were uniformily dispersed over the center 1.5- by 5-m portion of 20 plots. No seeds were added during the remainder of the study. Therefore, the soil seed population of 20 plots consisted of native seeds plus seeds that were manually added, whereas the seed population of the other 20 plots consisted of only native seeds.

Soil disturbance treatments. In late autumn and late winter, all plots were mowed with a lawn mower to prevent build-up of dense stands of winter vegetation. In March of each year, the few winter weeds (predominately small annuals) in all plots were eliminated by spraying with 1.1 kg ha^{-1} paraquat (1,1-dimethyl-4,4′-bipyridinium ion). Designated plots were then tilled to depths of 5, 10, and 15 cm with the tractor-drawn light cultivator, disc, and deep-cutting disc, respectively. Trials were previously conducted to determine proper setting of implements to achieve desired depths. Tilled plots received two passes in opposite directions along the plot length. Disced plots also received two passes with the light cultivator to smooth the seed bed surface. Check plots were not tilled in the spring. In November, 1977, all plots were tilled to a depth of 5 cm to reduce winter weed stands and minimize soil crusting. However, the plots were not tilled in the autumn in subsequent years. Except for mowing to prevent build-up of vegetation, no attempt was made thereafter to eliminate winter weeds that emerged during November to March.

The experiment was a completely randomized block design with each treatment replicated 10 times. Five replications consisted of plots with native seed populations plus seeds added in 1976 and five replications consisted of plots with native seed populations only.

Weed emergence in the field. From April through September or October of each year, the species and number of weeds emerging in each plot were recorded at 2- or 3-week intervals. Immediately after each evaluation, emerged seedlings were sprayed with 1.1 kg ha^{-1} glyphosate [*N*-(phosphonomethyl)glycine] to prevent their inclusion in future counts. Glyphosate was previously shown not to inhibit subsequent weed germination and emergence (11).

Weeds were counted by placing a grid over the plot and determining the mean number of seedlings within five equally spaced areas (30 by 130 cm). Grasses were aggregated because newly emerged seedlings were not positively identified. Morningglory, spurge, and pigweed seedlings were recorded by genus. Environmental data included soil temperatures (5-cm depth) and rainfall recorded at Stoneville during the study[4].

Greenhouse bioassay of soil samples. In late August of 1977, 1978, and 1979, five soil cores (3.8-cm diam by 20 cm deep) were taken from the center of each plot adjacent to, but not within, each of the five areas where seedling counts were made. Thus, soil samples did not remove seeds from the area where emergence was determined. Soil cores from each plot were pooled, mixed thoroughly, spread 5 cm deep in shallow pans, watered to field capacity, and maintained in a greenhouse (temperature range from 23 to 35 C). Emerged seedlings were identified, counted, and discarded. When no additional seedlings emerged (after 8 to 10 weeks), the soil in each pan was dried and stirred to being nongerminated seeds near the soil surface. The pans were rewatered and additional seedlings were identified and counted. This dry-stir-wet cycle was repeated a second time and the accumulative number of seedlings that emerged after all cycles was recorded. Weed emergence was considered a measure of number of viable seeds in the soil. Emerged grasses were aggregated. Morningglory, spurge, and pigweed seedlings were recorded by genera. In order to quantitatively compare seedling emergence from the soil samples with seedling emergence in the field, the number of seedlings that emerged from each soil sample was multiplied by a conversion factor. The factor (339.1) was obtained by dividing the soil volume under the average area where seedling emergence was determined in the field (78 000 cm^3) by the volume of the soil sample (230 cm^3).

Statistics. Weed emergence results were subjected to analysis of variance and mean differences were separated by LSD ($P = 0.05$). Regressions were also performed to determine interactions between treatments and results measured over time. Significant ($P = 0.05$) differences between trends for treatments over time were determined based on the t-test of homogeneity of slopes.

[4]The data was provided by the U.S. Dep. Commerce, Nat. Oceanic and Atmospheric Admin., Nat. Weather Serv., Mid South Agric. Weather Service Ctr., Stoneville, MS.

Table 1. Effect of annual spring tillage on prickly sida, velvetleaf, and spurred anoda emergence during each of 5 yr in the absence of reseeding[a].

		Emergence as affected by tillage depth (cm)							
		From native seed population				From native seed population plus seeds added in 1976			
Weed species	Year	0	5	10	15	0	5	10	15
		no. m^{-2}							
Prickly sida	1977	38.5	38.0	28.7	36.9	42.1	35.4	40.0	62.1
	1978	14.1	9.2	7.2	17.4	11.3	13.3	10.5	16.2
	1979	5.4	8.2	4.1	10.8	5.6	13.3	10.5	9.5
	1980	5.1	5.9	2.6	13.3	3.3	8.5	10.3	7.4
	1981	0.8	0.8	0.8	1.5	0.8	3.3	3.3	2.6
Velvetleaf	1977	3.6	0.0	2.1	0.0	53.9	8.7	10.3	6.2
	1978	0.3	0.8	0.5	1.3	10.5	1.8	7.2	12.6
	1979	0.3	0.5	0.3	0.5	2.3	5.1	2.1	4.4
	1980	0.0	0.3	0.3	0.5	2.1	2.1	0.5	1.5
	1981	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.8
Spurred anoda	1977	1.0	1.0	0.0	0.0	90.8	39.5	47.7	32.3
	1978	13.1	1.3	0.3	0.8	12.3	18.0	10.8	15.4
	1979	0.3	0.5	0.3	1.3	1.0	10.0	6.4	6.4
	1980	0.3	0.0	0.0	0.3	0.8	3.6	1.5	1.8
	1981	3.0	0.3	0.3	0.5	0.3	0.5	1.0	0.8

[a]LSD values across tillage treatments for all years and both populations (horizontally) were prickly sida 15.7, velvetleaf 4.1, and spurred anoda 9.5. LSD values down years for all treatments and both populations (vertically) were prickly sida 14.4, velvetleaf 3.9, and spurred anoda 9.5.

Table 2. Effect of annual spring tillage on morningglory, hemp sesbania, pigweed, and grass emergence during each of 5 yr in the absence of reseeding[a].

		Emergence as affected by tillage depth (cm)							
		From native seed population				From native seed population plus seeds added in 1976			
Weed species	Year	0	5	10	15	0	5	10	15
		no. m^{-2}							
Morningglory	1977	16.4	0.5	10.8	13.3	56.9	30.3	36.9	24.6
	1978	0.8	0.8	0.3	0.5	5.6	6.2	6.2	9.0
	1979	0.3	0.5	0.5	0.8	1.3	3.6	2.6	3.1
	1980	0.3	0.5	1.0	1.5	1.3	2.3	2.1	0.3
	1981	0.3	0.5	0.3	0.5	0.8	1.0	0.5	0.8
Hemp sesbania	1977	0.0	1.0	0.0	0.0	40.0	34.9	41.0	31.8
	1978	1.3	2.1	0.3	0.3	8.5	8.5	6.9	7.2
	1979	0.3	1.0	0.3	0.5	5.9	9.5	0.3	4.9
	1980	0.3	0.8	0.3	0.8	1.0	2.6	1.8	1.3
	1981	0.0	0.3	0.0	0.0	1.0	0.5	0.0	0.3
Pigweed	1977	8.2	15.4	9.7	7.2	48.7	23.1	19.0	21.5
	1978	2.1	6.2	4.1	4.1	5.6	4.6	5.9	8.7
	1979	0.6	1.5	0.5	0.5	1.0	0.5	0.5	0.5
	1980	0.3	0.5	0.3	1.0	2.6	1.8	1.0	0.3
	1981	0.5	0.5	0.3	0.8	0.5	0.8	0.5	0.8
Grass	1977	224	290	474	203	15	46	41	36
	1978	69	67	141	67	67	105	110	69
	1979	15	36	49	23	21	39	44	36
	1980	31	41	41	46	15	46	41	36
	1981	8	10	15	15	8	13	13	10

[a]LSD values across tillage treatments for all years and both populations (horizontally) were morningglory 10.8, hemp sesbania 3.3, pigweed 5.6, and grass 146. LSD values down years for all treatments and both populations (vertically) were morningglory 10.5, hemp sesbania 3.1, pigweed 5.4, and grass 128.

RESULTS AND DISCUSSION

Tillage effects. During the first year, a greater number of velvetleaf, spurred anoda, morningglory, and pigweed seedlings emerged in the nontilled plots compared to the tilled plots (Tables 1 and 2). The first-year differences in emergence between nontilled and tilled plots may have been due to a high germination rate for the added seeds on or near the surface before they were tilled into the soil. Tillage may have buried some added seeds to depths where conditions were less favorable for germination and where some seeds could pass into deeper or secondary dormancy (8). Tillage with the light cultivator to the 5-cm depth and with the discs to 10- and 15-cm depths produced similar results. Possibly type and depth of tillage were insufficiently different to produce different results. The implements cut into the soil to different depths but did not invert the soil as would a moldboard plow (23). Also, more frequent tillage probably would increase the chances for effects on germination and emergence (20). Where native seed populations were initially high, there were no significant differences between the effects of the nontilled and tilled treatments regardless of whether or not seeds were added in the fall of 1976. The added seeds of prickly sida and grasses were probably diluted by the relatively high native seed populations of those species, and tillage effects were not as dramatically expressed (Tables 1 and 2). The native populations of horse purslane (*Trianthema portulacastrum* L.) # TRTPO, common purslane (*Porlulaca oleracea* L.) # POROL, and spurge were not overseeded and, in those plots, tillage had little or no measurable effect (Table 3).

Results of the bioassay of soil samples for viable seeds were variable and few differences due to tillage were discernable in any year (Tables 4 and 5). Differences between results for plots containing the native population plus seeds added manually were not evident in the soil sample results. Apparently, the large native seed population diluted the impact of added seeds upon weed emergence. For a given species in 1977 to 1979, more seedlings were detected emerging from the 3.8- by 20-cm soil samples in the greenhouse than were detected emerging from the plots in the field (Tables 1 to 5). Although the greenhouse and field results were expressed on equal soil area bases, the opportunities for germination and emergence were greater in the greenhouse than in the field. Seeds requiring light would probably not germinate at the 20-cm depth in the field, but they could germinate in the greenhouse where the soil sample was spread out in a shallow pan and the seeds were brought near the soil surface (1, 10). The repeated drying-stirring-wetting procedure in the greenhouse also may favor germination of seeds that normally remain dormant in the field.

Decline of weed emergence and seed population. In plots where seeds of velvetleaf, spurred anoda, pigweed, and

Table 3. Effect of annual spring tillage upon horse purslane, spurge, and common purslane emergence from the native seed population during each of 5 or 3 yr in the absence of reseeding[a].

Weed species	Year	Emergences as affected by tillage depth (cm) 0	5	10	15
		no. m^{-2}			
Horse purslane	1977	2.1	1.5	8.2	8.2
	1978	0.5	1.0	3.3	3.1
	1979	0.5	1.8	1.8	1.5
	1980	0.5	0.3	0.8	0.5
	1981	0.5	0.5	1.0	0.5
Spurge	1977	25.1	19.5	12.8	25.1
	1978	4.6	7.7	3.3	9.5
	1979	2.3	3.1	2.1	2.6
	1980	1.8	1.5	0.5	2.3
	1981	0.3	1.0	0.3	0.3
Common purslane	1977	192	128	95	69
	1978	103	46	62	49
	1979	49	80	46	26

[a]LSD values across tillage treatments for all years and both populations (horizontally) were horse purslane 5.4, spurge 10.8, and common purslane 113. LSD values down years for all treatments and both populations (vertically) were horse purslane 4.4, spurge 11.0 and common purslane 64.

morningglory were added to the native seed population, emergence was dramatically reduced after just 1 yr (Figure 1, Tables 1 and 2). The reduction was greatest in nontilled plots. This decrease was evident in both the weed emergence results from soil samples in the greenhouse and in the weed emergence counts in the field. Thus, the substantial decline in weed emergence in the field during the first 2 yr was substantiated by a dramatic decline in viable seeds in the soil samples detected by the greenhouse bioassay. Although the soil sample and field results were not quantitatively similar, the reductions were relatively similar.

With few exceptions, the number of emerged weeds for each species or group was comparable from the second through the fifth year regardless of tillage (Figure 1, Tables 1 and 2).

Emergence of velvetleaf, spurred anoda, hemp sesbania, and horse purslane did not decline during the first year if these seeds were not added to the native populations. When native populations were high (prickly sida, pigweed, and grasses) the decline in emergence from both the native seed population only and the native population plus added seeds was similar throughout the 5 yr. Even when native seed populations were low, adding seeds significantly increased weed emergence (velvetleaf, spurred anoda, pigweed, hemp sesbania, and morningglory) during the first or second year. The numbers emerging from all plots regardless of beginning seed populations were similar during the third through the fifth year.

Rate of weed emergence decline. The percentage of the 5-yr emergence totals for each year is shown in Figure 1 for some of the plots where seeds were added. In the nontilled plots, from 61 to 88% of the 5-yr totals emerged during the first year. Subsequently, from 9 to 23% emerged the second year, from 1 to 11% the third year, from 0.2 to 6% the fourth year, and from 0.4 to 3% the fifth year. Weeds that had a high percentage emergence the first year had much lower emergence percentages during the second year. This trend over the 5 yr was similar for all plots that initially had high native seed populations and had not received added seeds (data not shown).

In most instances, tillage reduced the percentage of weeds that emerged during the first year (Figure 1; Tables 1 and 2). The reductions were offset by greater weed emergence from tilled than from nontilled plots during the second year. During the third, fourth, and fifth years, weed emergence percentages were similar regardless of tillage. Thus, depending upon the species or group of weeds, from 72 to 97% of the 5-yr totals germinated and emerged during the first 2 yr.

Table 4. Effect of annual spring tillage on the decline of viable pigweed, spurge, and grass seeds in soil samples collected in each of 3 yr in the absence of reseeding[a].

Weed species	Year	Viable seeds as affected by tillage depth (cm): From native seed population 0	5	10	15	From native seed population plus seeds added in 1976 0	5	10	15
		no. m^{-2}							
Pigweed	1977	4277	3685	2956	3790	4346	2921	3233	2226
	1978	0	280	69	36	105	69	105	105
	1979	0	0	0	0	0	0	0	0
Spurge	1977	1390	833	869	869	1531	695	869	1287
	1978	521	174	280	280	313	139	105	382
	1979	0	0	0	0	0	0	0	0
Grass	1977	3859	2990	2433	2156	3233	2018	1287	903
	1978	1146	2608	1321	1007	1146	1218	1044	1495
	1979	174	36	139	36	174	36	69	69

[a]LSD values across tillage treatments for all years and both populations (horizontally) were pigweed 562, spurge 495, and grass 2454. LSD values down years for all treatments and both populations (vertically) were pigweed 556, spurge 508, and grass 1144.

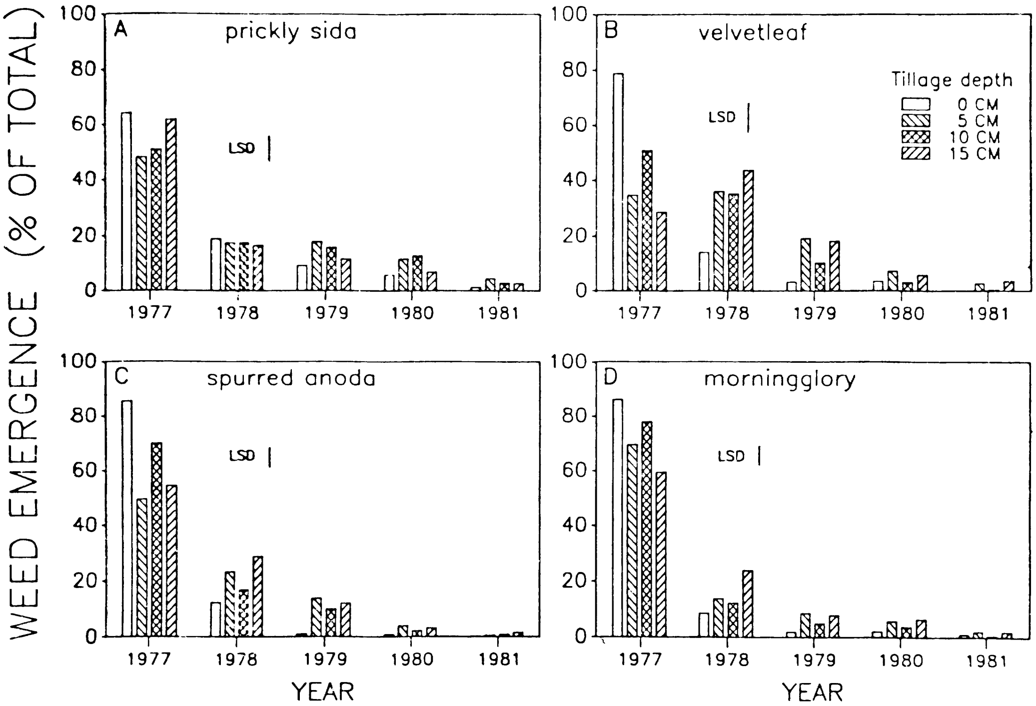

Figure 1. Effects of an annual spring tillage on the percentage of weeds emerging each year based upon the total emergence during all 5 yr. Tillage depths were 0 (nontilled), 5 cm, 10 cm, and 15 cm. Weeds were (A) prickly sida, (B) velvetleaf, (C) spurred anoda, and (D) morningglory.

This is in general agreement with other observations on decline in weed emergence over time when reseeding is prevented (22, 24). In the present study, tillage did not significantly influence the decline rate after the first year. Other reports indicated that tillage two and four times a year resulted in 32 and 36% annual decreases in viable weeds over a 6-yr period (21). In the present study, tillage was probably too infrequent to produce results comparable to those of the other studies.

To illustrate the rates of decline in grass, pigweed, velvetleaf, and hemp sesbania emergence during the 5 yr, the results from the control and tilled treatments were combined and averaged by species or group and plotted semilogarithmically (Figure 2). The decline rates for the three species and grasses were linear during the 5-yr period.

Weed emergence from seeds added in 1976. Because the native populations of velvetleaf, spurred anoda, hemp sesbania, and morningglory seeds were very low prior to

Table 5. Effect of annual spring tillage upon the decline of viable prickly sida, spurred anoda, and common purslane seeds in soil samples collected in each of 3 yr in the absence of reseeding[a].

		Viable seeds as affected by tillage depth (cm)							
		From native seed population				From native seed population plus seeds added in 1976			
Weed species	Year	0	5	10	15	0	5	10	15
		no. m^{-2}							
Prickly sida	1977	869	1008	836	592	590	626	590	869
	1978	244	36	174	139	36	69	174	36
	1979	0	36	0	0	0	0	69	0
Spurred anoda	1977	35	0	0	0	70	208	105	105
	1978	0	0	0	0	0	0	0	0
	1979	0	0	0	0	0	0	0	0
Common purslane	1977	6605	4241	4139	2121	4310	2295	3477	2190
	1978	2574	1008	2295	280	1844	590	244	349
	1979	280	69	244	60	521	105	69	139

[a]LSD values across tillage treatments for all years and both populations (horizontally) were prickly sida 354, spurred anoda 92, and common purslane 2982. LSD values down years for all treatments and both populations (vertically) were prickly sida 336, spurred anoda 92, and common purslane 2454.

Table 6. Average monthly maximum and minimum soil temperatures at the 5-cm depth at Stoneville, MS, from 1977 through 1981[a].

	1977		1978		1979		1980		1981	
	C									
January	4	1	6	2	6	3	11	5	11	4
February	14	4	8	1	10	4	12	5	14	6
March	21	10	17	7	19	9	16	8	20	9
April	27	16	29	16	25	16	24	13	29	18
May	35	22	31	19	30	19	28	19	30	18
June	40	26	38	24	35	23	36	26	36	26
July	41	27	45	28	38	26	41	29	38	27
August	41	27	40	27	37	25	40	28	37	26
September	35	23	33	23	32	21	36	26	32	21
October	26	13	28	15	27	15	27	16	24	16
November	18	10	20	12	17	8	19	10	20	11
December	12	4	13	5	12	5	14	6	12	12

[a]From records of the U.S. Dep. Commerce, Nat. Oceanic and Atmospheric Admin., Nat. Weather Serv., Mid South Agric. Weather Serv. Ctr., Stoneville, MS.

addition of seeds of these species in 1976, it was possible to estimate rates of their emergence during the five subsequent years. Numbers of each species that emerged from the plots that did not receive added seeds were subtracted from those that emerged from the plots that did receive seeds and the difference was assumed due to the 93 additional seeds that were applied within the area where emergence was determined. Thus, 27.1% of the velvetleaf seeds that were added in 1976 germinated and emerged from the nontilled plots during the 5-yr period. A total of 9.7% germinated and emerged from the deepest tilled plot. Significantly more velvetleaf seedlings emerged from the nontilled plots than from the tilled plots. Similar results occurred with spurred anoda, but the treatments produced no significant differences in emergence of hemp sesbania and morningglory. For these four species, from 7 to 43% of the added seed population resulted in emerged seedlings during the 5 yr, with the lower percentages consistently emerging from the tilled plots. Apparently, tillage moved the added seeds from the surface to sites where fewer germinated and emerged during the subsequent 5 yr. These seeds then became incorporated into the seed bank and some seeds remained dormant for several years.

Soil temperature and rainfall. In each of the 5 yr, monthly high soil temperatures at the 5-cm depth showed a general trend of spring warming to 24 to 29 C in May and progressed to a peak of 38 to 45 C in July before decreasing throughout the remainder of the year (Table 6). During the 5-yr period, the monthly lows were 19 to 22 C in May and were maintained at 23 to 29 C during June, July, and August. This consistent annual cycling of soil warming and cooling strongly influences in which season germination can occur (1). However, the present study concerned only spring and summer annuals. Although the very slight soil temperature differences among the years might advance or delay their germination a few days or weeks, it is doubtful that total yearly germination and emergence were affected.

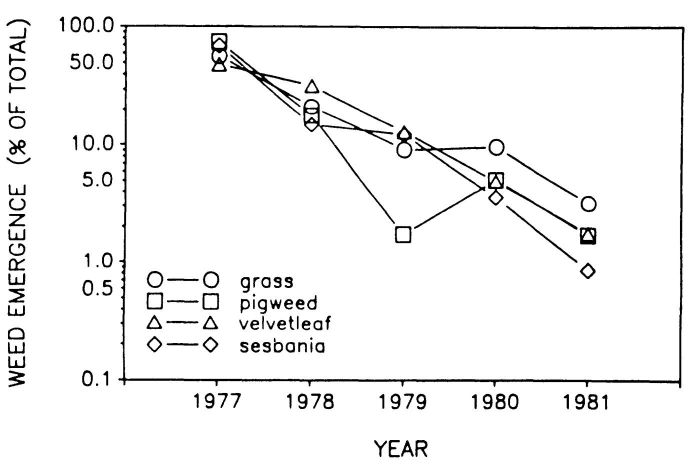

Figure 2. The percentage of weeds emerging each year based upon the total emerging during all 5 yr. Weed emergence results from the tillage depth treatments were averaged for each weed species, genus, or family.

Table 7. Monthly rainfall totals at Stoneville, MS, from 1977 through 1981[a].

Month	1977	1978	1979	1980	1981
	cm				
January	9.1	14.7	29.6	11.1	3.9
February	4.1	6.7	10.8	6.9	6.2
March	17.0	4.1	14.0	30.4	10.8
April	10.9	8.5	26.0	22.0	2.5
May	3.3	31.2	20.2	15.5	12.1
June	7.1	17.9	9.4	6.1	8.4
July	7.9	3.2	16.0	3.7	7.9
August	2.6	10.9	7.2	3.5	4.0
September	13.6	5.4	14.1	10.9	12.6
October	8.3	2.3	9.1	6.9	7.9
November	18.7	9.7	17.9	7.8	6.5
December	9.0	16.5	8.1	1.4	5.8
Total	113.7	131.1	182.4	126.1	88.4

[a]From records of the U.S. Dep. Commerce, Nat. Oceanic and Atmospheric Admin., Nat. Weather Serv., Mid South Agric. Weather Serv. Ctr., Stoneville, MS.

Rainfall varied considerably over the 5-yr period (Table 7). Total rainfall in 1977 was below normal, with May through August being quite dry. The winter and spring of 1978 were also dry, with May and June being very wet followed by a dry July and August. However, 1978 had nearly normal total rainfall while 1979 was a very wet year with above-normal rainfall in each month from April through November. The months of March, April, and May 1980 were wet, while the summer was dry. Except for near normal rainfall in May and October, 1981 was a very dry year. However, the yearly rainfall variations were not evident in the linear rates of weed emergence decline over the 5 yr (Figure 2).

This research indicated that one strategy to reduce long-term weed seed survival is not to till the soil for at least 1 yr after dispersal of fresh seeds onto the soil surface. Providing that soil conditions are favorable, this provides an opportunity for the germination of a maximum number of seeds during the first year. Otherwise, tillage may incorporate additional seeds into the seed bank. The emerged plants then must be controlled to prevent production of new seeds and replenishment of the soil seed population. A similar strategy has also been discussed by others (21).

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