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Native Midwestern Pastures: Their Origin, Composition, and Degeneration

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Number 22

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**NATIVE
MIDWESTERN
PASTURES**

**THEIR ORIGIN, COMPOSITION,
AND DEGENERATION**

**J. E. WEAVER
W. W. HANSEN**



**UNIVERSITY OF NEBRASKA
CONSERVATION AND SURVEY DIVISION**

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NATIVE MIDWESTERN PASTURES
THEIR ORIGIN, COMPOSITION, AND DEGENERATION

By

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AND

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Introduction

ACCORDING to Doctor J. E. Weaver and Mr. W. W. Hansen the purpose of this bulletin is to present certain facts involved in range and pasture management by outlining in some detail the fundamental phenomenon of vegetational change upon which all rational pasture studies must be based. They maintain that the native prairie vegetation is an organic entity in close adjustment with soil and climate, which has developed gradually to its present condition of dynamic stabilization. When the prairie is grazed and trampled, various changes occur, the nature and extent of which vary somewhat directly with the degree of disturbance, but under protection or deferred grazing, repair of moderate damage normally occurs rapidly. Once degeneration of the prairie is well under way, however, it proceeds so gradually and effectively that it is usually not observed until great loss in productivity is sustained, and several years are required for recovery. The stages in degeneration, how and why they occur, the types of pasture that are produced, and causes of complete disintegration are fully outlined and illustrated in this bulletin, which states that a knowledge of the stages of prairie degeneration affords a scientific basis for planned range improvement and pasture management.

Doctor Weaver is eminently fitted by long study of grasslands in the midwestern and far western states to understand and analyze the problems of grazing native pastures. His scientific training is tempered by an unusual interest in the application of scientific facts to practical problems of crop production. He knows that native forage produced in pastures is an important crop largely within the control of man, a fact greatly emphasized by the recent drought. This crop may be decreased or increased next year and the next, depending much upon the present treatment of the range.

This bulletin on the fundamental, underlying principles of the origin, composition, and deterioration of native midwestern pastures is to be followed by one recording extensive experiments on the improvement of pasture under protection.

G. E. CONDRA, *Dean and Director*
Conservation and Survey Division

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Fig. 1 (upper).—Upland true prairie of needle grass and little bluestem at Nebraska City. The mid grasses reach a height of 1.5 to 3.5 feet in midsummer.

Fig. 2 (lower).—Common grasses of true prairie. Little bluestem (left) in seed at a height of 30 inches; side-oats grama (center) of similar height; and June grass (right) which is only 18 inches tall.

Native Midwestern Pastures

THEIR ORIGIN, COMPOSITION, AND DEGENERATION

INTRODUCTION

WHEN the first settlers came to Iowa and Nebraska they entered an almost boundless area of grassland. Throughout the years the prairie has been largely broken for crop production, but even today there still remain considerable tracts of native grassland annually mowed for hay and far greater ones of native pasture.

The area of this research lies in the central portion of this great body of grassland, now largely broken, known as true prairie. The true prairie extends much more widely, from southern Manitoba to Texas. It includes much of Illinois on the east and the western boundary extends from Oklahoma through central Kansas and Nebraska northward through the Dakotas. Throughout, the dominant species are grasses of medium height (mid grasses), such as little bluestem, needle grass, side-oats grama, and many others, fig. 1. The mixed prairie lies west of the true prairie, from southern Canada to northwestern Texas. The name is derived from the intimate mixture of mid and short grasses, that is, mid grasses with buffalo grass, blue grama grass, and similar species which are about 5 to 16 inches high.

A very large number of grasses are adapted to this central portion of true prairie. The eastern third of Nebraska, for example, is a transition zone between the more humid conditions of the east and the more arid ones westward. Over a period of years of favorable rainfall, little bluestem, Kentucky bluegrass, and even big bluestem thrive; during periods of drought they suffer great losses and more drought-resistant grasses of western and southwestern origin become far more abundant and important. The mid-latitude, moreover, makes it possible for grasses adapted to cool seasons, such as June grass, needle grass, and nodding wild rye, to flourish. They intermingle with the grasses of southern extraction—bluestems, Indian grass, and tall panic grass—which are adapted to growth only during the warm seasons of the year, fig. 2. Thus, from early April until late October various species of grasses and forbs are blossoming, setting seed, or having seed scattered over the soil (Frolik & Keim 1938).

In 1929 there was begun an extensive study of the native grasslands of western Iowa, eastern Nebraska, and portions of four adjoining states, to the north and south, respectively. Field work of

this survey was completed in 1933 and a monograph, "The Prairie," was published as a result (Weaver & Fitzpatrick 1932, 1934). Examination of native pastures was also begun in 1929, five years before the great drought of 1934, and continued to the end of 1940. The present paper is a record of the results obtained from a study of scores of pastures examined in this territory before the drought. Since this time profound changes have occurred; these have also been studied over a period of seven years and are here recorded.

Native pastures, like the remaining native prairies, occur on typical soils and topography of the particular region in which they are found. They vary in size usually from 20 to 160 acres, although westward ranges 320 or more acres in extent are not infrequent. Where cultivation is intensive, native grassland, crossed by one or more deep ravines, has been kept for pastures.

THE PROCESS OF DEGENERATION

Climax grassland, when grazed lightly, may retain essentially its natural composition over extremely long periods. It is only when grazing animals are circumscribed in their range by fences and when too large a population is thus confined that grazing and trampling become so excessive that the normal cover cannot be maintained. Cattle, especially, and horses to a lesser degree, are the grazing animals concerned in this study.

The selection of grass types and preference for certain species by livestock is marked when forage is plentiful. Repeated partial removal of the most palatable grasses results in better growth of the remaining vegetation. In fact, if certain favored plants are grazed too early, too often, and too closely, they will disappear entirely. Less desirable species then receive more light and increased water, as well as additional nutrients, which are normally used by the more palatable grasses. In consequence, they flourish and may actually increase, often with marked rapidity. This is especially true of species that propagate by underground parts, which are so frequent in grassland. Thus, during the early stages of grassland degeneration there is considerable shifting of the plant population but entirely among the species which are normal components of the native prairie.

As the hold of native species is weakened by continued pasturing or intense overgrazing, invaders come in. The great stability of natural grassland and the absence of weeds have been emphasized by Weaver & Flory (1934) and Flory (1936). But under pasturing many small bare places appear. These are due to various causes: the death of greatly weakened species resulting from

drought or winterkilling, since weakening the tops also weakens the roots (Biswell & Weaver 1933; Robertson 1933), and the occurrence of bare spots where dung has smothered the grasses or where animals have pawed or trampled the earth or slipped on wet soil.

Regardless of the cause, the bare areas invite invaders, which, once established, furnish seed for a new population. Gradually, the native grasses and forbs are partially or entirely replaced by invading species which are better adapted to close grazing and trampling. Nearly all of these are less productive, or less palatable, or both, than the original occupants. With the disappearance of most of the native population the prairies are far advanced on their way toward final disintegration.

Continued grazing and trampling, augmented by midsummer drought, further bare the cover and permit the entrance of a final crop of weeds. These are mostly annuals. The once continuous cover of grasses is broken and the soil may be held only by patches of vegetation. Inedible weeds alone may remain to hold the soil against erosion. Forage production is at such low ebb that the pasture is almost worthless. The topsoil is washed into the ravines where it covers the remaining grasses. Numerous deeply worn paths crisscross the pasture. They have been made by hungry animals in search of food. If the farmer has other native prairie used for hay he will almost surely resort to it for temporary grazing and thus again start a cycle of pasturing and degeneration.

STAGES OF DEGENERATION

Five more or less distinct stages have been determined in the degeneration of prairie and pasture. The grade or quality of pasture represented in each stage will be designated by the numbers 1 to 5, in increasing order of deterioration.

Although a pasture or range rarely degenerates uniformly throughout, yet most pastures, except about gates, watering places, etc., could readily be classified, after examination, into one of the five groups. A few were exceptional and showed two or three types as broad belts either because of distance from watering places or because of topography. Certain areas are favored by herds as resting places during the heat of the day. Where no shade is to be found, ridges or flat uplands where the cooling effect of wind may be felt are used regularly. Here much trampling occurs and just beyond there is intensive grazing, which grades perceptibly through a belt of vegetation perhaps into an excellent cover or, where the pasture is understocked, to one very irregularly grazed. Elsewhere the resting area may merely have degen-

erated into the bluegrass or short-grass stage. This illustrates the fact that early stages of deterioration are sometimes quite irregular. A few places were seen where cattle were concentrated in such numbers that the transition from prairie to a fourth grade pasture occurred within a span of four years. This, however, is very exceptional. Under proper management, native pastures have been kept in excellent productivity throughout many decades. Deterioration is not necessarily a continuous process.



Fig. 3.—Upland, climax true prairie that might well be an ungrazed No. 1 pasture except for the abundance of the legume, many-flowered psoralea.

There are usually wetter years or those with reduced stocking when for a time recuperation occurs. Hence, in studying pastures, information on their past history and treatment as well as a knowledge of present conditions is valuable (Sampson 1939).

The relation of grazing to watering places must be carefully considered. Where a 160-acre or larger pasture is only a quarter of a mile wide, the fact that water is at one end may result in a high degree of overgrazing on the first 40 acres while a similar unit most distant may be undergrazed. Position of salting places is also important.

Number 1 pastures possess several definite characteristics. They are prairies that have not been misused. The forage usually exceeds the needs of the grazing animals. Grazing is very irregular

or if regular not too close so that 20 to 25 per cent of the forage is left at the end of the growing season. Kentucky bluegrass (*Poa pratensis*), which usually becomes dry and bleached during the hot midsummer, has only a slight hold. Hence, during ordinary drought such pastures appear green and not dry. A few more or less inedible indicator species such as ironweed (*Vernonia baldwini*), prairie cat's-foot (*Antennaria campestris*), and many-flowered aster (*Aster multiflorus*) usually show an increase.



Fig. 4.—Lightly grazed upland prairie. The bunches are little blue-stem. Note the continuous cover and absence of weeds in this No. 2 type of pasture.

Others such as the very palatable ground plum (*Astragalus crassicaarpus*), many-flowered psoralea (*Psoralea floribunda*), and upland sunflower (*Helianthus rigidus*) may more or less completely disappear.

If such pastures are ungrazed for a year or more, however, they are readily mistaken for undisturbed grassland, fig. 3. Numbers of such well-kept pastures were found; one of 35 acres, because of lack of water, was grazed only in the morning but more or less continuously over 30 years.

In No. 2 pastures, favored areas are completely but not too closely grazed, but others are undergrazed as is shown by old tufts and bunches and debris of former years. Grasses about

dunged places are ungrazed or irregularly nipped at a height of 4 to 6 inches. The hold of bluegrass or short grasses, such as blue grama grass (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*), is increasing. Although the amount of bluegrass may still be small in some pastures, in others it is extensive, especially under big bluestem (*Andropogon furcatus*) in ravines. Bluegrass is still local along pathways, flat ravine bottoms, and similar well-grazed places. Here all of the native bunch grasses have disappeared and the original occupants may constitute only

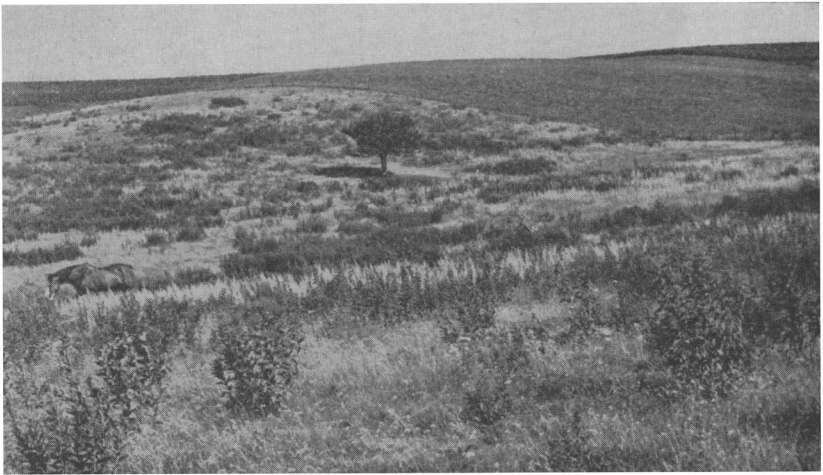


Fig. 5.—View of portion of an old No. 3 pasture with native prairie beyond, near Corning, Iowa. It consists largely of bluegrass and native prairie grasses, chiefly bluestems. Ironweed (foreground), prairie sage (light colored), and buckbrush are the chief weeds.

half of the plant cover. Side-oats grama (*Bouteloua curtipendula*) nearly always shows distinct increases in abundance. Numerous legumes such as round-headed bush clover (*Lespedeza capitata*) and silvery psoralea (*Psoralea argophylla*), although frequent or abundant in prairie outside the fence, have almost entirely disappeared within the pasture. Although the shiftings are thus far among the native plant populations, a few invading weeds may occur sparingly to form a potential menace. Examples are tumblegrass (*Schedonnardus paniculatus*), Pursh's plantain (*Plantago purshii*), and western ragweed (*Ambrosia psilostachya*). Often, however, a striking feature throughout large pastures is the absence of weeds, fig. 4. Dunged areas are still of minor significance; they are soon reclaimed by the grasses and are not infested with weeds; and the cover remains nearly complete. Pastures of this type, while more often observed than the No. 1 type, are not

nearly so abundant as are those in the third stage of deterioration.

In No. 3 pastures bluegrass or short grasses or alternating areas of these either equal or overbalance the usual prairie species and form the background or matrix of the vegetation. Usually the cattle graze as they travel about the pasture and there are few or no well-defined paths. The prairie sod is still sufficiently intact so that no cracking of the soil occurs even during moderate drought. Ravines have often gone over entirely to bluegrass. The



Fig. 6.—A very good No. 4 type of pasture near Anita, Iowa. Prairie grasses have been entirely replaced by bluegrass. Note abundance of dunged patches and weeds where the sod is broken.

original prairie species are clearly on the decline, although still abundant. Bluegrass, for example, has often entirely replaced the much-grazed big bluestem which formerly was found in ravines. The grass cover is yet well intact. Close grazing has sometimes resulted in islands of pure bluegrass in areas of little bluestem (*Andropogon scoparius*) or side-oats grama. There is a moderate number of relict prairie forbs such as stiff goldenrod (*Solidago rigida*), yarrow (*Achillea occidentalis*), many-flowered aster (*Aster multiflorus*), and prairie sage (*Artemisia gnaphalodes*), most or all of which are little eaten and hence are increasing. A moderate number of introduced weeds have appeared. Common among these are annual ragweed (*Ambrosia elatior*), vervain (*Verbena stricta*), horseweed (*Leptilon canadense*), and sheep sorrel (*Rumex acetosella*). They are mostly confined to local, usu-

ally small, bared areas. All of the native grasses are grazed evenly and much closer to the soil than in the earlier stages. In general, the cover is good, but trampled places and dunged areas are the centers of weed infestation. While many species of weeds are present, usually only a few are abundant, fig. 5.



Fig. 7.—Ungrazed No. 4 type of pasture near Lincoln, Neb. In the foreground the buffalo grass sod has broken up into patches, and many kinds of weeds are abundant.

Number 4 pastures differ from No. 3 grasslands in having a practically pure stand of bluegrass or short grasses. In the best pastures the cover may be well intact but frequently it is broken, fig. 6. Little bluestem has usually disappeared. Both perennial and annual weeds are abundant. Prairie forbs may be represented by a few relict species but individuals are usually few in number. Often there are many square rods of bluegrass without a single prairie remnant. Areas of grass alternate frequently with bare ground or soil clothed only with weeds. The vegetation is cropped close to the soil. Banks bordering the ravines where the slope is steep or even moderately so are held longest by the native plants, since here bluegrass finds invasion difficult, consequently on dry years they appear greenest. While most grasses long resist the impact of grazing, native forbs, with few exceptions, tend to dis-

appear. Western wheat grass may occur on knolls and trampled places, and in old declining pastures it is often scattered wherever bluegrass or the short grasses have lost their hold. Usually very large alternates of short grasses occur, especially on the hills, or short grasses may entirely dominate in drier pastures westward, fig. 7. In fact, both bluegrass and short grasses are often so



Fig. 8.—No. 5 type of pasture of buffalo grass near Carleton, Neb. The dark areas are without grass and are either entirely bare or partially covered with dead, short-lived annuals.

severely grazed that the stand becomes thin. Many places in the sod are trampled bare. Bare areas are also common along the formerly sodded steep banks of ravines. Even on rough banks where bluegrass scarcely invades, the soil is trampled and broken and the sod is deteriorating. Small bare areas occur everywhere; paths bare of vegetation are common along the fences where cattle have trampled in their effort to reach over or through the fence to secure the forage. Paths worn 2 to 4 inches deep are common, especially in long, narrow pastures. Elsewhere they may radiate outward from the watering places, fading out only in the most distant portions of the pasture. Banks of ravines heretofore grazed not at all or only slightly are now terraced by parallel paths. Cracking of the soil during drought is common.

In the final stage of degeneration (No. 5 pasture) annual weeds dominate. The cover is open everywhere, the bared soil awaiting or being clothed with a weedy population. There are only frag-

ments of the former cover of bluegrass, short grasses, or sand dropseed, fig. 8. Relict patches of much weakened and open growths of bluegrass, grama grass, buffalo grass, and sand dropseed or some of these usually occur somewhere in pastures of considerable area and diversified topography. The deterioration has not taken place uniformly but has spread from the earlier centers of infestation. Often over considerable areas 75 per cent of all vegetation has disappeared, and in places 90 per cent of the soil is bared.



Fig. 9.—No. 5 pasture where remaining patches of weakened bluegrass and blue grama grass and bare places support a variety of weeds. The tall, narrow ones are horseweed; western ragweed, peppergrass, aster, and yarrow are abundant.

Only the merest remnants of original prairie species, as well as the absence of old fence lines or ridges or depressions of furrows, indicate the virgin nature of the pasture, i.e., that the land has never been plowed. Such original species are prairie cat's-foot, flowering, if at all, close to the ground; prairie sage, closely grazed and in thin local patches, and perhaps certain other prairie species, with stems extremely few and slender, some delayed several weeks in getting out of the ground. Remnants of aster, blue-eyed grass (*Sisyrinchium*), and, rarely, lead plant (*Amorpha canescens*) are observed with the preceding if early spring grazing is delayed. Even the annuals are trampled out over large areas. Where shrubs or other edible woody plants occur, the new shoots

are eaten to the ground. The soil may crack in large irregular blocks, the cracks being one-quarter inch to two inches in width, extending deeply, and thus exposing large surfaces to evaporation.

The closer the grazing and the lower the grade of pasture on a given soil type, the more subject the soil is to cracking. This phenomenon is especially noticeable during drought. It results in part from the mellow surface being eroded and the deeper soil often with higher content of clay being exposed, and partly to the disappearance of the two or more tons per acre of soil-binding fiber furnished by underground plant parts (Weaver & Harmon 1935). On drying, the clay shrinks so greatly that cracks form and extend irregularly from distances of a few inches to many feet. On slopes where the depletion of cover has long been severe and the A horizon has been largely eroded, soil cracking is pronounced.

The continuous cover on rounded banks of low-grade pastures begins to break down at the same time that runoff from the slopes above is greatly increased. Their barrenness is aggravated by the trampling of stock which normally graze here but little. In dry weather the soil crumbles, during rains it is carried away. Gradually it accumulates in the ravines where it buries any remaining bluegrass. Upon it stinkgrass (*Eragrostis cilianensis*), tumblegrass (*Schedonnardus paniculatus*), and many other weeds appear.

Where erosion has started by the undercutting of soil at the heads of sloughs and draws, it is accelerated by the stock walking down the banks or climbing up over them. Blocks of sod which are thus loosened are pulled down by gravity, crumble, and are later washed away. Animals rub on the sides of steep banks and produce further crumbling. These practices are accentuated when pastures are overstocked.

Such low-grade pastures are beyond natural recovery within reasonable limits of time and if grazed further the surface soil becomes even more seriously eroded and the value of the land is greatly reduced, fig. 9.

CLASSIFICATION OF PLANTS BASED UPON THEIR RESPONSE TO GRAZING

Plants found in pastures may be classified according to the manner in which they respond to grazing. Lists have been compiled only after constantly checking the behavior of the species concerned in many pastures over a period of 12 years. The plants have been observed under varying degrees of grazing and their normal abundance checked in adjacent prairies or in strips of native prairie just over the fence along roadsides. The following types occur:

Prairie grasses that decrease under grazing
 Prairie forbs that decrease under grazing
 Prairie grasses that increase under grazing
 Prairie forbs that increase under grazing
 Grasses that invade pastures
 Weedy forbs that invade pastures.

Prairie Grasses that Decrease under Grazing.—A considerable number of prairie grasses tend to decrease in abundance more or less rapidly when true prairie is grazed. Finally all may disappear. The most important species, all perennials, are:

Andropogon furcatus	Panicum virgatum
Andropogon scoparius	Stipa spartea
Sorghastrum nutans	Koeleria cristata
Spartina pectinata	Sporobolus heterolepis
Elymus canadensis	Sporobolus asper

Andropogon furcatus.—The two types of prairie of greatest importance and widest extent were those characterized by little bluestem (*Andropogon scoparius*) and big bluestem (*A. furcatus*), respectively (Weaver & Fitzpatrick 1934). Big bluestem was the most important species of the grasslands which occupied the broad valleys of the larger streams, fig. 10. It also occurred in ravines and on slopes and hillsides, and was even found on hillsides, where it constituted 5 to 15 per cent of the basal cover.

Big bluestem has high palatability and is not only readily grazed but also is selected by stock where other forage is abundant. In prairie, even in pure stands, the stems are usually separated by a distance of a centimeter and the tufts or small bunches by 5 to 10 centimeters. The basal cover is usually only about 13 per cent, fig. 11. When grazed, however, many new shoots are produced from bases of stems and shallow rhizomes. These give rise to an abundance of leaves just above the soil surface. Even when grazed to within 1 to 1.5 inches of the soil there is left considerable green tissue. Leafiness thus increases with grazing. This grass makes its greatest radial spread in spring while using the food reserves of the previous summer. Hence, early grazing limits normal development, decreasing growth of both rhizomes and new shoots.

Since the best stands on rolling land occur in and along ravines, grazing here is soon uniform and intense. With the increase in light, consequent to the pasturing of the bluestem, bluegrass spreads rapidly between the stems and tufts of this taller grass. Both grasses are then closely eaten, in No. 3 pastures often within an inch of the ground. A uniform type of grazing in ravines of even No. 2 pastures is frequent; no flower stalks of bluestem are

formed; year by year bluegrass increases and finally the bluestem entirely disappears.



Fig. 10.—Prairie of big bluestem on Salt Creek near Greenwood, Neb., in September. Grasses in foreground are 5 to 6 feet tall; those in the background (dark) were mowed in midsummer.



Fig. 11.—Detail of ground cover of big bluestem. Note wide spacing of plants and almost complete absence of other vegetation, due to dense shade.

On uplands big bluestem persists longer, the last remnants being found on steep slopes of the rougher land and on banks of deep ravines. Unless grazed in the earlier part of the season, it becomes less palatable and the woody stems are left during late summer and fall if better forage is available. Even where grazed, flower stalks of the isolated bunches may escape being eaten or trampled for a long time. Then the old, dry leaves and flower stalks are conspicuous the following season, intermingling with those of the current year's growth. But where forage is less abundant, the green stems are sought, and even the cured leaves are not unpalatable. In pastures where there is only moderate grazing pressure, the bunches are often eaten only above the height of 4 to 5 inches. The clumps are gradually weakened with increasingly close grazing and in No. 3 pastures a bunch a foot in diameter may have only 15 to 20 scattered, weak stems. Other grasses, especially bluegrass, migrate in, and soon outlines of the former clumps are scarcely distinguishable, if indeed, as in Nos. 3 and 4 pastures, big bluestem has not entirely disappeared.

Andropogon scoparius.—Little bluestem was the principal dominant of the most extensive upland type of true prairie, fig. 2. This species often exceeded in importance all other upland grasses combined. It usually occurred in the bunch form, but frequently in mats or tufts. In these, the densely crowded stems had complete control and other species occurred only between units of little bluestem. The stand was dense where the soil was fertile and moisture abundant, but the bunches were widely spaced on poor sites. It frequently constituted 70 per cent of the cover and in places 90 per cent (Weaver & Fitzpatrick 1934).

This species is not as palatable as big bluestem. It is readily eaten in spring and early summer, but often avoided after the rather woody stems are produced. Where moderately or closely grazed it produces good forage throughout the entire growing season. This is in sharp contrast with its grazing value in the sand-hill region of Nebraska and certain other places in the west where it is often regarded as worthless to livestock.

Chemical analyses of plants in eastern Kansas indicate that ungrazed bluestems are very nutritious until July. After this they become less leafy in proportion to stems and are gradually reduced in nutritive content and palatability (Aldous 1938). Bluestems are valuable pasture plants since, if soil moisture is adequate, the excellent growth of June and July is supplemented by a substantial amount of forage in August. A moderately grazed bluestem pasture will provide palatable and nutritious forage throughout the growing season.

Probably because of its habit of growing in tufts and bunches, it does not withstand grazing as well as big bluestem, and disappears earlier, lingering longest on the least grazed, roughest lands. It has usually all died before grazing and trampling have reduced the prairie to a grade 4 pasture. Grazing experiments show that the greatest injury to both big bluestem and little bluestem arises from close grazing at the beginning of the growing season. This is due to the fact that it is during this time that food reserves are mainly accumulated. Hence, pastures are greatly improved by protection or light grazing during May and early June. Later grazing is much less harmful. Deferring grazing until after the seed is mature results in a great waste of forage. Deferred grazing in Kansas until about June 15 every two or three years is believed to be sufficient to maintain the normal stand and vigor of the vegetation. This treatment gave an increased carrying capacity of about 25 per cent over that of pastures grazed the entire season (Aldous 1938).

In early stages of grazing, many bunches are left entirely unmolested. Bunches 9 inches in diameter and 30 inches tall, having more than 300 stems, were common in No. 2 pastures. Such stems may persist in an erect position for at least two years. These bunches frequently shelter fragments of big bluestem, June grass, and other species which are regularly grazed elsewhere. On the steeper hillsides of rolling uplands, the ungrazed bunches appear at a distance not unlike the half-shed shaggy coats of animals, but on level or moderately sloping land where grazing has been uniform, all are gone.

Even clumps of little bluestem in the most unfavored grazing areas ultimately disappear, as grazing pressure increases with general deterioration of the pasture or during dry years. Hungry stock is tempted by the abundance of green foliage protruding from the bunches. They may first crop the sides opposite the clinging dead leaves, which often lodge and fall to one side before the combined effects of wind and snow, or repeatedly graze the tops closer and closer until finally this last stronghold of native vegetation disappears as the grass within is reduced to the common grazing level. In No. 3 pastures, bunches thus grazed one-half to two-thirds laterally or reduced to one-half to three-fourths their former height are plentiful. Horses are more effective than cattle in this process. During the early years of drought when forage was scarce, bunches on such areas rapidly disappeared. Once closely grazed, they are regularly grazed thereafter and bluegrass or short grasses exert continuously greater competitive pressure. Often bunches grazed to within an inch of the soil adjoin

those untouched by animals. In fact, for a long time, relict bunches are left standing either as isolated individuals or in small irregularly shaped islands, depending upon the grazing pattern. These islands of bluestems are usually surrounded by a continuous sod of bluegrass, blue grama grass, or buffalo grass.

Once the dead tops are removed close grazing may result and the bunches deteriorate. The older, central portion usually dies first. Peripheral growth continues but stems become progressively sparser year by year. The bunch often breaks up into many fragments which may succumb but slowly or disappear rapidly depending upon the closeness of pasturing.

Sorghastrum nutans.—Indian grass, although similar in its habitat relations to big bluestem, is much less abundant in prairie. It usually constitutes only a small per cent—often 1 to 3—of the basal cover on both lowlands and rolling hills. It is seldom of much importance in pastures unless there has previously been considerable disturbance of the prairie cover by repeated burning, or occasional flooding on low ground. No evidence has been found that Indian grass increases even temporarily at the expense of other grasses under grazing. It is somewhat less palatable and less nutritious than big bluestem.

The response to grazing is intermediate to that of little and big bluestem. In second grade pastures, large bunches may remain intact near the valleys and on lower slopes, or perhaps few have escaped grazing sufficiently to enable them to produce flower stalks. Elsewhere, the broad green leaves, a foot high late in May, are intermixed in the old debris. Even in some third grade pastures this species was commonly scattered throughout, except on the driest ridges, and many clumps had seeded. In other No. 3 pastures, Indian grass had been regularly and closely grazed and a fine growth of foliage, much like that of big bluestem, had developed. The rapid growth of the leaves after grazing, as in big bluestem, places them well above those of the competing bluegrass and other shorter grasses. Hence, there is much foliage consumed and the damage is considerable when the leaves are continuously removed. The species has nearly always entirely disappeared by the time degeneration has reached the No. 4 pasture stage.

Spartina pectinata.—Slough grass is a coarse sod-forming species which grows usually in nearly pure stands in soils too wet and therefore too poorly aerated for the growth of big bluestem or even for nodding wild rye (*Elymus canadensis*) and tall panic grass (*Panicum virgatum*), which are somewhat more tolerant than the bluestem to poor aeration. In upland prairie, it is frequent in ribbonlike belts in wet ravines.

This grass is grazed readily in its earlier stages of development, but once the coarse woody stems are formed only the tops are eaten, fig. 12. The stems are often broken by trampling. Slough grass usually has disappeared from third grade pastures, although remnants sometimes sparingly persist in the next lower one. Besides grazing, a chief cause of its disappearance is the filling in of the ravine with deposits of soil and its replacement by species of smartweed (*Polygonum*), or ragweed (*Ambrosia*), or by snow-on-the-mountain (*Euphorbia marginata*). Elsewhere it may have



Fig. 12.—Slough grass (dark patches) partially grazed in native pasture near Beaver Creek, Minn. Prairie grasses and bluegrass cover the lowland; on upland (foreground) patches of blue grama grass occur.

been destroyed by lowering of the water table resulting from deep gulleying of the ravine. Its former presence in either instance is shown by its abundance in similar sites on adjoining prairie.

Elymus canadensis.—Nodding wild rye is a coarse grass found typically in moist habitats. Although widely distributed over the lowland prairie it is a dominant of minor importance. It usually constitutes a 1 to 5 per cent mixture among other lowland species. With tall panic grass it forms a reliable indicator on upper slopes and heads of ravines of increased water content due to run-in water. This grass renews growth much earlier than most species. Being quite palatable and occurring either in bunches or as a very open sod it is readily grazed out and disappears early. If properly protected it becomes quickly re-established.

Panicum virgatum.—Tall panic grass has habitat requirements similar to nodding wild rye. Together they form the panic grass-wild rye type. This is a lowland type occurring on soils where con-

ditions are intermediate between those best for slough grass on the wetter side but favorable to big bluestem on the drier side. Panic grass is a coarse, rank, sod-forming species, which is palatable when young but practically worthless for forage at maturity when the stems become lignified, except that the leaves and panicles may be eaten. It is usually not abundant except on low ground. The sod is very open and does not well resist heavy grazing and trampling. It is usually rare in No. 3 pastures but relicts are sometimes found even in the No. 4 type.



Fig. 13.—Upland prairie of needle grass near Valparaiso, Neb. Photo May 20.

Stipa spartea.—Needle grass is typically an upland species. Steep, dry ridges and xeric slopes, especially where the soil is thin and perhaps sandy or gravelly, are frequently dominated with more or less pure stands of *Stipa*, fig. 13. It associates chiefly with little bluestem, June grass, and prairie dropseed, but is found in various mixtures (Weaver & Fitzpatrick 1934). *Stipa* is also frequently more or less abundant on flat lands at the heads of draws and is readily distributed on lower slopes at the foot of broad washes that are subject to overflow during exceptionally heavy rains.

This bunch grass renews growth very early in spring, produces seed in late May and early June, and, in prairies, remains more or less quiescent until fall, when it continues growth until overtaken by freezing weather. It is very palatable and nutritious, being sought especially by horses. The bunches are grazed rather closely and eaten repeatedly as new foliage appears. Even in Nos. 1 and

2 pastures, it is only rarely that isolated bunches are found with fruiting stalks. Consequently, there is very little reseeding and the original stand, grazed early in spring and late in fall when most other forage is often dry, disappears early. Frequently old No. 2 pastures have none, and in No. 3 types it is practically always absent, although occurring in abundance in prairies just beyond the fence. Its last hold is on steep banks which are seldom grazed.

Koeleria cristata.—June grass, a bunch grass of small stature, shows a preference for uplands, but occurs not infrequently on lower midslopes and on well-drained lowlands. It is an excellent forage grass and is relished by all classes of stock. Since the scattered tufts are small, averaging about 4 by 5 cm. in basal area, and the rather short leaves are mainly basal, the forage value is not nearly so great as that of most prairie grasses.

June grass renews growth very early in spring, often 4 to 6 weeks before the bluestems. As indicated by the name, it flowers and seeds early, fig. 2. It is semidormant in summer but in autumn it makes an excellent growth and remains green after most of the grasses have dried. These bunches seem to have a short life span, but are readily replaced by new ones. Although green flower stalks as well as foliage of this very palatable species are readily eaten, some heads escape grazing because of the small size and great abundance of the bunches. *Koeleria* usually disappears in the early stages of prairie degeneration, frequently little is found even in No. 2 pastures. But where conditions for seeding become favorable, even with slight opening of the cover, it may increase, especially in pastures that are not grazed early and regularly. Thus, while in No. 3 pastures there was usually little or none, in others an abundance of small tufts occurred scattered throughout, widely and regularly. Small bunches are liable to be pulled up in grazing if the soil is light. It is sometimes abundant on banks of ravines where it has seeded from plants growing in places above, which are rather inaccessible to stock. It is its prolific seeding habit that causes great irregularity in distribution. When the bluegrass or short-grass sod becomes well developed, however, this grass disappears.

Sporobolus heterolepis.—Prairie dropseed is a bunch grass which formed a very minor but distinct upland type in true prairie. It was always most abundant in the driest uplands, where it dominated local areas, forming 80 per cent or more of the cover. More usually it occurred as scattered bunches, intermingling with needle grass and little bluestem. The bunches are usually larger than those of needle grass, often 4 to 7 inches in diameter, but

sometimes much larger, fig. 14. This grass renews growth early and develops rapidly, the foliage reaching a height of 8 to 15 inches by the first of June. Prairie dropseed is palatable to all kinds of stock and furnishes considerable forage when it is not allowed to mature. Green shoots in old bunches filled with debris are readily grazed. Repeated grazing reduces the number of stems, until only a mere fringe of green outlines the clump. It withstands grazing poorly and usually almost disappears from old No. 2 pastures, and



Fig. 14.—Bunches of prairie dropseed in early fruiting stage on September 5. Flower stalks are about 30 inches tall. Bunches are of only moderate size.

was found only as relicts in the No. 3 type. Since the drought, this xeric species has spread widely in prairie (Weaver & Albertson 1939).

Sporobolus asper.—The tall dropseed decreases slowly in grazed prairie. Ordinarily this bunch grass is not much grazed since the forage is of only fair quality and palatable and nutritious only when young. It rarely occurred in abundance. The coarse bases of the clumps at least remain in No. 3 pastures. As forage becomes less plentiful, rather close grazing of this coarse grass causes it to disappear. This species has increased greatly in prairie since 1934, partly because of lack of mowing, thus permitting the late ripening seeds to mature.

EXPERIMENTS ON DEGENERATION UNDER CLIPPING.—Experiments were begun in 1937 on the effects of frequent clipping to simulate

close grazing during a period of two to three years. Species employed were *Andropogon furcatus*, *Stipa spartea*, *Sporobolus heterolepis*, and *Koeleria cristata*. *Andropogon scoparius* was not used since extensive experiments with it had been made previously (Aldous 1930; Weaver & Hougen 1939).

Decrease in Big Bluestem.—The effect of frequent cutting upon big bluestem was determined by a three-year experiment near Greenwood, in eastern Nebraska. Here a tract of native tall-grass



Fig. 15.—Experimental plot in big bluestem prairie, June 28, 1937. The grass has just been clipped a second time. The unclipped grass is 2 feet tall but is overtopped by a native milkweed (*Asclepias sullivantii*).

prairie occurred on nearly level land on the floodplain of Salt Creek. It lay a half mile from the stream and at the outer edge of the floodplain. The natural rainfall was supplemented by runoff from surrounding low hills and from the upper portion of the prairie which extended half a mile up a broad depression to higher land. The dominant grass occupied fully 95 per cent of the experimental area, fig. 10. The prairie was mowed for hay, usually once a year, in September.

An area 2 meters wide and 18 meters long was staked for frequent clipping in 1937 and there was a similar control plot to be cut once in the fall to determine the seasonal productivity. These plots were maintained four years. The grass was cut with hand shears at a height of 1.5 inches, fig. 15.

The soil was so wet during 1937 that even as late as June the surface was constantly saturated. This was by far the best year

for growth, and the yield of hay was approximately four tons per acre. The following season was much drier since there was only one heavy spring rain, but the upper soil was saturated in early spring. In 1939, a moderately good growing season in spring and early summer was followed by severe drought in late summer and fall. Height of the bluestem at each cutting for the several years is shown in table 1.

Table 1.—Height in inches of clipped and control bluestem during 1937 to 1939 inclusive.

YEAR	JUNE 1	JUNE 26	AUG. 5	SEPT. 1	CONTROL	SEPT. 1
1937	17	11	17	10	34*	62†
1938	6	7	8	6	29	57
1939	7	8	13	8	30	60

* Height of foliage.

† Height of flower stalks.

Each clipping during the first year was followed by a prompt renewal of growth, the height attained depending largely upon the time interval. A decrease in height of one-third to more than one-half occurred in 1938, the drier year being also reflected in the decreased height of the controls. The clipped plants were slightly taller in 1939, as were also the controls, but never regained their vigorous former development.

Total yield of the clipped plants was only 61 per cent as great as the control the first year, 41 per cent as great the second, and 48 per cent the third. The increased percentage the third season over the second was due to more favorable conditions for growth; the yield of the control was 6.7 per cent greater than that of the second year. The percentage of total annual yield during the early period of growth decreased from 42 to 36 and then to 26 (1937 to 1939). This was probably owing to the depletion of the stored food in the rhizomes of the big bluestem.

By August 5 of the first year, bluegrass had made great increases throughout the plot. The following spring the soil was almost completely covered with bluegrass, although very little was found in the control. About 60 per cent of the basal cover consisted of bluegrass and only 30 per cent of big bluestem, fig. 16.

A continuous cover of bluegrass was established by the third summer. It made repeatedly a vigorous growth after each cutting, except during the very hot and dry month of August. In appearance, it was almost identical with that of a well-established bluegrass pasture.

On June 1, 1939, counts were made, as during previous seasons, of the number of stems of big bluestem in one-quarter square meter plots, selected at random. The control area yielded 1080 stems per square meter; there were 1432 after one year of clipping,

and 994 after two years. These results illustrate the usual effects of frequent removal of tops of this grass, which are first an increased production of stems from the rhizomes but later a decrease as the stored food supply diminishes. This was also reflected in the diameter of stems which was much reduced in the two-year-old plot. Similar counts on the number of fruiting stems of bluegrass revealed only 2 per square meter in the control area but 145 where clipping had been practiced for one year and 1169 where it



Fig. 16.—Detail of experimental plot on June 16, 1938, after one year of frequent clipping. The plot had been clipped once (June 1) in 1938. Much of the bluegrass is flowering at a height of 17 inches.

had continued for two growing seasons. Moreover, bluegrass was represented in only one-half of the total square decimeter areas at the end of a single year but in every unit, without exception, after it grew under these favorable conditions for two years.

On May 25, 1940, when the grass was 8 inches tall, three square meters of control big bluestem were clipped at the soil surface, the forbs removed, and the grass air dried and weighed. Here no bluegrass was found. Big bluestem was only 4 inches tall in the clipped plot where the bluegrass had headed sparingly, owing to a dry spring. Average yield of the bluestem in the plot was only 15 per cent as great as the control. Blue grass constituted 80 per cent of the yield of grasses in the clipped plots. That the bluestem was much weakened was further shown by the fact that unclipped

plants in the large plot were only 9 inches tall by midsummer while the controls were 20 inches. All these changes occurred under conditions of clipping which were much less severe than those of close grazing.

Decrease in Needle Grass.—Twenty meter quadrats were laid out in a randomized (checkerboard) pattern in a community of nearly pure *Stipa spartea* on a 2 per cent slope. This was done early in the spring of 1937. Alternating quadrats for clipping and controls were separated by a distance of about one-half meter, a clipped border about 12 inches wide being maintained about each frequently clipped unit.

The first cutting was made on May 14, when the grass was 12 inches high and in the second to third-leaf stage. This, and all subsequent cuttings, were made at a height of 1.5 inches, a level to which this species is usually grazed. Although all plants in the quadrat were clipped, yield of *Stipa* alone was ascertained. The well-developed bunches of grass averaged 28 per quadrat, and the number of stems 40 per bunch. Upon clipping, the yield of needle grass from each unit area was air dried and the dry weight determined to the nearest tenth of a gram.

During the 32 days following clipping, the grass grew at the rate of one-half inch per day and was 16.5 inches tall when again clipped on June 15, each stem having 2 or 3 leaves.

It was now past the normal time of seeding and the grass grew but slowly. It was 7.7 inches high on August 10, when again clipped. Much deterioration in the bunches had occurred. The number of growing stems in bunches which originally had 40 was reduced to about 10.

A fourth and last cutting was made on September 16, the time at which the 10 control quadrats were also harvested. *Stipa* had recovered poorly. The height attained was only 2.7 inches. The controls, which had reached a height of 31 inches and seeded abundantly, yielded an average of 259 gm., fig. 17. Average yields for each clipping, and total yields for both the clipped plants and controls are shown in table 2. Yields of the controls exceeded those of clipped plants by 5.5 per cent.

Stipa made a good fall growth in the control areas; some flower stalks had fallen here from adjacent vegetation and lodged, and with the usual debris formed an almost continuous covering of the soil. Little or no fall growth had been made by the vegetation weakened by frequent removal of tops; in fact, many of the crowns were dead. Wind and water had gradually removed the exposed debris, and much of the soil was bare.

Only a few living bunches remained at the first clipping, on

May 28, 1938, and these were poorly furnished with stems. The high winds in spring had removed both the surface mulch and the loose topsoil and invasion by Pennsylvania sedge and side-oats

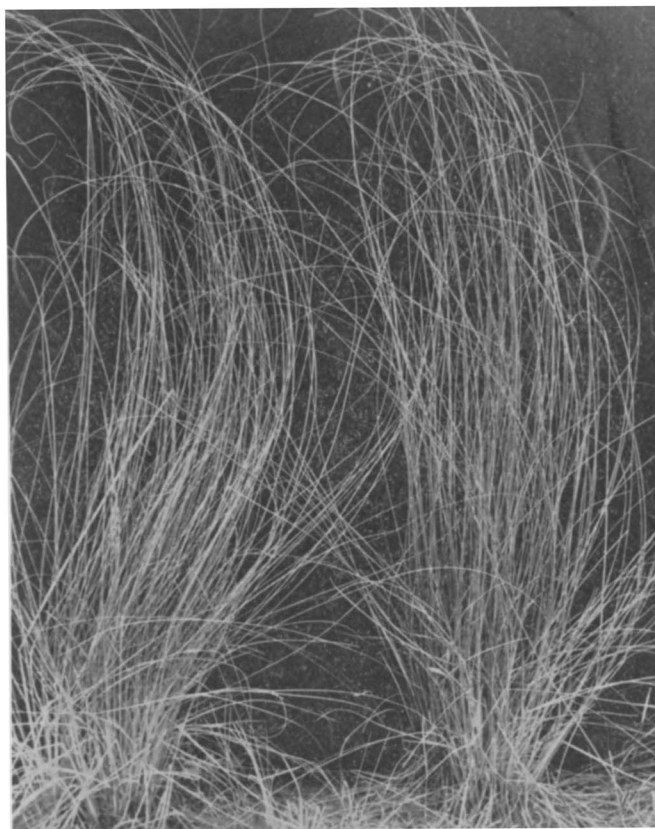


Fig. 17.—Needle grass early in August 1938. Each bunch has about 95 stems and has attained a height of 45 inches; flower stalks have blown away.

grama was beginning. Needle grass was only 13 inches tall and had produced no flower stalks. This was in striking contrast to the controls which were about 2 feet high and had an abundance of fruiting stalks 44 inches tall. Average yield was only 25 per cent of that of the first clipping in 1937, which was made 14 days earlier. Average number of living bunches per quadrat had decreased from 28 to 10, and average number of stems per bunch from 40 to 10.

Only 8 bunches per quadrat remained alive by June 30, and these had but 1 to 5 green stems each. A height of 10 inches had been attained during the 33 days since the May cutting. Each unit contributed a little to the scanty yield which averaged 3.6 gm., table 2.

Table 2.—Yield in grams of air-dried materials of clipped quadrats and controls of needle grass during 1937 and 1938.

1937						
QUADRAT	MAY 14	JUNE 15	AUG. 10	SEPT. 16	TOTAL	CONTROLS
1	63.5	115.7	31.3	15.1	225.6	212.3
2	51.8	95.3	56.1	18.9	222.1	242.5
3	62.8	94.7	37.6	9.8	204.9	227.4
4	60.2	104.5	56.5	11.9	233.1	243.0
5	80.5	111.8	44.0	11.5	247.8	258.6
6	85.2	118.7	26.0	6.1	236.0	252.7
7	100.3	145.5	48.0	16.2	310.0	356.6
8	109.8	118.2	60.0	4.4	292.4	160.5
9	83.7	121.0	35.4	8.3	248.4	366.2
10	89.9	112.0	27.1	7.1	236.1	271.9
Av.	78.7	113.7	42.2	10.9	245.6	259.2

1938						
QUADRAT	MAY 28	JUNE 30	AUG. 25	SEPT. 17	TOTAL	CONTROLS
1	58.0	4.6	.4	.3	63.3	428.9
2	19.5	3.1	.2	.1	22.9	835.0
3	17.5	6.6	.4	.1	24.6	473.1
4	9.4	3.6	Dead	Dead	13.0	495.0
5	9.5	.6	Dead	Dead	10.1	549.5
6	13.5	8.3	.2	.1	22.1	571.0
7	8.6	2.6	.1	Dead	11.3	408.0
8	10.8	4.3	.1	Dead	15.2	601.2
9	28.0	1.1	Dead	Dead	29.1	504.9
10	24.2	1.2	.3	.1	25.8	454.8
Av.	19.9	3.6	.24*	.14*	23.7	532.1

* Average yield from quadrats with living plants.

At the time of clipping on August 25, all of the needle grass in three of the quadrats was dead; the average yield was .24 gm. The soil surface was hard and cracks had appeared, and all but 5 per cent of the surface was bare.

Half of the quadrats had no living needle grass on September 17 and mere remnants occurred in the remainder. These produced only a fraction of a gram per square meter. Total partial yields averaged 23.7 gm. which was less than 5 per cent of that of the control.

Decrease in Prairie Dropseed.—Thirty-nine bunches of *Sporobolus heterolepis* were selected and each marked with a stake in the upland prairie on June 1, 1937. Ten were kept as controls and 29 were clipped to within 1.5 inches of the soil. Clipping was repeated on July 19 and also on October 3 when the control bunches were harvested. The controls had produced a good crop of seed. As shown in table 3, where data for only 10 bunches are given,

there was a decrease in the average number of stems from 99 to 72 and then to 18. Height growth at the several cuttings was 8.4, 6.3, and 2.1 inches, respectively. The corresponding yields were 6.86, 2.90, and .40 grams per bunch. The controls averaged 85 stems

Table 3.—Number of stems per bunch, height in inches, and oven-dry weight production in grams of 10 bunches of *Sporobolus heterolepis* at the several clippings in 1937 and 1938. Averages are for 29 bunches.

No. DRY			No. DRY			No. DRY			DRY	
STEMS	HEIGHT	WEIGHT	STEMS	HEIGHT	WEIGHT	STEMS	HEIGHT	WEIGHT	WEIGHT	
1937										
JUNE 1			JULY 19			OCT. 3			TOTAL	
162	11	13.47	129	7	5.85	2	2	.08	19.40	
92	10	6.71	64	7	2.23	5	2	.08	9.02	
151	10	10.79	56	7	6.85	27	2	1.15	18.79	
95	12	6.52	56	9	2.20	10	2	.20	8.92	
56	8	3.53	56	5	2.27	24	3	.37	6.17	
93	8	6.36	69	7	2.50	23	2	.46	9.32	
136	8	7.07	107	5	2.17	5	1	.09	9.33	
83	9	6.32	65	5	3.07	15	2	.45	9.84	
93	7	6.43	70	6	2.99	10	2	.25	9.67	
163	9	9.73	134	10	5.62	17	2	.19	15.54	
Av.	99	8.4	6.86	71.7	6.3	2.90	17.9	2.1	.40	10.16
1938										
JUNE 3			AUG. 3			OCT. 4			TOTAL	
4	6	.11		D*					.11	
3	3	.03		D					.03	
35	6	1.74	17	6	.45				2.19	
3	6	.09	3	7	.06				.15	
24	5	.89	16	3	.14		All		1.03	
25	7	1.26	6	3	.07		Died		1.33	
3	3	.04	2	1	.01				.05	
10	3	.14		D					.14	
6	7	.17		D					.17	
2	5	.10		D					.10	
Av.	19.3	5.6	.72	9	3.64	.14	0.0		.79	

* D indicates the bunch died. Such bunches were not used in calculating averages or percentages.

per bunch and plants were 9 inches tall at harvest. The average yield was 8.59 grams. Thus, the yield of the clipped plants exceeded that of the controls by 18 per cent.

The same bunches were again clipped on June 3 of the next year. Average number of stems had decreased from 99 to only 19; height growth was less, and the yield (.72 gm.) only 11 per cent as great. Nearly all of the bunches had dead centers, often invaded by sedge or side-oats grama. The few marginal stems were, however, fairly vigorous. Because of the poor growth, cutting was delayed until August 3. By this time 10 bunches had died and the number of stems, height, and dry weight were again greatly reduced. By October 4, all bunches were dead, despite the fact that the controls made a better growth than in 1937. They had increased considerably in number of stems and height and the yield had increased nearly threefold.

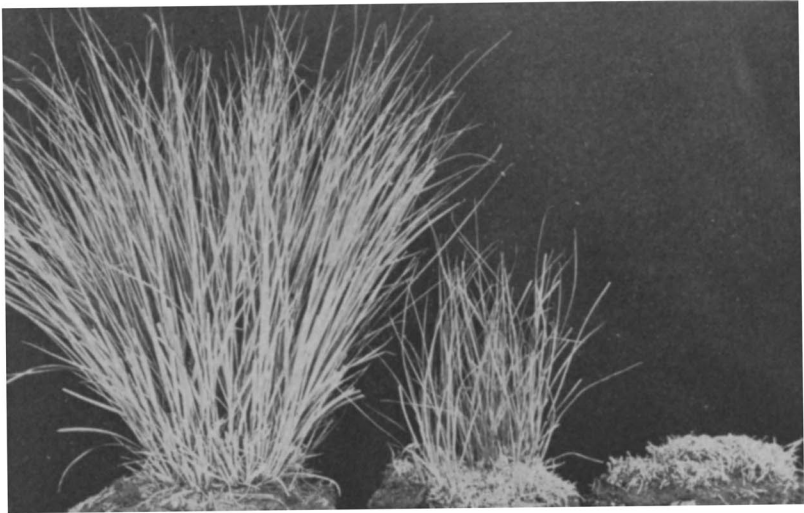


Fig. 18.—Control bunch of prairie dropseed (left); a bunch clipped the preceding year (center); and one which died during the second year of clipping (right). Photo June 20, 1939.

Table 4.—Number of stems per bunch, height in inches, and oven-dry weight production in grams of 10 bunches of *Koeleria cristata* at the several clippings in 1937 and 1938. Averages are for 30 bunches.

No. STEMS	HEIGHT	DRY WEIGHT	No. STEMS	HEIGHT	DRY WEIGHT	DRY WEIGHT
1937						
JUNE 1			OCT. 2		TOTAL	
36	14	9.05	31	5	1.21	10.26
59	13	9.18	2	1	.07	9.25
38	14	10.55	20	5	.85	11.40
41	10	10.35	5	2	.18	10.53
45	14	10.67	13	2	.30	10.97
23	10	6.00	8	3	.55	6.55
32	11	6.43	12	3	.75	7.18
50	14	10.31	13	2	.55	10.86
58	11	9.87	5	1	.19	10.06
54	12	10.05	17	3	.53	10.58
Av.	42.7	12.2	16.6	3.1	.58	9.74
1938						
JUNE 1			OCT. 22		TOTAL	
38	9	5.45	22	6	1.70	7.15
11	5	.76	9	2	.10	.86
32	7	6.42	26	6	2.00	8.42
5	8	.70	44	6	4.90	5.60
40	8	2.46	4	3	.10	2.56
20	7	3.40	9	6	.60	4.00
29	9	3.10	12	6	.70	3.80
61	8	7.29	28	6	1.10	8.39
7	6	.35	4	3	.05	.40
31	8	4.55	14	3	.50	5.05
Av.	30	7.5	15.6	4	.90*	4.76

* Average yield from the 25 living plants.

Among a lot of 10 other bunches clipped for the first time in 1938, all were greatly weakened and three died the first year. Thus, the early disappearance of this species from grazed prairie can readily be understood, fig. 18.

Decrease in June Grass.—Thirty vigorous bunches of *Koeleria cristata* were also selected on June 1, 1937, for clipping and 15

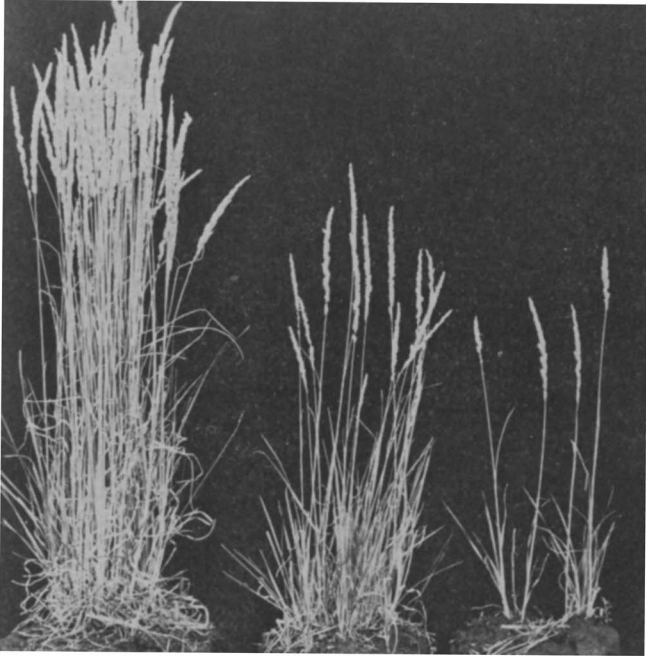


Fig. 19.—Control bunch of June grass 16 inches tall (left); bunch clipped twice during the preceding season (center); and one clipped twice during each of two preceding years. Photo June 20, 1939.

growing adjacent to these were kept for controls. The plants recovered so poorly from the June clipping that they were harvested again only when the controls were clipped on October 2. At this time the former average of 43 stems per bunch had decreased to 17. The height was about one-fourth of that in June, and the average yield of bunches decreased from 9.16 to .58 grams. The average yield of the controls was less (7.69 gm.), despite the larger number of stems (60) per bunch, since some of the dried stems and leaves had been blown away, table 4.

During the second season of cutting there were only 30 stems per bunch, a decrease of 13; the controls had 48, which was 12 less

than in 1937. Stems of the clipped plants were shorter but the controls much taller than before. While the yield of the controls was reduced by 10 per cent, the plants clipped in June as well as October suffered a loss of 51 per cent. This loss would have been even higher if the five plants that died had entered into the calculation, fig. 19.

A new lot of plants clipped in 1938 only showed similar trends, two bunches dying. Thus the very harmful effect of clipping or grazing upon this species is apparent.

Prairie Forbs that Decrease under Grazing.—Prairie plants other than grasses that decrease and may entirely disappear under long continued grazing constitute a long list of important species. All are perennials, in fact over 95 per cent of all important true-prairie species are long lived. Among these the legumes especially furnish much nutritious forage. For convenience of treatment, they are listed separately from the other forbs that are also readily eaten and which decrease in abundance under grazing.

Legumes

<i>Amorpha canescens</i>	<i>Meibomia illinoensis</i>
<i>Astragalus canadensis</i>	<i>Petalostemon candidus</i>
<i>Astragalus crassicaarpus</i>	<i>Petalostemon purpureus</i>
<i>Glycyrrhiza lepidota</i>	<i>Psoralea argophylla</i>
<i>Lespedeza capitata</i>	<i>Psoralea esculenta</i>
<i>Meibomia canadensis</i>	<i>Psoralea floribunda</i>
<i>Vicia americana</i>	

Other Forbs

<i>Allium</i> spp.	<i>Heliopsis scabra</i>
<i>Anemone cylindrica</i>	<i>Hieracium longipilum</i>
<i>Aster laevis</i>	<i>Kuhnia glutinosa</i>
<i>Aster salicifolius</i>	<i>Liatris punctata</i>
<i>Aster sericeus</i>	<i>Liatris scariosa</i>
<i>Ceanothus pubescens</i>	<i>Liatris squarrosa</i>
<i>Comandra umbellata</i>	<i>Lithospermum</i> spp.
<i>Coreopsis palmata</i>	<i>Meriolix serrulata</i>
<i>Echinacea pallida</i>	<i>Phlox pilosa</i>
<i>Equisetum arvense</i>	<i>Rhus toxicodendron</i>
<i>Equisetum laevigatum</i>	<i>Rosa arkansana</i>
<i>Euphorbia corollata</i>	<i>Senecio plattensis</i>
<i>Fragaria virginiana</i>	<i>Sisyrinchium</i> spp.
<i>Helianthus rigidus</i>	<i>Solidago altissima</i>
<i>Helianthus tuberosus</i>	<i>Solidago rigidiuscula</i>
<i>Helianthus grosseserratus</i>	<i>Viola pedatifida</i>

Amorpha canescens.—The prairie shoestring, or lead plant, is the most abundant, most conspicuous, and most important of all

upland forbs of true prairie.¹ Under the practice of mowing or grazing where the top is removed each year, the plants produce 2 to 5 or more stems from the crown. Plants frequently occur at the rate of 12 to more than 20 per square meter but the number of stems may average two or three times as many, fig. 20. They furnish very palatable forage in considerable quantities. Analysis



FIG. 20.—A thick stand of prairie shoestring or lead plant in ungrazed prairie near Guthrie Center, Iowa. Photo June 14.

of four clippings per season in a virgin prairie in western Iowa revealed that the seasonal yield of this plant alone was 200 pounds of air-dry forage per acre. The plant is leafy to the base so that not all of the leaves are removed in ordinary grazing. Stems regenerate from the stores of food in the root-crown and very deep, woody taproot. Hence, it may persist a long time. In many No. 3 pastures only remnants of this formerly abundant species were found. Small, widely scattered, much dwarfed specimens also sometimes occurred in pastures further degenerated.

Astragalus crassicaarpus.—The ground plum or buffalo bean is a large, coarse, decumbent plant, especially conspicuous in spring and early summer before the prairie grasses obscure it, fig. 21.

¹ Detailed descriptions of all the more important forbs and half shrubs of true prairie are given by Weaver and Fitzpatrick in "The Prairie."

It survives grazing quite well. After three or four years of close pasturing, some food is still left in the thick, deep taproot. It is freely grazed and usually disappears by the time the third stage of pasture deterioration is reached. If it does occur in poorer pastures it is only where protected by debris or on steep banks where grazing is light. In some No. 2 pastures it had been grazed out. Large clumps have been known to be reduced by a single year of close grazing to plants with a single weak branch and small flower



Fig. 21.—Branches of buffalo bean with fruits nearly fully grown. One of many pasture legumes which disappears under grazing.

cluster. Yet so effective is the thick taproot and root-crown in maintaining life, that remnants sometimes occur in the later stage of degeneration.

Astragalus canadensis is a far less abundant and a coarser perennial herb but its fate is like that of *A. crassicaarpus*.

Glycyrrhiza lepidota.—Wild licorice, a legume confined mostly to low ground, is greedily eaten by livestock especially when it is young. It disappears slowly because of its great store of food underground, the taproots penetrating to depths of 10 to 15 feet. Moreover, this species propagates by rhizomes. It is practically all dead by the time the pasture has reached the third stage of degeneration.

Species of Psoralea.—Several species of *Psoralea* are common in true prairie, fig. 22. The many-flowered psoralea is a legume of wide but irregular distribution on uplands. This plant is sometimes called “wild alfalfa” and indeed where the stand is thickest the prairie appears at a distance like an old, partially deteriorated field of alfalfa. The silvery psoralea (*P. argophylla*) is far more widely spread over the region as a whole and ranks seventh in importance among prairie forbs. The species with an edible root (*P. esculenta*), much used as food by the Indians, is far less abundant but is still a rather widely distributed legume.



Fig. 22.—Silvery psoralea, a legume widely distributed in native prairies and pastures; in little bluestem prairie near Wisner, Neb. Photo June 10.

Whether the several species of psoralea are eaten depends considerably upon the earliness of grazing. The plants put forth rather thick stems which elongate to 3 to 6 inches before branching occurs. Later, as the stems become woody, the leaves and tender branches only are grazed. Owing to the absence of lower leaves, when the stem is bitten or broken off, renewed growth must take place from the base. Usually in the third pasture stage the plants are closely grazed and in No. 4 pastures only infrequently do the thin-stemmed, much dwarfed individuals occur.

Other Legumes.—*Lespedeza capitata*, or round-headed bush clover, like nearly all legumes, is readily eaten when young. This plant is so rare as to be of little importance in grazing. The tick-trefoils (*Meibomia* spp.) are readily eaten and disappear early since they occur mostly in the much grazed big-bluestem type of

lower ground. *Petalostemon candidus* and *P. purpureus*, the white and purple prairie clovers, are readily grazed in their earlier development before they become woody. Although they regenerate from the root-crown, plants are rarely found in pastures degenerated beyond the third stage.

Other Forbs.—The wild onions (*Allium* spp.) are closely grazed with the grasses. Certain species seem to withstand grazing rather poorly despite the store of food in the bulbs. The very early ap-



FIG. 23.—Purple cone flower (*Echinacea pallida*) in bloom about June 20. The plants propagate only by seeds. They are readily grazed.

pearance and rapid growth in spring may account largely for this behavior. *Allium nuttaliana* is quite persistent in short-grass pastures.

The red-root or New Jersey tea (*Ceanothus pubescens*) is a native upland prairie shrub, which under annual mowing behaves as a perennial forb. It quickly disappears from pastures that are continuously grazed.

Echinacea pallida, the purple cone flower, is readily eaten when young, and disappears in the second or third pasture stage. It persists only along banks of ravines where pasturing is light, fig. 23.

Equisetum laevigatum, the horsetail or scouring rush, is grazed with the other vegetation and although the plant may grow

thickly just over the fence in prairie it is rarely found in abundance in any but Nos. 1 and 2 pastures.

Helianthus rigidus, the upland prairie sunflower, is the second most important upland prairie forb. It is so readily eaten that it does not long persist in pastures, despite the abundance of food stored in the rhizomes. The plants appear in early spring and the stem, even if only a few inches tall, may be destroyed by a single removal. Even mature plants are eaten (where grazing is deferred) except the bases. All plants may have disappeared in No. 2 pastures and usually none is found in the following stage, although abundant in adjacent prairie.

Helianthus tuberosus, a sunflower with potatolike tubers, furnishes a small amount of excellent forage but likewise disappears early. The early growth and high palatability of the saw-toothed sunflower (*H. grosseserratus*) subjects it to a similar fate in pastures.

The tender clumps of green stems of the false prairie boneset (*Kuhnia glutinosa*) do not develop until late in May. These are relished by grazing animals. Hence, the species decreases in number in the early stages of pasture degeneration. Under some conditions, however, usually on moderately low ground, this composite re-enters pastures in the fourth and fifth stages after much soil is laid bare. Here it may become very abundant and when only moderately grazed produces an enormous supply of highly mobile seed.

Several blazing stars (*Liatris* spp.) are conspicuous and abundant in native grassland. They are all closely grazed and disappear early when prairie becomes pasture. Usually this occurs in the second stage of degeneration. *Senecio plattensis* or ragwort likewise gradually disappears under grazing and the No. 3 type of pasture usually possesses only relicts of this species.

Although the prairie rose (*Rosa arkansana*) is common in adjoining prairie, it is found only as remnants in pastures, since the leaves and tender young shoots are regularly eaten. Except for a few widely scattered relicts, it disappears early. Although this rose may persist as a weed when prairie sod is broken and crops are grown, it succumbs under constant grazing. This species has a taproot extending 15 to 20 feet deep, and spreads widely by deeply seated underground stems. The abundant foliage of the tender tops is readily eaten by stock, and after the underground food reserves are much depleted in producing new shoots, the plant finally succumbs.

Poison ivy (*Rhus toxicodendron*), common in prairies, soon disappears from pastures where grazing becomes more or less uni-

form. Some plants, however, may persist a long time on steep banks of ravines.

Solidago rigidiuscula, a late-blooming goldenrod which grows in bunches, readily succumbs to grazing and soon entirely disappears. The tall goldenrod (*S. altissima*) is grazed when young, but only the tops and tender stem tips are eaten when the plants are half grown. However, by the time bluegrass has rather completely sodded over the ravines and lower slopes, where this species thrives, grazing and trampling have removed all but the last remnants.

Prairie Grasses that Increase under Grazing.—Although much grazed, certain native grasses profit so much by the changed conditions under pasturing and the waning of other important competing species that they increase greatly. Ten of the most important are:

<i>Poa pratensis</i>	<i>Buchloe dactyloides</i>
<i>Agropyron smithii</i>	<i>Panicum scribnerianum</i>
<i>Bouteloua curtipendula</i>	<i>Panicum wilcoxianum</i>
<i>Bouteloua gracilis</i>	<i>Carex pennsylvanica</i>
<i>Bouteloua hirsuta</i>	<i>Agrostis hyemalis</i>

Poa pratensis.—Kentucky bluegrass, contrary to the common belief, is probably not indigenous in the United States (Carrier & Bort 1916) although, with the exception of timothy, it is the most important perennial grass cultivated in North America (U. S. Forest Service 1937). Since the settlement of the midwest, it has successfully invaded true prairie, due to mowing and grazing, and has spread very widely. Bluegrass is now found practically everywhere in the Missouri valley. A survey of 100 upland prairies in six midwestern states showed that bluegrass was of wide distribution and of considerable abundance, comprising about 5 per cent of the basal cover of the vegetation. An even greater amount was found in low prairies where it constituted about 9 per cent. In this study it is treated with the native prairie grasses.

This bluegrass is a dense turf and sod-former, producing large numbers of slender, shallow, creeping rhizomes. These give rise to tufts of grass aboveground from which arise a profusion of fine fibrous roots. They penetrate soil in both prairie and pasture to a depth of 3 to 4 feet. It is a prolific seeder, the tufts from the seedlings soon developing into a compact sod. It is the first grass to resume growth in spring, and soon produces an abundance of nutritious forage which is highly palatable to all classes of stock. Bluegrass is not only unusually resistant to heavy grazing but also it is able to maintain its hold and actually to increase the

stand even where the soil is much trampled and the grass closely grazed, fig. 24. Its productivity decreases during the hot mid-summer, but renewed growth begins in the fall and continues until freezing weather prevails. During dormancy it is very resistant to adverse conditions.

Early spring growth, when the soil is usually moist and most other species dormant, greatly favors the spread of bluegrass. Its increase at first is very irregular and in isolated patches. Places



Fig. 24.—Bluegrass pasture near Corning, Iowa, grazed by sheep. The cover is almost complete and weeds are relatively few. Light-colored patches are flower stalks whose development is permitted by irregular grazing.

where other grasses have been killed by burial with dung, by burrowing of rodents, or trampling by stock are repopulated with bluegrass. It is favored by close, selective grazing of big bluestem, and makes its first appearance as a continuous sod in the bottoms of swales, along paths, and about gates. Although bluegrass is very palatable, aggressive, and persistent, it is rather low yielding.

In No. 3 pastures it usually occupies almost exclusively about half of the soil. It nearly always has full possession of ravines and gentle lower slopes and level lands. Invasion of uplands is much less complete. Although small alternes are common where grazing is uniformly close, there are only moderate amounts of bluegrass where it is light. There is little or none where lack of grazing has permitted the accumulation of litter from little bluestem. Steep banks and broken slopes are, for a long time, little invaded by bluegrass.

By the time deterioration has proceeded to the fourth stage, bluegrass is usually the chief species throughout many pastures. It frequently furnishes 80 per cent or more of the basal cover. But as overgrazing and trampling continue, the sod begins to wear thin and finally bare ground appears. The once dense sod is finally represented by isolated tufts at first spread thickly but later weakening and thinning under continual abuse and competition with weeds. Finally the last remnants may disappear.

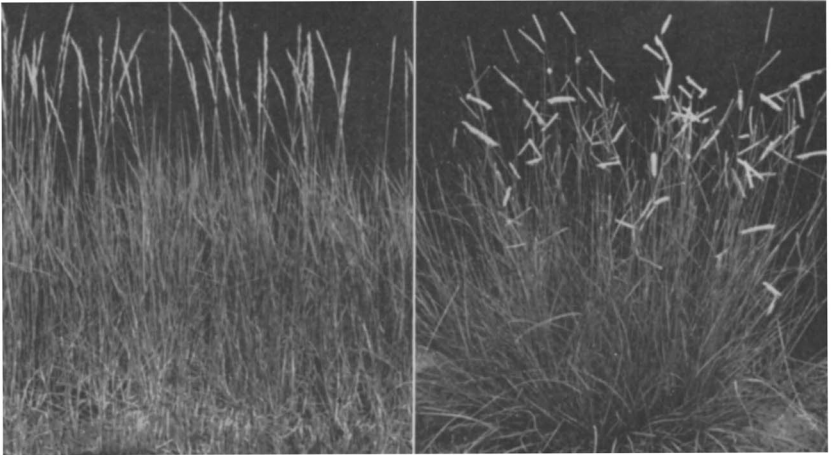


Fig. 25 (left).—Characteristic stand of western wheat grass in an old protected pasture. The flower stalks are 33 inches tall. Clipped area in foreground shows openness of basal cover. Photo June 15.

Fig. 26 (right).—A large, isolated bunch of blue grama grass, with foliage about 5 inches tall, in blossom on July 9. This has developed during a period of two years from a seedling established in a bare place in an old pasture.

The great drought of 1934 and subsequent years was profoundly detrimental to bluegrass and losses even in good pastures ranged from 85 to 99 per cent in many pastures west of the Missouri river. Only a few remnants were left at the foot of steep north-facing slopes or in the protecting shade of weeds.

Agropyron smithii.—Western wheat grass is an important species that has increased slowly under grazing. Since the great drought, its spread in both pastures and prairies has been so remarkable that its previous abundance is of especial interest, fig. 25.

This perennial is of northern origin as is shown by its rapid development in spring. It renews growth in March, usually four to six weeks before the bluestems and numerous other species,

and is often 6 to 8 inches tall by April 15. Height varies from 2 to about 3 feet when the spikes appear late in June. There may be as many as a thousand stems per square meter. The long, sharp-pointed, branched rhizomes permit of rapid spread when conditions are favorable. They form a good sod. This species is drought resistant, using available moisture in spring for rapid growth and early seeding. It is semidormant during midsummer, often drying, but resumes growth much as does bluegrass in the fall. In palatability and forage value, except when young, it ranks far below most native grasses of true prairie. It furnishes early forage but often only the tops of older plants are grazed even when other vegetation is not abundant.

Extensive surveys from 1928 to 1933 showed clearly that western wheat grass, although a dominant of other portions of the true prairie, constituted scarcely any part of this association in the central prairie region. It occurred along roadways, occupied the compacted soil by the sides of trails through the prairie, and was found in abundance locally in poorly drained meadows where conditions were unfavorable to the growth of the usual prairie grasses. It endures not only wet habitats but also saline soils. In Nos. 4 and 5 pastures it was sometimes found scattered thinly throughout. Once established it is very persistent. Since the beginning of the great drought its importance in pastures has increased enormously.

Bouteloua curtipendula.—Side-oats grama increases slowly but consistently under grazing. This occurs despite the fact that it is well liked by stock because of its leafiness and is closely cropped. In fact, it compares favorably in feeding qualities with the blue-stems, being readily eaten when dry. The flower stalks are relished only when young, although their leaves are eaten. Hence, even in low-grade pastures, if this species is still present, it is common to find flower stalks and some seed. It is a prolific seeder and seedlings are commonly found. Before the great drought it constituted about 1 per cent of the prairie cover, but has withstood the dry period well and spread so widely that it is now one of the most important prairie grasses. In fact, it has often persisted where nearly all other grasses of true prairie have succumbed (Weaver & Albertson 1939). The remarkable increase of this drought-resistant plant has been due in part to a prolific seeding habit and partly to propagation by rhizomes. Although it appears in bunches in prairie, under grazing the rhizomes, 2 to 4 inches long, promote the formation of small areas of sod. It readily invades places bared by death of other species. In prairie it was most abundant on dry slopes and steep banks. Under grazing it

may form a nearly pure cover over such areas, and remain as a relict in Nos. 4 and 5 pastures. Here it is represented by remnants in small patches or even by isolated stems. It is a good soil-binder.

Bouteloua gracilis.—Blue grama grass is one of the most important grasses of the midwestern ranges where it formerly occurred in mixed prairie as an understory to the native mid grasses. In true prairie it occurred sparingly and usually only in the driest situations, where the mid grasses did poorest and where this short grass was not entirely shaded out. In this region, this very palatable, drought-resistant grass forms a continuous sod or only patches of sod interrupted by other grasses, depending upon available soil moisture. It has the ability to remain dormant during drought periods, even those so severe as to kill the tops of the bluestems, and become green and immediately resume growth when water is again available during summer or fall. The numerous leaves, which vary from 1 to 4 inches in length, are mostly basal and grow so thickly that within the sod little space is left except under very close grazing. Blue grama is not readily injured by ordinary grazing. It is a choice species for all classes of stock and does best when lightly grazed while growing and more heavily thereafter. Since the grass is very palatable and nutritious when cured on the ground, the forage is not lost. Growth in spring and early summer is not so great as that of many other grasses.

When bluestem pastures are too closely grazed, blue grama grass may spread throughout the drier places, but appears prominently only when the seedlings have, by prolific tillering, formed bunches or tufts, fig. 26. From these larger mats a more or less continuous sod may develop locally. This results both from tillering and spread by short, scaly rhizomes. Very frequently, if the sod is continuous, it is intermixed with buffalo grass. These grasses, under moderate grazing, are cropped closely and uniformly with little apparent harm. The seasonal yield, however, is frequently only about 60 per cent as great as that of a good bluestem pasture (Weaver & Hougen 1939). Under close grazing the blue grama mat breaks up into more or less isolated tufts between which annuals, such as little barley, plantain, peppergrass, and numerous other plants, occur. Often the soil is eroded about the clumps so that they appear to be raised above the general soil level. This is especially common in low-grade pastures. Blue grama grass is usually most widely spread in Nos. 3 and 4 pastures.

Bouteloua hirsuta.—Black grama is similar in stature and general appearance to blue grama grass, except that it grows in small bunches. It furnishes forage of good quality. It seeds readily and the seedlings mature early. Relatively little of this grass occurs

in pastures resulting from the breaking down of the true prairie.

Buchloe dactyloides.—Buffalo grass is one of the most important forage species of the short grass ranges of the Great Plains. Like the blue grama it is of minor significance in native true prairie since it cannot endure the shading of its taller competitors. But under grazing it occurs widely, especially over the more arid western portion of the true prairie. Its rapid spread results from



Fig. 27.—A fine stand of staminate buffalo grass about 6 inches tall and in blossom on June 25.

propagation by stolons which root readily where they come in contact with moist soil. The hard seeds are produced within the grass mat. Unless crushed between the teeth of grazing animals, they may pass through the digestive tract unharmed. In Nos. 3 and 4 pastures, especially, small isolated patches of buffalo grass are commonly found. They are nearly always either of staminate or pistillate plants and not both and thus indicate their possible origin from a single plant of this dioecious perennial, fig. 27.

Buffalo grass makes a close, even turf, produces large amounts of nutritious forage, and also forms a sod which strongly resists erosion. The plants are seldom more than 4 to 5 inches tall but the leaves grow so near the soil that much green tissue remains

even under very close grazing. This explains in part why this grass can withstand heavy grazing and its persistence where all mid grasses have disappeared. The forage, like that of blue grama grass, is very palatable and nutritious even when it has cured in fall or as a result of drought in summer. Hence, buffalo grass may afford pasturage as long as the grass is not deeply covered with snow. It renews growth rather late in spring.

Preceding the great drought, pastures in which buffalo grass was the chief species were commonly found only in the western edge of true prairie. Since 1934, its spread has been very great and short grass pastures have advanced much farther eastward. The plant is well adapted to resist drought and may blossom and produce seed within 60 to 70 days after it becomes green in April.

Species of Panicum.—Several species of low-growing panic grasses, of which the most widely distributed and important are Scribner's panic grass (*Panicum scribnerianum*) and Wilcox's panic grass (*P. wilcoxianum*), increase considerably under grazing. In the prairie, they were held in check by the shade of the mid grasses. This increase was noticeable in No. 2 pastures, reached a maximum in No. 3, and then waned. Although these plants are palatable and readily grazed, they escape injury in part since many of the broad leaves are borne close to the soil and some of the flower stalks are nearly decumbent. Small areas bared by local disturbance are apt to be claimed by these prolific seeding grasses. Small panic grasses are often especially abundant in burned pastures. They usually disappear, however, with the blue-stems and are not characteristic of Nos. 4 and 5 pastures. None is abundant since the great drought.

Carex pennsylvanica.—This sedge, which attains a height of 5 to 7 inches in prairie, usually increases under grazing. Removal of the overshadowing mid grasses seems beneficial to this very drought-resistant rhizomatous species. Although a minor constituent of native prairie, this sedge, of early growth in spring, affords some forage in all grades of pastures, and since 1934 its importance has rapidly increased.

Agrostis hyemalis.—Hairgrass is an interstitial species found mostly on upland prairie but also on low ground. It occurs in small, isolated tufts. The grass is conspicuous only because of the large, widely spreading, purplish panicles with their rough, whorled branches. It usually becomes abundant in No. 3 pastures but is of minor importance except locally and occasionally.

Prairie Forbs that Increase under Grazing.—A considerable number of forbs are either entirely uneaten by stock or grazed so sparingly that they are not much handicapped. They profit greatly

by the release from shade and vigorous competition common in prairie and increase greatly in number and often in stature. The following list includes the most important species which will be discussed somewhat in the order of their importance:

Achillea occidentalis	Lygodesmia juncea
Antennaria campestris	Mesadenia tuberosa
Artemisia gnaphalodes	Oenothera spp.
Asclepias verticillata	Opuntia spp.
Aster multiflorus	Oxalis stricta
Baptisia leucophaea	Physalis heterophylla
Callirhoe alcaeoides	Physalis lanceolata
Erigeron annuus	Silphium integrifolium
Erigeron ramosus	Silphium laciniatum
Euthamia graminifolia	Solidago glaberrima
Gaura spp.	Solidago mollis
Hedeoma hispida	Solidago rigida
Lepachys columnaris	Vernonia baldwini
Linum sulcatum	Vernonia fasciculata

Vernonia baldwini, the ironweed, is a species of no great importance but of wide distribution in native grassland (Aldous 1935). It is a tall, coarse, very leafy perennial that resumes growth late in April and is 2 feet high by the first of June. Mature plants, with great clusters of purple flowers which appear after mid-summer, are 3 to 4 feet tall. In prairie, they nearly always occur as isolated stems or in groups of 2 or 3. Ironweed is usually found only in ravines in eastern Nebraska prairies. The leaves are bitter and the plant is avoided by stock, fig. 28. When the bluestems and other grasses about the plants are eaten, it rapidly increases its area and develops large bushlike clumps 1 to 3 feet in diameter, consisting of 50 to 150 or more stems 5 to 10 mm. in diameter. It gradually migrates out of the ravines by means of wind-blown seeds and becomes established in bared spots on uplands, although here the bunches are never so large. This forb is thus a reliable indicator of the length of time of grazing and something of the degree as well.

Plants may become especially abundant in ravines and on low ground. Their shade is so dense that even bluegrass is not found under well-developed clumps. Here the soil is bare. In grazing around the stems of smaller clumps of ironweed, stock leave small amounts of the native grasses which may produce seed. Fully developed flower stalks of big and little bluestem, for example, are thus not uncommon in otherwise well-grazed pastures. With closer grazing, more bare patches appear and ironweed increases. It is a common plant nearly everywhere in Nos. 4 and 5 pastures and



Fig. 28.—Baldwin's ironweed (left) and western ironweed (right). These plants are usually 3 to 4.5 feet tall. Bluestems have greatly shaded the lower leaves, causing them to drop.

sometimes is one of the most important. The root system is well developed and varies in depth from 4 to 10 feet; the plant remains green and thriving in pastures where the grasses have dried.

Western ironweed (*Vernonia fasciculata*) is found only in low, wet ground. The clumps are more open and the stems fewer. Like the preceding, it is wholly unpalatable. Under grazing it may increase greatly and become a noxious weed.

Aster multiflorus is a weed of much importance in uplands, fig. 29. When grasses are plentiful it is not grazed or grazed only incidentally with other vegetation. It has an excellent system of rhizomes, thrives under conditions of grazing, and increases con-

siderably. Often plants 6 to 10 inches tall and closely spaced were found uneaten in an otherwise closely grazed sod. Thus the species increases with degree of grazing, but as the pasture produces less grass, the cattle begin to eat first the stem tips and then more and more of the plant. Where abundant, the plants make an early dense growth and are usually 6 to 8 inches tall by May 1. The young stems are most edible, the older ones becoming tough and



Fig. 29.—Single plant of many-flowered aster about 2 feet tall. This drought-resistant plant spreads rapidly by seeds and rhizomes.

woody. Old pastures are often badly infested with this weed, which has increased enormously since the great drought.

Antennaria campestris, the prairie cat's-foot, is one of the most abundant forbs of the native grassland. The plant is a low mat-former and begins growth very early in spring. It is perennial and spreads by stolons. Its foliage is too near the soil and too woolly to be much grazed. Hence, the size and number of mats often increase greatly on dry hillsides well into the third stage of prairie deterioration. Indeed, it sometimes reaches its maximum abundance in No. 4 pastures after the bluegrass or short grass sod is broken, and alternates with patches of semibared soil. Here the stolons often occupy eroded places between the patches of grass.

The mats vary from a few inches to more than 3 feet in diameter and they are so dense that there is often no grass or grazing in them.

Artemisia gnaphalodes, the prairie sage, usually increases under moderate grazing and often reaches its greatest abundance in No. 3 pastures. Its increase is accomplished largely by spread of rhizomes. This plant is avoided when grasses are plentiful prob-



Fig. 30.—Dense growth of smooth goldenrod in a pasture near Lincoln, Neb. Propagation is by rhizomes.

ably because of its densely woolly character. When grazing pressure becomes greater, it is gradually reduced by cropping of the tops and by trampling, although it is sometimes found abundantly in No. 4 pastures.

Solidago glaberrima, the smooth goldenrod, is readily grazed where it is intermixed with the grasses as was usual in prairie, but has great regenerative powers and may persist even in the No. 5 pastures. Under grazing the plants become very leafy to the soil surface. Thus, it may be grazed with the bluegrass to a height of 1.5 inches but quickly recovers. With the thinning of the grasses, dense patches are formed as a result of the abundant shallow rhizomes. Such pure stands are often scarcely grazed, fig. 30.

Since the great drought and the resulting death of bluegrass and little bluestem, smooth goldenrod has assumed a role of great importance. Entire hillsides are covered with thick patches of this weed, if indeed they have not merged into one large irregular weedy area. Grasses are scattered sparingly in such places; light is greatly reduced; and competition for water is often severe. As long as other forage is available, the goldenrod is scarcely grazed, but as a last resort it is eaten to within an inch of the soil. More-

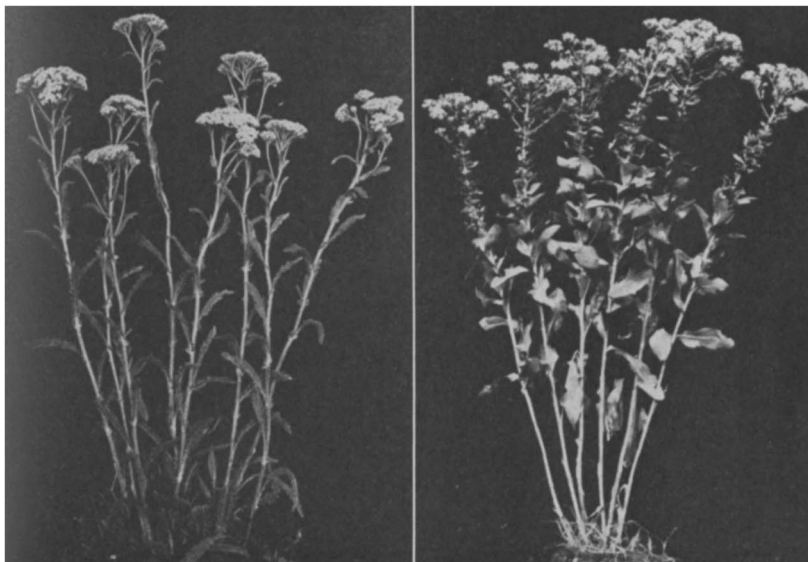


Fig. 31 (left).—Milfoil or yarrow, a common and persistent pasture weed. It often forms dense patches in old pastures.

Fig. 32 (right).—A plant of stiff goldenrod with several stems taken from a pasture near Marysville, Kans., where this weed formed a brush-like cover in little bluestem-bluegrass pasture.

over, even if parts above ground are killed by severe drought, the rhizomes put out abundant new shoots when soil moisture is restored.

Achillea occidentalis, milfoil or yarrow, is a common pasture weed of considerable importance, fig. 31. Low-growing leaves are eaten only under necessity, because of their bitter taste, and flowering stems often appear prominently with ironweed, vervain, and a few other weeds even in closely cropped pastures. Yarrow renews growth early in spring and often forms dense patches in old pastures.

Solidago rigida, the stiff goldenrod, a species very common and abundant as a pasture weed before the drought, is a native prairie perennial. The plant renews growth early and attains a height of 3 to 3.5 feet. The tough, woody stems and thick coriaceous leaves are not eaten. Seed is produced in abundance and new plants grow rapidly, especially in bare places. Thus, single-stalked plants are scattered throughout even No. 3 pastures. New stems grow from short thick rhizomes. Many pastures were studied where the stems stood thickly—60 to 90 per square meter—individual plants not infrequently being composed of 6 to 18 woody stems. The stems are not closely spaced and bluegrass persists between them in their shade, fig. 32. Stiff goldenrod has survived the drought poorly.



Fig. 33.—Stages in development of a cactus from seed (center), and one-year-old plants (right). A two-year-old plant is shown on the left. Large clumps 3 to 5 feet or more in diameter ultimately develop.

Erigeron ramosus or daisy fleabane often increases very greatly under grazing. The plant has little foliage, a coarse tough stem, and the leaves are bitter. Hence, it is eaten only in slight mixture with other species and is often conspicuous and abundant in many classes of pastures. Since the plant is an annual, the seasonal density of population varies greatly.

The genus *Opuntia* includes several species of pasture weeds commonly called cactus or prickly pear. They increase in short grass pastures in the western portions of the area when the ground becomes bare, and flourish where the competition of grasses is removed. They root shallowly, the roots extending several feet on all sides of the plant, and thus are in a position to absorb moisture when only the first few inches of soil are wetted. Further westward they are often the worst perennial weeds. Since the opening up of the grass cover by drought they have increased greatly, fig. 33.

Baptisia leucophaea, false wild indigo, is one of the few legumes that is not eaten. Stock do not like it. The ends of the branches and very young plants are sometimes nipped, but not when other forage is available. The species frequently occurs undisturbed even in Nos. 4 and 5 pastures. It profits by the removal of competing species and is often more abundant than in adjoining prairies. However, the thick-stalked plants are frequently injured or broken off by trampling. The old, dried parts are common debris in pastures. The taller and even coarser *B. leucantha* of

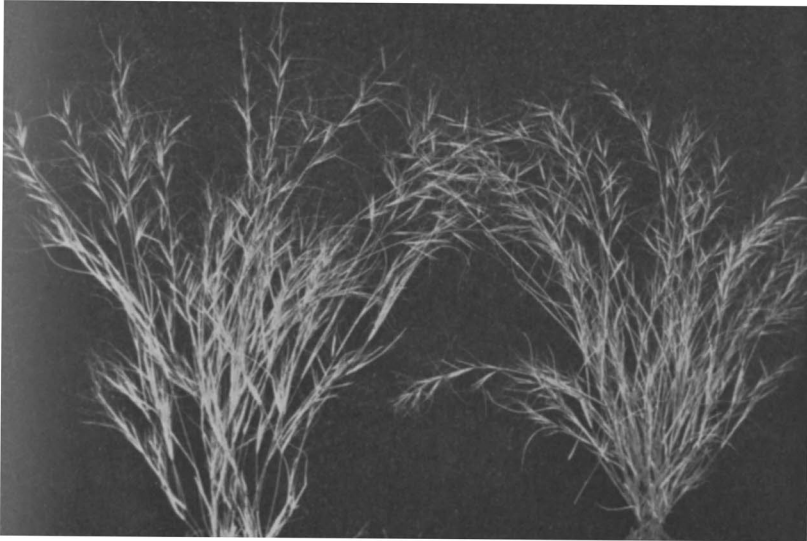


Fig. 34.—Three-awn grass or wiregrass is an annual weed common to low-grade pastures. Height depends largely upon soil fertility and amount of available water. These plants are of medium size, about 10 inches. Photo September 20.

low ground is not eaten and may stand conspicuously at a height of 4 to 5 feet in a closely grazed, old pasture.

Numerous other prairie forbs may increase under grazing but they are rarely if ever as important as the preceding.

Grasses that Invade Pastures.—When the tops of prairie plants are continuously more or less completely removed by grazing, light at the soil surface greatly increases. This, combined with the opening of the sod by the death of certain species, permits a host of weeds, none of which is found in virgin prairie, to become established. The change in the light relation is marked. Under a good stand of big bluestem, the light is frequently reduced to 1 to 3 per cent of full sunshine. In upland prairie, light intensities



Fig. 35.—Typical stand of downy chess, one of the weedy bromegrasses of low forage value that are common in old, low-grade pastures. Photo July 1.

of only 15 to 20 per cent have been regularly recorded. Moreover, with a reduced stand of grass, less water is absorbed by the plants and more is left for invaders.

The following list includes the more important species, most of which are weeds, that are not a component part of true prairie vegetation² and which regularly occur only in the lower grade pastures:

<i>Aristida oligantha</i>	<i>Hordeum jubatum</i>
<i>Bromus secalinus</i>	<i>Hordeum pusillum</i>
<i>Bromus tectorum</i>	<i>Panicum capillare</i>
<i>Chloris verticillata</i>	<i>Poa compressa</i>
<i>Digitaria sanguinalis</i>	<i>Schedonnardus paniculatus</i>
<i>Eragrostis cilianensis</i>	<i>Sporobolus cryptandrus</i>
<i>Eragrostis pectinacea</i>	<i>Sporobolus neglectus</i>
	<i>Sporobolus vaginiflorus</i>

Aristida oligantha is an annual three-awn grass or wiregrass, fig. 34. It was found frequently in No. 3 pastures, and was often a bad weed in bluegrass. It often invades, especially after close

² Since the great drought, which resulted in the death of most of the little bluestem and large amounts of other grasses, both small and large bare areas have occurred in nearly all prairies and some of these grasses have become established there as well but they are not regular components of the prairie flora (Weaver & Albertson 1936, 1940).

grazing by horses or sheep. Since it is not relished by grazing animals, the patches in which it occurs are frequently ungrazed. The abundant debris accumulates, and such places may remain untouched for a year or two. Where a slope breaks sharply into a ravine, wiregrass is often found plentifully. Here the bunches of dried plant remains are 5 to 6 inches tall and may be the only places where bluegrass, side-oats grama or other species are permitted to seed. Young plants in such deeply mulched soil are easily pulled up and then rejected by grazing animals.



Fig. 36.—Dense growth of squirreltail-grass. It is often found in wet soil. It may be distinguished from its near relative, little barley, by the longer awns and larger size.

Bromus secalinus (and closely related varieties of chess) and *B. tectorum* (downy chess) have long occurred in moderate amounts in Nos. 4 and 5 pastures, especially where the soil had been nearly bared. Since the drought, they have increased enormously, covering large areas, especially of moist soil in low grade pastures, fig. 35.

Chloris verticillata, commonly called windmill grass, is of southern origin and has entered into pastures of southern Nebraska only in moderate amounts. Its spreading in pastures, and lawns also, has increased during the hot, dry years of drought. It is a species of considerable forage value.

Hordeum jubatum, squirreltail-grass, is a more or less weedy species native to the midwest. It was found in draws or on low ground where it sometimes became extremely abundant, fig. 36.

Since the dry cycle it is far less abundant in the central and more westerly pastures of the area.

Hordeum pusillum, little barley, was never very abundant before the great drought. It was sometimes found associated with buffalo grass and blue grama grass or it formed small patches in trampled places. Upon the denudation of pastures by the death of bluegrass, especially, but of little bluestem and other stable species as well, it spread widely and rapidly. Dense, nearly pure populations of this species soon covered the major portions of



Fig. 37.—Old bluegrass pasture near Syracuse, Neb., where little barley has developed an almost pure stand following the death of bluegrass. Tall weeds on low ground are scarlet gaura (*Gaura coccinea*); those on the hillside are mostly ironweed.

much grazing land, fig. 37. Germination is early. Heading occurs late in May, usually when the plants are 3 to 8 inches high. Soon the seed ripens and the drying stems, often 100 or more per square decimeter, take on a light yellow color. This replaces the light green of the early spring landscape. Stock graze this species very indifferently, and not at all when good forage is available. Upon drying it is worthless for forage and hinders grazing of plants with which it may be associated. Since the drought, it is easily one of the worst pasture weeds from the Missouri river to the Rocky Mountains.

Eragrostis cilianensis, commonly called stinkgrass because of its odor, and *Digitaria sanguinalis* (crabgrass) were formerly found only in trampled areas about gates, watering troughs, and in old paths, where denudation was nearly complete, fig. 38. They now

occur much more plentifully and sometimes dominate No. 5 pastures.

Poa compressa, Canadian bluegrass, was a frequent but rarely important component of pastures, until they had greatly deteriorated. The cover afforded by this species is open and the forage much less in both quantity and palatability than that of Kentucky bluegrass. Drought seems to have promoted its abundance where it was already established.

Schedonnardus paniculatus (tumblegrass) behaves in this latitude either as an annual or short-lived perennial. It clothes many

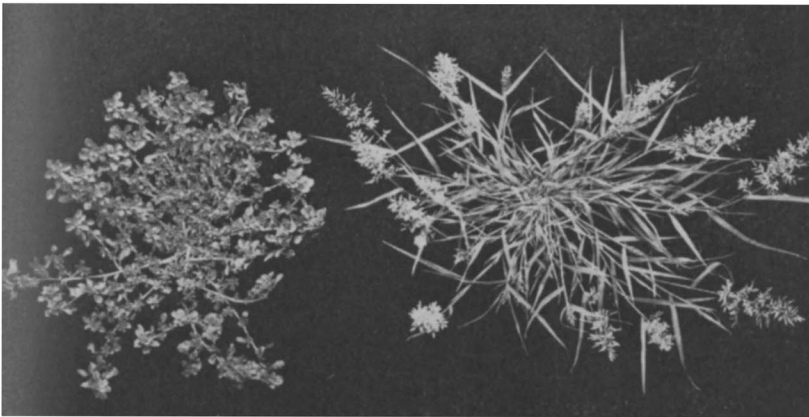


Fig. 38.—Stinkgrass (right) viewed from above. The plant is about 18 inches broad but only 8 inches high. At the left is a mat of prostrate amaranth (*Amaranthus blitoides*). Both species are common but only on rather open ground.

local areas where the grasses have mostly been grazed out and the soil trampled bare, and is an interstitial plant among thinning stands of native species. It is often associated with blue grama grass. Its occurrence, as single plants but mostly in tufts a few inches in diameter, is readily evaluated because its dull gray-green contrasts strikingly with that of other grasses.

Sporobolus cryptandrus (sand dropseed) has risen from the status of an occasional invader to one of a chief pasture grass. Hence, its story is of unusual interest. Before the great drought it was more or less common in No. 4 pastures as a chief invader along with the preceding list of mostly weedy species. It sometimes occurred in portions of No. 3 pastures, as on trampled ridges, which had degenerated to the No. 4 stage as a result of trampling. In such places it was never abundant. In low-grade

pastures, patches of one to a few square yards in extent were populated by this species, but its importance was not great. Field notes taken before the dry period began in 1932 reveal that formerly sand dropseed occurred only rarely or very sparingly. But following the destructive drought of 1934 it rapidly increased in abundance and in two or three years became one of the most important pasture grasses. In fact, it was regarded by most farmers and stockmen as a "new pasture grass," fig. 55 (page 79).

Weedy Forbs that Invade Pastures.—As long as prairie is undisturbed except by mowing, weeds find no place in it (Cratty 1929; Weaver & Flory 1934). But when grazing and trampling open the cover a host of these unwanted plants appear. At first they may find a home only in the trampled parts about gates or watering places and from there spread into the pasture as bare spots occur. Small bare places where weed infestation may occur are formed regularly where grass is covered with dung. Buffalo grass, bluegrass, and certain other grasses are killed and weeds appear, at least for a time until the grasses are reestablished. Low-grade pastures frequently are such because of overstocking. In these, dunged areas are very numerous. Viable seeds of many species of weeds are regularly deposited with the dung. Trampling by stock, resulting from the stamping of grazing animals to free themselves of flies, may cause bare ground where they congregate to rest. Paths, eroded and crumbling banks of ravines, cracking of soil in drought, and the work of burrowing animals, all contribute to bare the soil of vegetation. Horses, running in wet weather, may stop so suddenly as to slide 2 to 3 feet and in their tracks scrape the surface free of plants. Death of grasses from too close grazing, or that of weakened ones from winter-killing or drought is a constant cause of bare patches of soil. Whatever the cause of the bared ground, and there are many causes, the fact that weeds may here find space free from competition results in an introduced population. Invasion begins slowly in high-grade pastures, but proceeds rapidly as the perennial grasses gradually lose control. Since rather complete lists are given in tables 5 and 6, only a few of the most important ones are discussed.

The annual ragweed (*Ambrosia elatior*) is very widespread. It is sometimes scattered thinly throughout even No. 2 pastures, but is much dwarfed in the dense sod. Since the plant has a very bitter taste, it is scarcely eaten. In No. 3 pastures, it may be localized in dunged places or other bare spots where the plants grow thickly, or if it occurs abundantly elsewhere, it is usually in blue-

grass sod. It is very typical of bluegrass pastures where it may form a dense layer at a height of about 2 to 3.5 feet over almost the entire pasture, fig. 39. If the stand is thin, it usually thickens if grazing is continuous and where present this weed is always a potential menace. The layer may be only a foot in height where the bluegrass sod is dense. In any case, it considerably shades the grass. Mowing the pasture in late July or August, while the plants are in bloom, is a common practice.



Fig. 39.—Typical thick stand of annual ragweed in old bluegrass pasture in western Iowa. Note broken cover of bluegrass in foreground.

The perennial ragweed (*Ambrosia psilostachya*) propagates underground as well as by seed. It is found commonly and often abundantly in No. 3 or lower grade pastures, particularly those that have much bluegrass. Like most perennial weeds with stored food, growth of new tops begins early in spring and by the middle of April plants with 4 to 6 new leaves may be found, at a time when the seedlings are still in the cotyledon stage. Scattered stems or small groups of stems are common even in rather dense bluegrass or bluestem sod. In such pastures, however, it is a bad weed only in ravines and where grazing is too close. As the bluegrass sod becomes broken stands of this weed become more dense, 10 to 20 or more stems occupying a single square meter. Because of the perennial habit it is more persistent than the

annual ragweed. Both species have greatly decreased in eastern Nebraska during the prolonged drought.

Three species of thistles are commonly found in weedy pastures. The bull thistle (*Cirsium lanceolatum*) is an introduced weed. The tall plants of dark green are so well armed with stout prickles that they are avoided by stock. They frequently form such dense thicketlike growths locally, that they protect the grasses about them from grazing and the grass may thus seed even in well-grazed pastures. Bull thistle is seldom found abundantly until



Fig. 40.—Portion of a large patch of wavy-leaved thistle intermixed with little barley in a low-grade pasture.

the grass cover is much worn by grazing and bare places favorable to its growth appear.

The smaller *Cirsium arvense* or Canada thistle is less common, but a much more serious weed. It spreads rapidly and widely by underground offshoots and the wind-blown seeds give rise to seedlings in more distant places. Entire pastures are sometimes ruined by unchecked infestations of this very prickly, ungrazed, perennial weed (Hayden 1934).

The wavy-leaved thistle (*Cirsium undulatum*) is a forb common to mixed prairie and the western edge of true prairie, but occurs rarely except in pastures eastward. It is a large, coarse, light-colored plant with abundant root offshoots which produce clusters of rosettes very early in spring. Some rosettes overwinter. When fully developed they have a spread of 8 to 12 inches. The very leafy, erect stems attain a height of 2.5 to 3 feet or more. Once a plant becomes established, the number is gradually increased,

especially where they are not held in check by competition with the grasses, until a small patch is formed, fig. 40. They are avoided by stock, except hungry horses which may eat the flower heads, and may continue their spread until patches 25 feet in length and of irregular shape become established. A single low-grade pasture may have many centers of infestation. Since the plants are leafy to the base, little or no vegetation grows beneath the foliage.



Fig. 41.—Single large plant of vervain showing the numerous stems developed when competition of grasses is lacking. In dense sod, usually only one to three such stems are found.

The gumweed (*Grindelia squarrosa*) is a biennial. The first year the plant forms a rosette about the size of that of a dandelion. The next summer the erect stems grow to a height of 2 to 4 feet, branch considerably, and produce an abundance of yellow-flowered heads. These are quite glutinous, which accounts for the common name. Seedlings usually occur in abundance, if this weed is found at all, and these inedible plants frequently form a dense, brushlike cover in old pastures where there is much broken sod. It is found usually in No. 3 and lower grade pastures. The persistent dead stems are quite as bothersome to stock as the inedible green ones. This weed is especially common in old buffalo grass as well as bluegrass pastures. In the usual thick stand it casts much shade. The plant is not a persistent weed; it may be abun-

dant for a period of two years, and practically absent the next, possibly depending upon weather conditions favorable to seed ripening or germination. Other species of gumweed occur. Gumweed has been an extremely bad pasture weed in South Dakota during the drought.

Among the plantains the species of greatest importance is *Plantago purshii*. The seedlings of Pursh's plantain occur in enormous numbers in early spring and soon give a gray color to the landscape as large patches on hillsides. They grow rapidly, reach a height of 2 to 8 inches late in May, fruit abundantly, and then quickly dry. It is only by dense aggregation of this erect-leaved, low-growing species that it becomes a serious weed. Stock do not like this woolly pest nor its hard spikes which vary from 5 mm. to more than 10 cm. in length, depending upon the water supply. It may first occur sparingly in No. 2 pastures in the bare interspaces between clumps of blue grama. In older pastures it often increases very greatly as trampling and grazing make fit places for annual weeds in the sod. It is almost worthless as forage for cattle and horses.

Verbena stricta, an erect vervain, is a characteristic weed of nearly all pastures whether of medium or lower grade. This perennial renews growth rather tardily in spring. The woody stems grow rapidly and are 2.5 to 3 feet tall late in June when the first blooms appear. Blossoming continues until late fall. The individual blue flowers are small but clustered in erect spikes. This weed first enters pastures usually only after a considerable period of grazing. The stand thickens gradually through the years. At first only individual stems are seen, then a few in a clump, and finally many, fig. 41. This bitter-leaved species is rarely eaten even in No. 5 pastures where good forage is rare and the clumps of vervain best developed. In fact, an abundance of vervain is a fairly good sign of too much grazing pressure. In eroding ravines and flat lands bared of bluegrass, it sometimes forms dense patches. The clumps, however, are never as large as those of the ironweed nor the shade under them so dense. The larger clumps rarely include more than a dozen stems arising from a compact base about 4 inches in diameter. The old stems produce much undesirable litter; it is often one of the worst pasture weeds. Its drought endurance, resulting in part from a deep root system, is marked. When all the grasses are dry, this plant still remains green and often blossoming profusely.

The spotted spurge (*Euphorbia maculata*) and other similar mat-forming spurges are common in mid and late summer, often forming extensive mat-carpet in trampled soil. Even in good

bluegrass sod, where it is closely grazed, these spurges may form an important constituent of the cover.

Euphorbia marginata, commonly called snow-on-the-mountain because of its variegated bracts and upper leaves, is an indicator of advanced disturbance in a pasture or portions of it where this species occurs. It is worthless for forage but serves as an indicator of the last stages of degeneration of pastures, fig. 42.

Since the great drought several weeds formerly of little significance have become very abundant in many pastures over much of the area. Among these, Russian thistle (*Salsola pestifer*) has



Fig. 42.—Much overgrazed pasture of buffalo grass with snow-on-the-mountain occupying the open spaces in the broken sod. Photo September 5.

come in from the west, and the burning bush or fireweed (*Kochia scoparia*) has escaped from cultivation and spread widely. Both are coarse annuals, reproducing only by seed. Their large size and great abundance make them very conspicuous and very troublesome once they have gained entrance into low-grade pastures. Likewise, in many pastures, several species of stickseed (*Lappula*) and some other closely related borages have become exceedingly abundant.

A Census of Pasture Weeds.—An extended study was made of the distribution and relative importance of weedy prairie forbs and of other forbs and grasses commonly classified as pasture weeds. This survey included repeated observations in 41 large pastures or a total area of approximately 3000 acres of grazing land.

The relative ranking of a species was determined only after carefully studying its abundance, size, duration, density, and

basal and foliage cover. The various species were placed in one of each of five classes or ranks, from those that formed the chief groups to plants of infrequent occurrence. The actual criteria in classifying were the effect of the species upon the cover of grass (if any) and the portion of the ground cover and foliage cover that it furnished. Thus, species that occurred in great abundance

Table 6.—Distribution and relative importance of forbs and grasses found in pasture types 4 and 5 only.

SPECIES	PASTURE TYPE No. 4															TYPE No. 5									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5	6	7	8	9
<i>Acnida tamariscina</i>												5													
<i>Amaranthus graecizans</i>																4		4		3					3
<i>Ambrosia trifida</i>							4													5					
<i>Anthemis cotula</i>																									
<i>Apocynum</i> spp.							4																		
<i>Bromus hordeaceus</i>																				4					
<i>Cannabis sativa</i>												4	4											4	4
<i>Chamaecrista fasciculata</i>																				4					
<i>Cirsium arvense</i>																								3	
<i>Cirsium lanceolatum</i>																									
<i>Echinochloa crus-galli</i>																									
<i>Helianthus annuus</i>							4					4				4									
<i>Kuhnia glutinosa</i>							2	4	2			5												3	3
<i>Leptilon divaricatum</i>																									
<i>Malva rotundifolia</i>																									
<i>Oxytropis lambertii</i>																									
<i>Physalis</i> spp.																									
<i>Polygonum hydropiper</i>																									
<i>Polygonum pennsylvanicum</i>																									
<i>Rumex acetosella</i>																									
<i>Rumex altissimus</i>																									
<i>Rumex crispus</i>																									
<i>Salsola pestifer</i>																									
<i>Salvia pitcheri</i>																									
<i>Setaria viridus</i>																									
<i>Silene antirrhina</i>																									
<i>Sisymbrium altissimum</i>																									
<i>Solanum carolinense</i>																									
<i>Solanum nigrum</i>																									
<i>Solanum rostratum</i>																									
<i>Solidago altissima</i>																									
<i>Syntherisma sanguinale</i>																									
<i>Thlaspi arvense</i>																									
<i>Tragopogon pratensis</i>																									
<i>Vernonia fasciculata</i>																									
<i>Veronica peregrina</i>																									
<i>Xanthium commune</i>																									

and were of great importance in a pasture were given a ranking of 1. Species of great abundance and much importance but not sufficiently so as to be ranked as of first importance were given a rank of 2. On the other extreme, plants that were very widely scattered and so rare that they were found in only one or a few places were given a ranking of 5 for that particular pasture. Where they were of somewhat more frequent occurrence and importance the ranking was raised to 4. A large number of forbs and weeds that were not sufficiently important to be given second rank were found in almost every pasture, but they were of so great abun-

dance and occupied so much space in the plant cover that they were assigned to an intermediate rank of 3.³

A total of 12 weedy prairie forbs and 38 species not common to undisturbed true prairie were found to occur in some of the pastures of each type, table 5. A second lot of 37 species—nearly all weeds—were found in pasture types 4 and 5 only, table 6. Thus, aside from the prairie grasses, a total of 87 such species entered into the composition of these pastures.

The average number of species occurring in pasture types 1 and 2 was 9; in type 3 it was 15. This increased to 18 in type 4, and to 22 in the more degenerate type 5. About one-third of the species were infrequent. Most of these were found only in pasture types 4 and 5 and only a few in earlier stages of degeneration.

The total number of species occurring in the several types of pastures increased with deterioration from 25 in types 1 and 2 to 45 in type 3, and reached a maximum of 72 in type 4. Further deterioration, however, to type 5 was accompanied by a decrease in the number of species to 59. It is of significance that only one of the species found in types 4 and 5 only attained primary importance.

Eighteen species were found only in No. 4 pastures. These included *Cirsium lanceolatum*, three species of *Rumex*, *Solanum carolinense*, *S. nigrum*, and *Tragopogon pratensis*. Nine species occurred only in No. 5 pastures. Among these were *Anthemis cotula*, *Amaranthus graecizans*, and *Xanthium commune*. Of these 27 species, about two-thirds were annuals, and most were introduced weeds. Nearly all are regularly found in waste lands and have no place in well-kept pasture. Their occurrence in the different grades of pastures probably has little significance except that both types have bared areas entirely beyond the control of the grasses.

Ambrosia elatior, *Vernonia baldwini*, and *Grindelia squarrosa* surpassed all other species in number of pastures (8, 7, and 6, respectively) in which they occurred as weeds of primary importance.

The following species of prairie forbs increased in importance and occurrence with the deterioration of the pasture: *Achillea occidentalis*, *Antennaria campestris*, *Aster multiflorus*, *Cirsium undulatum*, *Oxalis stricta*, *Solidago rigida*, and *Vernonia baldwini*.

Hedeoma hispida, which before the drought was always associated with the short grasses, reached its greatest abundance in type 4 pastures. *Artemisia gnaphalodes* decreased but slightly and

³ This method has been used widely in the study of prairie forbs. See "The Prairie," pages 196 and 231.

Erigeron ramosus markedly with pasture deterioration. *Vernonia baldwini* occurred in all but 4 of the 41 pastures studied and was first or second in importance in 18. *Cirsium undulatum* occurred in 29 pastures but was of primary importance only once and held a ranking of 2 three times.

Verbena stricta and *Schedonnardus paniculatus*, occurring in 37 and 31 pastures, respectively, were with *Vernonia* the most widely distributed. *Verbena* attained primary importance three times in No. 4 pastures and ranked in the second class 10 times in types 3, 4, and 5. *Leptilon canadense*, *Plantago purshii*, and *Verbena bracteosa* each occurred in 22 pastures and were found in all types. In general, they were more abundant in the lower grade pastures.

Ambrosia elatior occurred in 20 pastures; it was absent from types 1 and 2, but often ranked high in types 4 and 5. The perennial, *A. psilostachya*, was recorded in 21 pastures. It was present in the early stages of deterioration but occurred only once in type 5 pastures. Species of *Lepidium* were not found in high-grade pastures; they occurred in 21 of the others and especially in types 4 and 5.

Sporobolus cryptandrus was found in 19 pastures including all types. Its rating did not exceed the fourth class in types 1 and 2, but it increased in importance and in type 5, if present, received a rating in the first class. *Eragrostis cilianensis* and *Hordeum pusillum* likewise became increasingly important as the pastures deteriorated. The enormous increase of both little barley and sand dropseed under conditions of drought was not suspected at the time these ratings were given during 1929 to 1934. Sand dropseed has since become one of the most important pasture grasses.

EXAMPLES OF PASTURE TYPES

Early Stages of Degeneration.—An early stage in prairie degeneration was well illustrated on an area that had been moderately grazed for 30 years. Since there was no water, the stock was allowed to graze there only half of each day. As in practically every pasture, there were some weeds near the gate where trampling had occurred. These were fetid marigold (*Boebera papposa*), prostrate amaranth (*Amaranthus blitoides*), rough pigweed (*A. retroflexus*), and stinkgrass. There were smaller amounts of yellow foxtail (*Setaria glauca*) and knotweed (*Polygonum aviculare*). A zone about 50 feet in width lying beyond was dominated by annual dropseed (*Sporobolus neglectus*), wiregrass (*Aristida oligantha*), crabgrass (*Digitaria sanguinalis*), and blue grama grass. Interspersed with these were a few of the preceding weeds and remnants of the prairie grasses. Here less trampling

but close grazing had occurred. This zone gave way to the general pasture vegetation. Of this, little and big bluestem constituted the matrix. There was somewhat more than the usual amount of bluegrass interspersed throughout. Practically all of the common upland grasses were represented in normal proportions, including small patches of blue grama and hairy grama grass on a dry slope.

The prairie-pasture was so well utilized that there was little old debris. Bunches and ungrazed patches of bluestems were



Fig. 43.—Pasture near Belleville, Kans., showing good management. The grasses are not grazed too closely, the cover is unbroken, and weeds, except cactus, are scarce. This weed should be removed and burned.

practically absent. Grazing was uniform but not so intensive that the cover was injured so as to permit invasion of weeds. Grazing was only moderate but rather even throughout, fig. 43. In spring, it was deferred until the middle of May when the vegetation had made a good early growth. This occurred promptly since the plants were not weakened; by the middle of April many new leaves were 4 to 5 inches tall. About 20 to 25 per cent of the cover remained when the cattle were removed in fall. Some flower stalks of nearly all of the prairie grasses except needle grass and prairie dropseed were found scattered sparingly throughout. Although not as robust as in ungrazed prairie, their presence indicated the vigor of the sod.

Although the composition of the cover had not been much modified, beginnings of certain changes were evident. Bluegrass

was favored by the constant removal of the overtopping mid grasses and most forbs. While in some parts of the pasture it was no more abundant than before grazing, in others it had increased severalfold, and in small patches it had gained partial control, especially in ravines. Side-oats grama had increased somewhat as had also Scribner's panic grass and purple eragrostis. Needle grass, prairie dropseed, and, to a smaller extent, June grass clearly showed decrease in abundance.

Certain forbs had entirely disappeared, although common along the roadside and also across the road in a prairie. They were many-flowered psoralea, silvery psoralea, round-headed bush clover, and ground cherry (*Physalis heterophylla*). The following native forbs occurred: prairie cat's-foot, lead plant, white prairie clover, daisy fleabane, aster, false prairie boneset, goldenrod, and wild flax. All except the mat-forming prairie cat's-foot were rather closely grazed, except for a few flower stalks which escaped and later bore seed. The following remained uneaten: wavy-leaved thistle, false indigo, Pitcher's sage, and ironweed. None but the ironweed was at all abundant. It averaged 6 to 8 stems per square rod and was clearly increasing even in this unbroken cover. The competition in the continuous sod was so great, however, that the small open clumps or isolated stems of this native pasture weed were dwarfed compared with those in old pastures. This was true also of the wavy-leaved thistle which has marked tendencies to form dense patches.

That forage was plentiful was well illustrated by a large open stand of buckbrush (*Symphoricarpos occidentalis*) with a more or less continuous layer of bluegrass beneath and bluestems near the margins. Not only had the bushes been left intact but also the bluegrass and bluestems which had an abundance of foliage extending well above the debris of previous years.

Scattered in the sod throughout the pasture were the ruderals—dwarfed spotted spurge (*Euphorbia maculata*), horseweed, witchgrass (*Panicum capillare*), and yellow foxtail. None of these annuals had a real foothold and were rather incidental. A few perennial vervains had invaded. The pasture was free from paths; the cattle upon entering the gate scattered at once to graze and did not follow one another to the opposite end of the pasture.

Pastures representing early stages of degeneration are frequently ungrazed during years of good rainfall or when the herd is at a minimum, but are mowed for hay. These rest periods are beneficial to the vegetation since the underground stores of food are replenished and species are afforded opportunity for seed production, except prairie dropseed and others of late seeding

habits. That they are pastured, even intermittently, can readily be detected not only by the absence of certain legumes, which quickly disappear, but also by the increased abundance of other native species and the invasion by certain plants not common to undisturbed grassland, fig. 44.

Such pastures under continuous and slightly increased grazing pressure readily grade into the No. 2 type. From here the transition to the far more common intermediate pasture types usually occurs, either as a result of too early grazing, overstocking, or both.



Fig. 44.—Hay meadows in the valley of the James river, S. D., with ranges on the adjoining bluffs and level upland. This assures an abundance of both summer and winter feed for livestock.

Intermediate Pasture Types.—Intermediate types of pastures include those where the native bluestems and other grasses have lost control over at least half and often over more of the area to bluegrass or to the short grasses. Often alternating areas of these occur. Sand dropseed and western wheat grass types are not included here, since they are mostly products of the drought and will be considered later.

Bluestem-Bluegrass Type.—This type is well illustrated by a pasture near Lincoln in which many experimental data were secured. It is midway between native prairie and the bluegrass stage. Steep, rough banks bore only the native flora. Well-watered, much-grazed bottoms of ravines were clothed with a continuous sod of bluegrass, which extended over the gentle banks and lower slopes where grazing was close and continuous. About

85 per cent of the pasture was characterized by an alternating mixture of bluegrass and relict patches of moderately grazed or almost ungrazed patches of prairie grasses. Along banks, even those only moderately steep, the closely grazed level or gently sloping land above gave way so abruptly to the ungrazed or slightly grazed bluestems, with their accumulations of debris, below that it seemed in contrast as if the level land had been mowed. Elsewhere, islands and narrow patches of bluegrass grazed to within 1 to 1.5 inches of the soil alternated with mixed native grasses, especially with little and big bluestem and side-oats grama, but also with June grass, certain sedges, and a few other prairie species. The vegetation appeared patchy. The big bluestem was practically always uniformly grazed, as was bluegrass, over areas of many square rods.

Over three-fourths of the pasture, grazing was somewhat uniform. The other portions were ungrazed or lightly grazed because of old bunches of little bluestem, slender grama, or sometimes blue grama.

In places in the broad, flat, alluvial valleys, the bluegrass sod contained a scattered growth of dandelion, rough pigweed, prostrate spurges, and horseweed. Where the sod was broken by trampling, as in the shade of willows, it bore knotweed and purslane (*Portulaca oleracea*). Higher up the ravine where erosion by runoff water from a field resulted in the cutting of a ditch, there were small amounts of hemp and tall dock.

A considerable portion of the pasture near the water tank had progressed far towards the bluegrass stage. In part of this area there was nothing but the dense stand of bluegrass and large patches of prairie sage. Bordering this area and irregularly but gradually merging into the general prairie condition, isolated clumps of bluestems and side-oats grama occurred in the bluegrass sod. These clumps were small, or if large in outline consisted of a few scattered stems. They varied from a single clump per square meter progressively until they formed one-third to one-half of the vegetation. Needle grass and prairie dropseed had been exterminated as had all of the legumes and various other prairie species. But June grass and tall panic grass were present, and ironweed and vervain were the chief weeds. Such intermediate types of pastures were very common before the great drought.

Bluestem-Short Grass Type.—The bluestem-short grass type, developed by the gradual encroachment of blue grama grass and buffalo grass, is similar in origin to that of bluegrass. Constant grazing slowly but surely caused the waning and death of the bluestems. Grama grass was often the only representative on up-

habits. That they are pastured, even intermittently, can readily be detected not only by the absence of certain legumes, which quickly disappear, but also by the increased abundance of other native species and the invasion by certain plants not common to undisturbed grassland, fig. 44.

Such pastures under continuous and slightly increased grazing pressure readily grade into the No. 2 type. From here the transition to the far more common intermediate pasture types usually occurs, either as a result of too early grazing, overstocking, or both.



Fig. 44.—Hay meadows in the valley of the James river, S. D., with ranges on the adjoining bluffs and level upland. This assures an abundance of both summer and winter feed for livestock.

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Bluestem-Bluegrass Type.—This type is well illustrated by a pasture near Lincoln in which many experimental data were secured. It is midway between native prairie and the bluegrass stage. Steep, rough banks bore only the native flora. Well-watered, much-grazed bottoms of ravines were clothed with a continuous sod of bluegrass, which extended over the gentle banks and lower slopes where grazing was close and continuous. About

No. 4 Bluegrass and Short Grass Pasture Types.—The typical bluegrass pasture has but the single important dominant, a dense sod of Kentucky bluegrass (*Poa pratensis*). This, at its best, forms a continuous and uniform sward. The usual height of the ungrazed and mature foliage is about 8 inches; the flower stalks are often 8 inches taller and occur in great abundance. Underground, the long, slender, white rhizomes and abundant fine, matted roots thoroughly penetrate the soil and keep it in an excellent granular structure very receptive to water penetration. Experiments have



Fig. 46.—Buffalo grass pasture near Lincoln, Neb., within sight of the state capitol. It is heavily grazed but the sod is fairly well intact.

shown that the dry weight of these underground parts in the surface 4 inches alone exceeds two tons per acre. Weeds are scarce in well-kept pastures. After the bluestems and other native species have been grazed out, the heads of bluegrass are sometimes stripped for seed by mechanical strippers, a practice common in portions of Iowa and Missouri.

Perhaps the commonest weeds in bluegrass pastures are the ragweeds, especially the annual ragweed. These are usually 2 to 3 feet high with 1000 or more stems per square meter where thickest. More often at least half the soil area is free of them, and here grazing is noticeably better. Usually the bluegrass forms a sod unbroken by the layer of ragweeds. While open grassland free of a thick growth of weeds may be grazed to within one-half inch of the soil, in other places the ungrazed and lodged

bluegrass is frequently 4 to 7 inches high. Mowing the weeds at a height of 3 to 4 inches is a common method of control. Many fine bluegrass pastures have an almost continuous cover of grass and very few weeds. But where grazing has broken the sod, hosts of weeds common to other pasture types appear. Among these, dandelions, thistles, vervains, horseweeds, and foxtail are often of first rank. Squirreltail-grass is common and fetid marigold is sometimes abundant in low, trampled ground.



Fig. 47.—Overgrazed buffalo grass pasture near Freeman, S. D., with Russian thistle occupying broken places in the patchy cover.

Bluegrass pastures flourished in the eastern portions of Kansas, Nebraska, and South Dakota before they were destroyed by the drought, but reached their best development in the region studied in western Iowa, southwestern Minnesota, and northwestern Missouri where they remain largely intact, figs. 6 and 24.

In No. 4 short-grass pastures there is considerable variability in the amount of cover, resulting both from their regional position and the degree of grazing. There may be an almost continuous mat of buffalo and blue grama grass after the mid grasses and most prairie forbs have disappeared, but usually the cover is more or less broken, figs. 46 and 47. Where the grazing is uniform and not too close, weeds are held in check, except for a few species of low-growing annuals and, more rarely, coarse perennials. But often close grazing and trampling have prevailed so long that a third or more of the soil is bare, except for a host of annual and longer-

lived weeds. Chief perennials are gumweed, wavy-leaved thistle, vervain, western ironweed, Baldwin's ironweed, stickseed (*Lappula*), and sometimes an abundance of cactus, chiefly species of *Opuntia*. Among the most common annuals are rough pennyroyal, stinkgrass, witchgrass, and buffalo bur (*Solanum rostratum*). These pastures of buffalo grass, or buffalo grass and blue grama grass about equally mixed, are the most important type on the western margin of true prairie. They merge, with change to a more xeric forb and weedy grass population, into the vast ranges of the great plains (Weaver & Albertson 1940).

No. 5 Pasture Type.—The new green cover of early spring on the most heavily grazed parts of No. 5 pastures is largely that of annuals—stinkgrass, rough pigweed, prostrate amaranth, yellow foxtail, crabgrass, dandelion, sparges, purslane, knotweed, and others. Representative of this type is a pasture on which were scattered widely the merest remnants of bluegrass, broken areas of blue grama grass and hairy grama grass, and fragments of buffalo grass. Occasional clumps of sand dropseed and stems of western wheat grass occurred. The annual dropseeds (*Sporobolus neglectus* and *S. vaginiflorus*) were common. The native grasses had been starved, their subterranean food supplies were exhausted, and their root-ends had rotted away. Stray clumps of grass—relict side-oats grama and big bluestem—protected by and overlooked because of coarse stems of ironweed or other useless weeds, alone gave promise of recovery. Great cracks in the soil, sometimes an inch wide and many feet in length, indicated the lost hold of root fiber, the decrease of humus and mellow top soil, and the general condition of degradation.


A typical example of the extreme reduction reached by native prairies by overgrazing and drought is afforded by a certain pasture that had degenerated beyond possible recovery in a period of time within economic limits. The land was a waste of aster and peppergrass. Aster occurred in more or less circular or irregular patches 2 to 5 feet in diameter. The stems were often so dense that no other vegetation was found. The patches occupied one-fourth to one-third of the entire local area and where they coalesced they were almost continuous. Although of some forage value when young, aster is a bad perennial weed. The basal cover was low, rarely exceeding 3 per cent. Peppergrass, an annual, blossoming at a height of 2 to 6 inches, was very thickly aggregated in stands of 3000 or more plants per square meter, the branched tops of the dwarfed plants completely obscuring the soil, and covering even more surface than the aster. Although it was grazed in spring, later the plants dried and were not only

worthless but by their shade retarded growth of other plants. When the peppergrass was removed, the ground was often almost bare except for the remnants of the undecayed crowns of the starved grasses.

Patches of bare soil were common; meter quadrats were placed in many such areas without enclosing a single stalk of grass. Several large areas on the bare hilltops where no weeds had grown presented surface soil which showed much evidence of erosion. These bared areas had in former years been closely covered with horseweed. Overstocking was shown also by many bared areas formerly covered with dung.

None of the former native grasses was observed save a single plant of side-oats grama and about two square rods of much depleted blue grama. The mats of blue grama were much worn and greatly fragmented and in many places dead except for marginal spears of green. In the ravines where bluegrass had formerly formed a continuous sod extending upward over the lower slopes, bare soil or weed-infested alluvium now occurred. The extensive deposits in the ravine, 1 to 3 feet deep, were clothed with seedlings of Russian thistle, annual sunflower, species of smartweeds, and hemp (*Cannabis sativa*).

Bluegrass had disappeared from the slopes, and only the merest remnants of a few prairie species remained, among which were prairie cat's-foot, violet (*Viola papilionacea*), and spiderwort (*Tradescantia bracteata*). Half of the steep banks were entirely bare except for Russian thistle. In fact, wherever bluegrass had formed an even sod over lowlands, trampling, formation of paths, and soil deposit had loosened its hold. It is difficult for this grass to grow where soil constantly washes into ravines from adjacent fields or eroding pastures, as often occurs. Only portions of the lowlands were retained by the grass; the rest was bare or it supported a population of coarse annual weeds. Where the ravines were deep, the steep banks were eroded by gravity or by animals rubbing against them or climbing up over them. The weedy bottoms were often much trampled.

Moles and  rodents had loosened the soil locally to an abnormal degree. Last year's Russian thistles had blown from the ravines and lodged in many places. When they were removed, thousands of seedlings were found underneath, populating every square foot of soil.

A few other prairie forbs still occurred. Smooth goldenrod was the second worst perennial. It formed dense patches from one-half to several square meters in area, the closely spaced stems growing from rhizomes which thickly threaded the soil. The

hungry cattle had grazed the upper parts of the plants only, but would have eaten them more closely had grazing begun earlier. In many areas occupied by goldenrod the ground was otherwise practically bare. Purple oxalis (*Oxalis violacea*), puccoon (*Lithospermum linearifolium*), ragwort (*Senecio plattensis*) and prairie sage persisted as mere remnants, as well as a few starved ground



Fig. 48.—No. 5 pasture showing weakened and dead crowns of sand dropseed, invasion of Russian thistle, and bare soil. Lincoln, Neb.

plums, almost smothered by peppergrass. Ironweed was frequent and thriving.

The following weeds were represented more or less abundantly: tall mustard (*Sisymbrium altissimum*), little barley, daisy fleabane, annual ragweed, and windmill grass (*Chloris verticillata*). Plantain occurred in great patches at the rate of 5000 fruiting plants per square meter. Among the thickets of wavy-leaved thistle, species of dandelion and other edible weeds flourished under protection. Vervain occurred occasionally and several extensive patches of bindweed (*Convolvulus arvensis*) had developed near the road.

No last year's stems of sand dropseed were found, so closely had they been grazed. The clumps were small and weak. Once the plant was everywhere but now the dead crowns were common and survivors few, fig. 48. Often only 2 to 3 plants per square meter were found. Wheat grass, a relatively recent arrival, had

extended into the area by wind-blown seeds and invasion by rhizomes from the roadside where it was plentiful. It formed a half-dozen small patches. That the plants were recent arrivals and had not yet had time to develop the usual stands was shown by the open growth. It was grazed closely and much trampled, as were most plants, by the hungry, wandering herd, fig. 49.



Fig. 49.—Last stage in degeneration of buffalo grass range. Stock has been kept out and the new stolons are of recent growth. Courtland, Kans.

CHANGES IN PASTURE TYPES DUE TO DROUGHT

Many changes in pastures and pasture types have resulted from the great drought. Drought became very severe in 1934 and even more marked in 1936. Since its inception, dry weather has occurred at some time every year and such periods have often been pronounced.

Death of Bluegrass and Little Bluestem.—The most severe drought recorded up to 1934 in this midwestern grassland occurred in that year, practically no rain having fallen even in spring. It was exceeded in severity, however, in 1936. A close relationship was found between root depth of most prairie grasses and resistance to drying. Among forbs, resistance to drought was also closely correlated with root extent (Weaver, Stoddart & Noll 1935). All of the prairie and pasture grasses suffered some loss, but death was greatest among those with relatively shorter roots,

such as June grass and needle grass but especially bluegrass and little bluestem, fig. 50. Big bluestem, because of its deeper root system, was less severely injured. By 1937, bluegrass was nearly all killed in bluegrass pastures west of the Missouri river, and some destruction was wrought even in western Iowa, figs. 51 and 52. Exceptions occurred in certain southeastern areas of higher rainfall and along some river valleys, for example the Elkhorn

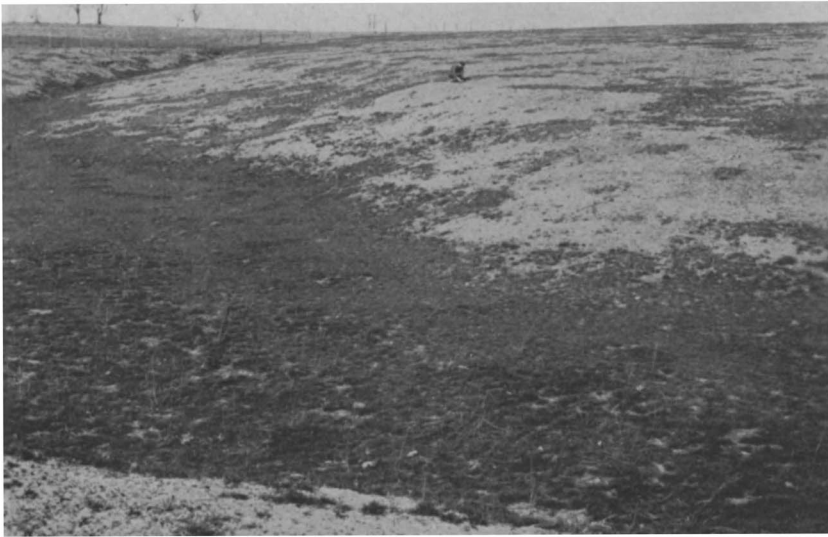


Fig. 50.—Bluegrass pasture at Lincoln, Neb., April 19, 1935. An open stand of bluegrass remains in the ravine and small amounts on slopes. Nearly all other vegetation is dead. The pasture was later dominated by sand dropseed.

river in Nebraska where the water table was shallow, and where lowland pastures received much runoff water from the surrounding area. Sometimes small amounts of bluegrass remained temporarily under the protection of weeds. In other places where ungrazed bunches of little bluestem or tall dropseed had protected the bluegrass from close grazing, it likewise survived, since here the vigorous, ungrazed plants had better developed root systems. In general, however, the loss was fully 95 per cent of the stand. Bluegrass in eastern Nebraska pastures was rooted only about 3 feet deep.

Losses of little bluestem, with a normal depth of rooting of about 4 feet, were likewise very great in pastures of higher types where this plant shared the area more or less equally with blue-



Fig. 51 (upper).—Excellent bluegrass pasture on lowland formerly occupied by big bluestem. Photo June 1933. The tall clumps of bluegrass are in dunged areas.

Fig. 52 (lower).—Same pasture, showing death of bluegrass and rank growth of rough pigweed and other weeds. Note death of willows. Photo June 1935, near Lincoln, Neb.

grass. In some pastures, especially where long-continued grazing had depleted both tops and roots, scarcely a plant remained; usually the losses were 80 to 95 per cent. Only in the best pastures in the more favorable region did any great amount of little bluestem remain. Similar losses occurred in prairies. Since this species alone frequently constituted 50 to more than 70 per cent of the entire cover on uplands, the total extent of bare areas left in pastures upon its death was very great. In addition, losses



Fig. 53.—Pasture of sand dropseed with bluegrass in the ravine (left background). Note rather low degree of utilization of forage by stock. Photo May 1, 1939. (Compare with figure 50.)

among certain other species such as Indian grass, Scribner's panic grass, and even big bluestem were high. Many native pasture forbs likewise practically disappeared. In fact, nearly all native species were more or less reduced in amount by the successive years of drought. Hence, the plant cover in pastures was greatly disrupted and often left almost bare except on the most protected lower slopes. The results were a tremendous increase in weeds, some of which constituted a veritable scourge, and the spreading of grasses of a more drought-resistant type than the bluegrass and bluestems.

Spread of Sand Dropseed and Western Wheat Grass.—Following the early years of drought and consequent widespread losses of pasture grasses, sand dropseed rapidly increased from the status of an occasional invader to a species of major importance (cf.

p. 53). Over thousands of pastures it has spread so widely as to become a dominant or the dominant species, fig. 53. It has reclothed vast areas left nearly bare by the death of bluegrass, little bluestem, and other pasture plants. Its behavior during the drought has shown both its forage value and its great resistance to aridity. Thus, this western species has given stability and good productivity to pasture lands too dry for more mesic grasses. Otherwise, these pastures for a long time would have supported only a population of weeds. In fact, where sand dropseed or

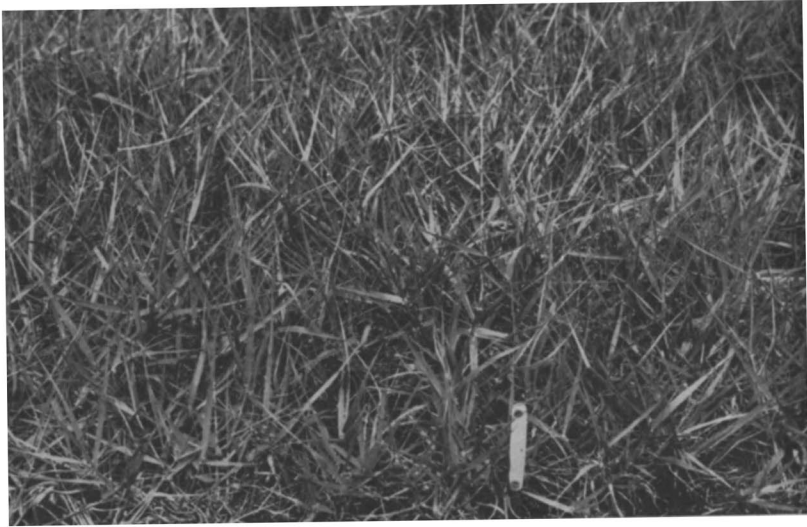


FIG. 54.—Detail of sand dropseed in a former bluegrass pasture near Emerald, Neb., on June 15, 1938. The plants, which have not yet been grazed, are 6 inches tall.

wheat grass did not appear, thousands of former bluegrass pastures were almost worthless and were either planted to temporary pasture grasses or used to produce grain crops.

Sporobolus cryptandrus is a perennial bunchgrass; under grazing, usually with a spreading base. In general the bunches are small but the larger ones may have 30 to 50 leafy stems and a basal diameter of 5 to 6 inches. The pithy, solid stems are mostly erect but some usually spread outward at various angles or may even grow parallel to the soil surface. Even vertical stems often curve outward at the base. The leaves are nearly all confined to the lower half of the mature plant. They are of moderate width (2 to 5 mm.), with conspicuous, long, white, tufted hairs where the blade joins the sheath. Spring growth begins about the same

time as that of the bluestems. By the middle of April (at Lincoln, Nebraska) the new leaves are an inch or more in length and enough new shoots occur at the bases of the old stems so that stock is tempted to graze them. Growth is fairly rapid and if the plants are ungrazed a height of 6 or more inches is attained by the middle of June, fig. 54. Production of flower stalks begins about



Fig. 55.—Typical bunches of sand dropseed on September 15. Height about 2 feet.

June 15, and during favorable seasons they are borne in great profusion and attain a height of 3 feet; but during dry years they may be reduced to one-third normal size. The pale leaden to purplish spikelets are partly enclosed in the topmost leaf sheaths. Blossoming begins late in June and continues until October. The small seeds are produced in enormous numbers. Ten thousand mature seeds have been obtained from a single panicle, fig. 55.

The great increase of sand dropseed has occurred from South Dakota to Kansas almost to the Missouri river. It has been found in only a few places eastward. Throughout the west it produces a

fairly large amount of foliage which is eaten by all classes of livestock, its palatability rating ranging from fair to very good. In the longitude of eastern Nebraska both cattle and horses graze it readily. Not only are the leaves eaten but also the stems and flower stalks at all stages of development.

Total production under constant grazing was determined during 1938. Five clippings were made in the pasture where the growth during the three-weeks' interval between clippings was protected by a series of small portable exclosures. The grass in the 30-square-foot area in each pasture exclosure was clipped at the soil



Fig. 56.—Invasion of western wheat grass into bluestem pasture buried under soil blown from adjacent plowed fields. Photo July 12, 1940, Lincoln, Neb.

surface and from the dry weight produced was subtracted the dry weight of the uneaten remnants of dropseed from adjacent areas of similar size. Thus, the approximate amount eaten by the stock was obtained. Neither lot of clipped areas was used for a second cutting, the exclosures being constantly relocated. The forage removed from the pasture by the cattle was 2 tons per acre. This grass withstands grazing well and where overgrazed recovers rapidly because of its excellent seeding habits and rapid growth of seedlings (Weaver & Hansen 1939).

Western wheat grass (*Agropyron smithii*), formerly present in trampled portions of pasture and along fences in small amounts (p. 39), swept through pastures and prairies with astounding rapidity after 1934. It often replaced bluegrass on low ground, reclothed areas where the former vegetation was killed by drought or buried by dust, and occurred irregularly in patches of variable size, fig. 56. Often it has taken nearly complete possession of ex-

tensive pastures and ranges. This has been accomplished both by wind-blown and rodent-distributed seed and by extensive propagation by long, slender, much-branched rhizomes. The rhizomes grew several feet a year and gave rise to a veritable thicket of new wheat grass stems. Frequently 1000 occur per square meter. This sod-forming grass shows its northern extraction by resuming growth very early in spring, after making a late fall growth the preceding year. During periods of low precipitation it thus so



Fig. 57.—Invasion of western wheat grass into a mixed buffalo-bluegrass pasture following the death of bluegrass.

greatly depletes the soil moisture before later growing species produce new growth that the latter can do so only slowly, if at all. Thus, where there is a good stand of western wheat grass, weeds are usually few or none. This species is readily eaten only when young. After the woody stems have developed stock graze this grass only partially. Often it is grazed above the 5 to 10-inch level.

In pastures where bluegrass alternated with buffalo grass, the complete loss of the former resulted in a very marked increase in buffalo grass and a widespread invasion of wheat grass, fig. 57. The wheat grass layer was not continuous. Although scattered shoots occurred even in the denser mats of the short grass, they were grazed closely with the buffalo grass and thus greatly handicapped in development. It was only where buffalo grass was sparse or absent that the wheat grass flourished.

In many short-grass pastures, small amounts of western wheat grass were present before the destructive drought. During the dry years following 1934 this plant frequently occupied all the bared portions in a nearly pure stand. Later it intermixed with the short grasses over much of their territory and would finally have largely displaced these if the temporary non-grazing policy had continued. Under protection both short grasses also spread, blue grama grass, especially, by seedlings. While the short grasses were again being pastured closely, grazing of the western wheat grass was very irregular, varying from nipping of the tops to eating them to within 4 inches of the soil. Following the western wheat grass invasion, weeds, especially annuals, soon became of little importance.

Increased Importance of Grama Grasses and Buffalo Grass.— Profound changes were wrought by the several years of drought even where grazing was moderate. In the No. 1 upland pasture described earlier (p. 63), where the bluestems constituted 70 per cent of the vegetation, great changes had occurred by 1938. The chief grasses were side-oats grama, which formed a scattered open growth over much of the area, and the short *boutelouas* (mostly *B. gracilis*) which had spread widely on the hilltop and half way down the slope. Although blue grama grass had greatly increased in area, it had lost much in density of basal cover. *Sporobolus cryptandrus* was third in importance and confined mostly to the more trampled hilltops, but patches and isolated plants occurred throughout. Its distribution clearly indicated recent arrival. Very few bluestems survived. There was much bare ground in the aggregate but few large bare areas. The light stand of bluegrass had entirely disappeared except for small tufts in the shade of the ironweed or larger ones under the protecting tops of a few large cottonwoods in a ravine. Here it grew thickly in an almost pure stand where it was shaded either in morning, noonday, or in the afternoon. By 1940 side-oats grama alone constituted 70 per cent of the grass population.

The resistance of side-oats grama both to grazing and to drought is very great. It is frequently an important component of the sand dropseed pasture type and also of the western wheat grass type. Its increase has been very great.

Of even greater drought resistance are blue grama grass and buffalo grass. These xeric, western range grasses have not only spread widely from centers already established in long-grazed pastures, but there has been a great movement of these species from west to east along the whole western front of true prairie. This eastward advance has been very marked over a belt 50 to 100

miles broad. Grazing, with exception of certain species, has been extremely close during the years of drought. This, combined with desiccation, has weakened or destroyed taller grasses less resistant to overgrazing and drought. Even side-oats grama has often succumbed. The short grasses have spread into the bared places. Entire prairies have thus been changed as well as very large areas of the more arid pasture lands.

Invasion of Weeds.—The early years of drought caused a great decrease or entire loss of many prairie forbs (Weaver & Albertson 1939, 1940a). Some of these, the legumes especially, were valuable forage plants, others were worthless weeds. Of great importance among the latter were many-flowered aster, smooth goldenrod, and daisy fleabane. These spread widely throughout pastures. In addition a very large weedy population dominated hundreds of pastures for two or more years following 1934. Peppergrass was a veritable scourge densely populating the bared ground. Dozens of plants grew on every square foot. But they vanished almost entirely after two or three years. Little barley became so abundant and persistent that it almost alone occupied exclusively thousands of acres of pasture land. Germinating in fall or in very early spring and making a rapid growth, these small plants densely covered the soil surface and gave to the pasture a false appearance of excellent productivity. Heading in May and ripening to the color of dry straw early in June, they terminated plant activity on that portion of the range for the season. The shattered spikes and densely crowded stems formed an excellent soil mulch, promoted water intake, and greatly mellowed the soil. In fact, where sand dropseed was intermixed, it rooted so shallowly under the mulch and in the soft soil that seedlings were pulled up in great numbers in the process of being grazed.

Little barley is found rather regularly intermixed with buffalo grass, especially in closely grazed pastures, and stands are dense on nearly bare ground. Here also stolons of the short grass, 6 to 10 inches long, may be found. The height of little barley (2 to 12 inches) as well as its abundance is inversely proportional to the density of the dominant grasses. Early in spring, portions of the pasture least infested with it are grazed. Then grazing is extended to include the green vegetation beneath the half-dried little barley. The thinnest stands of buffalo grass and other grasses where this annual grows most thickly are longest protected, but after the little barley ripens and is trampled, they too are grazed.

Invasions of sand dropseed and western wheat grass were usually preceded or accompanied by a wave of ruderals. Chief among these were downy brome grass, little barley, horseweed,

stickseed, and peppergrass. Plantain thickened up enormously when competition of grasses was reduced. Horseweeds, lamb's quarters, Russian thistles, and scores of other annuals became extremely abundant. This was nature's way of holding the soil until perennials again gained control. The roots and old crowns of dead plants decayed only slowly during drought. Even in death they stabilized the soil one to two years.



FIG. 58.—Pasture ungrazed for four years. The light-colored vegetation is blue grama grass and buffalo grass, the depth of the cover varying from 4 to 7 inches. Dark patches are side-oats grama. Photo Montrose, Kans., July 30, 1940.

Changes in Ungrazed Pastures.—Another widespread effect of the drought period was the complete or almost complete rest of many ranges near the western edge of the true prairie. In 1934 and certain years that followed, forage became so scarce because of an abundance of livestock and lack of adequate soil moisture, that it became imperative to ship thousands of starving cattle to pastures in the eastern and southeastern United States. Ranges were left undisturbed two to four years and many are still scarcely grazed. The badly depleted buffalo grass especially, but also blue grama, side-oats grama, and sand dropseed, benefiting by local periods of rainy weather in the best drought years, have made a remarkable recovery, usually east of the 24-inch rainfall line.

Pastures so closely grazed that buffalo grass prevailed almost alone have formed a thick cover. Debris has accumulated near

the soil, the stolons of the current year run over the dried tops and runners which were produced the preceding year until mats 4 to 7 inches thick have developed as a continuous cover. This material, when air dried, not infrequently amounts to 4 to 5.5 tons per acre. Stock graze the green tops but in doing so must eat much of the cured grass as well. Such debris forms an enormous fire hazard, but is an excellent preventive of erosion, fig. 58. Where pure stands of blue grama grass prevail, a similar accumulation of material maintains. The foliage level is often 8 inches and that of the flower stalks 4 to 6 inches greater.

Sand dropseed, where dominant, forms a continuous thicket of stems holding aloft the frayed leaves of last year to a height of 10 to 12 inches throughout the season. Accumulated foliage is abundant and intermixed thickly with the current year's growth. By midsummer the new leaves are about 8 inches tall and give a greenish tinge to the dead, gray foliage. At a distance, the whole range has a silvery or leaden aspect. The abundant bunches of side-oats grama with old, bare flower stalks but also with masses of both green and dried foliage, except for color, are not greatly unlike those of sand dropseed. Where the growth of these two species was not too dense, the short grasses were intermingled or alternated with the mid grasses.

When cattle are kept in such pastures, grazing at first is very selective, and, if the herd is small, continuously so. First the new growth of buffalo grass and grama grass is sought out. In grazing it the old stems of other grasses are eaten or trampled. These places are thereafter kept closely grazed. The new leaves of side-oats grama become so abundant and attractive that areas a few feet to a few yards square are cleared out, but not so uniformly, until the new foliage warrants a second or third grazing. The old parts of sand dropseed are not relished, but the new leaves and stems are eaten. With their removal, the old debris is gradually all eaten or trampled to the ground. In this way a large herd of steers or horses will clean up an old ungrazed pasture; new growth of the following year is much more easily and uniformly grazed.

In the ungrazed ranges just described, weeds are greatly suppressed and many entirely disappear, so great is the competition. The abundant population of jackrabbits travels about the range not in the usual indeterminate manner but largely along paths 6 to 8 inches wide where the grass is trampled down. These paths intersect, branch, and extend widely.

In sharp contrast to these pastures are those overgrazed by cattle which were kept despite the drought, since fodder was available from fields of drought-damaged corn and alfalfa or from

plantings of Sudan grass or sorghums. In general, these native pastures have suffered greatly and many are ruined.

Resulting Pasture Types.—Following the great impact of eight years of more or less continuous drought upon a rather mesophytic type of grassland, the following pasture types are clearly distinguishable.

The bluestem type in recently grazed prairies and in older, moderately grazed ones persists in those portions of the area that have been least affected by the drought. There has been a steady decline during the last quarter of a century in the grazing capacity of bluestem pastures. Aldous (1938), in discussing native bluestem pasture in eastern Kansas, states:

Prior to 1900 most of the pastures were stocked at the rate of 2 acres for a cow or mature steer. The average has been gradually decreased until in 1933, or before the present dry cycle started, the best pastures were carrying one mature animal to 4 acres, while the average for the bluestem region as a whole was 5 acres per head for the summer grazing period. During the past two years the average grazing capacity has been 7 acres for a cow or a 3-year-old steer.

East of the Missouri river the great majority of pastures (especially in Iowa) already had been so long grazed that bluegrass was almost in complete control. Such pastures mostly still persist in this great section least affected by desiccation.

Short-grass pastures along the western margin of true prairie have very greatly increased in numbers and in total area. They occur as far eastward as the Big Sioux river in South Dakota and were also found in extreme southwestern Minnesota. They are likewise common to within 40 miles of the Missouri river in southern Nebraska.

The sand dropseed and western wheat grass types have a wide range throughout the general area delimited for the short grasses, where they have replaced bluestem or bluegrass pastures.

Mixed pasture types are common since the drought and extend widely over the Dakota-Nebraska-Kansas area. They have resulted from an increase of side-oats grama and a great spreading of sand dropseed and western wheat grass. These grasses may be somewhat intermixed, especially side-oats grama with sand dropseed or western wheat grass, or each of the three species may dominate different portions of the same pasture. Where short grasses were formerly present in small amounts, they have often spread widely and now form a partial understory to these mid grasses or alternate with them, fig. 59.

Conversely, western wheat grass has become abundant in many seriously overgrazed short-grass pastures where stock was ex-



Fig. 59.—Mixed stand of western wheat grass (dark) and sand dropseed (light) on a large range near Superior, Neb. There is an undergrowth of buffalo grass and blue grama grass over a part of the area.



Fig. 60.—Block of sod (left) removed from an ungrazed salt grass pasture. The grass is fully grown and has set seed at a height of 10 inches. Western wheat grass (right) from a less saline adjacent area, showing fall growth after summer burning.

cluded for a time. A mixed short grass-wheat grass type has resulted.

A minor pasture type which occurs in saline areas is that composed of salt grass (*Distichlis stricta*), fig. 60. It is often 90 per

cent pure but sometimes is intermixed with considerable amounts of western wheat grass and blue grama grass. Salt grass is a short grass as regards stature. It is a dense sod-former and furnishes much fairly palatable forage.

SUMMARY

Extensive areas of unbroken prairie land still occur in eastern Nebraska, South Dakota, and Kansas, and in western Iowa, and adjacent portions of Minnesota and Missouri. These support the original prairie vegetation in part but on most of them the prairie has deteriorated into various types of pastures.

The native grasses and forbs of these midwestern prairies and pastures have been studied over a period of 12 years and the process of degeneration to pastures analyzed.

Light grazing or well managed moderate grazing may change but little the natural composition of native prairie. But if continuous grazing is too intense and begins too early in spring, many native species of grasses and forbs preferred by stock will gradually disappear. Those that withstand grazing best or are less desirable increase, and, in addition, many weedy grasses and forbs invade the pasture. Continuous early and intensive overgrazing finally results in the disappearance of nearly all palatable native plants, the appearance of much bare soil, and an abundance of annual weeds and grasses of very low forage value.

Five stages have been determined in degeneration of prairie to low-grade pastures; very large pastures or ranges may include more than one stage.

No. 1 pastures are prairies that have not been misused. The forage usually exceeds the needs of the grazing animals and 20 to 25 per cent is left at the end of the grazing season. There is little bluegrass. Many of the very palatable legumes and other forbs may remain. A few inedible species show a slight increase. The cover is unbroken and its composition little modified.

No. 2 pastures are uniformly grazed in favored areas and usually very irregularly elsewhere. Bluegrass or blue grama grass and buffalo grass are increasing in flat ravine bottoms, about gates or trampled places, and sometimes elsewhere; here the native bunch grasses have died. Side-oats grama nearly always shows distinct increases. Many legumes and certain other forbs have almost disappeared. A few invading weeds may occur sparingly, but the shiftings thus far are almost entirely among the native plant populations.

In No. 3 pastures, bluegrass or short grasses or alternating areas of these either equal or exceed the usual true prairie species and

form the matrix of the vegetation. Ravines are often entirely clothed with bluegrass. Close grazing has sometimes resulted in islands of bluegrass in areas of little bluestem and side-oats grama. Although the original prairie species are clearly on the decline, they are still abundant. The cover of grass is well intact. Certain prairie forbs have increased considerably, and a moderate number of introduced weeds have appeared in trampled places and dunged areas.

No. 4 pastures have practically pure stands of bluegrass or short grasses. In the best pastures, the cover may be well intact but frequently it is broken. Both perennial and annual weeds are typically abundant. Areas of grass frequently alternate with bare ground or soil clothed only with weeds. The grasses are often so severely grazed that the stand becomes thin. Deeply worn paths are common and many places in the sod are trampled bare.

The final stage of degeneration occurs in No. 5 pastures where weeds, mostly annuals, often dominate. There are only fragments of the former cover of bluegrass, short grasses, or sand dropseed. Deterioration has not taken place uniformly but has spread from the earlier centers of weed infestation. Often over considerable areas 75 per cent of all vegetation has disappeared. Only the merest remnants of original species, as well as the absence of old fence lines or depressions of furrows, indicate that the land has never been plowed. The soil is frequently cracked; the surface has been eroded; ravines are partly filled with alluvium; paths are numerous, and trampling excessive.

Examples of each pasture type are described.

According to their response to grazing, plants of prairie and pasture have been placed into six groups.

Prairie grasses that decrease under grazing include 10 of the most important native species. Each is discussed separately.

Big bluestem was the most important grass of lowlands and occurred on uplands more sparingly. Because of its high palatability it is not only readily grazed but also selected by stock where other forage is abundant. It is gradually weakened under close grazing and finally dies. After three years of clipping (to simulate grazing) it was nearly replaced by a continuous cover of bluegrass.

Little bluestem was the principal dominant of the most extensive upland type of true prairie. It is readily grazed in spring and summer and when moderately or closely grazed it produces good forage throughout the entire growing season. Probably because of its bunch habit, it does not withstand grazing as well as the sod-forming big bluestem.

Needle grass, June grass, and prairie dropseed are bunch grasses and typically upland species. All are relished by stock and disappear rather early when prairie is grazed. Experimental clipping of these grasses clearly illustrated the harmful effects of the frequent removal of the tops. It not only greatly decreased the yield but resulted in two years in the death of the plants.

Other important grasses that decrease are Indian grass, tall panic grass, nodding wild rye, slough grass, and tall dropseed.

Prairie forbs that decrease under grazing constitute a long list of important species. All of the 45 listed are perennials, and 13 are legumes. The most abundant and widely distributed is the lead plant, which alone may furnish annually 150 or more pounds of air-dry forage per acre. Buffalo bean, prairie clovers, psoraleas, round-headed bush clover, and American vetch are likewise readily eaten, especially when young. Native sunflowers, prairie rose, purple cone flower, blazing stars, and certain goldenrods more or less completely disappear under long-continued grazing.

Certain prairie grasses increase under pasturing. The sod-forming Kentucky bluegrass is the first grass to resume growth in spring. It is not only unusually resistant to heavy grazing but also maintains its hold and actually increases the stand even where the soil is trampled and the grass closely grazed. Western wheat grass increases slowly under grazing and very rapidly where other vegetation is greatly depleted by drought. This is due partly to its early growth and sod-forming habit. Side-oats grama increases slowly but consistently under grazing due to rhizomes and prolific seeding habits, despite the fact that, like bluegrass, it is well liked by stock. Blue grama grass and buffalo grass, if present, increase greatly when true prairie is overgrazed, and become dominant in the western part of the area.

Many prairie forbs increase under grazing since they are either entirely uneaten by stock or grazed so sparingly that they are not much handicapped. Among those that become bad weeds are yarrow, many-flowered aster, prickly pear, ironweeds, and some goldenrods.

Certain grasses, mostly weeds, invade old pastures when many of the native grasses have died, leaving the cover broken. These include wiregrass, species of bromegrass, crabgrass, stinkgrass, little barley, and certain dropseeds. All are annuals and of low forage value.

A host of weedy forbs also enter native pastures when too close grazing, excessive trampling, and other causes result in much bare soil. Examples of the most important species are ragweeds, various thistles, gumweed, plantain, vervain, and spotted spurge.

Recently, Russian thistles, burning bush, and stickseeds have become very abundant.

A census of weedy prairie forbs and other weedy forbs and grasses was taken over a period of years in 41 pastures with a total area of 3000 acres. All types of pastures were represented. Aside from the prairie grasses, a total of 87 such species entered into the composition of these pastures. Average number of species occurring in pasture types 1 and 2 was 9; type 3 had 15; 18 were found in type 4; and 22 in the more degenerate type 5. Likewise, total number of species in types 1 to 5 were 25, 45, 72, and 59, respectively.

The great drought resulted in marked changes in types of pastures. Many moderately deeply rooted species, such as little bluestem, bluegrass, and others, suffered losses as great as 80 to 95 per cent. Only in the best pastures in the least drought-stricken region did much little bluestem remain, and bluegrass was nearly all killed in pastures west of the Missouri river. A tremendous increase in weeds and the spreading of grasses of a more drought-resistant type followed.

Sand dropseed rapidly increased from the status of an occasional invader to a species of major importance. From South Dakota to Kansas it spread so widely over thousands of pastures as to become a dominant or the dominant species. This drought-resistant grass withstands grazing well, has excellent seeding habits, and furnishes fairly large amounts of forage of moderate palatability.

Western wheat grass, formerly present in small amounts only, swept through pastures with astounding rapidity after 1934. It often replaced bluegrass on low ground and reclothed other areas where the former vegetation was killed by drought or buried by dust. It frequently replaced bluegrass in buffalo-bluegrass pastures and formed an upper layer in short-grass pastures from which stock had been removed because of drought.

Side-oats grama increased greatly during the drought. Blue grama and buffalo grass, which are even more drought-resistant, have not only spread widely from centers already established, but there has been a great eastward movement of these species along the whole western front of true prairie.

A scourge of weeds occurred over a period of two to several years in pastures greatly depleted by drought. Peppergrass, little barley, downy brome grass, horseweed, plantain, and Russian thistle were extremely abundant.

Ranges ungrazed during drought, because starving cattle had been shipped to other pastures, benefiting by local periods of rainy weather in the best drought years, made a remarkable re-

covery. Mats of short grasses 6 to 8 inches thick were produced. Stages in the reduction, by grazing, of the vegetation to normal conditions are described.

Since the several years of drought, the following pasture types are clearly distinguishable: bluestem or true prairie type, bluegrass, shortgrass, sand dropseed, and western wheat grass types. In addition mixed pasture types of side-oats grama, sand dropseed, and western wheat grass occur. These may or may not have an understory of short grasses. An additional common type is that of western wheat grass and short grasses. Salt grass forms a minor type in saline soil.

BIBLIOGRAPHY

- ALDOUS, A. E. 1930. Effect of different clipping treatments on the yield and vigor of prairie grass vegetation. *Ecol.* **11**:752-9.
- ALDOUS, A. E. 1935. Management of Kansas permanent pastures. *Kans. Ag. Exp. Sta. Bul.* **272**.
- ALDOUS, A. E. 1938. Management of Kansas bluestem pastures. *Jour. Amer. Soc. Agron.* **30**:244-53.
- ANDERSON, K. L. 1940. Deferred grazing of bluestem pastures. *Kans. Ag. Exp. Sta. Bul.* **291**.
- BISWELL, H. H., and J. E. WEAVER. 1933. Effect of frequent clipping on the development of roots and tops of grasses in prairie sod. *Ecol.* **14**:368-90.
- CARRIER, L., and K. S. BORT. 1916. The history of Kentucky bluegrass and white clover in the United States. *Jour. Amer. Soc. Agron.* **8**:256-66.
- CLEMENTS, F. E., and V. E. SHELFORD. 1939. *Bio-ecology*. John Wiley and Sons, New York.
- CRATTY, R. I. 1929. The immigrant flora of Iowa. *Ia. State Col. Jour. Sci.* **3**:247-69.
- FLORY, E. L. 1936. Comparison of the environment and some physiological responses of prairie vegetation and cultivated maize. *Ecol.* **17**:67-103.
- FROLIK, A. L., and F. D. KEIM. 1938. Common native grasses of Nebraska. *Neb. Ag. Exp. Sta. Circ.* **59**.
- HAYDEN, A. 1934. Distribution and reproduction of Canada thistle in Iowa. *Amer. Jour. Bot.* **21**:355-73.
- HOOVER, M. M. 1939. Native and adapted grasses for conservation of soil and moisture in the Great Plains and western states. *U.S.D.A. Farmers Bul.* **1812**.
- ROBERTSON, J. H. 1933. Effect of frequent clipping on the development of certain grass seedlings. *Plant Physiol.* **8**:425-47.
- SAMPSON, A. W. 1939. Plant indicators—Concept and status. *Bot. Rev.* **3**:155-206.
- SHIMEK, B. 1931. The relation between the migrant and native flora of the prairie region. *Univ. Iowa Stud. Nat. Hist.* **14**(2):10-16.
- UNITED STATES FOREST SERVICE. 1937. *Range Plant Handbook*. U.S.D.A.
- WEAVER, J. E., and F. W. ALBERTSON. 1936. Effects of the great drought on the prairies of Iowa, Nebraska, and Kansas. *Ecol.* **17**:567-639.
- WEAVER, J. E., and F. W. ALBERTSON. 1939. Major changes in grassland as a result of continued drought. *Bot. Gaz.* **100**:576-91.
- WEAVER, J. E., and F. W. ALBERTSON. 1940. Deterioration of midwestern ranges. *Ecol.* **21**:216-36.
- WEAVER, J. E., and F. W. ALBERTSON. 1940a. Deterioration of grassland from stability to denudation with decrease in soil moisture. *Bot. Gaz.* **101**:598-624.

- WEAVER, J. E., and T. J. FITZPATRICK. 1932. Ecology and relative importance of the dominants of tall-grass prairie. *Bot. Gaz.* **93**:113-50.
- WEAVER, J. E., and T. J. FITZPATRICK. 1934. The prairie. *Ecol. Mono.* **4**:110-295.
- WEAVER, J. E., and E. L. FLORY. 1934. Stability of climax prairie and some environmental changes resulting from breaking. *Ecol.* **15**:333-47.
- WEAVER, J. E., and W. W. HANSEN. 1939. Increase of *Sporobolus cryptandrus* in pastures of eastern Nebraska. *Ecol.* **20**:374-81.
- WEAVER, J. E., and G. W. HARMON. 1935. Quantity of living plant materials in prairie soils in relation to runoff and soil erosion. *Univ. Neb. Cons. and Surv. Div. Bul.* **8**.
- WEAVER, J. E., and V. H. HOUGEN. 1939. Effect of frequent clipping on plant production in prairie and pasture. *Amer. Midl. Nat.* **21**:396-414.
- WEAVER, J. E., L. A. STODDART, and W. NOLL. 1935. Response of the prairie to the great drought of 1934. *Ecol.* **16**:612-29.