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Legume Distribution and Nodulation in Arapaho Prairie, Arthur County, Nebraska

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ABSTRACT

Vegetational sampling of the legumes of Arapaho Prairie, located in the southwest portion of the Sand Hills of Nebraska, was conducted in June, 1980. *Lathyrus polymorphus*, *Petalostemon purpureum*, *Psoralea digitata* and *Amorpha canescens* were the leading dominants. The overall density of legumes was 0.309 plants · m^{-2}.

Of eight examined, only *Petalostemon villosum* and *Glycyrrhiza lepidota* supported large numbers of nodules. The others including the dominant legumes were unnodulated or had only a few, usually degenerate nodules.

It appears that the legumes are of minor importance in the overall N economy of Arapaho Prairie. Nevertheless since many of the legumes tend to occupy disturbed areas (blowouts and gullies) dinitrogen fixation may be important during early stages of establishment.

Native temperate grasslands and rangelands operate with relatively low levels of biological N influx compared to agricultural systems. Estimates of biological dinitrogen fixation range from < 1-8.4 kg N ha^{-1} yr^{-1} (Paul et al. 1971; Steyn and Delwich 1970; Balandreau and Dommergues 1973; Vlassak et al. 1973; Kapustka and Rice 1976; DuBois and Kapustka in press). An additional 2-10 kg N ha^{-1} yr^{-1} may be derived from wetfall and dryfall (Woodmansee 1979). Although rhizobial-legume and actinorhizal symbionts may be important locally in certain grassland sites, asymbiotic, heterotrophic bacteria and heterocystic cyanobacteria (free-living or lichenized) contribute the majority of biologically fixed N under most conditions in temperate grasslands (Harris and Dart 1973; Kapustka and Rice 1976, 1978a, 1978b; Kapustka 1980; Dubois and Kapustka in press).

Acquisition of the Arapaho Prairie, Arthur County, Nebraska by The Nature Conservancy has stimulated research in what is probably the largest undisturbed continuous grassland remaining in the United States (Keeler et al. 1980). Until recently, the Sand Hills grasslands of Nebraska had received little attention ecologically. In this report we describe the abundance of legumes in Arapaho Prairie and assess their potential for dinitrogen fixation.

METHODS

Two parallel transects approximately 400 m on either side of the N-S boundary of Sections 31 (west) and 32 (east) (see Keeler et al. 1980) were sampled

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with 100 m^2 circular plots each 50 m along the transects during late June 1980. The west transect crossed Lesser North Basin, Ballinger's Hill, and Grasshopper Gorge while the east transect passed along the lower edge of Big Catstep Cliffs, through Little Old Field, and up the west edge of South Prairie. The number of individuals of each legume species present was recorded for each plot. The data were treated by standard procedures to yield density (number of individuals m^{-2}), frequency (percentage of plots at which a taxon occurred), the relative (normalized) values of each, and Importance Percentage (IP) (sum of relative density and relative frequency divided by 2). Topographic features and dominant vegetation of each plot were recorded.

Representatives of the more abundant legume species were excavated to a depth of 50 cm to determine the extent of nodulation.

RESULTS

Of the 16 legumes reported for Arapaho Prairie (Keeler et al. 1980), 11 were represented in the sampling data, but only 6 achieved an IP >5 Table 1).

Amorpha canescens Pursh. tended to occupy the higher dune crests of Lesser North Basin and Ballinger's Hill with about equal distribution in what has been described as slope and as ridge vegetation (see Keeler et al. 1980). Other ridge and slope vegetations of Arapaho Prairie appeared to have amounts of *A. canescens* similar to the sample area. This legume was distinctly absent from the valleys.

Oxytropus lambertii Pursh. and *Lathyrus polymorphus* Nutt. tended to occur in small and large disturbance areas and as such are prominent along the fringes of blowouts and gullies. Similarly, *Petalostemon villosum* Nutt. was restricted to the interior and margins of blowouts and gullies. All three species appear to provide stabilizing forces to these highly erodable localities.

Psoralea digitata Nutt. and *Petalostemon purpureum* (Vent.) Rydb. occurred throughout the entire area sampled except for Lesser North Basin, with no apparent affinities for slope, aspect, or degree of vegetation cover. However, it did not appear in the weed communities around the windmills.

Astragalus crassicarpus Nutt. occurs infrequently throughout Arapaho Prairie but can be found most readily in the old fields.

Attempts at further analysis such as indicies of association did not yield additional insights.

Excavation of the root systems was relatively easy in the sandy soil of the region. However, to avoid extensive disturbance to this relatively fragile environment only limited excavations were done. Even though there had been a drought for several weeks prior to our work there was sufficient moisture at a depth of 15 cm and greater to allow the plants to remain turgid. Of eight species examined for nodules only two (*P. villosum* and *Glycyrrhiza lepidota* Pursh., the latter restricted to a "gopher" mound disturbance area outside the transect sampling area) consistently were nodulated. *Petalostemon villosum* has an extensive rhizomatous growth with adventitious roots proliferating 15-25 cm below the soil surface. Numerous, fresh (pinkish) nodules were found throughout this zone. *Glycyrrhiza lepidota* had a fibrous root mass extending from 5 cm and downward. the finer roots were heavily nodulated. All the other species excavated, (*A.*

Table 1. Summary of sampling data from the east (E), west (W), and combined (E & W) transects.

	Frequency			Rel. Freq.			Density			Rel. Dens.			I.P.		
Species	E	W	E & W	E	W	E & W	E	W	E & W	E	W	E & W	E	W	E & W
Amorpha canescens	25.6	60.5	42.9	12.04	18.85	16.11	0.017	0.058	0.037	5.14	20.21	12.01	8.59	19.53	14.06
Astragalus ceramicus	5.1	2.6	3.9	2.40	0.81	1.46	0.001	0.000	0.000	0.30	0.00	0.00	1.35	0.40	0.73
A. crassicarpus	5.1	7.9	6.5	2.40	2.46	2.44	0.001	0.002	0.001	0.30	0.70	0.32	1.35	1.58	1.38
A. lotiflora	0.0	2.6	1.3	0.00	0.81	0.49	0.000	0.001	0.000	0.00	0.35	0.00	0.00	0.58	0.24
Lathyrus polymorphus	35.9	18.4	27.2	16.88	5.73	10.21	0.210	0.078	0.145	63.44	27.18	47.08	40.16	16.45	28.65
Oxytropus lambertii	30.8	39.5	35 .1	14.48	12.31	13.18	0.013	0.025	0.019	3.93	8.71	6.17	9.17	10.51	9.68
Petalostemon candidum	7.7	15.8	11.7	3.62	4.92	4.39	0.007	0.003	0.005	2.11	1.05	1.62	2.86	2.98	3.00
P. purpureum	33.3	63.2	48.1	15.66	19.69	18.06	0.028	0.074	0.051	8.46	25.78	16.56	12.06	22.74	17.31
P. villosum	17.9	31.6	24.7	8.42	9.84	9.28	0.038	0.019	0.029	11.48	6.62	9.42	9.95	8.23	9.35
Psoralea tenuiflora	2.6	10.5	6.5	1.22	3.27	2.44	0.001	0.001	0.001	0.30	0.35	0.32	0.76	1.81	1.38
P. digitata	48.7	68.4	58.4	22.90	21.31	21.93	0.015	0.026	0.020	4.53	9.06	6.49	13.72	15.18	14.21
TOTALS	212.7	261.0	266.3	100.02	100.0	99.99	0.331	0.287	0.308	99.99	100.01	99.99	99.97	99.99	99.99

canescens, *L. polymorphus*, *O. lambertii*, *P. purpureum*, *Psoralea tenuiflora* Pursh., and *P. digitata*) characteristically had taproots, often without lateral roots or any fine root system occurring in the 50 cm zone excavated. Those individuals with lateral branch roots such as *L. polymorphus*, often had a few nodules but only 2-3 per plant and these usually were degenerate.

DISCUSSION

The distribution of the legumes at Arapaho Prairie suggests trends of association with the dominant vegetation or perhaps more correctly, the disturbance history. Attempts at further analysis of our data such as indices of association were not helpful in interpreting affinities. This appears to be due to the large plot size relative to microhabitat variation. Associations which might exist were obscured.

Our focus, however, was to determine the overall densities of the legumes, and for this our plot size was suitable. The combined density of legumes was 0.287 m^{-2} on the west transect, 0.331 m^{-2} on the east transect, and 0.309 m^{-2} for both transects considered together. These values are considerably lower than the densities obtained in other temperate grasslands, especially the Tall Grass Prairie from which so much of the Sand Hills vegetation is derived. At the Oklahoma Grassland Research Area near Norman, Oklahoma, the density of legumes was 2.86 m^{-2} (Kapustka and Rice 1978b). Prairies in the vicinity of Lincoln, Nebraska, have 5-6 legumes m^{-2} (pers. com. A. T. Harrison). Weaver and Fitzpatrick (1934) reported *A. canescens* populations as high as 50 m^{-2} with typical areas having 12-20 m^{-2}.

Root depth, especially for those species characterized as having tap roots, can be expected to reach 5 m or more (Weaver and Fitzpatrick 1934). Furthermore, they reported nodulation throughout the root zone. Our observations indicate minor success in formation and/or maintenance of nodules, at least in the upper root zone. The moisture content usually is sufficiently high to permit survival of roots and nodules in this upper 50 cm of soil. The paucity of nodules may be related to the relatively low organic carbon content of these sandy soils since survival of the rhizobium in its free-living state is dependent on saprolytic nutrition (Schmidt 1978). No studies of distributions of rhizobium populations in the Sand Hills have been reported, consequently it is not known how important the symbiotic condition is in terms of establishment and survival of these legumes.

Rates of dinitrogen fixation for most of the legumes at Arapaho Prairie are unknown. Under optimal conditions the rates of most native legumes are moderately low compared to domestic legumes (Becker and Crockett 1976). Given the near absence of nodulation and the very low densitites of legumes at Arapaho Prairie it would appear that the contribution of combined N by legumes toward the total N economy of the region is negligible. It remains to be seen whether nodulation and subsequent dinitrogen fixation is important to the success of individual plants in terms of competitive advantage during early growth and establishment.

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