Growth and Development of Northern Great Plains Species in Relation to Nitrogen Fertilization[1]

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Highlight

Four range sites were fertilized at three different rates of nitrogen. Grass and sedge species react differently to the nitrogen treatments with respect to leaf height growth and phenological development. Leaf height increases in the grasses are generally small at lower levels of nitrogen. The sagebrush (*Artemisia*) species increase markedly in height at all rates of nitrogen fertilization. Stalk heights in the grasses and forbs generally follow patterns of height increase similar to those of the leaves.

Phenological development of plant species is variously affected by the different rates of nitrogen on different range sites. Leaf-tip drying of grasses is greater on a given date on plots with no nitrogen early in the season than on plots with nitrogen fertlizer. A reversal of this situation occurs later in the season.

Native grassland generally is composed of many grass, sedge and forb species, each having a characteristic growth pattern unique to the individual species. The seasonal development of the grassland from beginning of growth in the spring through rapid early-season leaf growth, then stalk development and flowering, fruiting, and finally drying of leaves and stems and shedding of mature seed is a matter of common observation. However, very little is actually known of the overall development and characteristic growth patterns of individual species in the grassland as a whole.

Data pertaining to the effect of nitrogen fertlization on the growth, vigor, and development of native forage species are virtually nonexistent in the literature. Where growth and developmental data are available they generally relate only to one specific area or range site and do not include the species reaction in the presence of nitrogen fertilizer.

The role of nitrogen fertlization in the improvement of forage production on native rangeland in the Northern Great Plains has been reported by different investigators in recent years. In most of the studies reported thus far, the plant response has been measured in terms of increased production as determined by actual oven-dry plant material and included a number of grasses, sedges, and forb species. The development of a given individual grass, sedge, or forb species as observed in terms of leaf height and other phenological developments in the presence of applied nitrogen, remains nearly totally lacking. A study of these reactions by selected species has been carried out on a native grassland in western North Dakota in the presence of nitrogen fertilizer on a range site basis.

A nearly 50-year study concerned with the recording of phenological events in eastern North Dakota was reported by Stevens (1956). The study included average flowering dates of a wide variety of plants, together with their range of dates of observation in different years. He states that individual plants vary in time of flowering for reasons which usually are not evident, this being especially true of midsummer plants. He concluded that where data for several years are available differences of more than three days in flowering date from a previous calculation, based on a 10-year average, are seldom evident.

Budd and Campbell (1959) observed a grassland flora in a 2-mile transect near the Swift Current Experiment Station, Swift Current, Saskatchewan. They concluded that the date of range readiness in any year can be forecast by observing the date at which the crocus anemone (*Anemone patens*) blooms, and then protecting the range for an additional seven weeks or until Wood's rose (*Rosa woodsii*) commences flowering.

Short and Wolfolk (1956) employed plant vigor as a criterion of range condition. Bluestem wheatgrass (*Agropyron smithii*) plants growing within and outside of prickly pear clumps were studied on ranges in poor and good condition for a period of three years at Miles City, Montana. Data gathered during the study period indicate that plant vigor, as expressed by bluestem wheatgrass heights, varied with range condition, with protection afforded by prickly pear, and with yearly precipitation. Primarily, the study established the usefulness of vigor, as reflected by plant height, as a criterion for the appraisal or estimation of range conditions. Similar observations and conclusions were reported by Evanko and Peterson (1955) in southwestern Montana. Bredemeier (1958) studied thoroughly the phenological development of a number of range grasses throughout an entire year at North Platte, Nebraska. He found that the time of beginning of the grand period of growth is essentially the same for five phenologically different but major grass species on the site. Maximum elongation was attained by all five species at essentially the same time, the end of August.

Goetz (1963) characterized a native mixed grass prairie site near Dickinson, North Dakota as to species of plants present and their rates of growth and development over the 8-year period, 1955–1962.

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The data for the growing season of 1955–1958 were recorded by Whitman (1958) and incorporated into this study. The study showed that the actual growing period of grasses and sedges was of short duration, while the forb species had a growing and flowering period which included nearly the entire summer. Plant species were more vigorous on protected than unprotected plots.

Experimental Procedure

Site Description

This study was carried out in conjunction with a forage yield and botanical composition investigation of the effects of three different rates of nitrogen on four range sites (Goetz, 1968). The study was conducted on four representative range sites within a 35-mile radius of the Dickinson Experiment Station, Dickinson, North Dakota during the years 1964–1966. The four range sites represent four soil types of importance in this area and include sites with inherently high and low potential for production. The range sites are designated by the soil series names and will be thus referred to throughout this discussion. The soil types are the Vebar fine sandy loam (sandy site), Havre silt loam (loamy site), Rhoades silt loam (panspots), and the Manning silt loam (shallow site). The long-term precipitation at the Dickinson Experiment Station is 15.42 inches, of which approximately 75 percent is received during the active growing season.

The Vebar sandy loam is a soil developed from weathered weakly-cemented tertiary sandstone and is associated mainly with gently undulating to moderately steep topography. The site is situated on a gentle, southwest-facing slope and is heavily grazed in late fall of each year. The species of major importance in the study of the site are western wheatgrass (*Agropyron smithii*), needle-and-thread (*Stipa comata*), plains reedgrass (*Calamagrostis montanensis*), blue grama grass (*Bouteloua gracilis*), threadleaf sedge (*Carex filifolia*), and white sagebrush (*Artemisia ludoviciana*).

The Havre silt loam soil series comprises a deep, light colored alluvial soil occupying creek bottom floodplains. This range site is found extensively only in the Badlands, where it is used for both summer and winter grazing. The study site is being summer grazed and is in excellent range condition. The most important dominants and species studied of this site are western wheatgrass, plains reedgrass, green needlegrass (*Stipa viridula*) and dwarf sagebrush (*Artemisia cana*).

The Rhoades soil series is classed as a silty loam and designated as a Solonetz, high in sodium, with a near-impervious layer of dispersed clay particles in the profile varying in depth from the soil surface to approximately 20 inches. The grazing capacity of this site is considerably reduced by claypans and barren panspots which support little or no vegetation. The major dominant species of this site are western wheatgrass, blue grama, Sandberg bluegrass (*Poa secunda*), and brittle prickly pear (*Opuntia fragilis*).

The Manning silt loam is a soil type developed on a high river terrace underlain by a gravel layer at about 18–24 inches below the surface. The site is generally heavily grazed during the early summer months and is in low good condition. Dominant grasses, sedges, and forbs of major importance in this study are western wheatgrass, needle-and-thread, blue grama, threadleaf sedge, and fringed sagebrush (*Artemisia frigida*).

Experimental Design

The experiment was designed as a random block of three different nitrogen treatments and a check plot (no nitrogen) replicated four times. Individual plots measured 30 × 100 feet with 6-foot wide alleyways between replications. Treatments consisted of check plots, 33 lb, 67 lb, and 100 lb/acre elemental nitrogen. The nitrogen was applied in early April of each year. Three steel-wire quonset-type cages measuring 3 × 7 ft were placed on each plot of each treatment and site. Plants were selected and measured inside the steel-wire cages.

Growth Measurements and Phenological Data

Plant heights were determined by measuring leaves and stems of 20 plants of each major species on all treatments to the nearest 1 cm at approximate 7- to 10-day intervals during the season. Plants were measured inside the steel cages at the same location each time.

For species in which leaves and stalks were distinctly separate, leaf heights were measured from ground level to the tips of the extended leaves. In the case of the single-stalked species, such as western wheatgrass and plains reedgrass, where the leaves are attached to a culm, height measurements were made by extending the leaves upward in a vertical position and measuring from ground level to the apex of the uppermost leaf. The fruiting stalk measurements were begun immediately following evidence of thickening of culms, and stalk heights were measured from ground level to the tip of the stalk or to the tip of the inflorescence after it had developed.

Phenological observations of grass included dates of fruiting stalk initiation, anthesis, seed development, seed maturity, earliest observed date of seed shedding, and estimation of percentage of dry leaf in relation to total leaf area. For the forbs, only height measurements and dates of flowering were recorded.

Results and Discussion

Height Growth of Species in Re'ation to Fertlizer Treatment

In general, the grass and sedge species show some stimulation in leaf height growth from the fertilizer application (Tables 1–4). The degree of response varies greatly between species, site, season, and

Table 1. Three-year average leaf heights in cm of selected grasses and sedges at approximate 15-day intervals on four range sites with no nitrogen fertilizer (1964–1966).

Species	Site	April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	Maximum average height
Agropyron smithii	Vebar	4.5	6.4	12.0	15.0	16.6	22.6*	22.7*	22.8*	22.8*	22.8*	22.8*
	Havre	5.2	7.6	14.0	21.0	27.1	34.0	39.3	30.0	28.0	28.0	39.3
	Rhoades	3.9	4.7	8.6	9.0*	15.0*	18.6*	22.3*	22.3*	22.3*	22.3*	22.3*
	Manning	6.5	7.4*	11.0	15.0*	23.1*	26.1	30.2	30.1	29.8	29.8	30.3
Stipa comata	Vebar	2.5	4.0*	6.0*	9.0*	16.4*	19.9*	26.5*	26.5*	26.5*	26.5*	26.7
	Havre	2.9	5.1	11.0	16.0	21.3	23.6	28.7	26.0	24.5	24.5	28.9
	Manning	3.0	5.1*	11.0*	16.0*	21.3*	23.6*	28.7*	26.0*	24.5	24.5	28.9*
Bouteloua gracilis	Vebar	0.5	1.5*	2.5	4.5*	8.0*	10.1*	11.3*	11.6*	11.6*	11.5*	11.6*
	Rhoades	0.3	0.6	2.0	3.5	5.7*	7.3*	8.8*	9.1*	9.1*	9.1*	9.1*
	Manning	1.0	1.2	2.0	6.2*	7.5*	8.7*	11.9*	12.1*	11.9*	11.9*	12.1*
Stipa viridula	Havre	3.9	9.0	13.0	26.0*	36.8	43.8*	50.5*	45.0*	44.0	44.0	50.5*
Poa secunda	Rhoades	0.1	3.4	3.9	4.3	5.5*	7.1*	8.1*	8.1*	8.1*	8.1*	8.1*
Carex filifolia	Vebar	2.5	4.7	7.6*	11.0	14.4*	13.1	13.0*	13.0	13.0	13.0	14.5
	Manning	3.0	3.8	5.0	9.1*	11.7*	11.7*	11.6*	11.5*	11.5*	11.5*	11.8*
Carex eleocharis	Vebar	2.0	3.6	5.0	8.0	9.5	12.4*	12.9*	12.9	12.8	12.8	13.0
	Rhoades	2.0	3.6	5.3	6.4*	8.1*	8.3*	8.6*	8.6*	8.6*	8.6*	8.6*
	Manning	2.0	4.3	7.0	9.7*	10.8*	11.6	12.2	12.1	11.9	11.9	12.2

*Denotes significant differences between check plots and fertilizer treatments (33, 67, and 100 lb N/acre) at the 0.05 level.

amounts of applied fertilizer. Significant differences in average leaf heights between treatments were generally observed in mid or late May to the end of the growing season on all species.

Western wheatgrass was stimulated by all rates of fertilizer on all sites studied. The greatest maximum leaf heights of this species were recorded on the Havre site, while the lowest overall height measurements were observed on the Rhoades site. The leaf heights from the Manning site were intermediate between the Havre and Rhoades sites.

Blue grama grass shows increases in maximum leaf heights at all rates of nitrogen fertilizer. Maximum leaf heights for this species were observed on the Manning site, intermediate on the Vebar site, and lowest on the Rhoades site.

Needle-and-thread is present only on the Vebar and Manning sites. The response to nitrogen by this species is greatest at the 67-lb rate of application. Higher rates of application did not result in further increases in leaf height. Green needlegrass, which is present only on the Havre site, was stimulated at all rates of nitrogen fertilizer.

In general, the 33-lb nitrogen rate of application did not greatly increase the maximum leaf heights of any of the species observed (Table 2). An exception to this observation was noted with Sandberg bluegrass on the Rhoades site and threadleaf sedge on the Vebar site. Maximum leaf heights of most species were obtained at the 67-lb nitrogen application (Table 3). In most species the 100-lb nitrogen rate does not greatly increase leaf height growth beyond that observed at the 67-lb nitrogen application (Table 4). Maximum stalk height increases generally follow the same course as the leaf height increases at the different treatments and sites.

The forb species of the different range sites varied considerably with respect to height response with nitrogen fertilizer. The species responding most markedly at all rates of fertilization are fringed sagebrush and white sagebrush. Fringed sagebrush is the dominant forb of the Manning site and white sagebrush the dominant on the Vebar site. The sagebrush species generally increase significantly with each increase in fertilizer on these two sites. In addition to the marked height response by the sage species, profuse branching occurs with both species in the presence of the nitrogen fertilizer. A significant height increase of dwarf sagebrush was observed on the Havre site.

Phenological Development of Grasses and Sedges

The majority of the phenological developments of the various species are not appreciably affected by the different rates of nitrogen fertilization on most sites. Complete annual phenological data are on file in the Botany Department of North Dakota State University.

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Table 2. Three-year average leaf heights in cm of selected grasses and sedges at approximate 15-day intervals on four range sites fertilized at the rate of 33-lb nitrogen per acre (1964–1966).

Species	Site	April 15	April 30	May 15	May 31	June 15	June 30	July 15	July 31	August 15	August 31	Maximum average height
Agropyron smithii	Vebar	4.5	7.0	12.0	16.8	19.2	20.6*	22.6*	22.6*	22.6*	22.6*	23.0*
	Havre	3.0	7.2	14.0	23.0	26.7	32.8	44.0	39.0	37.0	38.0	44.1
	Rhoades	2.6	4.8	9.1	10.0*	16.7*	19.0*	21.9*	21.9*	21.9*	21.9*	21.9*
	Manning	6.5	7.3*	11.0	15.0*	24.0*	27.2	29.7	29.7	29.5	29.5	30.1
Stipa comata	Vebar	2.5	5.0*	7.0*	10.0*	19.1*	22.6*	26.9*	26.9*	26.9*	26.8*	27.0
	Havre	3.1	5.7	12.0	16.0	24.3	25.7	27.3	24.0	23.0	23.0	27.4
	Manning	2.5	3.7*	7.0*	13.7*	17.6*	19.5*	21.2*	20.4*	20.5	20.5	21.8*
Bouteloua gracilis	Vebar	0.5	1.3*	2.5	5.0*	8.3*	11.3*	9.9*	12.5*	12.5*	12.5*	12.5*
	Rhoades			2.0	3.5	5.3*	6.2*	9.0*	9.3*	9.3*	9.3*	9.3*
	Manning	1.0	1.7	2.9	4.5*	8.0*	9.6*	14.2*	14.7*	12.7*	12.7*	14.7*
Stipa viridula	Havre	4.9	9.3	14.0	28.0*	35.6	42.5*	56.2*	50.0*	48.0	49.0	56.3*
Poa secunda	Rhoades	0.1	3.4	4.1	4.5	6.3*	7.8*	8.8*	8.8*	8.8*	8.8*	8.8*
Carex filifolia	Vebar	2.5	4.6	6.0*	13.1	14.1*	16.9	13.9*	14.4	14.4	14.3	16.9
	Manning	3.0	3.3	6.9	8.6*	11.6*	12.1*	13.1*	12.1*	12.0*	12.0*	13.8*
Carex eleocharis	Vebar	2.0	3.2	7.5	9.9	12.6	7.4*	13.0*	13.0	13.0	13.0	13.2
	Rhoades	2.0	4.3	6.1	6.6*	8.5*	9.1*	10.0*	10.0*	10.0*	10.0*	10.8*
	Manning	2.0	4.0	7.0	9.4*	11.3*	12.3	13.8	13.1	12.8	12.8	13.8

*Denotes significant differences between check plots and fertilizer treatments (33, 67, and 100 lb N/acre) at the 0.05 level.

Table 3. Three-year average leaf height in cm of selected grasses and sedges at approximate 15-day intervals on four range sites fertilized at the rate of 67-lb nitrogen per acre (1964–1966).

Species	Site	April		May		June		July		August		Maximum average height
		15	30	15	31	15	30	15	31	15	31	
Agropyron smithii	Vebar	2.0	5.7	12.6	16.0	20.7	23.2*	23.9*	27.3*	27.9*	27.9*	27.9*
	Havre	4.4	8.3	15.0	21.7	31.1	36.0	41.5	41.9	35.9	35.9	41.9
	Rhoades	1.5	4.1	8.3	10.9*	17.2*	20.5*	25.0*	25.0*	25.0*	24.8*	25.0*
	Manning	6.5	8.0*	13.0	19.9*	26.3*	28.5	29.7	34.8	30.8	34.8	34.8
Stipa comata	Vebar	2.5	6.6*	8.0*	14.0*	21.2*	24.7*	28.6*	28.6*	28.6*	28.6*	29.1
	Havre	4.0	6.4	11.6	16.0	24.5	27.9	29.7	23.0	22.0	22.0	29.9
	Manning	2.5	3.8*	8.5*	14.1*	19.3*	21.7*	24.0*	27.5*	25.6	25.6	27.5*
Bouteloua gracilis	Vebar	0.5	1.3*	3.0	6.0*	9.6*	13.0*	15.5*	15.5*	15.5*	15.5*	16.3*
	Rhoades	0.1	0.5	2.0	4.0	6.3*	8.7*	11.8*	12.0*	12.0*	12.0*	12.0*
	Manning	1.0	1.0	3.9	5.2*	7.9*	11.7*	13.1*	16.5*	14.4*	14.4*	16.5*
Stipa viridula	Havre	5.6	9.7	14.0	29.0*	41.4	52.0*	59.9*	58.0*	58.0	58.0	60.0*
Poa secunda	Rhoades	1.2	3.9	4.4	5.0	6.5*	8.5*	7.7*	7.7*	7.5*	7.3*	9.6*
Carex filifolia	Vebar	2.5	4.9	8.0*	12.6	15.9*	13.4	16.5*	16.5	16.5	16.4	16.6
	Manning	3.0	3.7	7.3	10.0*	12.6*	13.1*	12.5*	12.7*	12.9*	12.9*	13.2*
Carex eleocharis	Vebar	2.0	5.0	9.0	10.0	11.6	13.9*	14.6*	14.6	14.6	14.6	14.6
	Rhoades	1.6	3.1	7.0	7.0*	8.8*	10.3*	10.5*	10.5*	10.4*	10.3*	10.9*
	Manning	2.0	4.5	7.0	9.0*	12.2*	13.5	13.9	13.7	13.6	13.6	14.2

*Denotes significant differences between check plots and fertilizer treatments (33, 67, and 100 lb N/acre) at the 0.05 level.

sites may be conveniently placed into three distinct groups by observing the phenological development of each species. The first group, including needleleaf sedge (*Carex eleocharis*), threadleaf sedge and Sandberg bluegrass, contains species which complete their growth cycles early in the season. The second group, comprising five cool-season species including western wheatgrass and needle-and-thread, is of major importance in the mixed grass prairie. This group develops somewhat later than the first group but earlier than the warm-season grasses. Other species in this group are plains reedgrass, prairie Junegrass (*Koeleria cristata*) and green needlegrass.

Blue grama and prairie sandreed (*Calamovilfa longifolia*) are the representatives of the warm-season grasses constituting the third group. Blue grama is the only warm-season shortgrass on any of the study areas and is of major importance as one of the dominant grasses in the mixed grass prairie. Phenological events in blue grama closely parallel those of other warm-season grasses, except for the drying of leaf tips, which occurs somewhat earlier.

Prairie sandreed is a warm-season tallgrass occurring only on the Vebar study area (Table 5). The course of growth of this species is extremely slow in early spring but becomes rapid as summer progresses. This species continues growth longer into the season than any of the other species studied on the range sites.

The species differed markedly from each other in time of occurrence of specific phenological events (Tables 5–8). This inherent difference among species is further accentuated by presence of nitrogen fertilizer. Perhaps the most interesting response by all grasses and sedges to the nitrogen fertilizer is the degree of leaf drying. Sandberg bluegrass, for instance, initiates its growth slightly later than the sedge species but reaches 25 to 50% dry leaf area by June 20 on the plots without nitrogen and approximately 20 days later on the heavily fertilized plots (Table 7). The sedges, however, attain 25 to 50% dry leaf area by approximately the same date (July 10) irrespective of fertilizer treatment (Tables 5, 7, and 8). Otherwise, the same grass species on all sites initiate leaf-tip drying at an earlier date and drying progresses more rapidly early in the season without nitrogen fertilization. However, as the growing season progresses a reversal of events occurs, the species on the plots at the higher rates of nitrogen fertilization reach the 50 to 75 or over 75% dry condition well in advance of the species with no nitrogen. Flowering dates and other phenological events vary widely with both site and fertilizer treatments.

Conclusions

Growth and development of individual grass, sedge, and forb species is variously affected by addition of nitrogen fertilizer. In general, all grass and sedge species increased in height growth with increase in applied nitrogen. The

Table 4. Three-year average leaf heights in cm of selected grasses and sedges at approximate 15-day intervals on four range sites fertilized at the rate of 100-lb nitrogen per acre (1964–1966).

Species	Site	April		May		June		July		August		Maximum average height
		15	30	15	31	15	30	15	31	15	31	
Agropyron smithii	Vebar	4.5	8.1	11.5	17.0	21.5	22.5*	31.7*	32.7*	32.7*	32.7*	32.7*
	Havre	5.1	8.8	15.0	24.0	29.6	37.5	44.7	44.9	44.0	43.1	44.9
	Rhoades	2.1	5.8	8.9	11.1*	17.6*	19.0*	25.8*	25.8*	25.8*	25.8*	25.8*
	Manning	6.5	8.3*	14.9	18.0*	27.1*	30.3	31.7	35.3	33.2	33.2	35.3
Stipa comata	Vebar	2.5	5.7*	8.0*	14.0*	22.5*	25.2*	27.5*	28.2*	28.2*	28.2*	28.2
	Havre	3.1	5.8	11.1	16.8	29.5	32.0	34.3	34.5	34.4	34.4	34.5
	Manning	2.5	3.5*	8.5*	11.0*	19.8*	23.2*	24.3*	26.5*	24.6	24.6	26.5*
Bouteloua gracilis	Vebar	0.5	1.5*	3.0	5.4*	9.8*	13.0*	15.8*	15.8*	15.7*	15.7*	17.8*
	Rhoades	0.1	2.0	4.0	6.7	9.1*	12.1*	12.1*	12.1*	12.1*	12.1*	12.4*
	Manning	1.0	2.3	4.1	5.5*	7.4*	12.1*	14.1*	18.4*	15.8*	15.9*	18.4*
Stipa viridula	Havre	5.3	9.7	14.0	30.0*	37.7	46.0*	59.0*	59.1*	59.0	59.0	59.1*
Poa secunda	Rhoades	1.6	3.9	4.5	5.0	7.5*	8.7*	9.2*	9.2*	9.1*	9.0*	9.6*
Carex filifolia	Vebar	2.5	5.5	8.0*	12.6	15.6*	13.1	15.9*	15.9	15.8	15.8	17.6
	Manning	3.0	3.7	6.5	10.8*	13.1*	13.8*	13.2*	13.7*	13.8*	13.8*	14.1*
Carex eleocharis	Vebar	2.0	4.3	7.0	9.2	11.8	9.2*	9.2*	9.2	9.1	9.1	13.3
	Rhoades	1.9	2.7	6.1	7.0*	10.0*	11.4*	12.4*	12.4*	12.3*	12.2*	12.4*
	Manning	2.0	4.0	7.0	10.7*	12.7*	14.3	15.1	15.1	15.1	15.1	15.3

*Denotes significant differences between check plots and fertilizer treatments (33, 67, and 100 lb N/acre) at the 0.05 level.

Table 5. Three-year average date of first observation of significant phenological events in grasses and sedges from the Vebar range site fertilized with nitrogen at the rates of 33, 67, and 100 lb/acre (1964–1966).

Species	Anthesis				Leaf tip drying				Leaves 0-25% dry				Leaves 25-50% dry				Leaves 50-75% dry			
	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100
Agropyron smithii	7/17	7/17	7/11	7/11	6/14	6/16	6/14	6/16	8/6	8/22	7/19	7/14				9/8	10/1	10/1	10/1	
Bouteloua gracilis	7/16	7/16	7/16	7/16	6/19	6/15	6/15	6/15	8/4	8/4	7/26	8/1	8/29	8/28	8/25	8/27	10/1	10/1		
Calamagrostis montanensis	6/29	6/29	6/22	6/26	6/8	6/22	6/13	6/15	7/16	7/22	7/19	7/19	8/25	8/25	9/8	9/8	10/1	10/1	10/1	10/1
Calamovilfa longifolia	7/20	7/20	7/17	7/23	6/13	6/13	6/21	6/15	7/22	7/22	7/17	7/17	9/11	9/5	9/5	9/5				
Carex eleocharis	5/4	5/4	5/4	5/4	6/1	6/5	6/15	6/15	6/15	6/14	6/13	6/15	7/3	7/3	6/26	7/3	7/25	7/21	7/22	7/22
Carex filifolia	5/4	5/4	5/4	5/4	6/5	6/5	6/2	5/18	6/19	6/14	6/11	6/20	6/30	7/13	7/13	7/13	7/27	7/27	8/1	8/1
Carex pennsylvanica		5/4			6/9	6/10	6/18	6/18	6/15	6/15	7/3	7/3	7/11	7/11	7/29	7/23	8/22	8/22	8/15	8/18
Koeleria cristata	6/24	6/21	6/24	6/18	7/3	6/28	6/28	6/29	7/27	7/24	7/22	7/28	9/9	8/22	9/9	9/9		10/1		
Stipa comata	6/26	6/19	6/30	7/3	6/25	6/15	6/10	6/10	8/19	7/21	8/1	7/18	9/9	9/9	8/21	8/21	10/1	10/1		

Table 6. Three-year average date of first observation of significant phenological events in grasses and sedges from the Havre range site fertilized with nitrogen at the rates of 33, 67, and 100 lb/acre (1964–1966).

Species	Anthesis				Leaf tip drying				Leaves 0-25% dry				Leaves 25-50% dry				Leaves 50-75% dry			
	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100
Agropyron smithii	7/11	7/12	7/22	7/22	6/10	6/11	6/26	6/26	7/9	7/31	7/31	7/31	9/7	9/7	9/9	9/9	10/1			
Bouteloua gracilis	7/23	7/23	7/27	7/27	7/10	7/6	7/7	6/22	8/14	8/14	8/30	8/16								
Calamagrostis montanensis	7/7	7/7	7/7	7/7	7/2	6/21	7/2	7/2	7/30	8/14	7/27	8/2	8/9	8/23	8/2	8/24				
Stipa comata	6/24	6/19	6/19	6/29	6/26	7/6	6/30	6/30	8/6	8/6	7/31	7/31	8/17	9/7	8/24	8/24	9/9	9/19	9/9	9/9
Stipa viridula	6/29	6/24	6/24	6/24	6/7	6/7	6/8	6/8	7/1	7/19	7/14	7/19	8/23	8/20	8/24	8/17	9/12			

Table 7. Three-year average date of first observation of significant phenological events in grasses and sedges from the Rhoades range site fertilized with nitrogen at the rates of 33, 67, and 100 lb/acre (1964–1966).

Species	Anthesis				Leaf tip drying				Leaves 0-25% dry				Leaves 25-50% dry				Leaves 50-75% dry			
	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100
Agropyron smithii	7/12	7/12	7/12	7/15	6/1	6/1	6/14	6/22	7/1	7/4	7/8	7/23	8/5	8/2	8/9	8/9	9/2	9/2	9/7	8/23
Bouteloua gracilis	7/18	7/16	7/15	7/18	6/16	6/16	6/16	6/16	7/31	8/1	7/18	8/7	8/20	8/20	9/11	9/11	9/9	9/9		
Carex eleocharis	5/5	5/4	5/4	5/30	5/22				6/6	6/8	6/9	6/8	6/28	6/16	7/7	6/24	7/27	7/13	7/27	7/27
Koeleria cristata	6/24		6/24		7/7				7/18	7/7	6/11	7/7	8/25	8/25	8/25	8/25				
Poa secunda	6/21	6/8	6/21	6/21	6/10	6/12	6/12	6/12	6/14	6/4	6/29	7/5	6/18	7/10	7/12	7/7	7/6	7/6	7/16	7/16

Table 8. Three-year average date of first observation of significant phenological events in grasses and sedges from the Manning range site fertilized with nitrogen at the rates of 33, 67, and 100 lb/acre (1964–1966).

Species	Anthesis				Leaf tip drying				Leaves 0-25% dry				Leaves 25-50% dry				Leaves 50-75% dry			
	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100	0	33	67	100
Agropyron smithii	7/17	7/17	7/17	7/17	6/7	6/7	6/7	6/7	7/31	7/31	7/25	7/25			9/9	8/29	10/1	10/1	9/25	9/9
Bouteloua gracilis	7/20	7/20	7/20	7/20	6/22	6/22	6/20	6/29	8/6	8/6	7/28	7/31	9/6	9/5	8/25	8/25	9/9	9/9	9/9	9/9
Calamagrostis montanensis	6/18	6/18	6/18		6/9	6/9	6/9	6/9	7/13	7/25	7/11	7/11	9/9	10/1	9/9	9/9	10/1		10/1	
Carex eleocharis	5/5	5/5	5/5	5/5	5/31	5/26	5/22	5/21	6/7	6/7	6/7	6/7	6/30	6/30	7/6	7/13	7/13	7/27	7/27	7/27
Carex filifolia	5/5	5/4	5/4	5/4	5/26	5/26	5/22	5/21	6/9	6/7	6/7	6/7	7/30	7/7	7/1	7/13	7/31	7/17	8/6	8/13
Koeleria cristata	6/23	6/23	6/21	6/23	6/24	6/24	6/24	6/26	7/27	7/27	7/27	7/27				10/1				
Stipa comata	7/6	7/6	7/6	7/17	6/7	6/7	6/15	6/7	8/11	8/12	8/15	7/25	8/15	8/15	8/9	8/29	10/1	10/1		9/9

degree of response, however, varies with species, season, and range site. Range site appeared to be one single most important factor determining degree of response to added nitrogen by any one species. Western wheatgrass was the most important cool-season dominant on the Havre, Rhoades and Manning sites. Leaf height response was evident at all levels of fertilization increasing from the 33 to the 100-lb nitrogen application. The apparent vigor of this species was greatly enhanced by the additional available nitrogen. The greatest response to the nitrogen fertilizer occurred at the 67-lb nitrogen rate.

Blue grama, the shortgrass, warm-season dominant of the Vebar, Rhoades and Manning sites showed a high leaf height response, hence vigor, to the applied nitrogen. In most instances a 40 to 50% height increase was apparent at the high rates of fertilization. The greatest increase was also at the 67-lb nitrogen treatment with only a slightly higher response observed at the 100-lb nitrogen treatment.

Some of the other species, such as the sedges, showed varied responses to the nitrogen, generally increasing the plant height rapidly early in the season with each added increment of nitrogen but markedly decreasing in growth rate at the higher rates later in the summer months. The needlegrasses, needle-and-thread and green needlegrass, showed definite upper limits to nitrogen tolerance, generally reaching optimum growth at the 67-lb nitrogen rate. The forbs, mainly the *Artemisia* group, showed height increases at all rates of nitrogen fertilization.

Phenological events of all species, other than growth, show a wide range of response to applied nitrogen on all sites. Perhaps the most important observation is the degree and time of leaf drying of the grasses and sedges. The degree of early leaf drying, in the presence of adequate soil moisture, is appreciably delayed at the higher levels of fertilization but becomes more rapid later in the growing season.

An adequate knowledge of the reaction of individual species in terms of leaf height or vigor is important in range fertilization. A manipulation of the time, site, and amount of nitrogen to apply on a given native grassland site is of paramount importance in achieving maximum utilization and benefits from grazing livestock. The phenological development of the different species must be known in order to be able to predict species reaction and to manage a grazing system in accordance with these reactions.

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