A Possible Relationship of Little Bluestem Distribution to Soils[1]

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Little bluestem *(Andropogon scoparius)*[3] as well as sideoats grama *(Bouteloua curtipendula)* and plains muhly *(Muhlenbergia cuspidata)* have been reported as important species of the mesic midwestern prairies, while western wheatgrass *(Agropyron smithii)* and blue grama *(Bouteloua gracilis)* are considered to be more xeric species charactistic of the Great Plains (Weaver, 1954; Weaver and Albertson, 1956; Dix, 1958). However, in South Dakota little bluestem has been observed repeatedly on xeric locations while western wheatgrass occupies the more mesic locations. This relationship is particularly true for clay-textured soils.

Wilding (1960) and Dix and Butler (1960) summarized their observations and those of others who found little bluestem on steep, droughty slopes. Wilding (1960) suggested that seed germination, seedling establishment, efficiency of root system, and soil temperature may favor little bluestem on soils with nearly barren surfaces in western South Dakota. Dix and Butler (1960) concluded that little bluestem was better adapted to soils underlain at shallow depths by bedrock than to thick soils in Wisconsin.

The Study Area and Vegetation

The area studied is in the mixed prairie 12 miles southeast of Belvidere and receives about 17 inches average annual precipitation of which about 12 inches falls during April through September. The soils are derived from basal Tertiary shale or mudstone and lie on a southwest facing slope of about 12 per cent. A conspicuous feature of the study area is a series of small, low microridges which are oriented up and down slope. These parallel microridges, some 9 to 12 feet apart and about 3 feet broad, are 4 to 8 inches higher than the intervening microvalleys. This soil microrelief has been called "wavy gilgai" (Hallsworth *et al.*, 1955). In the study area, taller grasses are restricted to the microridges and accentuate the microrelief (Figure 1).

The genesis of soil microrelief has been discussed by White and Bonestell (1960). The microridge soils are more weakly developed than those in the microvalleys and are similar to most of the soils where Wilding (1960) found little bluestem. On most gently sloping or nearly level areas, microridge soils are more strongly developed than on steep slopes. Bluestems, sideoats grama, and plains muhly usually occur on clay soils only if they are weakly developed.

Vegetation found on six microridges and the five intervening microvalleys is reported in Table 1. These plants occurred in the microrelief positions, as judged by the micro-elevations, a few feet either side of the row of sacks across the area as shown in Figure 1. Most species at a particular microrelief position could have been found on each of the other analogous microrelief positions had the identification area been moved to different places on the slope. Sample location No. 5 is an exception which will be discused in more detail.

Little and big bluestem (*Andropogon gerardi*) grew only on microridges. Sideoats grama which occurred mainly on microridges also was found along the edges of the microvalleys where it may have spread by rhizomes from the microridges. Western

FIGURE 1. Wavy gilgai area with little bluestem, big bluestem and sideoats grama growing on the low microridges which run up and down the slope. Western wheatgrass and blue grama dominate the intervening microvalleys.

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[3] *The nomenclature follows Fernald (1950).*

wheatgrass and blue grama were the main species in microvalleys although they were not restricted to this microposition. The few plants of Japanese brome (*Bromus japonicus*) in the area were mainly in the microvalleys. A few stunted prickly pear (*Opuntia polyacantha*), coneflower (*Ratibida sp.*), and fringed sagewort (*Artemisia frigida*) plants were randomly distributed across the area. The bluestems were the only species restricted to one microposition.

Mulch and old vegetation completely covered the microvalley surface. However, on most microridges, the soil was exposed between individual grass bunches. Because of the unprotected surface and the slightly higher elevation of the microridges, runoff from microridges into microvalleys occurs during common, summer thundershowers. Likewise, any runoff from upslope would flow down the microvalleys. Snowdrifts formed by the prevailing northwest winter winds would normally be initiated at the taller bluestem bunches and would extend across the northeast-southwest oriented microvalleys. Thus, the bluestems seem to be growing on the driest portion of this slope.

The study area with little bluestem growing on weakly developed microridge soils, but not on the more mesic, thicker microvalley soils, seemed an ideal area to study the soil factor in little bluestem distribution. Soil samples were collected from microridges and microvalleys for laboratory analyses to determine if they were different enough to cause the segregation of the vegetation. Seeds of the main species were germinated in soil and root extracts to determine whether toxic substances might be present in the soil or be produced by the plants which inhibit some species and thus cause the vegetation pattern.

Methods

Soil from the surface 6 inches of six microridges and the intervening five microvalleys was collected. Each sample analyzed was a composite of six equal individual samples collected a foot apart up and down slope in the microposition center. A hole 18-inches deep was dug in each microposition center to determine the depth of moisture penetration and the presence of carbonates. Carbonates, presumably of calcium, were detected by effervescence with dilute HCl. Standard procedures were used for laboratory analyses. A Kjeldahl procedure was used for total nitrogen (Jackson, 1958). Available phosphorus was estimated by the Bray No. 1 method. The pipette-screen method was used for mechanical analyses (Tyner, 1940).

Duplicate seed germination tests were made with big and little bluestem and western wheatgrass seeds. Fifty or 100 seeds of each species were placed on a blotter in 4½″ by 4½″ plastic germinating boxes. Seeds were germinated for 3 weeks at nearly 100 per cent relative humidity with an alternating 8- and 16-hour period, respectively, of 30° C. and 15° C. temperatures. Bluestem seeds were exposed to a low intensity light during the 8-hour periods while western wheatgrass seeds were not exposed to light.

The germinating solutions in one test were 10 milliliter aliquots of an aqueous extract from either the microridge or the microvalley soils. These soil extracts were from a 2:1 water-soil mixture by weight made up of equal amounts of surface soil from 5 microvalleys or microridges. Soil from the location 5 microridge with western wheatgrass vegetation was not included. The water-soil suspensions were stirred, left stand a half hour and centrifuged. Supernatants were decanted and filtered through Whatman No. 42 filter paper to remove suspended plant parts.

In a second germination test, the germinating solutions were aqueous extracts prepared from pulverized little bluestem, big bluestem, and western wheatgrass roots.

The roots were obtained from Mellette County, South Dakota, plants which were transplanted in a uniform soil and grown in the greenhouse from November 1959 until used in March 1960. The washed roots were dried until no surface moisture could be detected, then pulverized, diluted with 100 milliliters of water, let stand a half hour and then the aqueous extract separated by filtering. Only live western wheatgrass roots (totalling 1.1 grams oven dry) were used. Live bluestem roots could not be clearly distinguished from dead roots so the entire root systems were used. Approximately one-half and one-third, respectively, of the total dried little bluestem (4.0 grams) and big bluestem (14.4 grams) roots appeared to be alive. The seeds were germinated like those previously treated with soil extracts.

Laboratory Results and Field Observations

Soil Analyses

Laboratory analyses of the surface soils are summarized in Table 2. Results of the pH, nitrogen, exchangeable potassium, exchangeable sodium, cation exchange capacity, clay, fine silt, and sand analyses of samples from microridges in comparison to those of microvalleys were significantly different at the one per cent level. Phosphorus content was significant at the five per cent level, while the difference in the coarse-silt contents and in the moisture-penetration depths were not significant. The coarse-silt fraction was determined by subtracting the percentage sum of the other size fractions from one hundred. Thus, errors in determining the other size fractions are apt to accumulate in the calculated coarse-silt fraction.

Microridge surface soils, therefore, are distinctly different from the microvalley surface soils. Because little bluestem and sideoats grama usually are most abundant on weakly developed soils regardless of the texture, the sand, silt, and clay contents probably are not important. Cation exchange capacities are related to the clay contents and probably are not a factor in the distribution of the vegetation. Exchangeable sodium is less than one-half per cent of the cation-exchange capacity of the soils, so it apparently would not affect the physical characteristics of the soil or the vegetation.

Weakly developed soils, such as those on the microridges or on steep slopes, usually have thin layers which have less available phosphorus and nitrogen than nearby, more strongly developed soils. In addition, the latter soils have more development in subsoil layers so the total quantity of available phosphorus and nitrogen would be greater than is shown by analyses of only the surface layer.

Of the soil properties characterized in this study, some can be excluded as factors in the distribution of the vegetation because soils which commonly support little bluestem, big bluestem, and sideoats grama also have these same characteristics. Other characteristics are common to soils in the study area and to soils of contiguous areas with the cool-season grass. For these reasons, the distribution of the grasses probably is related to the fertility differences of these soils which would favor the growth of one species in competition with others. The growth of western wheatgrass as a codominant on microridge number 5 (Table 1) which has more nitrogen, available phosphorus, and exchangeable potassium than the other microridges (Table 2) supports the hypothesis that soil fertility is an important cause in segregating the bluestems and most of the sideoats grama to the weakly developed clay soils. In addition, since the microridge height and surface configuration at location number 5 are not different from those at other microridges, these properties probably are not factors in the distribution of the vegetation.

Table 1. Relative abundance of species on soil micropositions in the study area.

	Vegetation on micropositions[1]										
	Microridge Number						Microvalley Number				
Vegetation	1	3	5	7	9	11	2	4	6	8	10
Western wheatgrass		X	C		X		C	C	C	D	D
Big bluestem	C	X		X		X					
Little bluestem				D		D					
Sideoats grama	C	D	X		D	X	X	X			
Blue gramma	C	X	C	X	X		C	C	C	X	X
Buffalo grass[2]							X				
Pen (?) sedge[3]				X	X				C	X	X
Plains muhly				X		X					
Green needlegrass[4]							X				

[1] *C—Co-dominant species; D—dominant species, X—minor species*
[2] *Buchloe dactyloides*
[3] *Carex pensylvanica (?)*
[4] *Stipa viridula*

Seed Germination

Several plant species produce inhibitors which retard seed germination and seedling development of their own and other species (Benedict, 1941; Bonner, 1950; Went *et al.*, 1952; Nielson *et al.*, 1960). For example, quackgrass *(Agropyron repens)* produces a water-soluble inhibiter which is stable for some time in the soil after live plants have been removed (Kommendahl *et al.*, 1959). In order to test whether a soil-stable inhibitor was in a microposition soil, little bluestem and western wheatgrass seeds were germinated with aqueous soil extracts. Seeds from indigenous plants were not available. Two samples of little bluestem seed supplied by Peppard Seed Company, Kansas City, Missouri, and little bluestem seed from Wyoming were used in the study. The germination variation between duplicates of a little bluestem seed treatment were as great as the

Table 2. Surface soil characteristics of the study area.

Characteristic Measured	Average of 5 microvalleys	Average of 6 microridges[1]	Microridge Number 5
pH	6.26	7.47**	7.2
Nitrogen per cent	0.194	0.148**	0.167
Available phosphorus, lbs./acre	29.5	9.8*	15.2
Exchangeable K. meq./100 grams	1.78	1.20**	1.45
Exchangeable Na, meq./100 grams	.12	.18**	.15
Cation exchange capacity, meq./100 grams	44.0	51.6**	51.6
Clay, per cent $<2\mu$ size	50.6	59.9**	61.4
Fine silt, per cent 2-20μ size	18.6	21.6**	21.1
Coarse silt, per cent 20-50μ size	7.6	7.1	6.4
Sand, per cent $>50\mu$ size	23.1	11.1**	11.1
Moisture penetration at sampling, inches	12.6	14.5	13.0

* Significant at 5 per cent level.
** Significant at 1 per cent level.
[1] Average includes microridge No. 5.

Table 3. Western wheatgrass seeds germinated per 100 seeds moistened with different solutions.

Germinating Solution	Seeds Germinated in Duplicates	
Distilled water	17	16
Microridge soil extract	10	14
Microvalley soil extract	33	20**

** Significant at 1 per cent level.

variation between treatments. There was no evidence that extracts from the two microposition soils influenced little bluestem seed germination. However, the microvalley soil extract seemed to stimulate western wheatgrass germination, (Table 3) while the microridge soil extract had no effect. The low germination of western wheatgrass seeds may be caused by seed dormancy. Some substance in the microvalley soils may have shortened the dormancy period and stimulate germination. Potassium nitrate solutions are used to germinate dormant seeds in testing laboratories. The increased western wheatgrass germination with microvalley extracts probably is not important since the grass could spread to microridges by rhizomes if other factors did not inhibit their growth.

A second test consisted of germinating little bluestem, big bluestem, and western wheatgrass seeds with aqueous extracts of pulverized roots of each of these species. The roots were from indigenous plants and the seeds were from the same samples used in the previous germination study. Differences between duplicates were as large as differences between treatments. Root extracts as prepared in this procedure had no influence on seed germination.

Effects of Grazing

The study area is in a winter pasture in very high condition. However, little bluestem occurs in nearby summer pastures where it is also restricted to weakly developed clay soils either on steep slopes or on microridges on moderately steep slopes. Grazing in these pastures has been moderate for the past 20 years. Prior to this period and before large stock-watering dams were constructed, at least part of a 10-square-mile summer pasture was lightly grazed because of the distance to water. On some areas in this pasture where grazing has been more intense little bluestem is missing, but sideoats grama and plains muhly are still present on weakly developed microridge soils located either on steep slopes or on knolls. In contrast, on the gentle slopes most mocroridges throughout the pasture have western wheatgrass and blue grama as the dominant species. However, these microridge soils seem more strongly developed and darker colored than those on the steep slopes.

Soil Moisture

In the study area the drier sites are occupied by grasses commonly considered as mesic rather than by those usually considered as more xeric species. Wisconsin soils underlain at a shallow depth by limestone are considered better sites for little bluestem because they have a better water-retaining capacity (Dix and Butler 1960). In contrast, the unconsolidated mantle thickness above the bedrock in the South Dakota study area did not appear to be a factor in little bluestem distribution since the shale substratum is at nearly a uniform depth. Where bedrock is at a shallow depth or on steep slopes of unconsolidated material, geologic erosion usually is rapid and the soils are weakly developed. Microridge soils are weakly developed and resemble soils on slopes susceptible to rapid geologic erosion. Because little bluestem is especially important on steep slopes throughout an extensive area of widely differing precipitation, the kind of soil profile may be more important than the moisture supply.

Archer and Bunch (1953) state that little bluestem starts growth early in the spring and continues all summer. On the other hand, western wheatgrass starts growth early in the spring, is dormant during the drier summer months, but can make further growth in the fall if moisture is available. Western wheatgrass should be able to utilize soil moisture prior to little bluestem growth in the spring (Weaver, 1954). Thus, little bluestem apparently has no seasonal advantage in utilizing soil moisture in the microrelief area since nearly half of the annual precipitation falls in April, May, and June.

The average moisture penetration (Table 2) was greater in microridge than in the microvalleys and appeared inversely related to the cover of mulch and vegetation on the surface. Moisture absorbed by the litter would evaporate and thus would not enter the soil. However, differences in moisture penetration were not statistically significant.

Other Related Factors

Soil aeration probably is not a factor because sloping soils rarely contain enough moisture to temporarily fill the soil air pores in a semiarid climate. In addition, little bluestem is more abundant on weakly developed, medium- and moderately fine-textured soils than on comparable thick, more strongly developed soils in western South Dakota. Well-drained soil profiles with these textures normally have sufficient aeration pore space.

Soil temperature does not appear to be a factor in the grass distribution in the microrelief area. Surface soils are lighter colored on the microridges than in the microvalleys. The most heat would be reflected from the lighter colored surface. On microridges, small, matted areas of little bluestem and surface mulch would have insulating properties equal to or greater than those in the microvalleys, dominated mainly by western wheatgrass. Heat also would be reflected by the mulch because of the light color of dead vegetation.

Aspect apparently is not an important factor controlling species distribution since little bluestem and most of the sideoats grama are restricted to microridges on steep slopes regardless of the direction they face. The vegetation - microposition relationship is not peculiar to soils formed from Tertiary-age shales but also occurs on soils developed from Pierre shale.

Conclusion

The presence of the bluestems and most of the sideoats grama on the soil microridges in the study area cannot be attributed to a more favorable moisture regime than is in the adjacent soil microvalleys which have western wheatgrass as the main species. The distribution of the grasses seems to be related to the fertility of the soils. It is postulated that western wheatgrass which grows rapidly in the early spring and becomes semidormant in the summer is unable to absorb enough nutrients from an infertile microridge soil to produce plants sufficiently vigorous to use the soil moisture prior to the growth of the warm season species. Conversely, the warm-season mid- and tallgrasses which commence growth later than western wheatgrass, but grow throughout the summer, could absorb sufficient nutrients as they are released at a slow rate from an infertile soil. Therefore, in the climate of the study area they could compete successfully with western wheatgrass on the more xeric sites with infertile clay soils, but not on similar sites with fertile clay soils.

Summary

Little bluestem occurrence on the microridges and not on the microvalleys of a wavy gilgai soil pattern in semiarid western South Dakota seems to be caused by fertility differences of the soils. Little bluestem apparently can compete successfully with western wheatgrass on the infertile microridge soils. Microridge soils are weakly developed and similar to soils on steep slopes where little bluestem frequently is abundant. Soil fertility may be the most important factor in little bluestem distribution on clay - textured soils. Other factors, including the possible presence of a germination inhibitor in the soil or in the roots of associated species, were studied but did not appear to influence the distribution of the species.

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