CHARACTERIZATION OF SEED BANK COMPOSITION AND SEEDLING EMERGENCE

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ABSTRACT

Understanding weed seed emergence from soil seed banks may improve herbicide recommendations. Seedling emergence and seed populations by species were used to determine seed germination. Two areas at the SDSU Brookings research farm during 1990 were divided into one hundred 0.0093-m^2 grid areas for sampling. Seeds from 40 plant species representing 15 families were present in the seed bank. Thirty-six species emerged. Small (<1.5 mm) seeded weed species including pigweed (*Amaranthus* spp.), common lambsquarters (*Chenopodium album* L.), yellow woodsorrel (*Oxalis stricta* L.), and common purslane (*Portulaca oleracea* L.) dominated the seed banks. Large (>1.5 mm) seeded species such as Pennsylvania smartweed (*Polygonum pennsylvanicum* L.), wild buckwheat (*Polygonum convolvulus* L.), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), and green and yellow foxtail (*Setaria viridis* (L.) Beauv. and *S. glauca* (L.) Beauv.) were numerous. Emergence patterns of individual species were similar in both treatments. Total seedling emergence was estimated at 0.8%. Annual dicotyledons had <1% and annual grasses 7% emergence in both areas. However, seedling emergence by species ranged from 0 to 47% with larger seeded species attaining higher germination than smaller seeded species. Due to emergence variability, predictive weed density estimates from seed banks must consider seed size and weed species.

INTRODUCTION

Weed control strategies often are applied without knowledge of potential weed populations. The ability to accurately predict the severity of weed infestations will improve weed control efficiency (Naylor, 1970; Wilson et al., 1985) and help develop weed control strategies. The composition the weed seed bank and patterns and processes that influence seed bank dynamics must be understood before predictions can be made.

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Roberts and Ricketts (1979) suggested that at least two requirements must be met to use weed seed studies predictively. These are: i) seed populations can be estimated from seeds extracted from soil samples; and ii) seedling emergence can be estimated from seed populations. By completing these requirements, a predictive value may be calculated to relate potential and actual weed floras.

Through random sampling of twenty soil cores and twenty 15- by 15-cm random quadrats in a field, Roberts and Ricketts (1979) determined that three to six percent of the viable seeds in the top 10-cm may produce seedlings after cultivation. Debaeke (1988) observed similar emergence percentages when he compared the number of established seedlings with the number of seeds in the seed bank of plowed or minimum tillage areas. Roberts and Dawkins (1967) reported a 1% weed seedling emergence in undisturbed soil compared to 7% on areas that were cultivated twice each year and 9% on areas that were cultivated to a depth of 23 cm four times each year.

Seedling emergence will be influenced by many factors (Cardina et al., 1991; Cavers and Benoit, 1989; Forcella, 1984 and 1986; Forcella and Gill, 1986; Fround-Willams et al., 1981 and 1983; Roberts et al., 1965, 1967, and 1979; Wilson et al., 1985). Seed dormancy, whether innate, induced, or enforced, needs to be considered when predicting emergence. Environmental factors that influence weed seedling emergence include soil temperature and soil moisture. Depth of seed burial and predation also impact emergence.

Most weed seed bank studies have not attempted to describe the weed seed bank and seedling emergence by species. This study was conducted to determine if emergence could be estimated from weed seed populations in small plot areas. Emergence patterns also were determined by species.

MATERIALS AND METHODS

Study Site

The weed flora and seed bank relationship was investigated at two areas at the South Dakota State University Experimental Farm in Brookings County in 1990. The study areas were 0.93 m^2 divided into one hundred 0.0093-m^2 quadrats. Soil type was a Vienna loam (fine loamy mixed; Udic Haploborolls) with a pH of 6.8. Total rainfall from April through August in 1990 was 53.55 cm. Daily rainfall amounts and air and soil temperatures (under sod cover; 5 cm) for the study period are shown in Figure 1. Growing degree days (base 10°C) are listed in Table 1.

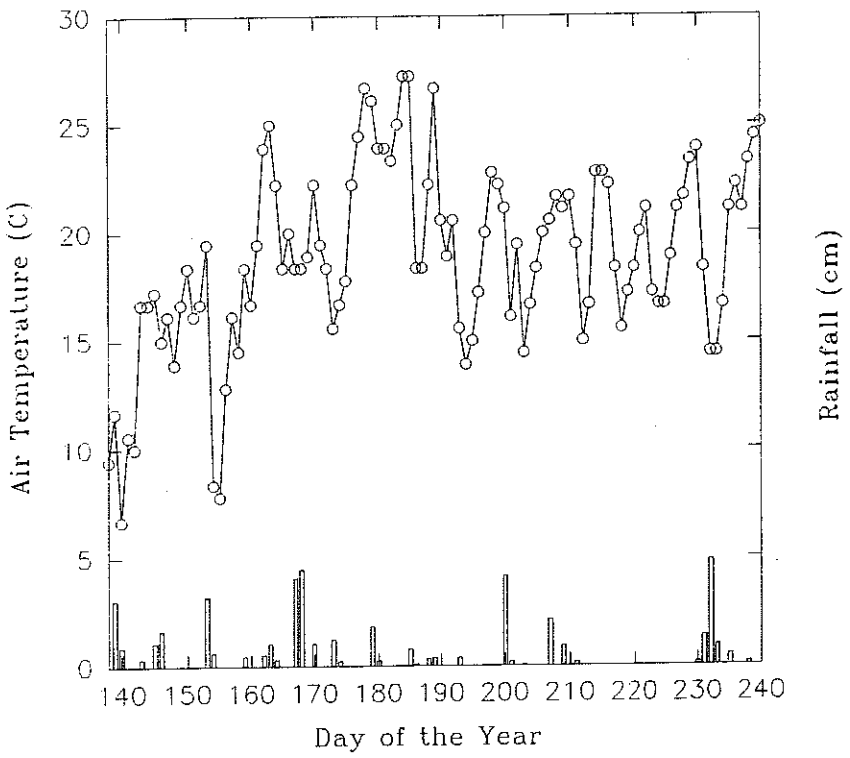

Figure 1. Daily rainfall amount and air temperature from days 138-240.

Table 1. Growing degree days (base 10°C) accumulated on a monthly and seasonal basis during 1990 at Brookings, SD.

Month	Day of the Year	Monthly Total	Seasonal Total
		number of growing degree days	
April	91-120	100.0	100.0
May	121-151	152.2	252.5
June	152-181	487.5	740.0
July	182-212	545.0	1285.0
August	213-243	557.5	1842.5

Seed Bank Sampling

Seed banks were sampled May 18 (138 day of the year) and August 28 (240 day of the year). One soil core, 0.5-cm diameter by 15-cm deep, was taken from the center of each quadrat during the spring sampling period. Soil from each quadrat was excavated to a depth of 15 cm during the August sampling. Seventeen kg of excavated soil from each quadrat was throughly mixed and a 1-kg subsample removed.

Seed Extraction.

Soil samples from each quadrat at each sampling date were extracted separately. The entire soil core (approximately 30 g) was extracted at the spring sampling period. A 150-g sample was extracted from the August sampling. Each weighed soil sample was placed in an Erlenmeyer flask. An equivalent volume of 0.004M sodium metaphosphate dispersant solution was added to the soil. Erlenmeyer flasks were placed on a mechanical shaker (30 excursions/s) for 900 s and then allowed to sit overnight.

Seeds were separated from the soil slurry using a hydropneumatic root elutriator (Gross and Renner, 1989) system (air pressure, 69 kPa; water pressure, 448 kPa) with the contents passing through a 508-μm sieve. Material retained on the sieve was rinsed to remove clay and silt particles. Remaining material was rinsed into a mesh bag (105-mesh polypropylene screening material) and oven-dried at 50°C. Dried material was separated further by removing debris with a Seedburo seed separator (opening set at 6.5; fan time, 120-180 s). Remaining extracted material was transferred to a petri dish. Intact seeds were identified and enumerated with the use of a dissecting microscope. A seed manual (Delorit, 1970) was used as an identification reference. The extraction efficiency of soil samples spiked with 100 pigweed and 100 yellow foxtail seeds was 95% $\pm$ 2% for each species.

Weed Emergence

Between 18 May (138 day of the year) and 18 August (240 day of the year), weed seedlings were identified by species, counted, and removed from each quadrat approximately every 7 days. Totals of selected species were accumulated.

Data analysis

Seed counts from the quadrat soil samples were converted to m^2 basis. Mean seed count and standard error were calculated for each plot by species. Percent seed emergence was calculated on a plot basis by adding the number of seedlings to the seed counts and dividing the total into the number of seedlings.

RESULTS AND DISCUSSION

Weed seed bank

Total seed bank populations using the spring soil core method for the two plot areas were estimated at 391,000 and 204,000 seeds m^{-2} for Location 1 and 2, respectively. Based on the excavation method used in the fall, total seed bank populations were estimated at 505,000 and 320,000 seeds m^{-2} for Location 1 and 2, respectively. Forty species of seeds representing 15 families were present in the seed banks (Table 2). The seed banks of both areas had more annuals than perennials. Dicotyledonous species comprised approximately 95% of the seed bank. Roberts (1981) reported a higher percentage of dicotyledon seeds (50%) compared to grass seeds (30%) in plowed plots.

Two different seed size classes were evident in the samples. Small (<1.5 mm) seeded weed species dominated the seed bank of both areas. Species represented included pigweed, common lambsquarters, yellow woodsorrel, and common purslane. Large (>1.5 mm) seeded weeds were less numerous, especially in samples taken from Location 1. Large seeded species present included Pennsylvania smartweed, wild buckwheat, barnyardgrass, and green and yellow foxtail.

Weed Seed Emergence

May 18 (138 day of the year) and August 28 (240 day of the year), 36 species of weed seedlings from 15 plant families emerged (Table 2). Total emergence percentage was approximately 0.8% in both locations. These data agree with the data Froud-Williams et al. (1983). In their study, actual weed flora was <1% of its potential in both cultivated and uncultivated treatments. Annual dicotyledons comprised 87% and annual grasses comprised 13% of the flora at Location 1. Annual grasses comprised 76% and annual dicotyledons comprised 24% of the flora at Location 2.

Small seeded weeds dominated the flora of Location 1 (Table 3). Principal species present were common lambsquarters, pigweed, yellow woodsorrel, and common purslane plants. Large seeded weeds dominated the flora of Location 2. These included wild buckwheat, Pennsylvania smartweed, barnyardgrass, and green and yellow foxtail.

Based on seed counts, the percentage of the seed bank that emerged by species ranged from 0% to 47% (Table 3). Overall, annual dicotyledons had an emergence of 0.7% at Location 1 and 0.2% at Location 2. Emergence percentages of pigweed, common lambsquarters, yellow woodsorrel, Pennsylvania smartweed, and common purslane ranged from 0.2% to 1.3% at Location 1 and from 0.01% to 0.6% at Location 2. Emergence percentages of wild buckwheat were 20% and 2% for Locations 1 and 2, respectively.

Table 2. Seeds in the soil seed bank and weed seedlings emerged from no-till and chisel plow plots, Brookings, SD, 1990. The (+) sign denotes the presence and the (-) sign denotes the absence of seed or seedlings at each location.

Family	Location 1		Location 2	
Species	Seeds	Seedlings	Seeds	Seedlings
DICOTS				
Amaranthaceae				
Amaranthus spp.[a]	+	+	+	+
Asclepiadaceae				
Asclepias syriaca	-	-	-	+
Asteraceae				
Cirsium arvense	-	+	-	+
Helianthus annuus	-	+	-	+
Iva xanthifolia	+	-	+	-
Senecio vulgaris	-	+	-	-
Silphium laciniatum	-	+	-	-
Sonchus spp.[b]	-	+	-	-
Taraxacum officinale	+	-	+	+
Brassicaceae				
Camelina sativa	+	-	+	-
Capsella bursa-pastoris	-	-	-	+
Lepidium densiflorum	-	+	-	-
L. virginicum	-	-	-	+
Sinapis arvensis	+	+	+	-
Chenopodiaceae				
Chenopodium album	+	+	+	+
Kochia scoparia	+	-	+	+
Salsola iberica	-	+	-	-
Convolvulaceae				
Convolvulus arvensis	-	+	-	-
Euphorbiaceae				
Euphorbia humistrata	+	+	+	+
Euphorbia maculata	-	+	-	-
Fabaceae				
Medicago lupulina	-	-	+	+
Medicago sativa	-	-	-	+
Trifolium spp.[c]	-	+	-	-
Malvaceae				
Hibiscus trionum	-	-	-	+
Malva neglecta	-	+	-	-
Oxalidaceae				
Oxalis stricta	+	+	+	+
Polygonaceae				
Polygonum aviculare	+	+	+	-
Polygonum convolvulus	+	+	+	+
Polygonum pennsylvanicum	+	+	+	+
Portulaceae				
Portulaca oleracea	+	+	+	+
Solanaceae				
Solanum nigrum	-	+	+	-
Verbenaceae				
Verbena spp.[d]	+	+	+	+
MONOCOTS				
Poaceae				
Elytrigia repens	-	-	-	+
Cenchrus incertus	+	-	+	-
Digitaria sanguinalis	-	-	+	+
Echinochloa crus-galli	+	+	+	+
Panicum capillare	+	+	+	+
Panicum dichotomiflorum	-	+	-	+
Setaria glauca	+	+	+	+
Setaria viridis	+	+	+	+

[a]Pigweed seeds and seedlings were not separated beyond the genus. Tumble pigweed, *A. albus* L.; prostrate pigweed, *A. blitoides* S. Wats.; smooth pigweed, *A. hybridus* L.; and redroot pigweed, *A. retroflexus* L. are found throughout South Dakota.

[b]Sow thistle seeds and seedlings were not separated beyond the genus. Perennial sowthistle, *S. arvensis* L. and annual sowthistle, *S. oleraceus* L. are found throughout South Dakota.

[c]Clover seeds and seedlings were not separated beyond the genus. Red clover, *T. pratense* and white clover, *T. repens* L. are found throughout South Dakota.

[d]Vervain seeds and seedlings were not separated beyond the genus. Prostrate vervain, *V. bracteata* Lag. & Rodr.; hoary vervain, *V. stricta* Vent.; and white vervain, *V. urticifolia* L. are found throughout South Dakota.

Individual grass species had large emergence differences among species (Table 3). The percentage of barnyardgrass seed that emerged was 47%, green foxtail 20%, and yellow foxtail 14% at Location 1. At Location 2, barnyardgrass and green foxtail each had an emergence of 9%. Yellow foxtail had an emergence of 4%. Although these three grass species had a high percent emergence, total annual grass seed emergence was low; approximately 7% for both locations. High numbers of field sandbur (*Cenchrus incertus* M. A. Curtis) and witchgrass (*Panicum capillare* L.) seeds were present in each of the plots and had low seedling numbers.

Table 3. Comparison of seeds, total plants, and seedling emergence between locations.

	Location 1			Location 2		
Species	Seed Number	Total Plants	Seedling Emergence	Seed Number	Total Plants	Seedling Emergence
	no. m^{-2}	no. m^{-2}	%	no. m^{-2}	no. m^{-2}	%
Amaranthus spp.						
	7204 (280)[a]	19.2	0.3	23656 (806)	3.0	0.01
Chenopodium album						
	7312 (430)	16.1	0.2	4301 (323)	11.2	0.3
Oxalis stricta						
	10753 (387)	146.8	1.3	1290 (108)	7.8	0.6
Polygonum pennsylvanicum						
	161 (43)	0.3	0.2	11290 (667)	22.2	0.2
P. convolvulus						
	54 (22)	13.8	21.0	1183 (140)	24.3	2.0
Portulaca oleracea						
	5269 (258)	12.8	0.2	4086 (237)	4.4	0.1
Echinochloa crus-galli						
	22 (11)	13.4	47.0	1290 (183)	131.3	9.0
Setaria viridis						
	11 (11)	1.8	20.0	355 (54)	35.2	9.0
Setaria glauca						
	43 (22)	5.9	14.0	2043 (161)	83.0	4.0

[a]Number in parenthesis is mean square error.

In this study, small seeded weeds had very low emergence percentages compared with larger seeded species. Weeds with small seeds have been described as persistent in the seed bank (Thompson and Grime, 1979). Small seeded species usually have a low germination rate in any one year but the seeds may remain viable for many years. Large seeded weeds are considered transient. They have seed viability of approximately one year. Their seeds remain at the soil surface and are capable of immediate germination. The weed seed bank at both locations contained species that were absent as seedlings (Table 2). Some of these species include kochia (*Kochia scoparia* (L.) Schrad.) and black medic (*Medicago lupulina* L.) at Location 1; prostrate knotweed (*Polygonum aviculare* L.) and black nightshade (*Solanum nigrum* L.) at Location 2; and marshelder (*Iva xanthifolia* Nutt.), largeseed falseflax (*Camelina sativa* (L.) Crantz), and field sandbur at both locations. Conversely, species absent from the weed seed bank were present as seedlings. Examples include common groundsel (*Senecio vulgaris* L.), greenflower pepperweed (*Lepidium densiflorum* Schrad.), and black nightshade at Location 1; common milkweed (*Asclepias syriaca* L.), fall panicum (*Panicum dichotomiflorum* Michx.), and quackgrass (*Elytrigia repens* (L.) Nevski.) at Location 2; and Canada thistle (*Cirsium arvense* (L.) Scop.) in both locations. Quackgrass shoots arose from rhizomatous growth from plants outside the study area throughout the growing season. Canada thistle plants emerged from seed early in the season. However, late emerging Canada thistle shoots originated from rhizomes from plants outside the sample areas.

Emergence pattern

In most instances, the pattern of plant emergence was similar between locations. Wild buckwheat was the first weed to emerge at both locations. Pigweed, yellow woodsorrel, Pennsylvania smartweed, and common purslane seedlings were first identified at the 16 June (167 day of the year) sampling period and had completed 90% of their emergence by 16 July (197 day of the year). Although weed emergence was monitored to 18 August (240 day of the year), most species were >90% emerged by 13 July (194 day of the year). Rainfall and warm temperatures after 13 July (194 day of the year) (Figure 1) did not promote further significant weed flushes. The one exception to this emergence pattern was common lambsquarters that had 70% emergence at location 1 and 85% at location 2 after 13 July (194 day of the year).

Of the monocotyledonous species, barnyardgrass was the first to emerge followed by yellow and green foxtail at both locations (Figure 3). Although cumulative emergence patterns between locations were similar, barnyardgrass seedlings had a higher emer-

gence rate from 30 May to 21 June (150-172 days of the year) at Location 1 compared with Location 2. Green and yellow foxtail seeds had higher germination rates from 16 June to 2 July (167-183 days of the year) at Location 2 when compared with Location 1.

Weed Seed Bank - Seedling -- Sampling Correlation

The number of plants of four plant species were correlated with seed counts. Yellow woodsorrel and yellow foxtail plants were correlated with seed counts, r = 0.252* and r = 0.289**, respectively, at Location 1. Common lambsquarters had seedling - seed correlation at the 10% level of significance at Location 1. At Location 2, common purslane and barnyardgrass plants were correlated with seed counts, r = 0.204* and r = 0.309**, respectively.

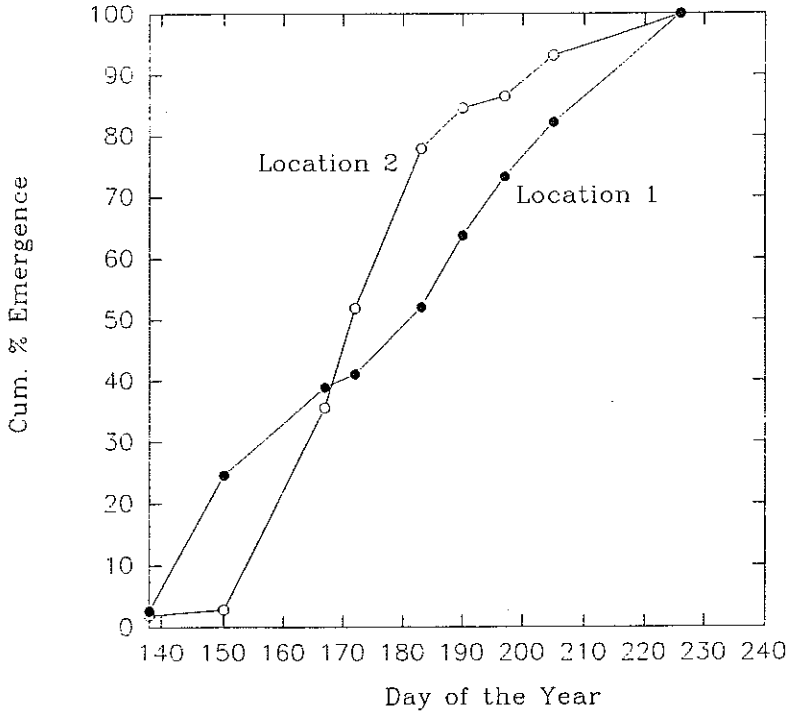

Figure 2. Comparison of common lambsquarters cumulative emergence patterns at Locations 1 and 2.

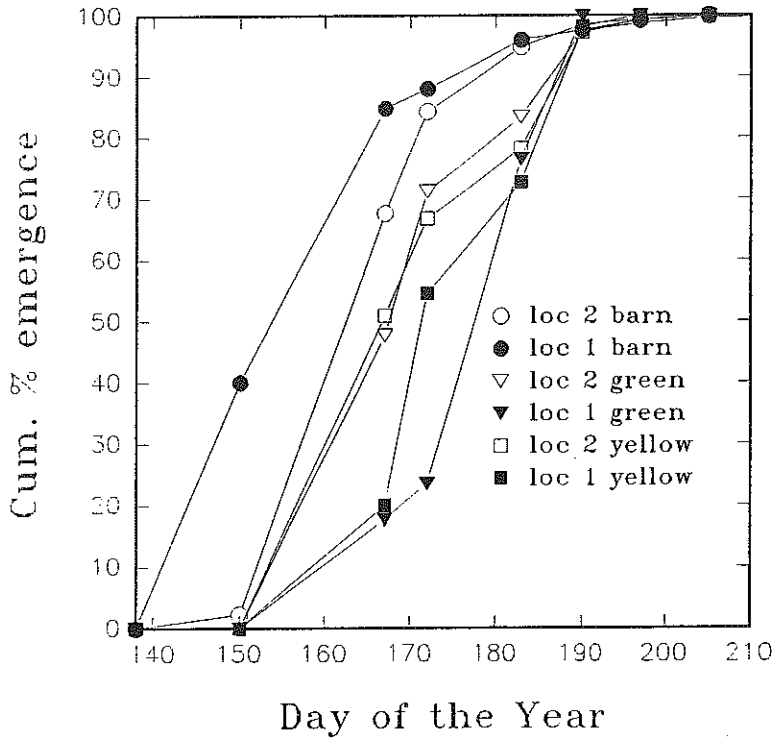

Figure 3. Comparison of annual grass cumulative emergence patterns at Locations 1 and 2. The abbreviations are: barn is barnyardgrass, *Echinochloa crus-galli*; green is green foxtail, *Setaria viridis*; and yellow is yellow foxtail, *Setaria glauca*.

SUMMARY

The weed seed bank and seedling composition were defined within small plot areas. Seeds of dicotyledons were dominant for both plots. Seedlings of monocotyledons dominated Location 2. Dicotyledonous seedlings dominated Location 1. Total emergence percentages based on seedling counts and seed estimates were less than 1% for both locations. However, percent emergence by species ranged from 0 to 47%. Generally, large seeded species had higher emergence percentages when compared with small seeded species. There was limited correlation of seed counts within the seed bank to seedling densities for the same area. However, these correlations were both species and location dependent. Due to emergence variability, predictive weed density estimates from seed banks must consider seed size and weed species.

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