AN ABSTRACT OF THE THESIS OF

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Title: Soil Seed Banks in Kansas Prairie and Reseeded Old Fields

Abstract approved: Thomas A. Eddy

Viable seeds in the soil seed banks of a native prairie pasture and two old fields seeded with native grasses were estimated. Samples, each with a surface area of 25 cm^2 and a depth of 5 cm or 15 cm, were collected from these Lyon County, Kansas sites during the period of time from February 12 to March 21, 1987. They were divided into depths of 0-2.5, 2.5-5, and 5-15 cm, sieved, and placed over sand in trays in a greenhouse. Samples were maintained until July 24, 1987. Seedlings were counted at least once per week, with one exception.

An equivalent of 10,980 seeds$\cdot m^{-2}$ (57% monocots, 41% dicots, 1% unidentified) emerged from the top 5 cm of the recently reseeded old field, 7,260 seeds$\cdot m^{-2}$ (65% monocots, 33% dicots, 2% unidentified) from the native prairie pasture, and 4,850 seeds$\cdot m^{-2}$ (49% monocots, 50% dicots, 1% unidentified) from the older reseeded old field. Numbers of seedlings and monocot-dicot ratios declined with depth; the amount of decline varied with the site.

In conclusion, the results of this study seem to indicate that the seed bank populations of reseeded old fields are not maintained over time. After approximately eighteen years the seed bank of an old field, in terms of seed numbers, becomes more like that of a native prairie pasture than an abandoned field. However, species composition, reflected in the monocot-dicot ratios, may remain quite different.

SOIL SEED BANKS IN KANSAS
PRAIRIE AND RESEEDED OLD FIELDS

A Thesis

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the Division of Biological Sciences

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Approved for Major Department

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INTRODUCTION

Harper (1977) summarizes the dynamics of the population of seeds in the soil (the soil seed bank) using a diagrammatic flow chart. Deposits to the seed bank are made as seeds fall on the soil surface. This seed rain consists of seeds produced on the area and seeds transported into the area from elsewhere. Withdrawals take place as a result of predation, seed decay and senescence leading to death, and germination into seedlings. The seed bank itself has a "deposit account" (seeds in a dormant state) and a "current account" (seeds which only need water and a favorable temperature to germinate). Various stimuli cause dormant seeds to become part of the active seed bank.

Seed banks are an important part of a plant community. Major and Pyott (1966) maintain that the buried viable seeds should be included in complete descriptions of plant communities. The seed bank reflects the history of vegetation on and around the particular area and represents a source from which new vegetation may arise if the existing stand is destroyed (Harper 1977). In his discussion on the ecological significance of seed banks, Fenner (1985) includes the importance of the pool of genetic information found in the seeds of the seed bank along with mentioning the importance of understanding the population dynamics of buried viable seeds in the areas of agriculture, forestry, and conservation.

Harper (1977) summarized the results of a number of studies which have estimated the numbers of seeds in the seed banks of forests, grasslands, and arable lands. Included are studies of sown grassland in the United Kingdom (Champness 1949), of bunch-grassland in California

(Major and Pyott 1966), and of various habitats in mixed prairie located in western Kansas (Lippert and Hopkins 1950). Thompson and Grime (1979) studied the seasonal variation in the seed banks of herbaceous species in ten contrasting habitats in northern England. Roberts and Chancellor (1986) investigated the changes that occur in the soil seed bank under practical farming conditions by determining the number of viable seeds in 64 fields on farms in central England over time.

A few studies have focused on plant communities in the grasslands found in central North America. In Nebraska, Blake (1935) studied the viability and germination of seeds of prairie plants along with their early life history. Archibold (1981) compared agricultural sites and native prairie in central Saskatchewan, Canada. Rabinowitz (1981) compared the number of buried viable seeds in a tall-grass prairie in Missouri with the seed rain. Johnson and Anderson (1986) studied the seed bank of a tallgrass prairie in Illinois.

Poggi (1934, cited by Weaver 1954) states that Illinois prairie was discovered to be good cropland in about 1830. Since that time much of the sod of the tall-grass prairie region has been plowed. Lyon County, Kansas is located on the western edge of this region. The bulk of the early immigration flowed to the county in 1857 (Andreas [1883] 1976). Much of the soil in the county has remained as unbroken rangeland. Erosion is a major hazard on about 75 percent of the cropland (Neill 1981). If the surface layer or topsoil is lost, productivity is reduced and the land is removed from cultivation. Fields abandoned in this manner are called old fields. The District Conservationist of the Soil Conservation Service includes rangeland needing only reestablishment and bromegrass pastureland on Class IV and VI land in the category of old fields (Pritchard 1987). This land had been previously cultivated. The rangeland has never been reseeded. The pastureland has been reseeded, however, the stands have failed. In 1979, the total area of these two land use categories amounted to 12,185 hectares (30,111 acres) in Lyon County (United States Department of Agriculture, Soil Conservation Service 1979).

The return of this land to prairie is often a slow process (Weaver 1954; Cavanaugh 1987). As early as the 1940s many farmers and ranchers were revegetating previously cultivated fields with perennial grasses (Cornelius 1946). The grasses could be used for grazing or cut for hay. From the standpoint of soil health, erosion could be controlled and soil fertility improved. Reseeding continues to be an important practice. The Conservation Reserve Program (CRP) was established as part of the 1985 Farm Bill by the Congress of the United States in an effort to remove highly erodible land from cultivation and protect it with vegetative cover (United States Department of Agriculture et al.).

Previous studies at Emporia State University, Emporia, Kansas have focused on reseeded old fields. Cavanaugh (1987) investigated the feasibility of establishing stands of desirable grasses by spraying old fields with herbicide and then seeding directly into the dead weeds and litter. Crandall (1987) compared the nitrogen forms in reseeded old fields with those in native prairie.

In the present study the viable seeds in the soil seed banks of a recently reseeded old field, an older reseeded old field, and a native prairie pasture are compared. Total numbers of seeds, numbers of monocots and dicots, and depth distributions are investigated. It is of interest to see if the seed bank is maintained after the old fields have been reseeded with a mixture of five grasses. It is also of interest to see how these old fields compare with a native prairie pasture, the model community for reseeding projects.

DESCRIPTION OF STUDY AREA

The study area consisted of three sites, two reseeded old fields and one native prairie pasture, located in Lyon County, Kansas. The locations of the sites are shown in Figure 1. Site 1, referred to in this paper as the recently reseeded old field, is located in the W 1/2 of the NW 1/4 of the NE 1/4 of Section 27, Township 18S, Range 10E. It was abandoned cropland for a minimum of ten years (Pritchard 1987) before being seeded in 1981 with a mixture of five grasses: *Andropogon gerardi*, *Andropogon scoparius*, *Sorghastrum nutans*, *Panicum virgatum*, and *Bouteloua curtipendula* (Crandall 1987). The amount of pure live seed planted at that time was 1.1, 1.1, 1.2, 0.5, and 1.1 pounds per acre respectively for the five grasses.

Site 2, referred to as the native prairie pasture, is located just east of Site 1 in the E 1/2 of the NW 1/4 of the NE 1/4 of Section 27, Township 18S, Range 10E. The grasses on this site had been cut for hay until 1985, at which time grazing was allowed (Pritchard 1987).

Site 3, referred to as the older reseeded old field is located in the W 1/2 of the SW 1/4 of the NW 1/4 of Section 3, Township 18S, Range 11E. It had been farmed in a four year wheat-milo rotation (wheat-wheat-milo-milo) (Pritchard 1987) before being seeded in 1969 with the same five grasses as Site 1 but with slightly different amounts. The seeding rate was 1.2, 1.0, 1.2, 1.0, and 0.6 pounds per acre respectively for the five grasses cited above (Crandall 1987).

At Site 1 the native grass seed was planted into milo stubble (Pritchard 1987). No chemicals were used for weed control. Grazing began at this site in 1985. Site 3 is assumed to have been seeded in

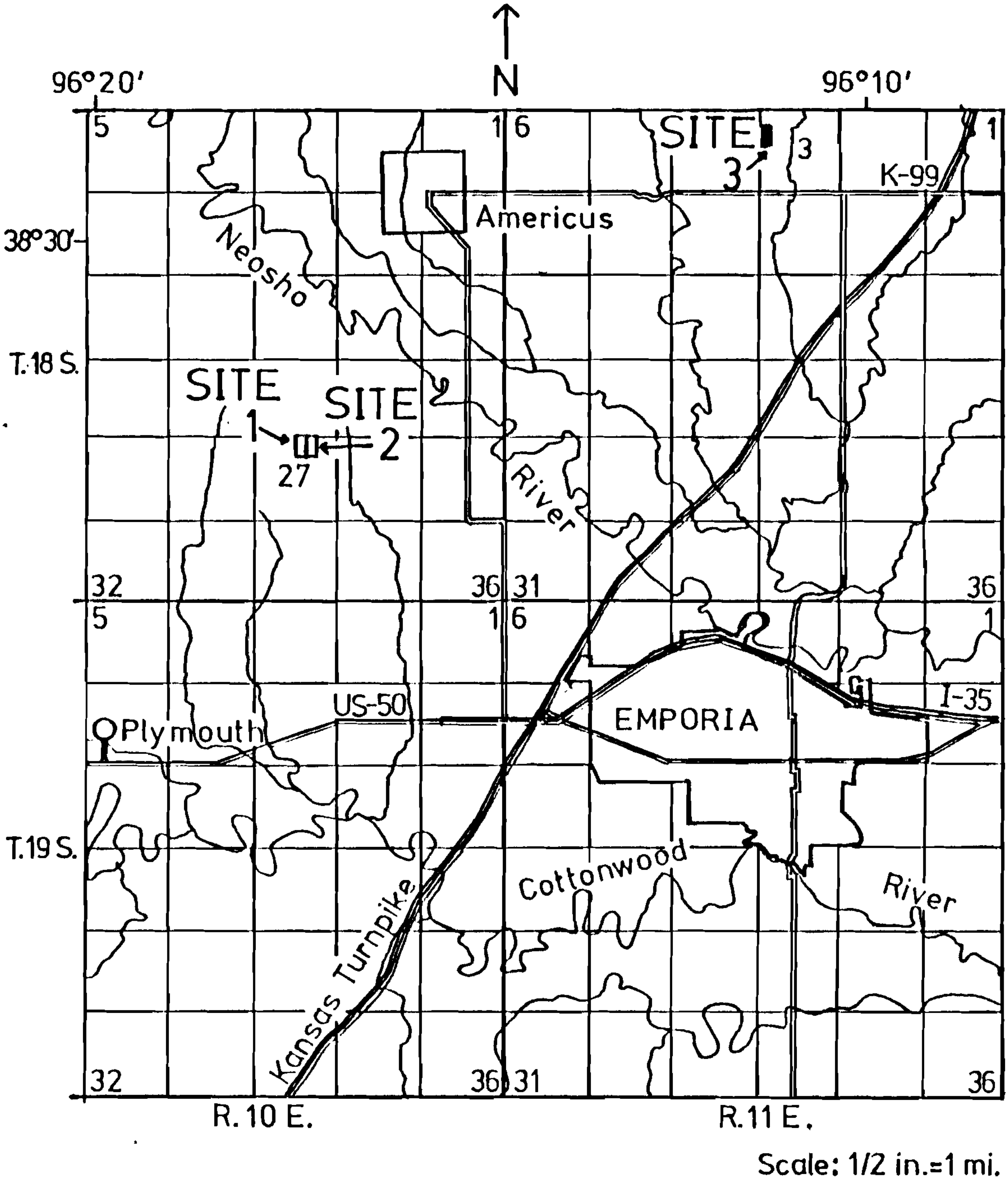

Figure 1. Portion of Lyon County, Kansas showing the locations of the study sites in relation to range and township divisions, latitude and longitude, rivers, roadways, and towns. (Map source: Neill 1981.)

the same manner as Site 1, after the second or third year of milo in the rotation. The broadleaf herbicide 2,4-D (2,4-Dichlorophenoxyacetic acid) may have been used for weed control. This site was not used until grazing was allowed four or five years later. All three sites were burned during the spring of 1986 and grazed through the summer (Crandall 1987).

According to the Soil Survey of Lyon County, Kansas (Neill 1981), the soil of Sites 1 and 2 and of the southern five percent of Site 3 is Ladysmith silty clay loam, 0 to 2 percent slopes. The rest of the soil of Site 3 is Kenoma silt loam, 1 to 3 percent slopes and Kenoma silty clay loam, 1 to 3 percent slopes, eroded. The Kenoma soil is a fine, montmorillonitic, thermic Vertic Argiudoll. The Ladysmith is a fine, montmorillonitic, mesic Pachic Argiustoll. The Soil Conservation Service District Conservationist suggests that except for differences in slope, these soils are very similar (Pritchard 1987). There is, however, a distinct difference in both of these soils between the topsoil and the subsoil. Erosion has removed most of the original topsoil (the A horizon) from the abandoned fields. The range site designation for both soils is Clay Upland (Neill 1981). Total dry weight production for these soils in a normal year is 4500-5000 kilograms per hectare (4000-4500 pounds per acre).

Crandall (1987) determined the vegetation composition of these three sites in 1986 and 1987 using the step loop method (Wilk and Mayo 1987). The recently reseeded old field was dominated by <u>Sorghastrum nutans</u> (41%) with <u>Andropogon gerardi</u>, <u>Andropogon scoparius</u>, <u>Panicum virgatum</u>, <u>Bromus</u> spp., and <u>Sporobolus asper</u> present in amounts less than

10%. The vegetation of the native prairie pasture consisted mainly of _Andropogon gerardi_ (50%), _Agrostis_ spp. (17%), and _Andropogon scoparius_ (14%). _Panicum virgatum_, _Sorghastrum nutans_, and _Carex_ spp. were present in amounts less than 10%. The older reseeded old field had two strongly represented species, _Panicum virgatum_ (43%) and _Sorghastrum nutans_ (32%). _Andropogon scoparius_, _Carex_ spp., _Schedonnardus paniculatus_, and _Bromus_ spp. were present in amounts less than 10%.

Each of the sites described above are approximately 8 hectares (20 acres) in area. Only part of this area was used for sample collections. Boundaries were established considering possible edge effect, some soil type boundaries, and the need for areas that could be subdivided into square plots with ten meters per side. A seven meter border, from field edge to the edge of the collection area, was used on the north and west sides of each site to attempt to eliminate results due to edge effect. The length (north-south) of each collection area was 350 meters. The widths (east-west) were: Site 1--200 meters, Site 2--120 meters, and Site 3--180 meters. See Figures 2-4 for details.

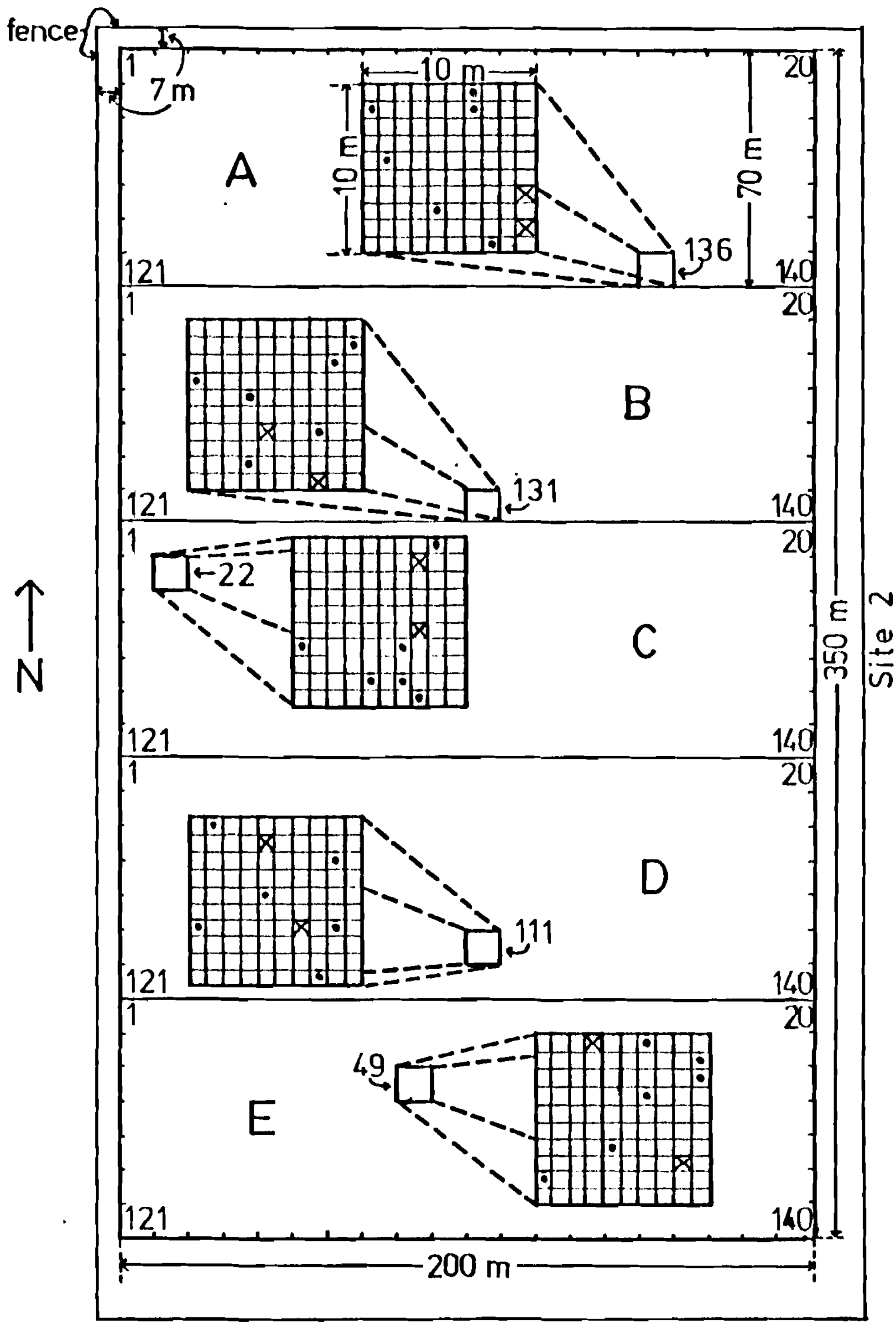

Figure 2. Recently reseeded old field (Site 1) with collection areas, subfields A - E, sample collection plots and subplots, and their dimensions. (Plots and subplots were numbered from left to right and top to bottom. Sample depths: ⊡ = 5 cm; ⊠ = 15 cm)

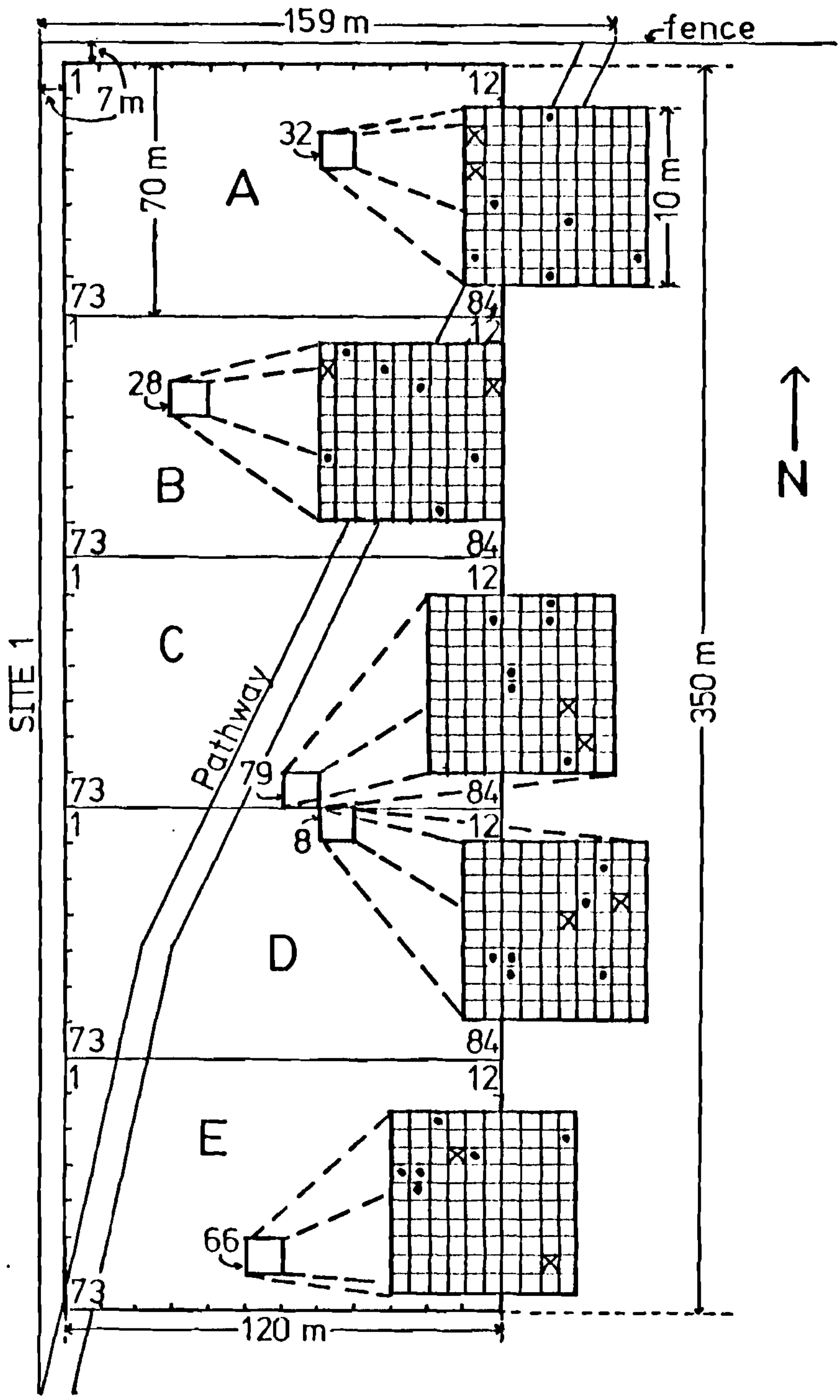

Figure 3. Native prairie pasture (Site 2) with collection areas, subfields A - E, sample collection plots and subplots, and their dimensions. (Plots and subplots were numbered from left to right and top to bottom. Sample depths: ⊡ = 5 cm; ⊠ = 15 cm)

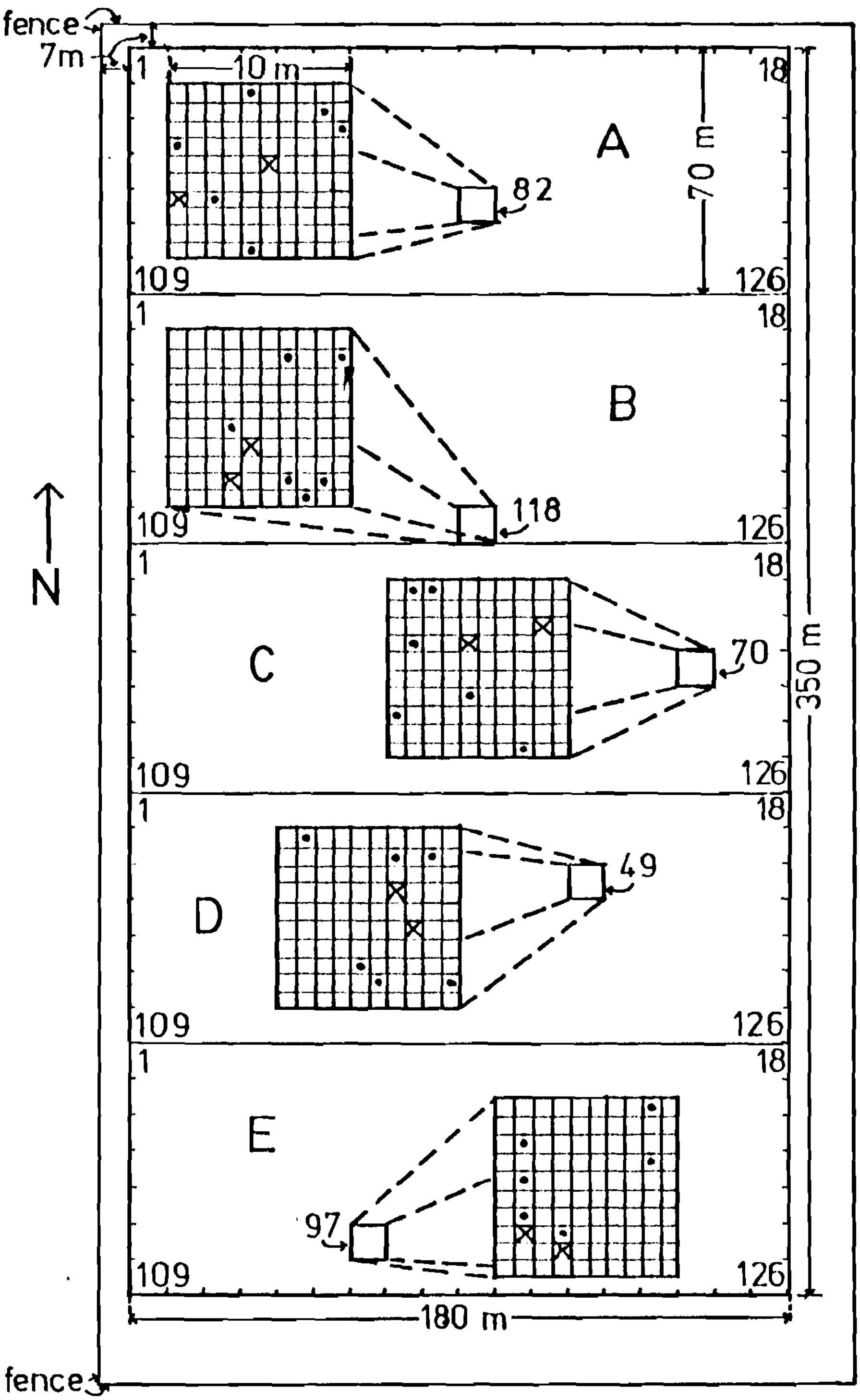

Figure 4. Older reseeded old field (Site 3) with collection areas, subfields A – E, sample collection plots and subplots, and their dimensions. (Plots and subplots were numbered from left to right and top to bottom. Sample depths: ⊡ = 5 cm; ⊠ = 15 cm)

METHODS AND MATERIALS

The method used in this study is common to soil seed bank studies described by Harper (1977) and Fenner (1985). It consists of taking soil samples of known surface area and depth, spreading out the soil on trays in conditions favorable for germination, and then counting and identifying the seedlings that emerge.

Forcella (1984) determined that to obtain statistically representative estimates of the numbers of species in the soil seed bank of subterranean clover-annual ryegrass pastures, individual plot replicates should have a soil surface area of about 200 cm^2 and the combined soil surface areas of the replicates at each site should be about 1000 cm^2. These figures were used as a guide in this study. Each of the sample collection areas of the three sites were divided into five 70 meter wide (north-south) portions designated subfields A, B, C, D, and E. The subfields were further subdivided into 10 meter square plots. Eight 25 cm^2 samples were collected from one of these plots in each subfield. (These divisions and subdivisions are shown in Figures 2-4.)

The division of the site into five subfields insured that individual plots would not be clustered in one area of the field. In each of the five subfields one 10 meter square plot was randomly chosen (using the RAN# function on a CASIO fx-85 Scientific Calculator and the equation X = INT(RAN# * N) + 1, where N = the total number of choices and INT indicates that the value is to be rounded down to the nearest whole number). One condition was placed on this plot selection process: if the chosen plot fell on an obvious roadway through the field, another was chosen. This plot was further subdivided into 1 meter squares. Eight of these squares were randomly chosen (in the same manner as above) as sample collection locations. Two of these eight were randomly selected for reasons described below. Figures 2-4 also show the sample collection locations at the three sites.

Sample depths used in soil seed bank studies of grasslands and arable lands have included: 1.3 cm (0.5 inch) for a mixed prairie study (Lippert and Hopkins 1950); 3 cm for a study of a variety of habitats (Thompson and Grime 1979); 10 cm for studies of prairie and agricultural sites (Archibold 1981), subterranean clover-annual ryegrass pasture (Forcella 1984), and tallgrass prairie (Johnson and Anderson 1986); 12 cm for a tallgrass prairie study (Rabinowitz 1981); 15 cm (or 6 inches) for studies on arable land (Brenchley and Warington 1930, 1933, 1936; Roberts and Chancellor 1986); and 30 cm (12 inches) for a grassland depth profile study (Chippindale and Milton 1934). The depth originally considered for this study was 15 cm, representing what is considered the plow layer depth. The plow layer depth was considered because two of the sites had originally been cultivated. Due to time and space limitations, a sample depth of 5 cm was used for six of the eight samples per plot and a depth of 15 cm was used for the remaining two samples.

The sample collection process involved using a knife to cut a 5.0 cm x 5.0 cm square on the soil surface between clumps of grass near the center of a square meter collection location. If the spot chosen had an obvious hoof print another was chosen close to it. The soil on three sides of the sample was removed, using a trowel, knife, or shovel, leaving a column 5 or 15 cm in height depending on the collection requirement. The soil on the fourth side was left in place to support the column until the sample was ready to be removed. The knife was used as necessary to define the edges of the sample as the depth increased and also to cut the sample away from the supporting side. A sturdy garden trowel was used to free the base of the column at a depth beyond that required in the sample.

After removal from the ground, each of the 5 cm deep blocks of soil was cut in half so that the top half represented the top 2.5 cm of soil and the bottom half represented the next 2.5 cm of soil (2.5-5.0 cm). The 15 cm deep blocks of soil were divided into three sections--the two mentioned above and a third representing a soil depth from 5.0 cm to 15.0 cm. These different sections were designated by the lower case letters a, b, and c. The top 5 cm portions of the first three sets of samples were separated into the two different depths in the lab. The remainder were divided in the field for reasons of convenience. Samples were stored in opened Ziploc plastic bags. Refrigeration was used to retard germination until further processing was possible (see Table 1).

Further processing involved sieving the samples through a screen to remove coarse plant fragments and other material (after Lippert and Hopkins 1950). A 0.64 cm (1/4 inch) mesh screen was used. Thompson and Grime (1979) used a 1 cm mesh screen. Forcella (1984) sieved to remove material greater in size than 0.5 cm. The screen was rinsed in tap water between changes in depth and subfield to keep mixing of samples to a minimum. Following this the samples were again placed in the plastic bags until being transferred to trays in the greenhouse.

Table 1. Sample collection and preparation time table. (Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field; capital letters designate subfields; d=dug samples, c=cut to size, s=sieved, t=placed in greenhouse trays/flats; r=stored in cold room or refrigerator, w=stored at room temperature, g=stored in greenhouse, a=stored in automobile trunk, na=removed from trunk; h=sprinkled with a modified 1/2 strength Hoagland's solution (Hoagland and Arnon 1950); *=only depth c (5-15 cm) samples involved.)

	Expt		Site 1					Site 2					Site 3				
Date	Day	Wk	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
2/12	1	1	d														
2/13	2		cr					dcr									
2/20	9	2	wsg					wsg									
2/23	12	3											dcr				
2/24	13			dcr					dcr					dcr			
2/26	15		t					t					ws				
2/27	16												st				
3/4	21	4	h					h					h				
3/5	22														dcr		
3/10	27	5		ws					ws					ws			
3/11	28			t					t					s*t			
3/12	29				dcw					dcw					w		
3/13	30			t*					t*					t*			
3/16	33	6													s		
3/17	34									s							
3/19	36				s					s							
3/20	37				st					t					t		
3/21	38				a*	dca	dca			a*	dca	dca			a*	dca	dca
3/30	47	8			nas*	na	na			nas*	na	na			nas*	na	nas
3/31	48										st	st				st	t
4/1	49					st	st										
4/15	63	10				s*	s*				s*	s*				s*	s*
4/24	72	11			t*	t*	t*			t*	t*	t*			t*	t*	t*
7/24	162	24		Final day of experiment.													

Commercial plastic trays (12-packs) were rinsed in water, individually soaked in a commercial bleach, rinsed again, and spread out in a four by eighteen grid on a bench on the north side of the Emporia State University Division of Biology greenhouse. A small square of paper toweling was placed over the hole in the bottom of each compartment to prevent sand from running out. Clean sand (Super Blast Sand, coarse (8-20), packaged by Rich Mix Products, Inc. of Wichita, KS) was poured into each compartment so that the levels were relatively even and 1-2 cm from the top of the compartment. Lippert and Hopkins (1950), Thompson and Grime (1979), and Forcella (1984) all used sand as a substratum in their investigations.

The top 5 cm of each soil sample was spread evenly in one-half of a 12-pack—the top 2.5 cm in three compartments and the next 2.5 cm in the other three compartments, resulting in a depth of 1-2 cm. A variety of depths have been used by different investigators: 4 cm by Archibold (1981); 3 cm by Forcella (1984); 2 cm by Thompson and Grime (1979); 1.3 cm (0.5 in.) by Lippert and Hopkins (1950); and about 1 cm by Rabinowitz (1981).

Both the order in which a sample's location on the bench was determined and the ultimate location on the bench were randomly chosen (by drawing numbered sheets of paper from a container). Prior to deciding the locations of samples, the equivalent of twelve 12-packs were designated as controls and removed as options in the drawing. No soil was added to the sand in these compartments. Some shifting of trays occurred later to place the sand controls, rather than samples, under locations where water dripped from the watering system. Sample locations on the greenhouse bench are illustrated in Figure 5.

The 5-15 cm samples were placed one per 12-pack, prepared as above, on another table. Their arrangement was not randomized until the tenth week of the study. Two 12-packs were designated as controls. Figure 6 illustrates the arrangement of these samples on a greenhouse bench to the right of and adjacent to the other one.

Sample collection and processing took place over a two and one-half month period beginning on February 12 in the late winter and spring of 1987 as shown in Table 1. A period of cold-moist stratification is required by many prairie plants to break dormancy (Schramm 1978). Therefore, a late winter date was chosen for sample collection to allow pre-germination requirements of the seeds to occur naturally in the soil (after Johnson and Anderson 1986). According to Blake (1935), the spring, particularly April and May, has been found to be the best time for studying the viability of native prairie seeds using germination as the test for viability. The length of time from the first to the last collection date is partly due to periods of rainfall (see Figure 7) during which collection was not considered possible. All samples were collected prior to the last spring minimum of 32 ^{o}F (0 ^{o}C) or below.

The samples were maintained through July 24, 1987. This was four months after the last sample collection date. Forcella (1984) found four months to be the maximum time necessary in order to obtain statistically representative estimates of the number of species present in the soil seed bank.

North Wall of Greenhouse

2C89	3A5 +2D63	2C98	2B26	3C2 *1B68	2B2	1A11	2C14	1D61	1D67	2D18 *2C7	1E30	3E62	3B17	2A95	1C18	3B98 *1A75	1C67
3C98	Sand +1B98	1A70	3D19	Sand *1B29	3E22	1E7	Sand	3D58	3A63	Sand *3A19	3E42	1D69	Sand	2A52	1A98	Sand *3B89	2B30
2D63 +3A5	Sand +1E4	2D37	2A31	Sand *3C2	1B68 *3D17	2E20	Sand *3C32a/35b—>	3A61	2C7	Sand *2D18	1A7	3B87	Sand	3E72	1A75 *1C98	Sand *3B98	2B61
1B98 +Sand	1E37 +Sand	3C65	2E24	3A31 *Sand	1B29 *Sand	3D75	3A30	1D29	3A19 *Sand	2B69 *Sand	3C3	1C87	2C45	3B65	3B89 *Sand	2A5 *Sand	2B11
1D2 +Sand	1E4 +Sand	3B84	2E25	3D17 *Sand	1D45 *Sand	2D46	2B14	1B31	3D90 *Sand	3C32a 3C35b<—*Sand	3D37	2A66	1D15	3C29	1E20 *Sand	1C98 *Sand	2E42
1C9 +2E31	Sand +1E37	1C61	1C85	Sand *1A90	2C68 *3A31	2D39	Sand	3C71	1A42 *3D2	Sand 2B69	1B20	3C35a 3C32b	Sand	1E81	1B84 *2E3	Sand *2A5	1E79
1A17	Sand +1D2	3A95	3E39	Sand *1D45	3E84	2B97	Sand	2A81	3E9	Sand *3D90	2D78	3A46	Sand	1B44	3B54	Sand *1E20	3E74
2C17	2E31 +1C9	1B65	2E32	1A90 *2C68	1C58	2D62	2E89	3B20	3D86	3D2 *1A42	2A90	1E65	2A11	1D98	2D73	2E3 *1B84	2C55

Aisle

Figure 5. Locations of 0-5 cm depth samples on greenhouse bench. (The numerals 1, 2 and 3 represent the sites. Capital letters designate subfields. The numerals after the letters represent subplots. The top three compartments of the six-pack at each location were filled to a depth of 1-2 cm with soil from depth a (0-2.5 cm); the bottom three compartments were filled to the same depth with soil from depth b (2.5-5 cm). Some of the samples were shifted around on April 10 (final locations are indicated by the *) and May 19 (final locations are indicated by the +) to remove test samples from locations of persistent drips from the watering system.)

North Wall of Greenhouse

1E79	1C58	2B11	1B98	3E72	2C89	2D46	3A61
2B30	3A46	2C68	Sand	1D15	1D67	3E84	3C35
3D37	3D58	2A52	Sand	2E24	1B65	1A90	2D39
1A70	3C29	1C18	3B84	2E89	2A11	3B65	1E4

Aisle

Figure 6. Locations on greenhouse bench of depth c (5-15 cm) samples. (The numerals 1, 2 and 3 represent the sites. Capital letters designate subfields. The numerals after the letters represent subplots. Each 12-pack, represented by rectangles, was filled with soil to a depth of 1-2 cm. The trays were set up in this array on April 24. Prior to this date no particular order was maintained.)

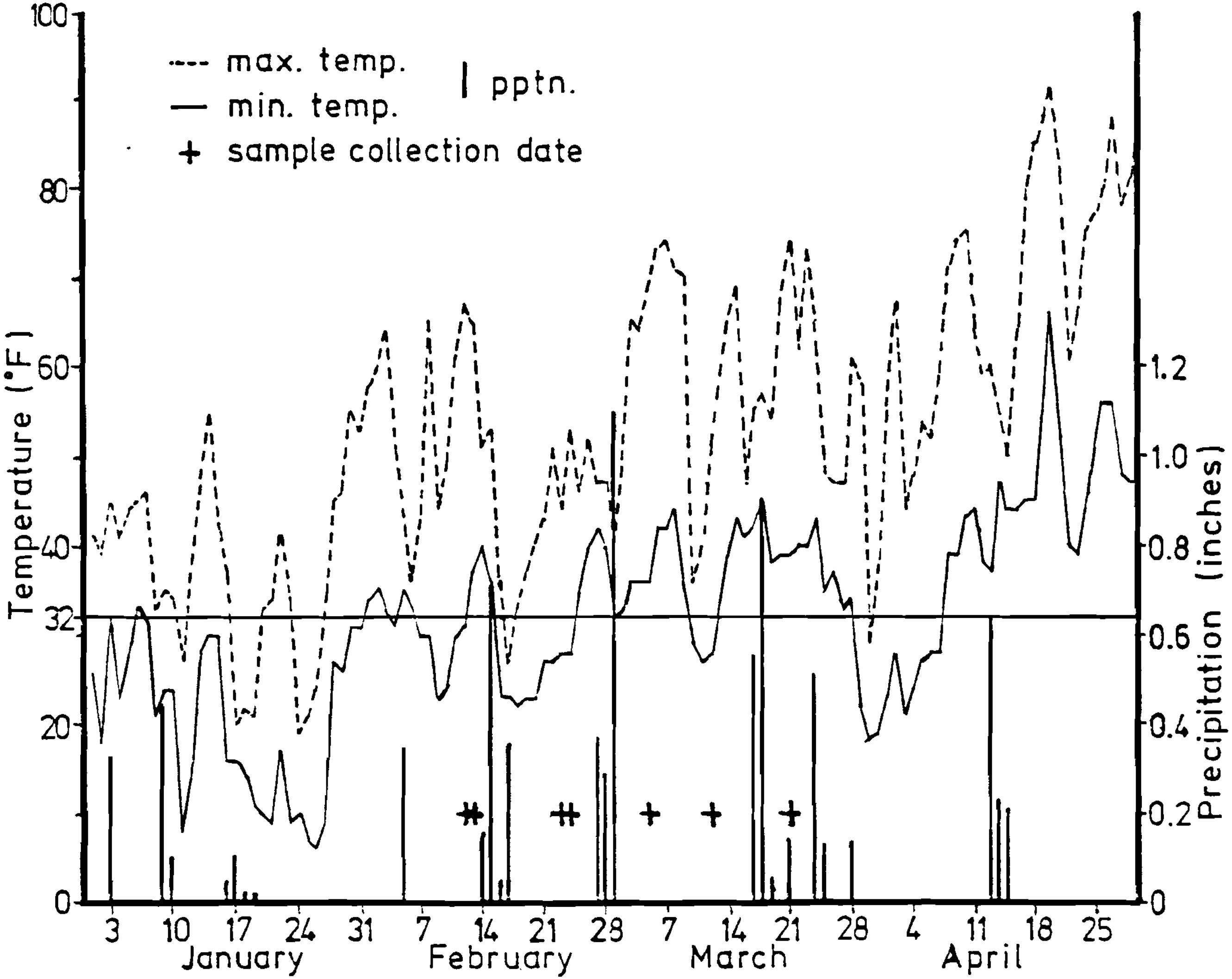

Figure 7. Sample collection dates in relation to weather data from January through April, 1987 for Emporia, Kansas. (Source: National Oceanic and Atmospheric Administration 1987)

The first sets of samples in the trays were watered with a spray bottle and later a hand-held pressurized sprayer. The intent was to water the samples as needed. On the two days of March 4 and 5, the samples were watered with half-strength Hoagland's solution (Hoagland and Arnon 1950) prepared without FeEDTA and micronutrients. This had been considered for all samples, but was thought to be unmanageable with the diverse starting dates and the temperature and humidity fluctuations in the greenhouse. On March 10 a misting system was set up and put into operation.

Seedlings were counted at least once a week, with the exception of week 22. Their identity was determined at least to the level of monocot or dicot. Some seedlings, such as Hibiscus trionum L. and Oxalis sp. were identified specifically using texts by Gates (1941) and Stucky (1981).

All seedlings were removed when the samples were sieved. After that individual seedlings were removed periodically. A few of the seedlings matured and developed flowers. They were removed as soon as this was noticed. Since seedlings were present, the samples were not regularly cultivated. Some investigators have cultivated their samples regularly (Harper 1977; Forcella 1984) or at a certain time (Rabinowitz 1981), while others have refrained from stirring the soil (Archibold 1981; Thompson and Grime 1979). On June 23, the top 5 cm samples were all cultivated. This was done with the 5-15 cm samples the next week. An attempt was made to alleviate water-logged conditions by either poking holes through the samples or by stirring the sample with a dissecting needle.

In preparation for data analysis, the total number of monocot, dicot, and unidentified seedlings counted in each depth section of each soil core sample were combined by subfield and depth. Means, standard deviations, coefficients of variation, and 95% confidence limits were determined for each depth of each subfield. The coefficient of variation is the standard deviation expressed as a percentage of the mean (Sokal and Rohlf 1981). This statistic was developed to allow the comparison of relative amounts of variation in populations having different means.

The data for depths a (0-2.5 cm) and b (2.5-5 cm) were statistically analyzed using a two-way analysis of variance (site by soil depth) that was part of a computerized biostatistical package, BIOSTAT I (Pimentel and Smith 1985). According to Zar (1974), the analysis of variance is robust enough to tolerate considerable heterogeneity of variances when sample sizes are equal or nearly equal. Also, great deviations from normality in the underlying populations have only a slight effect on the validity of the analysis. In running the anova, effects of subfields were ignored and numbers of unidentified seedlings (1.5% of the total) were not included.

RESULTS AND DISCUSSION

The results of this study are presented in Tables 2, 3, and 4. Each of these tables shows the number of monocot, dicot, and unidentified seedlings which emerged from each depth section of the individual soil cores obtained from the three study sites. The data are arranged by depth and subfield. As in other soil seed bank studies, these numbers of seedlings are estimates of the numbers of seeds present in the respective seed banks. The data for the top two depths (0-2.5 cm and 2.5-5 cm) are combined in Table 5 and are presented in the same manner as in the other three tables.

Table 6 shows the numbers of monocot, dicot, and unidentified seedlings counted for each depth of each subfield and their sums. Total numbers of monocot, dicot, and unidentified seedlings are given for each depth of each site. These totals represent the numbers of seeds per 0.1 m^2 surface area per 2.5 cm depth. Multiplying the site totals by ten gives the numbers of seedlings per meter squared. The values from this study compare well with those found by other researchers (see Table 7). When the greenhouse trays were cleaned up over one month after the last seedling count, seedlings were present. On July 24, all visible seedlings were removed. The seedlings present had emerged after that date and were not included in this study. This implies that the estimates of the seed bank determined by this study for the three sites are probably below the actual totals.

Site totals are also graphically depicted in Figure 8. The total number of seedlings counted at depths a (0-2.5 cm) and b (2.5-5 cm) decrease in order from recently reseeded old field (Site 1) to native

Table 2. Total number of seedlings per sample and subfield: Site 1 (the recently reseeded old field), depths a (0-2.5 cm), b (2.5-5 cm), and c (5-15 cm). (M=monocot, D=dicot, ?=unidentified)

	Subfield																			
	A				B				C				D				E			
	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	11	6	1	18	7	4	0	11	10	4	1	15	33	4	0	37	6	2	0	8
	6	2	0	8	22	3	0	25	33	0	0	33	5	1	0	6	2	1	0	3
	10	18	0	28	15	4	0	19	20	2	0	22	4	3	0	7	16	6	0	22
	6	6	0	12	1	9	2	12	18	2	1	21	3	4	0	7	11	0	0	11
Depth a	7	13	2	22	11	9	0	20	13	2	1	16	27	14	0	41	1	5	0	6
	26	11	0	37	7	7	0	14	62	4	0	66	10	4	0	14	3	3	0	6
	16	28	2	46	5	15	1	21	74	10	1	85	19	7	0	26	12	2	0	14
	7	26	1	34	3	4	0	7	11	5	0	16	4	0	0	4	8	1	0	9
Totals	89	110	6	205	71	55	3	129	241	29	4	274	105	37	0	142	59	20	0	79
	0	7	0	7	0	3	0	3	3	4	0	7	0	7	0	7	0	0	0	0
	0	3	0	3	1	3	0	4	3	1	0	4	0	0	0	0	0	4	0	4
	4	13	0	17	0	1	0	1	3	6	0	9	1	1	0	2	0	2	0	2
	20	12	0	32	0	8	0	8	2	4	0	6	0	4	0	4	3	4	0	7
Depth b	1	9	0	10	1	5	0	6	0	6	0	6	1	4	0	5	0	4	0	4
	4	7	0	11	1	6	0	7	4	1	0	5	1	1	0	2	0	5	0	5
	0	16	1	17	0	6	0	6	3	9	0	12	2	4	0	6	1	1	0	2
	0	11	0	11	0	11	0	11	2	1	0	3	2	5	0	7	3	3	0	6
Totals	29	78	1	108	3	43	0	46	20	32	0	52	7	26	0	33	7	23	0	30
	0	17	0	17	0	21	0	21	0	6	0	6	1	12	0	13	1	16	0	17
Depth c	2	39	1	42	0	3	0	3	0	5	0	5	0	22	0	22	0	6	0	6
Totals	2	56	1	59	0	24	0	24	0	11	0	11	1	34	0	35	1	22	0	23

Table 3. Total number of seedlings per sample and subfield: Site 2 (the native prairie pasture), depths a (0-2.5 cm), b (2.5-5 cm), and c (5-15 cm). (M=monocot, D=dicot, ?=unidentified)

	Subfield																			
	A				B				C				D				E			
	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	9	5	0	14	16	2	0	18	6	7	0	13	14	1	0	15	8	3	0	11
	5	6	1	12	15	4	0	19	10	9	0	19	6	3	4	13	13	1	0	14
	5	5	1	11	11	3	0	14	12	7	0	19	8	0	0	8	4	1	0	5
	10	4	0	14	15	11	0	26	12	17	1	30	18	4	0	22	11	0	0	11
Depth a	9	11	0	20	8	6	1	15	5	7	0	12	9	0	2	11	7	3	0	10
	12	3	1	16	7	7	0	14	11	6	0	17	9	0	0	9	6	0	0	6
	18	2	1	21	8	6	0	14	12	8	0	20	6	5	2	13	4	4	0	8
	12	4	0	16	10	1	0	11	17	6	0	23	15	3	1	19	9	3	0	12
Totals	80	40	4	124	90	40	1	131	85	67	1	153	85	16	9	110	62	15	0	77
	1	1	0	2	3	2	0	5	0	2	0	2	0	1	0	1	1	2	0	3
	1	1	0	2	3	2	0	5	4	4	0	8	1	1	0	2	0	1	0	1
	0	0	0	0	1	2	0	3	2	5	0	7	3	1	0	4	1	1	0	2
	0	1	0	1	0	3	0	3	2	7	0	9	2	0	0	2	3	0	0	3
Depth b	2	3	0	5	0	1	0	1	0	0	0	0	0	0	0	0	1	2	0	3
	4	0	0	4	4	2	0	6	7	0	0	7	5	1	0	6	1	0	0	1
	0	0	0	0	2	2	0	4	1	2	0	3	3	1	0	4	0	0	0	0
	6	4	0	10	0	1	0	1	3	3	0	6	2	2	0	4	0	1	0	1
Totals	14	10	0	24	13	15	0	28	19	23	0	42	16	7	0	23	7	7	0	14
	0	7	0	7	3	2	0	5	2	2	0	4	0	20	0	20	0	2	0	2
Depth c	1	1	0	2	0	1	0	1	0	8	0	8	0	18	0	18	0	4	0	4
Totals	1	8	0	9	3	3	0	6	2	10	0	12	0	38	0	38	0	6	0	6

Table 4. Total number of seedlings per sample and subfield: Site 3 (the older reseeded old field), depths a (0–2.5 cm), b (2.5–5 cm), and c (5–15 cm). (M=monocot, D=dicot, ?=unidentified)

	Subfield A				Subfield B				Subfield C				Subfield D				Subfield E			
	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	1	2	0	3	7	10	0	17	1	4	0	5	11	3	0	14	4	2	0	6
	7	7	0	14	6	3	0	9	3	10	2	15	4	2	0	6	0	1	0	1
	13	4	0	17	7	14	0	21	0	2	0	2	3	3	0	6	6	1	0	7
	1	2	0	3	5	11	0	16	0	1	0	1	2	7	0	9	13	5	0	18
Depth a	1	2	0	3	12	4	0	16	2	0	0	2	20	4	0	24	8	0	2	10
	6	4	0	10	3	11	0	14	4	7	0	11	6	2	0	8	4	2	0	6
	22	2	0	24	1	9	1	11	2	4	0	6	0	1	0	1	3	3	0	6
	8	2	0	10	0	1	0	1	3	2	0	5	1	0	0	1	4	2	0	6
Totals	59	25	0	84	41	63	1	105	15	30	2	47	47	22	0	69	42	16	2	60
	0	1	0	1	1	15	0	16	0	3	0	3	0	0	0	0	0	1	0	1
	1	9	0	10	1	4	0	5	1	5	0	6	0	1	0	1	0	2	0	2
	2	1	0	3	0	0	0	0	1	6	0	7	0	0	0	0	0	1	0	1
	2	0	0	2	0	2	0	2	0	1	0	1	0	2	0	2	3	1	0	4
Depth b	0	11	0	11	3	2	0	5	0	0	0	0	5	3	0	8	0	1	0	1
	0	0	0	0	0	3	0	3	1	2	0	3	0	0	0	0	3	2	0	5
	6	3	0	9	0	1	0	1	0	2	0	2	0	0	0	0	1	0	0	1
	1	1	0	2	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1
Totals	12	26	0	38	5	27	0	32	3	20	0	23	5	6	0	11	8	8	0	16
	0	5	0	5	1	15	0	16	0	5	0	5	0	8	0	8	0	6	0	6
Depth c	0	23	0	23	0	12	0	12	0	18	0	18	0	7	0	7	1	18	0	19
Totals	0	28	0	28	1	27	0	28	0	23	0	23	0	15	0	15	1	24	0	25

Table 5. Total number of seedlings per sample and subfield: all sites, depths a + b (0–5 cm). (Site 1=recently reseeded old field, Site 2=native prairie pasture, Site 3=older reseeded old field; M=monocot, D=dicot, ?=unidentified)

	Subfield A				Subfield B				Subfield C				Subfield D				Subfield E			
	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	11	13	1	25	7	7	0	14	13	8	1	22	33	11	0	44	6	2	0	8
	6	5	0	11	23	6	0	29	36	1	0	37	5	1	0	6	2	5	0	7
	14	31	0	45	15	5	0	20	23	8	0	31	5	4	0	9	16	8	0	24
	26	18	0	44	1	17	2	20	20	6	1	27	3	8	0	11	14	4	0	18
Site 1	8	22	2	32	12	14	0	26	13	8	1	22	28	18	0	46	1	9	0	10
	30	18	0	48	8	13	0	21	66	5	0	71	11	5	0	16	3	8	0	11
	16	44	3	63	5	21	1	27	77	19	1	97	21	11	0	32	13	3	0	16
	7	37	1	45	3	15	0	18	13	6	0	19	6	5	0	11	11	4	0	15
Totals	118	188	7	313	74	98	3	175	261	61	4	326	112	63	0	175	66	43	0	109
	10	6	0	16	19	4	0	23	6	9	0	15	14	2	0	16	9	5	0	14
	6	7	1	14	18	6	0	24	14	13	0	27	7	4	4	15	13	2	0	15
	5	5	1	11	12	5	0	17	14	12	0	26	11	1	0	12	5	2	0	7
	10	5	0	15	15	14	0	29	14	24	1	39	20	4	0	24	14	0	0	14
Site 2	11	14	0	25	8	7	1	16	5	7	0	12	9	0	2	11	8	5	0	13
	16	3	1	20	11	9	0	20	18	6	0	24	14	1	0	15	7	0	0	7
	18	2	1	21	10	8	0	18	13	10	0	23	9	6	2	17	4	4	0	8
	18	8	0	26	10	2	0	12	20	9	0	29	17	5	1	23	9	4	0	13
Totals	94	50	4	148	103	55	1	159	104	90	1	195	101	23	9	133	69	22	0	91

Table 5. (Continued)

	Subfield A				B				C				D				E			
	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	1	3	0	4	8	25	0	33	1	7	0	8	11	3	0	14	4	3	0	7
	8	16	0	24	7	7	0	14	4	15	2	21	4	3	0	7	0	3	0	3
	15	5	0	20	7	14	0	21	1	8	0	9	3	3	0	6	6	2	0	8
	3	2	0	5	5	13	0	18	0	2	0	2	2	9	0	11	16	6	0	22
Site 3	1	13	0	14	15	6	0	21	2	0	0	2	25	7	0	32	8	1	2	11
	6	4	0	10	3	14	0	17	5	9	0	14	6	2	0	8	7	4	0	11
	28	5	0	33	1	10	1	12	2	6	0	8	0	1	0	1	4	3	0	7
	9	3	0	12	0	1	0	1	3	3	0	6	1	0	0	1	5	2	0	7
Totals	71	51	0	122	46	90	1	137	18	50	2	70	52	28	0	80	50	24	2	76

Table 6. Total number of seedlings per subfield and site and the percentages of monocot, dicot, and unidentified seedlings for each site and depth. (Site 1=recently reseeded old field, Site 2=native prairie pasture, Site 3=older reseeded old field; depths: a (0-2.5 cm), b (2.5-5 cm), c (5-15 cm), and a + b (0-5 cm); M=monocot, D=dicot, ?=unidentified)

		Site 1				Site 2				Site 3			
Depth	Sub-field	M	D	?	Sum	M	D	?	Sum	M	D	?	Sum
	A	89	110	6	205	80	40	4	124	59	25	0	84
	B	71	55	3	129	90	40	1	131	41	63	1	105
a	C	241	29	4	274	85	67	1	153	15	30	2	47
	D	105	37	0	142	85	16	9	110	47	22	0	69
	E	59	20	0	79	62	15	0	77	42	16	2	60
	TOTALS	565	251	13	829	402	178	15	595	204	156	5	365
		68%	30%	2%	100%	68%	30%	3%	100%	56%	43%	1%	100%
	A	29	78	1	108	14	10	0	24	12	26	0	38
	B	3	43	0	46	13	15	0	28	5	27	0	32
b	C	20	32	0	52	19	23	0	42	3	20	0	23
	D	7	26	0	33	16	7	0	23	5	6	0	11
	E	7	23	0	30	7	7	0	14	8	8	0	16
	TOTALS	66	202	1	269	69	62	0	131	33	87	0	120
		25%	75%	0%	100%	53%	47%	0%	100%	28%	72%	0%	100%
	A	2	56	1	59	1	8	0	9	0	28	0	28
	B	0	24	0	24	3	3	0	6	1	27	0	28
c	C	0	11	0	11	2	10	0	12	0	23	0	23
	D	1	34	0	35	0	38	0	38	0	15	0	15
	E	1	22	0	23	0	6	0	6	1	24	0	25
	TOTALS	4	147	1	152	6	65	0	71	2	117	0	119
		3%	97%	1%	100%	8%	92%	0%	100%	2%	98%	0%	100%
	A	118	188	7	313	94	50	4	148	71	51	0	122
	B	74	98	3	175	103	55	1	159	46	90	1	137
a + b	C	261	61	4	326	104	90	1	195	18	50	2	70
	D	112	63	0	175	101	23	9	133	52	28	0	80
	E	66	43	0	109	69	22	0	91	50	24	2	76
	TOTALS	631	453	14	1098	471	240	15	726	237	243	5	485
		57%	41%	1%	100%	65%	33%	2%	100%	49%	50%	1%	100%

Table 7. Estimates of the number of seeds in the soil seed banks of various grassland sites. (*--the numbers given for this study represent the number of seedlings which emerged and the number of nongerminated seeds, in that order; Site 1 was seeded in 1981; Site 3 was seeded in 1969.)

Sites	Sample depth (cm)	$Seeds \cdot m^{-2}$	Source
Old-fields:			
recently reseeded (Site 1)	5	10,980	This study
older reseeded (Site 3)	5	4,850	
Native prairie pasture (Site 2)	5	7,260	
Tall grass prairie:			
in Missouri	12	6,470	Rabinowitz (1981)
in Illinois	10	2,019	Johnson and Anderson (1986)
Mixed prairie (western Kansas):			Lippert and Hopkins (1950)
meadow and grass communities	1.3	290-1200	
disturbed and naturally revegetating habitats	1.3	5000-23,000	
Saskatchewan, Canada:			
native midgrass prairie	10	739 + 19	*Archibold (1981)
grazed pasture	10	476 + 387	
wheat stubble	10	520 + 685	
summer fallow	10	1667 + 1007	
Bunch-grassland, California:			Major and Pyott (1966)
ungrazed area	5	8,230	
grazed area	5	12,200	
United Kingdom			
sown grassland (newly sown leys)		4940-18,900	Champness (1949)

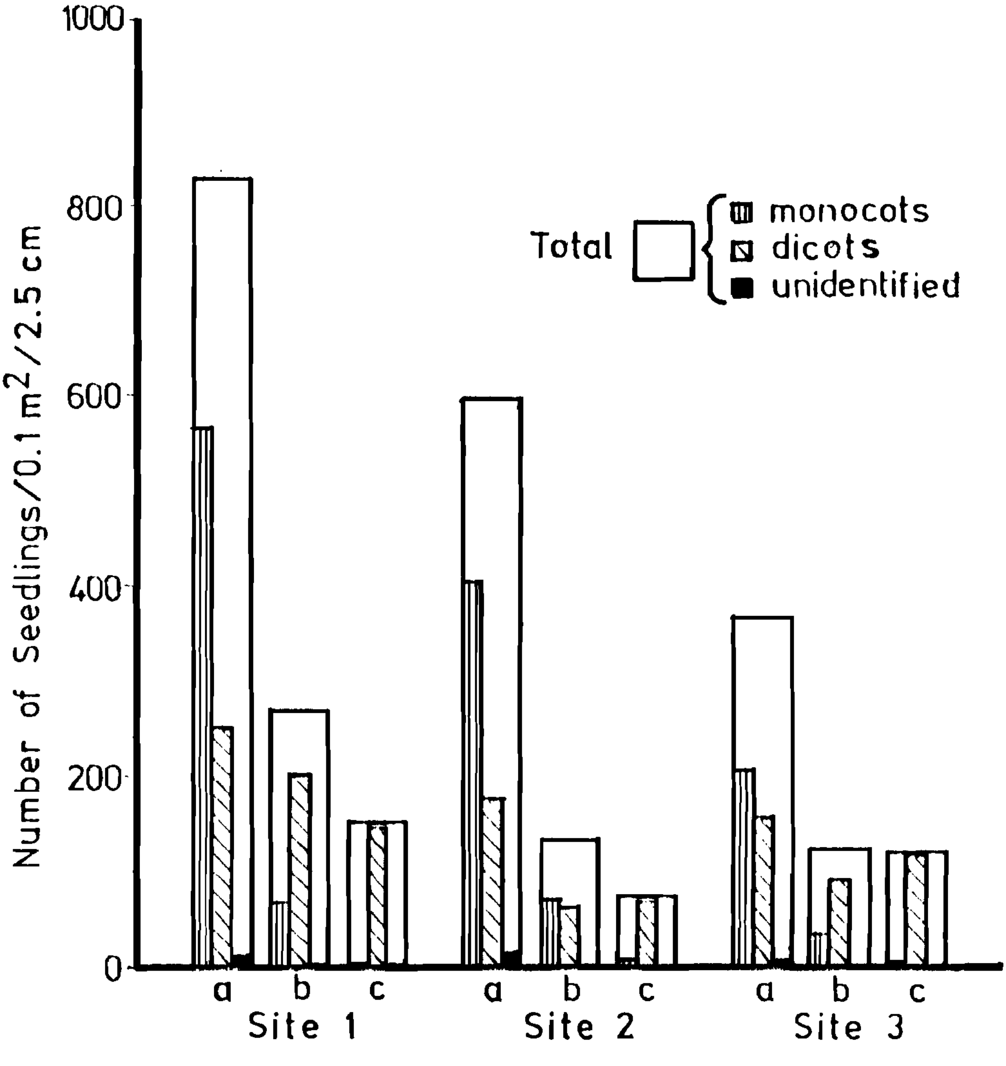

Figure 8. Number of seedlings per 0.1 m^2 per 2.5 cm. (Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field; depths: a (0–2.5 cm), b (2.5–5 cm), c (5–15 cm))

prairie pasture (Site 2) to older reseeded old field (Site 3). The same progression holds when comparing the three sites with depths a and b combined (see Table 6), resulting in the top 5 cm of soil being considered. When all depth a and b samples were combined and averaged for each site, it was found by two-way anova (site by soil depth; Table 8 is the anova table) that there was highly significant variation among the means ($P < 0.001$). Multiple range tests showed the three site means to be significantly different from each other. When comparing the numbers of seedlings per site for depth c (5-15 cm), the rank order changes. Site 1 continues to have the most seedlings, but Site 3 has the intermediate number and Site 2 the lowest number.

Numbers of seedlings counted decrease with depth in every case except when comparing depths b (2.5-5 cm) and c (5-15 cm) of the older reseeded old field (Site 3). The mean of all the depth a (0-2.5 cm) samples was found, by the same two-way anova mentioned above, to be significantly different from the mean of all depth b (2.5-5 cm) samples ($P < 0.001$). The decrease with depth depends also in part on the site. The interaction term determined by the two-way anova was significant ($0.01 < P < 0.001$). Figure 9 illustrates this relationship.

The results of studies cited by Harper (1977) and Radosevich and Holt (1984) would suggest that arable lands have more seeds in their soil seed banks than most grasslands. Archibold (1981) estimated the buried viable propagules in native prairie, grazed pasture, wheat stubble, and summer fallow in central Saskatchewan. He found that the combined seedling counts and nongerminating seed reserves increased as land disturbance became more severe (see Table 7). Lippert and

Table 8. Analysis of variance table for two-way anova (site by soil depth; sites are level one, soil depths are level two; effects of subfields are ignored; a = 3, b = 2, n = 40; generated by the computer program BIOSTAT 1: multiway analysis of variance (ver. 1.0) (Pimental and Smith 1985))

Source	Error term	SS	df	Mean square	F	Prob.
A	N(AB)	2384.308	2	1192.154	17.669	0.000
B	N(AB)	6709.837	1	6709.837	99.445	0.000
AB	N(AB)	651.6753	2	325.8376	4.829	0.009
N(AB)		15788.68	234	67.47300		

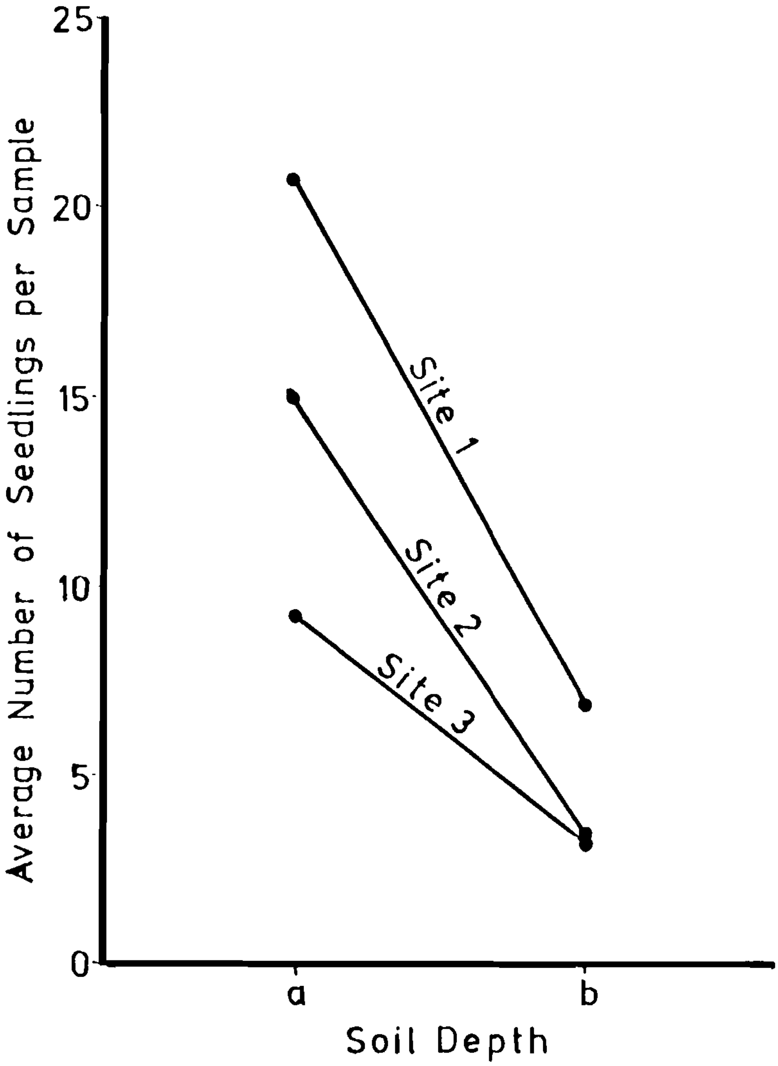

Figure 9. Site by soil depth interaction: average number of seedlings per sample for each site by soil depth. (Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field; depths: a (0-2.5 cm) and b (2.5-5 cm); means determined by computer using the program BIOSTAT 1: multiway analysis of variance (ver. 1.0) (Pimental and Smith, 1985); unidentified seedlings are not included)

Hopkins (1950), in a study of mixed prairie in Kansas, found more seedlings in habitats which were being naturally revegetated, a denuded pasture corner, and an overgrazed short grass community than in a weedy meadow, short grass, mid grass, and mixed grass communities. Other studies on old field succession have been done in woodland communities (Harper 1977). The closest comparable study to the current study of artificially revegetated old fields is a study in which the effect of different grass and legume seed mixtures on the buried viable seed content of the soil was investigated (Champness 1949). The numbers from that study, representing the seed bank population at the end of the seeding year, were comparable to those of most grassland studies.

From a study of the literature cited above, one would expect the tilled precursors of the reseeded old fields in this study to have a greater number of seeds in the seed bank than native prairie. Since the native prairie pasture in this study has a history of being cut for hay, its seed bank population may be higher than that of native prairie, bringing it closer to those expected for the reseeded old fields. A comparison of the results of this study with those of Rabinowitz (1981) and Johnson and Anderson (1986) supports this idea (see Table 7). The recently reseeded old field was abandoned cropland before being seeded only six years ago in 1981. One would not expect much change during that short period of time and would expect its seed bank population to be greater than that of the native prairie pasture. That expectation is met in this study. The older reseeded old field had been farmed until being reseeded 18 years ago in 1969. One might expect its seed bank population to number between those of the other two sites. It is surprising to see the numbers for this site even below that of the native prairie pasture.

Soil seed banks are reduced by germination, predation, and decay (Harper 1977). The effects of these factors on the current study sites is unknown. In a study of the fate of seeds of three species of Ranunculus, Sarukhan (1974) found that predation, seed decay, and germination, as well as dormancy, varied with the species. Seed longevity in soil also varies among plants (Radosevich and Holt 1984) and is heritable (Harper 1977). Harper generalizes from the literature that long-lived seeds are characteristic of disturbed habitats. This would suggest that the seeds in the reseeded old fields might be viable longer. The environment can have an effect on seed decay by affecting the activity of seed decomposers. Certain conditions (acidic and/or waterlogged soils) may be considered good for seed storage. Crandall (1987) found the clay content and the acidity of the two reseeded old fields to be to be greater than that of the native prairie pasture. This suggests slightly better storage conditions in the soil of the reseeded old fields. Both the better storage conditions and the longer viability suggested for seeds in the reseeded old fields should result in higher seed bank numbers at these sites than at the native prairie pasture. However, the results of this study show the native prairie pasture to have more buried viable seeds than the older reseeded old field.

Replenishment of the seed bank would occur through the seed rain (Harper 1977) onto the ground surface, into the top soil layer, and later permeating to lower depths. The current study and other studies which have included different soil depths (Chippindale and Milton 1934; Johnson and Anderson 1986) show that most seeds are found in the top soil layer with numbers decreasing with depth. The difference between soil depths is much less for the older reseeded old field than the other two sites (Figure 9). This and the fact that it has significantly fewer seeds in the top 2.5 cm would suggest that it is not being replenished like the other two. Perhaps the five native grasses planted in the reseeded old fields do not contribute much to the seed bank. Harper (1977) suggests that the seed production from perennials is low compared with many annual species and is also rather unpredictable. The large seed bank population of the recently reseeded old field may be due to annuals not found at the other sites. The older reseeded old field may simply lack the diversity of vegetation found in the native prairie. This could result in a smaller seed rain and fewer seeds with which to replenish the seed bank.

The greater number of seeds in the native prairie pasture, when compared with the older reseeded old field may also be due to differences in grazing. Crandall (1987) reported that during the summer of 1986 the reseeded old fields exhibited light to moderate use while the native prairie received quite heavy use. Studies by Lippert and Hopkins (1950), Major and Pyott (1966), and Archibold (1981) seem to indicate an increased grazing intensity results in an increased soil seed bank.

Though the dominant species were different for each of the three sites, the sites were all dominated by perennial grasses. The older reseeded old field had relatively fewer monocots than did the other two (Figure 8). This might be partly explained by the presence of prolific or potentially prolific seed producers in the recently reseeded old field and the native prairie pasture. In the recently reseeded old field the presence of a prolific monocot seed producer is suggested by the numbers of seedlings (62 and 74 per 25 cm^2 or 24,800 and 29,600 per meter squared) which germinated from two of the samples in Subfield C (Table 2). Crandall (1987) reported a considerable amount of *Agrostis* spp. in the native prairie pasture. Harper (1977) reports that species of *Agrostis* produce a very high density of seeds.

Monocots outnumbered dicots in the top 2.5 cm of soil for all three sites (Figure 8). As noted previously, the older reseeded old field had a lower proportion of monocots (56%) than the other two, which were equal at 68% (Table 6). The reverse held true for the next 2.5 cm of soil from both of the reseeded old fields (25-28% monocots, 75-72% dicots), while the numbers for the native prairie were about even (53% monocots, 47% dicots). When the top 5 cm is considered, monocots outnumber dicots in the recently reseeded old field (57% monocots, 41% dicots) and the native prairie pasture 65% monocots, 33% dicots), while being about the same or slightly outnumbered in the older reseeded old field (49% monocots, 50% dicots). Dicots outnumbered monocots in depth c (5-15 cm) of all three sites. The difference was quite definite in the reseeded old fields (2-3% monocots, 98-97% dicots). When the results from all three depths were combined, resulting in the top 15 cm of soil being considered, there were more monocots than dicots (60% to 38%) in the native prairie pasture, about the same number of monocots and dicots (51% to 48%) in the recently reseeded old field, and fewer monocots than dicots (40% to 60%) in the older reseeded old field.

One factor which may account for the greater number of dicot seeds with depth could be seed longevity. Radosevich and Holt (1984) mention that seed longevity appears to be short for grasses. They may lose viability before some event could occur that would result in their burial. Seed texture, shape, size, and the presence of awns may affect ease of burial.

Lippert and Hopkins (1950), when sampling the top 1.27 cm (0.5 inch) of soil, found grasses to account for more than 92% of the seeds in the soil seed bank of the overgrazed short grass community and the two sites being revegetated naturally. The short grass community had approximately 50% monocot seeds while the other two grassy sites and the weedy meadow had less than 32% of the seed bank represented by monocots. In the denuded pasture corner 1% of the seeds which germinated were monocots with 99% being dicots. Rabinowitz (1981) sampled the top 12 cm of tall-grass prairie soil and reported that of the total number of seedlings identified, 70% were monocots and 30% were dicots. Johnson and Anderson (1986) sampled the top 10 cm of soil in a remnant tallgrass prairie finding 20.6% of the identified seedlings to be monocotyledonous and 79.4% to be dicotyledonous.

Sand controls were used in the greenhouse as a means of detecting possible contamination of the soil samples. Sixteen seedlings (0.67 seedlings per six-pack) germinated in the controls among the depth a

(0-2.5 cm) and depth b (2.5-5 cm) samples and five seedlings (2.5 seedlings per 12-pack) germinated among the depth c (5-15 cm) samples. In comparison, the total number of seedlings which germinated in the depth a and b samples was 2309 (19.24 seedlings per six-pack). The total for depth c samples was 342 seedlings (11.40 seedlings per 12-pack).

All twenty-one seedlings from the sand controls were dicots. Of the sixteen seedlings counted in the sand controls among the samples from depths a and b, there were ten *Oxalis* sp. (0.42 per six-pack) and one which was possibly a dandelion (*Taraxacum* sp.). All five seedlings counted in the sand controls among the depth c samples were *Oxalis* sp. Table 9 shows the numbers of identified seedlings in the soil samples and the sand controls. Sixty-nine *Oxalis* sp. seedlings (0.58 per six-pack) were counted from the depth a and b samples and 197 (6.57 per 12-pack) were counted from the depth c samples. *Oxalis* sp. was also found to grow in the greenhouse. On June 16 and 23 seed pods of some *Oxalis* sp. plants in the greenhouse were examined and found to be unopened. Seedlings from plants of this genus appeared as early as May 7 indicating the *Oxalis* sp. seedlings were not just greenhouse contaminants. However, the large number of *Oxalis* sp. seedlings in the depth c samples may be greenhouse contaminants. Fifty-four percent of these seedlings germinated after June 23. Figure 10 shows a concentration of *Oxalis* sp. in the right hand portion of the greenhouse trays. The numbers in these samples cannot be directly compared with the sand controls since neither of the controls had been placed among them.

Table 9. Numbers of identified seedlings in samples and sand controls. (Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field; depths: a (0-2.5 cm), b (2.5-5 cm), c (5-15 cm); Ox=<u>Oxalis</u> sp., H.t.=<u>Hibiscus trionum</u>, Trxcm=<u>Taraxacum</u> sp.(?); depth a and b samples in 120 six-packs, sand among them in 24 six-packs; depth c samples in 30 12-packs, sand among them in two 12-packs.)

		Site 1			Site 2			Site 3		
Depth	Subfield	Ox.	H.t.	Trxcm	Ox.	H.t.	Trxcm	Ox.	H.t.	Trxcm
	A	8	5		3			1		
	B	2			1			2	13	
a	C	3	1		7			4	4	
	D	1			2			4	1	
	E	1	6		3			1	3	
	Sum	15	12	0	16	0	0	12	21	0
	A		7		1			1	1	
	B	3	11		2			11	4	1
b	C	3	6		4		1	5	4	
	D	1	2		1			1		
	E		2		2			1	6	
	Sum	7	28	0	10	0	1	19	15	1
Sand		10		1						
	A	18	11		5			20	4	
	B	9	7		1			13	7	1
c	C	3			7			15	3	
	D	14	4		35			7		
	E	12	1		5		1	23		
		56	23	0	53	0	1	78	14	1
Sand		5								

North Wall of Greenhouse

2 6 1E	2 5 1C	1 5 2B	3 3 1B	5 6 3E	7 8 2C	16 18 2D	20 23 3A
1 2B	5 3A	4 2C	1 1 SAND	1 13 1D	13 22 1D	18 19 3E	13 18 3C
3 8 3D	4 7 3D	2 2A	4 4 SAND	1 2 2E	6 21 1B	13 42 1A	19 20 2D
5 17 1A	2 5 3C	1 6 1C	3 12 3B	4 4 2E	5 7 2A	10 16 3B	10 17 1E

Aisle

Figure 10. Distribution of Oxalis sp. seedlings on greenhouse bench filled with depth c (5-15 cm) samples. (The top left number in each rectangle represents the number of Oxalis sp. seedlings counted in that sample. The middle right number in each rectangle represents the total number of seedlings counted in that sample. The symbols in the lower left of each rectangle designate the site and subfield of that sample. Site 1 = recently reseeded old field; Site 2 = native prairie pasture; Site 3 = older reseeded old field)

If this greenhouse contamination did take place, the reduced number of seedlings would indicate fewer seeds at the 5-15 cm depth. The extremely unequal monocot-dicot relationship at this depth would become less pronounced. The depth distribution presented in Figure 8 would be altered, though the relationships would remain the basically the same.

Seedlings of the genus Taraxacum were probably introduced when the samples were in the greenhouse. The four dandelion seedlings which germinated in the greenhouse flats probably grew from seeds that were blown into the greenhouse and onto the soil or sand. This is suggested by repeated observations during the course of the experiment of seeds of this genus on the top of the soil and sand in a number of compartments. Incidently, seedlings of Hibiscus trionum were found only in the reseeded old fields.

Another source of contamination, which may account for the seedlings found in the sand controls, may be neighboring soil samples. While the trays were filled with soil and later when "pithing" the samples to provide drainage, soil spilled from some compartments into adjacent ones. It was replaced if possible. When watering with the pressurized hand sprayer soil particles could have been washed from one compartment to another also resulting in the transfer of seeds.

The effect(s) of different collection dates, processing schedules, and time intervals in greenhouse trays is difficult to determine. Variation can be seen among the subfield means and standard deviations shown in Table 10. The relative amounts of variation are shown by the coefficients of variation. They range from 7% to 202% with all but three greater than 20%. This agrees with the observation made by

Table 10. Means, standard deviations, and coefficients of variation of subfield data: all sites and depths. (s = standard deviation, V% = coefficient of variation expressed as a percent, n = number of samples; Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field; depths: a (0-2.5 cm), b (2.5-5 cm), c (5-15 cm), and a+b (0-5 cm); A-E represents all 40 samples at the site)

			Site 1			Site 2			Site 3		
Depth	n	Sub-field	Mean	s	(V%)	Mean	s	(V%)	Mean	s	(V%)
a	8	A	25.6	13.03	(51)	15.5	3.55	(23)	10.5	7.62	(72)
		B	16.1	6.06	(38)	16.4	4.63	(28)	13.1	6.13	(47)
		C	34.2	26.59	(78)	19.1	5.69	(30)	5.9	4.85	(83)
		D	17.8	14.89	(84)	13.8	4.80	(35)	8.6	7.52	(87)
		E	9.9	5.94	(60)	9.6	3.07	(32)	7.5	4.90	(65)
	40	A-E	20.7	16.82	(81)	14.9	5.28	(36)	9.1	6.50	(71)
b	8	A	13.5	8.82	(65)	3.0	3.34	(111)	4.8	4.46	(94)
		B	5.8	3.10	(54)	3.5	1.85	(53)	4.0	5.24	(131)
		C	6.5	2.88	(44)	5.2	3.20	(61)	2.9	2.48	(86)
		D	4.1	2.59	(63)	2.9	1.96	(68)	1.4	2.77	(202)
		E	3.8	2.32	(62)	1.8	1.16	(67)	2.0	1.60	(80)
	40	A-E	6.7	5.67	(84)	3.3	2.59	(79)	3.0	3.61	(120)
c	2	A	29.5	17.68	(60)	4.5	3.54	(79)	14.0	12.73	(91)
		B	12.0	12.73	(106)	3.0	2.83	(94)	14.0	2.83	(20)
		C	5.5	0.71	(13)	6.0	2.83	(47)	11.5	9.19	(80)
		D	17.5	6.36	(36)	19.0	1.41	(7)	7.5	0.71	(9)
		E	11.5	7.78	(68)	3.0	1.41	(47)	12.5	9.19	(74)
	10	A-E	15.2	11.70	(77)	7.1	6.66	(94)	11.9	6.64	(56)
a+b	8	A	39.1	16.00	(41)	18.5	5.37	(29)	15.2	9.90	(65)
		B	21.9	5.06	(23)	19.9	5.33	(27)	17.1	9.09	(53)
		C	40.8	28.17	(69)	24.4	8.35	(34)	8.8	6.30	(72)
		D	21.9	16.31	(75)	16.6	4.69	(28)	10.0	9.94	(99)
		E	13.6	5.73	(42)	11.4	3.42	(30)	9.5	5.66	(60)
	40	A-E	27.4	19.04	(69)	18.2	6.88	(38)	12.1	8.65	(71)

Archibold (1981) that variation within sites is high for all studies of buried viable propagules.

Figure 11 shows the 95% confidence intervals for each of the subfields of the three sites. Data from depths a (0-2.5 cm) and b (2.5-5 cm) were combined in determining the confidence limits. A straight line parallel to one of the axes can be drawn through all of the intervals for Site 3 but only 80% of the intervals for Sites 1 and 2. The confidence limit for Subfield E is excluded from the 80% in each case. Table 10 shows the smaller means to be among the subfields sampled last (see Table 1 for the collection dates). This could be expected since the time interval over which seedlings were counted in the greenhouse was shorter than for ones collected earlier. Monocot and dicot seedlings were noticed in the field on February 12, the first collection date. Seedlings found growing from the sample cores were included in the seedling counts for this study. The graph of weather data from January through April of 1987 (Figure 7) shows a wet and cool spring--conditions not ideal for the germination of most seedlings. The warming trend from spring into summer began after the last samples were collected. Thus seedlings lost prior to collection would not seem to be a factor leading to the differences found among subfield means.

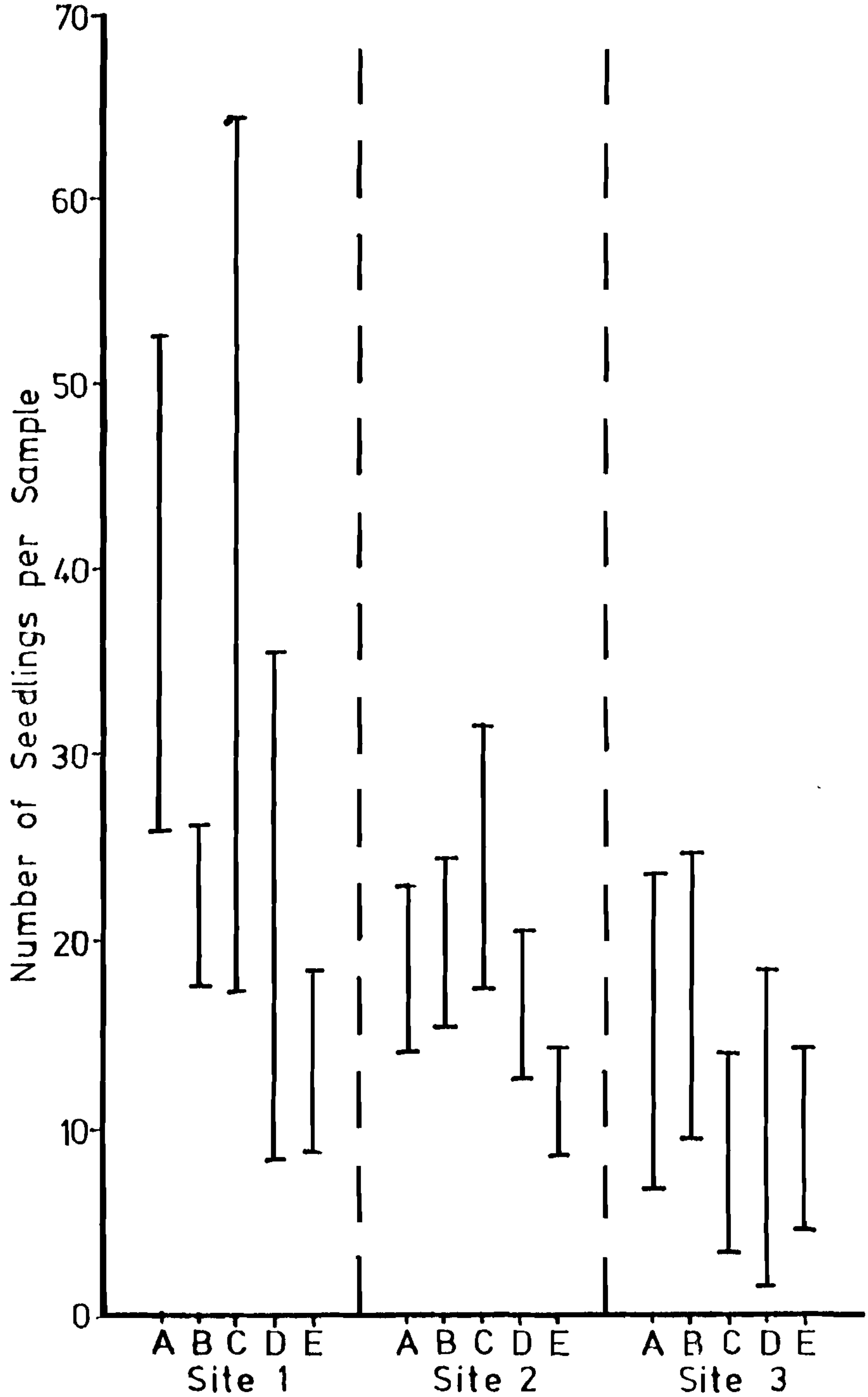

Figure 11. 95% confidence intervals for the subfields at each site. (subfields are indicated by capital letters; Site 1 = recently reseeded old field, Site 2 = native prairie pasture, Site 3 = older reseeded old field)

SUMMARY

Viable seeds in the soil seed banks of a native prairie pasture, an old field seeded with native grasses in 1969, and an old field seeded with native grasses in 1981 were estimated for three soil depths—0-2.5 cm, 2.5-5 cm, and 5-15 cm. All three sites, located in Lyon County, Kansas, have similar soils and are used for grazing.

Eight samples, each with a surface area of 25 cm^2, were obtained from each of the five subfields artificially partitioning each of the three sites. The samples were divided by depth, sieved through a 0.64 cm (1/4 in) screen, and placed over a sand substratum in trays in a greenhouse. The sand was left uncovered in some of the trays to serve as controls.

Samples were collected during late winter and early spring of 1987 (February 12 to March 21) before the last spring minimum of 32 ^{o}F (0 ^{o}C) or below. Samples were maintained in the greenhouse until July 24, 1987. The numbers of new monocot, dicot, and unidentified seedlings were counted at least once per week, with one exception. _Oxalis_ sp. and _Hibiscus trionum_ were identified specifically.

An estimated 10,980 seeds$\cdot m^{-2}$ (57% monocots, 41% dicots, 1% unidentified) emerged from the top 5 cm of the recently reseeded old field. The native prairie pasture, with 7,260 seeds$\cdot m^{-2}$ (65% monocots, 33% dicots, 2% unidentified), had a higher number than the 4,850 seeds$\cdot m^{-2}$ (49% monocots, 50% dicots, 1% unidentified) found in the older reseeded old field. Analysis by two-way anova (site by soil depth) and multiple range tests showed these differences were highly significant

($P < 0.001$). These numbers compare well with estimates of similar plant communities done by other investigators.

From a study of the literature, one would expect the seed banks of both reseeded old fields to be higher than that of the native prairie pasture. The effects of germination, predation, and decay is unknown for the current sites. Assuming decay rates to be similar for the two reseeded old fields, one would expect fewer viable seeds in the older reseeded old field than in the recently reseeded old field. Site histories and the replenishment of the seed bank through the seed rain are factors most likely to have effected the differences noted. The presence of prolific seed producers in the prairie pasture but most noticeable in the recently reseeded old field may account for some of the difference between these two sites and the older reseeded old field. Use of the native prairie pasture for hay could have opened up the stand of vegetation allowing in weedy species with their prolific seed production. The heavy grazing intensity noticed at this site could have had the same effect. As abandoned cropland, the recently reseeded old field would also have been open to an influx of weedy species and their seeds. Weed control practices during the wheat-milo crop rotations on the older reseeded old field prior to seeding with native grasses could have reduced the impact of weedy species at this site. A lack of diversity at this site could also have reduced inputs to the seed bank.

Numbers of seeds declined with depth as expected. Means for the top two depths were significantly different ($P < 0.001$). A significant ($0.01 > P > 0.001$) site by soil depth interaction was also present. Monocots outnumbered dicots in the top 2.5 cm of soil for all three sites. The proportion of dicots increased with depth. The older reseeded old field had a lower ratio of monocots to dicots in the top 2.5 cm than the other two sites, which had the same monocot-dicot ratio. For the 2.5-5 cm depth, the ratios for the reseeded old fields were quite similar and less than that of the native prairie pasture. When results for the two depths were combined, the native prairie pasture had a higher percentage of monocots (69%) than the recently reseeded old field (57%) and the older reseeded old field (49%).

The number of seedlings counted in the sand controls suggest greenhouse contamination of the 5-15 cm depth samples by *Oxalis* sp. The reduction of the totals to reflect this would only further exaggerate differences found due to depth.

In conclusion, the results of this study seem to indicate that the seed bank populations of reseeded old fields are not maintained over time. After approximately eighteen years the seed bank of an old field, in terms of seed numbers, becomes more like that of a native prairie pasture than an abandoned field. However, species composition, reflected in the monocot-dicot ratios, may remain quite different.

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