Seedling Growth and Soil Drought Resistance of Northern Great Plains Legumes, Alfalfa and Four Grasses[1]

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VAST acreages of depleted western range lands and croplands are being reseeded to perennial grasses and legumes to increase the forage supply. The part of non-grass plants in these seeding mixtures has been much discussed and it is natural to consider the use of some native legumes. If they are to be used in reseeding operations, more should be known of their relative seedling resistance to soil drought. One of the principal limiting factors in reseeding operations in the Great Plains is the drought period which often strikes seedling plants one to several months old. On light soils especially, this drought is often the result of the drying of upper soil layers. Plants of rapid establishment and extensive root growth should have an advantage of survival as their roots extend into deeper and moist soil zones, keeping ahead of the drought.

Recent interest has led to a few investigations on the abundance and distribution of legumes in native grasslands (Whitman and Stevens 1952). Some 65 percent of the native legumes of North Dakota were mentioned as being palatable and of sufficient growth to furnish some forage, although in total providing only a minor percentage of the available forage. The general contributions of legumes in grassland flora to soil fertility and forage value are known but little specific information of the many species has been reported.

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Some drought studies are available on cultivated legumes; Schultz and Hayes (1938) worked on legumes of sod and seedling stage but exposed to atmospheric drought of high temperature and low humidity.

This report is concerned with the comparative growth and reaction of seedling plants to a period of favorable soil moisture, followed by soil drought under controlled conditions in the greenhouse at North Dakota Agricultural College, Fargo, North Dakota. Comparison is made of twenty-three species of native legumes, plus alfalfa and four species of grasses commonly used in pasture reseeding. The germination of four species of native legumes, *Amorpha canescens* (lead plant), *Astragalus goniatus* (nickleaf milkvetch), *Astragalus striatus* (prairie milkvetch), and *Petalostemon purpureum* (purple prairie clover) was so low they were omitted from the analyses.

Materials and Methods

All native legume seeds were collected from plants in the field in North Dakota during the summers of 1949–51, cleaned, and stored at room temperature. The grass seeds were commercial seedhouse material for 1952. The alfalfa was Ladak alfalfa, F.C. 23905, U.S.D.A. All samples of legume seeds were treated in concentrated sulphuric acid for 15 minutes and then thoroughly washed in running water for at least one hour before planting. Hard coated legume seeds are common and this is a common practice to

insure more uniform germination. Grass seeds were subjected to the period of washing without the acid treatment to provide the same conditions for germination except for the acid treatment.

Twelve seeds of each species were planted in each of 420 one-quart waxed cardboard milk cartons, the tops of which had been removed and the cartons filled with Bearden sandy loam from which the principal root material had been removed by sifting through a window screen. After germination the number of plants in each container was reduced to nine. Germination was rather low in many species so that a standard number of plants per container was not obtained.

The bottoms of all containers were perforated with a stamping device to provide the same number and size of holes for moisture supply by subirrigation during the first 30 days growth. All containers were placed in metal tanks in which the water level was maintained at about three-quarters of an inch depth. During the first 30 days all trials were grown under favorable moisture conditions with the soil essentially at field capacity. Each treatment was represented by three replicate containers for each of the 28 species.

Treatment A—Plants were examined for height, green weight of shoot, dry weight of shoot, and dry weight of root at the end of the 30-day period of abundant moisture. At this time, all remaining containers were deprived of water supply until all plants in each container showed signs of permanent wilting with no sign of having recovered overnight.

Treatment B At the time of permanent wilting, the plants were examined in regard to height, green weight of shoot, oven-dry weight of shoot, oven-dry weight of root, and number of days to permanent wilting.

Treatment C—Plants were left in permanently wilted condition for one day, then water was added and plants maintained in soil near field capacity for three weeks at which time they were examined for percentage of plants recovering and the green weight of the living parts of the shoot.

Treatments D and *E* varied from *C* only in leaving the plants in the wilted condition for three and five days, respectively.

Results

A summary of some of the results is given in Table I, showing the averages of the three replicas. Those results which are significantly superior or inferior at the 5 percent level when alfalfa is used as a standard are so indicated.

The general growth characteristics of the plants after 30 days of optimum soil moisture and again after a period of drought to the point of permanent wilting are as follows:

Height

At the end of 30 days of optimum growing conditions the height of alfalfa was exceeded only by crested wheatgrass, intermediate wheatgrass, and bromegrass. This is to be expected because of their grass form; however, Russian wild-rye was inferior in height. No other legumes exceeded alfalfa in height. At the point of permanent wilting only crested wheatgrass was significantly higher, while among the grasses Russian wild-rye was still significantly lower. The legumes which had heights not significantly different from alfalfa after an optimum 30-day growth period were: *Astragalus lotiflorus*, prairie bird's-foot trefoil, long-leaved milk-vetch, wild bean, and false lupine.

Except for *Astragalus lotiflorus* these same species of legumes maintained heights equivalent to alfalfa until the point of permanent wilting under treatment B. permanent wilting, only Russian wild-rye was significantly lower in dry weight, all others being not significantly different from alfalfa. It is interesting to note that

TABLE I

Summary of growth features and drought resistance

GROWTH FEATURES	HEIGHT		DRY WEIGHTS				PLANT RECOVERY			REGROWTH		
			Shoot		Root							
Treatments	A	B	A	B	A	B	C	D	E	C	D	E
	centimeters		*milligrams*				*percent*			*milligrams*		
*Astragalus bisulcatus** (two-grooved milk-vetch)*	*6.8*†	*8.7*	*23*	73	6	*30*	Not sig-	88	100	*259*	335	*242*
A. canadensis (little rattlepod)		*9.4*		80		*37*	nificant		100			484
A. caryocarpus (ground plum)	*2.4*	*3.4*	*19*	*19*	10	*19*	at 5%	100	100	*110*	*94*	*128*
A. flexuosus (slender milkvetch)	*4.5*	16.0	*20*	50	7	*25*	level		100			*410*
A longifolius (long-leaved milkvetch)	11.2	17.3	*26*	*33*	9	*16*		100		*180*	290	
A. lotiflorus	8.3	*6.6*	*16*	50	6	*8*		100	67	*103*	339	*128*
A. missouriensis (Missouri milkvetch)	*2.8*	*4.4*	*10*	*23*	*3*	*8*		100	78	*74*	*108*	*103*
A. racemosus	*5.9*	*12.5*	*24*	64	9	*17*		100	100		515	*268*
A tenellus (looseflower milkvetch)	*6.6*	*7.6*	*19*	*17*	10	*11*		100	100	*205*	167	*304*
A. triphyllus (tufted milkvetch)		*2.8*		*16*		*7*		100	100	*93*	*123*	*85*
Hedysarum boreale (sweet vetch)	*5.9*	*8.3*	*20*	*26*	11	*28*		83	58	*205*	*98*	*24*
Lotus americanus (prairie bird's foot trefoil)	10.4	21.0	41	70	14	*20*		83	*0*	*267*	416	*0*
Medicago lupulina (black medic)		*6.8*		50		*15*			100			507
Oxytropis lamberti (purple loco)	*3.8*	*9.1*	*14*	43	6	*15*			100	*152*		*99*
Petalostemum villosum (hairy prairie-clover)		*9.5*		*28*		*13*		100			237	
Psoralea esculenta (tipsin)	*8.0*	*8.2*	42	*28*	14	68		*8*	*0*	*121*	*37*	*0*
Strophostyles leiosperma (wild bean)	13.5	20.2	**57**	**142**	20	41		80	42	*438*	346	*381*
Thermopsis rhombifolia (false lupine)	16.6	17.6	32	*20*	22	*29*		86	75	*76*	*44*	*42*
Vicia sparsifolia (prairie vetch)	*4.9*	*9.1*	30	63	10	53		100	100	*221*	223	*160*
Medicago sativa (alfalfa)	13.3	19.2	40	81	15	60		100	78	1816	357	747
Agropyron cristatum (crested wheatgrass)	**21.8**‡	**25.3**	*27*	61	18	46		93	94	*268*	170	*132*
A. intermedium (intermediate wheatgrass)	**22.1**	22.5	*27*	41	**25**	43		*78*	52	*245*	*141*	*145*
Bromus inermis (smooth brome)	**22.0**	22.0	*20*	38	**28**	62		96	74	*407*	398	*205*
Elymus junceus (Russian wild-rye)	12.4	*13.0*	*10*	*15*	*4*	*22*		*59*	61	*111*	*92*	*88*
Average	10.2	12.5	26	47	12	29		88	77	282	227	209
L.S.D. at 5 percent	3.7	4.4	12	46	9	22		22	45	679	207	324

* Common and scientific names follow O. A. Stevens, "Handbook of North Dakota Plants."

† Italics indicate results significantly inferior to alfalfa at the 5 percent level.

‡ Bold face type indicates results significantly superior to alfalfa at the 5 percent level.

Green Shoot Weight

No grasses or legumes were significantly greater than alfalfa in green weight at the end of the favorable growing period or at the time of permanent wilting.

Dry Shoot Weight

All the grasses were significantly lower than alfalfa after 30 days of optimum soil moisture. However, at the time of only five legumes were equal to or exceeding alfalfa in shoot weight at the end of the favorable growing season. They were prairie bird's-foot trefoil, tipsin, false lupine, prairie vetch, and wild bean. The last of these was the only one that was significantly greater than alfalfa. After a period of drought and at the time when permanent wilting was reached, ten species of legumes were equal to or exceeding alfalfa in dry shoot

weight. Five species which had been significantly lower in shoot weight under optimum soil moisture became equal to alfalfa by the time of permanent wilting. The species equal to or exceeding alfalfa in dry weight when the soil had been depleted of its available moisture were: two-grooved milkvetch, little rattlepod, slender milkvetch, *Astragalus lotiflorus*, *A. racemosus*, prairie bird's-foot trefoil, black medic, purple loco, prairie vetch, and wild bean. Again, only wild bean was significantly greater in weight than alfalfa.

Dry Root Weight

The comparative weights of roots are interesting in relation to reaction to drought, survival, and recovery ability. At the end of the 30-day favorable growing period only two species, Missouri milkvetch and Russian wild-rye, were significantly lower in root weight than alfalfa. Two species, intermediate wheatgrass and bromegrass, were the only ones significantly greater than alfalfa. All others were essentially similar in weight. However, at the time of permanent wilting, when growth had proceeded to the point of withdrawing all of the available moisture, no species was significantly greater than alfalfa in root weight. Furthermore, at this point only three legumes, tipsin, prairie vetch, and wild bean were essentially equal to the root weight of alfalfa. This inability of the majority of seedling legumes to maintain their equality to alfalfa in root system development during the period of soil moisture decline from field capacity to wilting coefficient is very noteworthy. This may in part explain the relative success of alfalfa. During this same time, three of four grass species maintained an equivalent weight of root system to that of alfalfa.

Recovery and Regrowth after Extended Periods of Drought

Treatments C, D, and E were a series of different drought periods at permanent wilting of 1, 3, and 5 days respectively before the renewal of soil moisture. By the end of the drought period, about 70 days after planting, the three annual species: prairie bird's-foot trefoil, black medic, and wild bean were in flower and fruit. Some pods contained ripe seeds. In spite of their mature condition, some of these annuals produced new axillary basal shoots upon receiving soil moisture after a 3 and 5-day period of permanent wilting. The reaction of the perennials varied with leaf morphology and degree of succulence, some had folded or rolled leaves, others were dried and stiff. The last portions to die were the terminal growing points and the axillary buds.

It is shown in Table I that a number of legume species had survival percentages equal to alfalfa. Increased periods at permanent wilting to the point where no species maintained complete survival might have revealed superior species under more severe drought. In the present experiment, however, with a 5-day period at permanent wilting only two of these species of high survival had green weights of regrowth that were not significantly lower than that of alfalfa. Among the grasses, none were significantly better than alfalfa in percentage survival and all were significantly lower in green weight of regrowth after the treatment of a 5-day drought at permanent wilting. Russian wild-rye was consistently the lowest and bromegrass was consistently the greatest in amount of regrowth capacity.

Root Nodule Development

The following observations were made on the seedling plants which were re-

moved from the soil at the end of a 30-day favorable growing period with the soil at nearly field capacity. Outstanding in the presence of nodules was wild bean. The species possessing nodules are listed below in decreasing order of the average abundance of nodules:

8.5 nodules per plant, very large	Wild bean
5.5 nodules per plant, large	Sweet vetch
4 nodules per plant, small	Two-grooved milkvetch, long-leaved milkvetch, and alfalfa
3 nodules per plant, large	*Astragalus racemosus*
0.3–1.5 nodules per plant, small	Ground plum, slender milkvetch, *Astragalus goniatus*, *A. lotiflorus*, Missouri milkvetch, *Astragalus tenellus*, purple loco, tipsin, and false lupine
0 nodules per plant	Tufted milkvetch, prairie bird's-foot trefoil, prairie vetch

Others of the twenty-four legumes were not available for sampling.

Summary

Nineteen native legumes and four species of grasses were compared with alfalfa as to seedling growth and resistance to soil drought.

Among the grasses, Russian wild-rye was consistently lowest in shoot size, root development, and drought recovery. After a favorable growth period of 30 days and a drought period, no grasses produced significantly higher forage yields per plant than alfalfa. Significantly higher results for grasses were expressed, however, in root weights of intermediate wheatgrass and bromegrass at the end of the favorable growing period. This advantage was decreased to root systems not significantly greater than alfalfa by the time of permanent wilting, which points out the steady development and taproot habit of alfalfa roots even under droughty conditions. In the amount of regrowth after drought, bromegrass was outstanding among the grasses, but did not exceed that of alfalfa.

Among the native legumes, no species was significantly greater in green weight of shoots than alfalfa at any stage in the study. Excluding the superior wild bean, from the end of the favorable growing period to the point of permanent wilting, the number of native legume species having dry shoot weights equivalent to alfalfa increased from four to nine. This indicates favorable relative growth rates for these native legumes under drought conditions. They were: two-grooved milkvetch, little rattlepod, slender milkvetch, *Astragalus lotiflorus*, *A. racemosus*, prairie bird's-foot trefoil, black medic, purple loco, and prairie vetch.

There was a significant decrease (relative to alfalfa) in the extent of root development from the 30-day old seedlings to the point of permanent wilting for all native legumes except for tipsin, prairie vetch, and wild bean.

In the ability to produce shoot regrowth after a 5-day period of permanent wilting, only little rattlepod and black medic of all the native legumes were not significantly lower than alfalfa.

In root nodule development, wild bean was outstanding, followed by sweet vetch, two-grooved milkvetch, long-leaved milkvetch, alfalfa and *Astragalus racemosus*.

In general, then, no native legume was consistently superior to alfalfa in growth during decreasing soil moisture or in drought recovery. Wild bean, an annual, was shown in this study to be superior to

alfalfa in herbage production in seedling stage after 30 days of favorable growing conditions and at the point of permanent wilting in light sandy loam soil, superior in root nodule production, but inferior in regrowth after a period of permanent wilting. The value of this annual in a reseeding mixture would depend on the possible increased soil fertility from its abundant root nodules which would be available for more than the first year, and upon its ability to reseed itself. Being an annual it never would develop the deep taproot of the perennial alfalfa and could not compete in regions of available subsoil moisture where alfalfa could continue growth as a perennial. Where this is lacking, as in many western areas, an annual may be more successful.

Also deserving of further field trials from the viewpoint of forage yield, regrowth after drought, and nodule development, are the native legumes: little rattlepod, two-grooved milkvetch, and *Astragalus racemosus*. Further trials of the latter two for range forage would be deterred because of their property of fixing selenium, common to western soils, which results in a poisonous toxicity.

LITERATURE CITED

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