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Paul A. Christiansen
Cornell College

Roger Q. Landers
Iowa State University

our information on the northern range of *A. hybridus* which appears to be presently limited in the midwest at the latitude of northern Iowa.

Despite the continual mixing of genotypes of these weed populations by agricultural practices and seed introductions, it appears that these three species have evolved genetically adapted populations in response to different environments throughout their ranges.

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Notes on Prairie Species in Iowa. I. Germination and Establishment of Several Species

PAUL A. CHRISTIANSEN[1] AND ROGER Q. LANDERS[2]

Abstract. Information is given concerning the germination and early establishment of 30 prairie species. A stratification treatment was included for all seeds, and scarification was also used for the legumes. Germination percentage in greenhouse flats was generally higher than in field plots with variation in germination ranging from 96% in compassplant, *Silphium laciniatum,* to zero in some such as *Rosa suffulta* and *Gentiana puberula.* Seedlings in field plots were subjected to five levels of competition throughout the growing season. Establishment, measured by numbers of seedlings and vigor in September, was most successful on weed free treatments, least successful on cover crop treatments.

1 Assistant Professor, Cornell College, Mt. Vernon.
2 Associate Professor, Iowa State University, Ames.

The establishment of prairie species has received very little attention of a quantitative nature. Several prairie areas have been described which were largely recontructed such as the Curtis Prairie in the University of Wisconsin Arboretum (Greene and Curtis 1953; Cottam and Wilson 1966) and the Trelease Prairie near the University of Illinois, Urbana, Illinois (Hadley and Kieckhefer 1963). These reconstructions, however, have not generally been followed rigorously to provide information on the performance of individual species under various establishment techniques. Nor have studies on regeneration of native prairies emphasized the performance of more than a few of the dominant species (Weaver 1954; Cornelius 1946).

Germination has been studied to a greater degree. Greene and Curtis (1950) reported on germination of 82 prairie species, and Blake (1935) reported on several prairie species. Generally these investigations revealed that stratification was beneficial to 70% of the species, ineffective on 17%, and detrimental to germination of 13% of the species. They also investigated the differences in germination of annual seed collections.

Some native grasses have attracted attention as forage crops, and their germination and establishment have been studied intensively. Cornelius and Atkins (1946) followed the establishment of six prairie grasses for four years in Kansas. Robocker and Miller (1955) studied establishment of several native prairie grasses under different management schemes. Blake (1935) sowed seeds of prairie grasses and forbs into prairie sod and found none survived after the second yeer due to moisture stress and competition.

This paper deals with germination and establishment of thirty prairie species found in Iowa. It is a portion of a continuing project on the dynamics of prairie vegetation. Germination studies were accomplished in 1)flats of soil in which the seeds had been planted in early winter to remain outdoors until spring and 2) in field plots by planting seeds in spring which had been stratified by refrigeration. Establishment was recorded in the field plots in relation to several levels of competition.

Materials and Methods

Seeds of most of the species tested were collected in the fall of 1964 from railroad rights-of-way near Ames, Iowa. The fruits and seeds were air dried in the laboratory and then hand threshed and cleaned using facilities of the Iowa State University Seed Testing Laboratory. Threshing and cleaning were done with a hand rubbing board, sieves and a South Dakota Seed

Blower, Model B. Cleaned seeds were stored at room temperature until used.

Seeds of several species were obtained from Sy Angstrom of Huxley, Iowa, from plants growing in his garden of native plants.

Germination in flats.

Flats for germination studies were set up in late December, 1964, following a procedure described by Blake (1935); flats were filled with screened, steam-treated greenhouse soil; seeds were sown in lots of fifty in most cases, with six to eight lots per flat, set out in three blocks; the lots were separated by placing wooden pot labels on edge in the soil with the top edge flush with the soil surface; seeds were then covered with ¼″ screened soil and the soil gently tamped; screened *Sphagnum* moss was scattered in a thin layer over the soil and the soil was then moistened with a fine spray and allowed to drain.

The flats were transferred outdoors on the ground and covered with cheese cloth. With the first signs of germination in the spring, the cheese cloth was removed and a wire netting cover was placed over the flats to protect the seedlings.

Counting of seedlings was begun in April 22, 1965 and continued weekly until June 8. Previously counted seedlings were identified by placing a tooth pick adjacent to each seedling.

Germination and establishment in field plots

Field germination and establishment plots were laid out in the Ash Avenue experimental area at Ames which had been prepared and seeded to winter wheat as a cover crop. Seeds were planted May 12-14, 1965. Various levels of competition were achieved by keeping one treatment free of all vegetation except prairie species, removing only the cover crop in another area, and allowing the cover crop to remain in a third. The latter two areas were each split into two treatments by mowing in early July. Five treatments resulted: 1) weed free, 2) cover crop, 3) cover crop and mowed, 4) without cover crop, and 5) without cover crop and mowed. Three blocks were set up containing each of the five treatments. Numerous weed species were present in all the treatments except number one.

Seeds were pre-treated for field experiments by stratification for all species and scarification for legumes. Stratification was accomplished by placing each lot of seeds in approximately 10 cc of steam-treated greenhouse soil at field capacity. Scarification of legumes was accomplished by rubbing the seeds between sheets of #100 Aloxite metal cloth until the seed coat appeared dull. After thorough mixing the seeds and soil were transferred to pint-size plastic bags and loosely closed. The bags were stored at 5° C until planting. This procedure is similar to that successfully used at the University of Wisconsin in their prairie establishment work (Greene and Curtis 1953).

The seed bed was prepared by raking away large lumps of soil, scattering the soil-seed mixture into plots 20 x 50 cm, and covering by screening a 1 cm deep layer of topsoil over the plot. The soil was then lightly tamped. When seedling counts were made a 20 x 50 cm quadrat was placed over the plot to identify its limits.

Observations

Germination in flats

Of the 21 species investigated, 17 species showed some germination (See table 1). Germination of grasses was low with the exception of *Elymus canadensis*[3] and *Sporobolus asper*. The representatives of the Compositae germinated generally higher.

Table 1. Per cent germination of Prairie species in flats.

Species	Germination present study	Blake*	Greene and Curtis**	
Andropogon gerardi	3.6	13.5	-	16
Andropogon scoparius	0.0	11	-	16
Elymus canadensis	48	55	-	92
Panicum virgatum	0.0	14	-	-
Sorghastrum nutans	5.6	5	-	16
Spartina pectinata	0.66	-	-	-
Sporobolus asper	78	83	-	-
Sporobolus heterolepis	16.6	-	43	53
Stipa spartea	7.6	9	-	10
Aster ericoides	44	-	-	8
Echinacea pallida	56	38	66	-
Liatris aspera	60	-	48	29
Liatris pycnostachya	56	-	51	-
Ratibida pinnata	70	-	60	-
Silphium laciniatum	96	-	96	25
Solidago rigida	18	-	-	24
Anemone cylindrica	24	-	10	20
Asclepias verticellata	58	-	-	40
Eryngium yuccifolium	54	-	56	40
Gentiana puberula	0.0	-	High	50
Rosa suffulta	0.0	0.5	-	-

* Germination procedure similar to present study.
** Left hand column — germination procedure similar to present study. Right hand column — germination after stratifying 2-3 month at 40°F in moist soil.

Comparisons of our data are made in Table 1 with results obtained by Greene and Curtis (1950) and Blake (1935). In some cases striking similarity is seen, but in others the results are quite different.

All species showing germination, with the exception of *Spartina pectinata*, were subjected to an analysis of variance after

[3] Nomenclature according to Gleason and Cronquist (1963).

converting percentages to arcsin values. Use of Duncan's multiple range test (Steele and Torrie 1960) placed those species germinating in three distinct groups. Germination of *Silphium laciniatum* was significantly different from all other species. A central group contained all other composites with the exception of *Solidago rigida* and included two grasses, *Sporobolus asper* and *Elymus canadensis*. Others in this central group were *Eryngium yuccifolium* and *Asclepias verticellata*. The lower group included *Solidago rigida, Anemone cylindrica* and four grass species.

Germination and establishment in field plots.

Field germination was generally below that obtained in flats except for three grass species (See Table 2). These germination figures are not directly comparable with those of flat germination because they represent plants present the last week in June, 1965, and no record was made of plants dying prior to this time.

The percentage of plants living in September, 1965, is also presented in Table 2. Late counts of most grass species in weeded plots was impossible due to inability to distinguish individuals. As an alternative measurement, the total basal area within a plot was measured. The correlation coefficient between early count and basal area was 0.92 which tends to justify the use of this alternate method.

Analysis of variance of both early and late counts indicated that there was significant difference between weed-free and non-weeded treatment totals and also between treatment totals with and without cover crop. Mowing of cover crop and non-cover crop treatments did not alter late count treatment totals significantly.

Generally the weed-free treatment favored highest germination and establishment. Non-weeded treatments without a cover crop produced less establishment, and treatments with cover crop produced least establishment. A contributing factor probably was the establishment of the cover crop before seeding of the prairie species.

The vigor of the prairie species, measured by height of the tallest plant in a plot, also reflects the differences in treatments. Analysis of varience showed significant differences between weed-free and nonweeded treatment totals, and between treatment totals with and without a cover crop (see figure 1). Data for several species in one block are presented in table 3. Flowering, another indicator of vigor, was observed in several species in the weed-free treatment, and in an annual, in all treatments.

Table 2. Mean percent establishment in various treatments, early count is upper figure; late count is lower figure.

Species	Weed-free	Unweeded				Overall mean
		Without cover crop		With cover crop		
		Unmowed	Mowed	Unmowed	Mowed	
Andropogen gerardi	28.6	16.0	24.0	14.7	20.7	21.9
	(70.8)*	14.0	24.0	6.0	12.0	14.0
Andropogon scoparius	8.7	4.7	5.2	6.7	6.0	6.4
	(35.68)	8.0	4.7	6.7	6.7	6.5
Elymus canadensis	23.3	22.7	27.2	12.7	18.0	22.3
	(59.4)	26.7	20.0	22.7	19.3	22.2
Sorghastrum nutans	18.0	14.7	14.7	12.7	9.3	13.9
	(36.0)	12.0	15.3	4.0	8.7	10.0
Spartina pectinata	4.7	0.0	0.0	0.0	0.0	0.93
	0.7	0.0	0.0	0.0	0.0	0.13
Sporobolus asper	17.3	12.0	9.0	12.0	8.0	13.8
	(27.68)	14.7	6.0	6.7	6.7	8.3
Sporobolus heterolepis	1.3	3.2	0.7	0.0	0.7	1.2
	(4.5)	0.0	0.0	0.0	0.0	<1.0
Stipa spartea	5.0	0.0	0.0	0.0	0.0	0.4
	(1.2)	0.0	0.0	0.0	0.0	<1.0
Echinacea pallida	39.2	37.2	42.0	25.3	27.3	30.1
	39.3	22.7	22.0	19.3	10.7	22.8
Liatris aspera	20.0	22.5	12.5	10.0	20.0	17.5
	25.0	20.0	10.0	0.0	5.0	14.4
Liatris pycnostachya	6.7	19.0	9.0	9.0	21.0	12.5
	5.3	16.0	2.0	1.0	4.0	5.5
Ratibida pinnata	16.0	13.3	9.3	5.3	10.7	10.9
	13.3	11.3	8.0	6.7	3.3	8.5
Silphium laciniatum	26.0	39.3	38.0	26.0	22.7	30.4
	27.2	22.0	14.7	11.3	8.0	16.7
Baptisia leucantha	50.0	50.0	15.0	10.0	0.0	26.2
	45.0	20.0	10.0	10.0	0.0	18.7
Dalea alopecuroides	20.6	26.0	34.0	20.0	17.3	23.6
	19.3	14.7	17.3	10.0	7.3	13.6
Desmodium canadense	46.7	44.7	23.7	40.0	24.0	35.9
	44.7	40.7	12.0	10.7	2.7	22.1
Lespedeza capitata	19.3	23.3	30.0	22.6	16.0	22.5
	23.3	18.7	12.0	6.0	8.0	13.6
Lespedeza leptostachya	10.0	0.0	5.0	5.0	0.0	4.5
	10.0	0.0	5.0	0.0	0.0	3.6
Petalostemon candidum	4.7	21.3	9.3	15.3	4.7	11.1
	3.3	14.0	2.0	2.7	0.0	4.3
Petalostemon purpureum	12.0	26.7	14.6	17.3	9.2	16.0
	14.6	14.6	8.0	0.0	2.7	8.0
Anemone cylindrica	8.0	0.0	0.0	0.0	0.0	0.2
	6.0	0.0	0.0	0.0	0.0	0.15
Eryngium yuccifolium	28.0	18.0	7.3	14.6	5.3	14.7
	24.7	15.3	4.0	3.3	2.0	9.9
Potentilla arguta	2.0	0.0	0.0	0.0	0.0	0.4
	2.7	0.0	0.0	0.0	0.0	0.5

* Figures in parentheses are basal area in cm^2.

Species not germinating: *Panicum virgatum, Delphinium* sp., *Gentiana puberula, Lobelia cardinalis, Rosa suffulta*

Table 3. Height in cm of tallest plant of each species in field establishment.

Species	Weedfree	Unweeded			
		Without cover crop		With cover crop	
		Unmowed	Mowed	Unmowed	Mowed
Andropogon gerardi	48	25	36	17	10
Andropogon scoparius	18	15	15	10	14
Elymus canadensis	80*	45	25	—	11
Sorghastrum nutans	93*	30	35	24	16
Echinacea pallida	24	95	14	10	5
Echinacea pallida	24	9	14	10	5
Ratibida pinnata	24	16	15	8	—
Silphium laciniatum	20	30	14	20	16
Dalea alopecuroides	73*	55*	65*	45*	35*
Desmodium canadense	62*	18	14	9	3
Lespedeza capitata	32	11	11	10	5
Petalostemon candidum	22	15	12	4	—
Petalostemon purpureum	24	8	7	—	5
Eryngium yuccifolium	18*	11	5	—	5

* Producing flowers

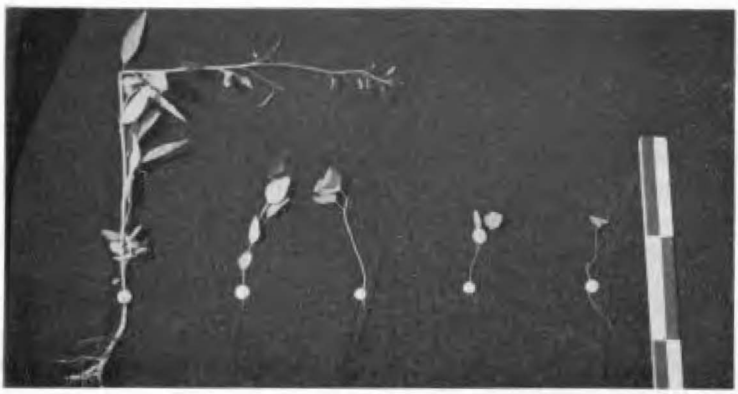

Fig. 1. Effect of treatments on *Desmodium canadense*. Left to right: weed-free, unweeded, unweeded and mowed, cover crop, cover crop and mowed. (Sept., 1965).

Discussion and Conclusions

Prairie species display a wide range of variability in germination trials. Some germinated very well in our treatments while others did not germinate at all. The rather high percentage of germination for composites and some grasses under these protected conditions suggests that the same thing could be expected for other members of these groups. For many prairie species it appears that establishment from seeds can be reasonably successful. However, it is apparent that requirements for germination are extremely diverse.

The germination and establishment of prairie species under natural conditions has been poorly observed. It is unusual to observe seedlings of the perennial species in intact prairie sod. However, if the surface is disturbed by fire or animal activity, there are usually abundant seedlings present, dependent mostly upon the seed sources present. It is obvious that we know relatively little about the triggering of germination by these natural events.

The cultural treatments attempted in this study under field conditions represented the practical extremes of competition. Weed free plots allowed extensive development of certain plants during the first growing season. It was surprising to observe flowering in some of the perennial species such as *Elymus canadensis, Sorghastrum nutans, Desmodium canadense,* and *Eryngium yuccifolium.* The time consuming problem of hand weeding would eliminate this treatment from practical consideration of establishment except in very small areas.

Seedlings in wheat cover crop were generally very small at the end of the growing season. Competition was very severe although it did not eliminate all the seedlings of any species except *Sporobolus heterolepis.* In less severe treatments without a cover crop *Petalostemon candidum* and *Liatris pycnostachya* became established at a higher percentage than in the weed-free treatment. This indicates that in some cases the environmental buffering effect of surrounding vegetation more than compensates for the added competition. The relationship of seedling establishment and competition would be interesting to examine in successional changes as weed populations are replaced.

The germination of species in flats is not directly comparable with germination under field conditions. Interpretation was confounded by different stratification treatments and planting dates. However, germination in flats can be a standardized procedure which probably is useful in approximating the best germination that can be expected in the field. It can be used successfully in comparison of germination in different years, in a species from different collection sites, and for different pregermination treatments.

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Seed Character Relationships in the Leguminosae[1]

Haig Kopooshian and Duane Isely[2]

Abstract. The Leguminosae posses two basic seed types, a generalized form characteristic of the Mimosoideae and Caesalpinioideae, and a derived type characteristic of the Papilionoideae. Intermediates between caesalpinioid and papilionoid seeds strengthen the hypothesis that the phyletic roots of the Papilionoideae are in the Caesalpinioideae. Seed data affirm a relationship between the Mimosoideae and Caesalpinioideae but provide little new information as to the nature of this kinship. The Mimosoideae are not closely related to the Papilionoideae on the basis of seeds or other features.

The Leguminosae are conventionally treated as including three reasonably discrete subfamilies — the Mimosoideae, Caesalpinioideae, and Papilionoideae. Some authors (7) have preferred to regard the taxon as an order with three families. Thus, although there have been differences in viewpoint regarding the appropriate rank for the taxa involved, systematists have largely been in agreement regarding their circumscription.

On the basis of floral characters, these three subfamilies have usually been regarded as representing an evolutionary sequence from the Mimosoideae as "primitive" to Papilionideae as most derived or specialized.

The structure of leguminous seeds has been studied from several viewpoints (4, 6, 10, 11,). Corner (4) appears to have conducted the most extensive sampling within the family; he examined material of 45 genera. Both Corner (4) and Isely (6) observed that there appeared to be two basic seed types within the family; those characteristic of (a) the Mimosoideae and Caesalpinioideae, together, and (b) the Papilionioideae.

Materials and Methods

The seed characters of the Leguminosae have now been investigated more thoroughly — seeds of 213 species representing

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[2] Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa. Present address of the senior author: Institut de Recherches Agronomiques, Republique Libanaise