Growth Rate of Mixed Prairie in Response to Nitrogen and Phosphorus Fertilization

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Highlight: *Earlier initiation of spring growth and increased dry matter production of mixed prairie are important to the livestock industry, particularly in the northern Plains where the winter feeding period is often prolonged. The effect of N and P levels on growth rate and production of mixed prairie was studied over an 8-year period at the Northern Great Plains Research Center near Mandan, North Dakota. Annual application of N had no effect on growth rate prior to May 1; however, during the May 1–May 15 period, and during each successive growth period, rate of growth increased as N level increased up to 160 lb elemental N/acre (160-N). By May 15, plots receiving 40-N produced more dry matter than did plots without N by June 1. As the season progressed, the production lag of the nonfertilized plots became greater. The yield level reached on June 15 by plots receiving 40-N was not attained by the 0-N plots until July 15. Yield levels reached by fertilized plots on July 1 were never attained by nonfertilized plots.*

Dry matter production can be increased by application of N or N + P fertilizer to mixed prairie in many areas of the northern plains of the United States and in the prairie provinces of Canada. The cool-season species found in the mixed prairie begin growth early in the spring, a time when low soil temperature restricts natural nitrification processes. Therefore, response to fertilizer N early in the growing season is sizeable, even on soils relatively high in total N. The significant interaction between N level and harvest date reported by Lorenz and Rogler (1973) indicates that spring growth can be stimulated by application of fertilizer N. Earlier initiation of spring growth and accelerated growth rate early in the season following application of N have been observed by others (Rogler and Lorenz, 1957 and 1965; Johnston et al., 1967).

The relative growth rate of above-ground portions of the plant, particularly early in the season, is of considerable importance to total dry matter accumulation for the season. Livestock are often allowed to graze mixed prairie early in the spring before the plants have made enough growth to provide both photosynthetic tissue for continued optimum plant growth and forage for grazing livestock. Therefore, any practice capable of increasing early spring growth rate will be important. This study was initiated at the Northern Great Plains Research Center, Mandan, N. Dak., to evaluate the influence of N and N + P fertility level on spring growth rate, and to determine the proportion of the growth above and below a 1-inch height of harvest.

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Study Area and Procedure

The study area was selected for uniformity of topography, slope, and vegetative cover on a nearly level site located on the Missouri Plateau west of the Missouri River near Mandan, N. Dak. The soil series is Temvik. The vegetation is mixed prairie with western wheatgrass (*Agropyron smithii* Rydb.) and needleandthread (*Stipa comata* Trin. & Rupr.) the dominant cool-season midgrass species and blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) the dominant warm-season shortgrass. Threadleaf sedge (*Carex filifolia* Nutt.), sun sedge (*Carex heliophila* Mack.) and prairie junegrass (*Koeleria cristata* (L.) Pers.) are also important cool-season species.

The 1915–1971 average annual precipitation at the Northern Great Plains Research Center is 15.88 inches; the average annual growing season (April to August) precipitation is 11.21 inches.

The change in growth rate of mixed praire following fertilization was evaluated by comparing dry matter yields obtained by harvesting seven sets of plots, one each on each of seven consecutive dates each year for 8 years (1958-1965).

Table 1. Dry matter yield (lb/acre) of mixed prairie on successive harvest dates when cut at 1-inch height in each of 8 years, and the increase in dry matter (lb/acre) on each successive harvest date.

Harvest date	Yield[1]									Average increase/period	
	1958	1959	1960	1961	1962	1963	1964	1965	Avg	Amount	Percent
May 1	98	16	15	[2]	[2]	63	[2]	[2]	24	–	–
May 15	174	69	52	38	241	167	207	167	139	115	479
June 1	425	104	284	142	529	515	285	424	338	199	143
June 15	802	233	536	170	1379	745	348	882	637	299	88
July 1	1227	490	1213	306	2222	1566	987	1537	1194	557	87
July 15	1598	521	1856	333	3416	1391	1834	1914	1608	414	35
August 1	1496	479	1621	416	4157	1356	1838	2180	1693	85	5
LSD 0.05	103	53	140	32	224	80	108	127	70		
0.01	136	70	185	42	297	106	143	168	93		

[1] Each value is the average of six fertilizer treatments replicated three times.
[2] Not enough growth for harvest on May 1.

Harvest dates were the first and 15th of each month, beginning with May 1 and concluding with August 1. Fertilizer treatments included in each set of plots were 0, 40, 80, and 160 lb elemental N/acre (0-N, 40-N, 80-N, and 160-N) without P, and 0-N and 80-N each with 18 lb elemental P/acre (0-18 and 80-18). Fertilizer was applied on November 3, 1957, and in October each year thereafter through 1964. Ammonium nitrate was the source of N and treble superphosphate was the source of P.

The experimental design was a randomized block replicated three times. Plot size was 6 x 20 ft; a 3- x 20-ft swath was cut from each plot at a height of 1 inch. In addition to the mower harvest, three 1- x 2-ft areas were clipped at the soil surface in an unmowed area of each plot. A record of these surface-harvest areas was maintained to prevent use of the same area more than once in either the 1958-60 period or in the 1963-65 period. Harvest at the soil surface was omitted in 1961 and 1962 to allow a longer period between repeated use of the surface-harvest areas.

All dry matter produced above the 1-inch height can be assumed to be available for management in a grazing system. Total dry matter production as measured by harvest at the soil surface can be used in considering treatment effects on plant growth.

Results and Discussion

Production varied considerably from year to year, primarily in response to precipitation. Yields were extremely low in 1959 and 1961, 2 years in which precipitation was nearly 4 inches below the 1915-1971 average. Unusually high yields in 1962 and 1965 reflect timely May and June rains in 1962 and above average precipitation in 1965. Yields reported herein were obtained during an 8-year period in which precipitation ranged from 3.9 inches below to 7.5 inches above the long-time average. In 3 of the 8 years, precipitation was within ± 1 inch of the long-time average.

During the 8-year period, yields from harvest at 1-inch height were lowest in 1961 and highest in 1962, the 2 years in which harvest at the soil surface was omitted. Thus, the 6-year averages for the surface harvest data lack the effects of these 2 years. In summarizing any data in which surface and 1-inch harvest yields are compared, 1961 and 1962 have been omitted from the 1-inch harvest data.

Seasonal Growth Pattern

The yields obtained on each harvest date when cut 1 inch above the soil surface and the average increase in dry matter since the previous harvest date are shown in Table 1. The values for each of the 8 years are the average of all fertilizer treatments on each date. In 4 out of the 8 years, there was not enough growth on May 1 to permit harvest. By May 15, yields averaged 139 lb/acre, 5.8 times the May 1 yield. May 1 to May 15 was the period of greatest yield increase on a percentage basis, but the actual yield increase was only 115 lb/acre. Percentage increase in dry matter decreased for each successive growth period, but the increase in weight was larger for each successive period through the June 15-July 1 period.

Average of all fertilizer treatment yields obtained on each

Table 2. Dry matter yield (lb/acre) of mixed prairie on successive harvest dates when cut at the soil surface in each of 6 years, the average increase in dry matter (lb/acre) on each successive harvest date, and the average dry matter production (lb/acre) below 1 inch.

Harvest date	Yield[1]							Average increase/period		Production below 1 inch[3]	
	1958	1959	1960	1963	1964	1965	Avg	Amount	Percent	Amount	Percent
May 1	863	663	665	722	[2]	[2]	486	–	–	454	93
May 15	764	925	874	961	1156	1117	966	480	99	827	86
June 1	1345	957	1313	1684	1382	1400	1347	381	39	1007	75
June 15	1616	1492	1592	1933	1489	2023	1691	344	26	1100	65
July 1	2072	1855	2472	3266	2597	2927	2532	841	50	1362	54
July 15	2299	1706	3101	2866	3132	3234	2723	191	8	1204	44
August 1	2404	1503	2675	2637	3089	3440	2625	–98	–4	1130	43
LSD 0.05	187	117	179	170	184	190	103				
0.01	248	155	238	224	245	253	137				

[1] Each value is the average of six fertilizer treatments replicated three times.
[2] Not enough growth for harvest on May 1.
[3] Based on 1-inch harvest yields without the 1961 and 1962 data.

date of harvest in each of 6 years and the average increase in dry matter since the previous harvest date for the surface harvest data are shown in Table 2. In most years, highly significant yield increases occurred between each successive date of first harvest through July 15. Total yield obtained by harvest at the soil surface increased rapidly in May and June, and the maximum yield was obtained in July or August of each year, followed by a significant dry matter loss in 3 out of the 6 years. The period of most rapid growth was between June 15 and July 1 in 5 of the 6 years. The increase in dry matter for this period averaged 841 lb/acre, and ranged from 363 lb/acre in 1959 to 1333 lb/acre in 1963. During this period, climatic factors are favorable for growth of both the cool-season and warm-season species.

The increase in dry matter weight for each period up to July 1 was much larger for the yields obtained by harvest at the soil surface (Table 2) than it was for the yield above 1 inch (Table 1), but the percentage increase was always greatest for the production above 1 inch. Excluding 1961 and 1962, the average dry matter yields above 1 inch become 32, 139, 340, 591, 1170, 1519, and 1495 lb/acre for the seven harvest dates, respectively. New growth below 1 inch for each of the seven growth periods is then 373, 180, 93, 262, -158, and -74 lb/acre, respectively. As would be expected, most new growth is below 1 inch early in May. The reduction in weight of dry matter (negative values for new growth) below 1 inch after July 1 can be attributed to dropping of the lower leaves and to physiological factors not measured in this study.

Fertilizer and Growth Rate

The effect of the fertilizer treatments on the 6-year average forage production as measured by harvest at the soil surface is shown in Figure 1. Differences between treatments were very small on May 1. The increase in rate of growth due to N fertilization was evident by May 15. As N level increased through the 80-N level, the magnitude of the increase became greater. A period of rapid dry matter increase occurred between June 15 and July 1, in which the 80-0 treatment produced a greater yield increase than did the 40-0 treatment. This was also true for the July 1 to July 15 period. This reduced growth rate indicates that the 40-N level was not adequate for maintaining optimum growth throughout the season. Plots receiving the 80-18 treatment produced significantly more than did those receiving the 80-0 treatment for all periods after June 1. There was no significant difference between the 0-0 and the 0-18 treatment yields, and often the differences between the 80-0 and 160-0 treatment yields were not significant. However, application of 18-P with 80-N produced a highly significant yield increase over the 160-0

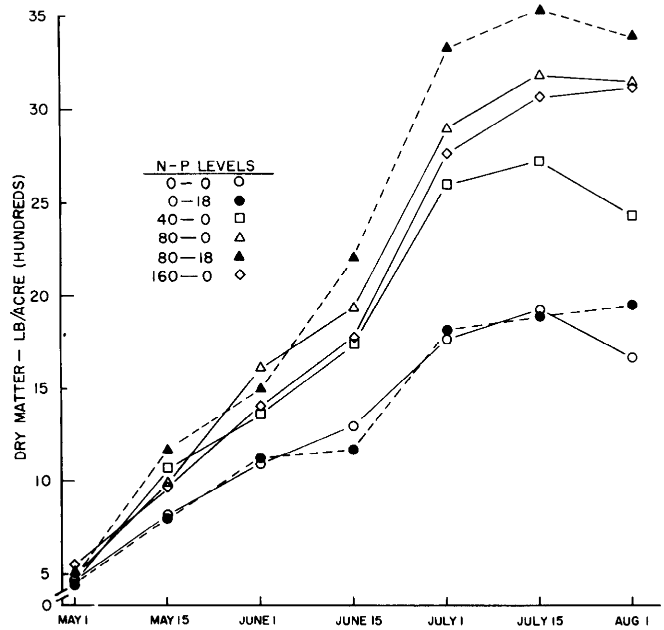

Fig. 1. *Effect of fertility level on 6-year average dry matter production of mixed prairie when cut at the soil surface on successive dates during the growing season.*

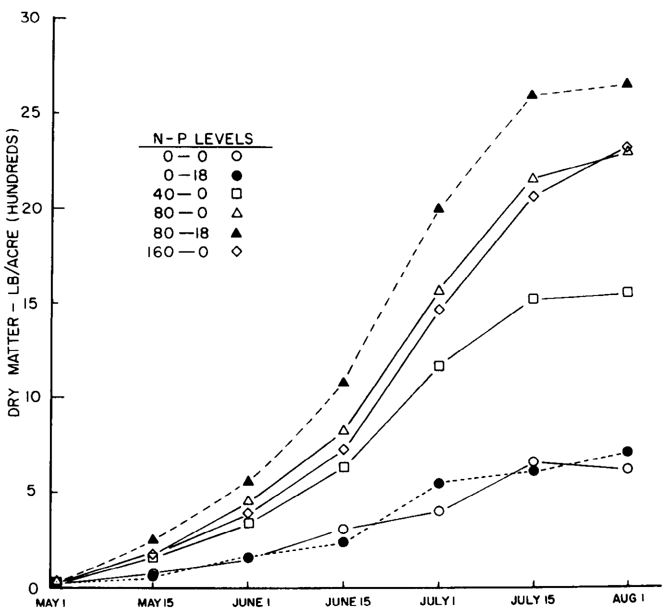

Fig. 2. *Effect of fertility level on 8-year average dry matter production of mixed prairie when cut at 1-inch height on successive dates during the growing season.*

Table 3. Six-year average daily increase in dry matter (lb/acre) produced by mixed prairie when fertilized with various levels of N and P.

	Average daily increase or decrease in dry matter											
	Total production						Production above 1 inch					
Growth period	0–0	0–18	40–0	80–0	80–18	160–0	0–0	0–18	40–0	80–0	80–18	160–0
May 1–May 15	24	22	41	32	45	28	2	2	8	8	13	10
May 15–June 1	18	22	19	42	22	29	6	7	12	19	20	17
June 1–June 15	14	3	27	21	48	24	10	5	17	21	28	18
June 15–July 1	32	43	56	65	75	66	6	20	37	54	62	52
July 1–July 15	10	5	8	19	14	20	17	3	18	30	36	36
July 15–August 1	−17	5	−19	−2	−9	4	0	3	−5	3	−20	5
May 1–August 1	13	16	21	29	32	28	6	7	14	22	23	22

treatment, indicating that inadequate P was limiting growth at the high N level.

The 8-year average dry matter yields for each fertilizer treatment on each harvest date when cut at the 1-inch height are shown in Figure 2. There was no yield increase from fertilizer application for the May 1 harvest,but for each harvest after May 1, response to N and to P at the 80-N level was sizeable and highly significant. The effect of N on growth was evident by May 15 of each year. In only 2 out of 8 years did May 15 yield above 1 inch exceed 100 lb/acre for the 0-N plots, while yields from plots receiving N exceeded 100 lb/acre on this date in all but 2 years, and averaged 181 lb/acre over the 8-year period. The 40-0 treatment yields averaged 91, 182, 332, 770, 862, and 925 lb/acre more than did those of the 0-0 treatment on the six harvest dates, May 15 through August 1, respectively. The increase in manageable forage (above 1 inch) ranged from 108 to 193%. Thus, 40-N more than doubled dry matter above 1 inch on each harvest date during the season and almost tripled it by July 15. Plots receiving 80-0 produced 98, 304, 519, 1,179, 1,490, and 1,678 lb/acre more on these six harvest dates, respectively, than did plots receiving no fertilizer. The increases ranged from 163 to 295%. Plots receiving 160-0 produced 108, 237, 416, 1,070, 1,399, and 1,696 lb/acre more on the six harvest dates, respectively, than did plots receiving no fertilizer. These yield increases were not significantly different from those of the plots receiving 80-0, consequently the percent increase over the check on each harvest date was about the same for the 160-0 and 80-0 treatments.

Of particular interest is the fact that yield above the 1-inch height from plots receiving 40-N averaged 150 lb/acre on May 15, while it was not until June 1 that plots without N reached this yield level. As the season progressed, the production lag of the nonfertilized plots became greater. The yield level reached on June 15 by plots receiving 40-N was not attained by the 0-N plots until July 15. Yield levels reached by fertilized plots on July 1 were never attained by nonfertilized plots.

Fertilizer and Daily Dry Matter Increase

The rate of increase in total dry matter is indicative of plant vigor. Large increases on a daily basis reflect rapid increase in leaf area, which enables the plant to maintain a satisfactory growth rate in spite of partial defoliation by grazing. The daily increase in dry matter, combined with other management considerations, provides a guide to grazing capacity of mixed prairie during each portion of the growing season. Application of N increased total daily dry matter production for each period between May 1 and July 15 (Table 3). After July 15, total dry matter often decreased. The increase was highly variable between treatments and from year to year.

The effect of N on daily increase in dry matter above the 1-inch height is also shown in Table 3. During May, daily increase in dry matter was from 2 to 6.5 times greater with N than without. During June and July the relative increase was somewhat less, but the actual weight of the increase was considerably larger than it was in May.

Fertilizer and Production Below 1 Inch

Whether grazing intensity is regulated by height of remaining stubble or by percent of the total production remaining, the amount of photosynthetic tissue at any given time will determine plant vigor under specific growing conditions. The data presented allow calculation of the percent of the production below 1 inch on specific dates. On the average, the percentage of the total dry matter below 1 inch decreased steadily throughout the season, beginning with 93% on May 1 and ending with 43% on August 1 (Table 2). A summary of the data for each fertility level on each date of harvest is shown in Table 4. On May 1 the percent dry matter below 1 inch was about the same for all fertilizer levels; all were 95% or more. By May 15, the range was from 81% for the high fertility levels to 92% for the nonfertilized treatment. As the season advanced, the percent dry matter below 1 inch decreased, but the difference between fertilizer levels increased. In all cases, the percent below 1 inch was lowest for the 80-0, 80-18 and 160-0 treatments and the highest for the 0-0 and 0-18 treatments. Removal of forage to a given height would therefore remove a far greater percentage of the total above-ground portion of the plant when fertilizer was used than it would when no fertilizer was used.

Table 4. Percent of the forage yield of mixed prairie vegetation found below 1 inch on each harvest date when fertilized with various levels of N and P. Values are 6-year averages.

Harvest date	Dry matter below 1 inch					
	0–0	0–18	40–0	80–0	80–18	160–0
May 1	97	97	96	95	95	96
May 15	92	93	86	85	81	81
June 1	87	86	77	74	64	70
June 15	77	80	68	62	58	62
July 1	77	70	57	47	44	47
July 15	67	69	50	38	34	37
August 1	68	71	46	38	40	36

Two factors account for most of the change in proportion of the dry matter below 1 inch with increase in fertility level: (1) increased height of individual plants in response to fertilizer, and (2) reduction of basal cover of the shortgrass, blue grama, while the single-stemmed midgrass, western wheatgrass increased per unit area as N level increased (Lorenz and Rogler, 1972). Guidelines for grazing intensity based on either stubble height or percent of total production will have to take into account the effect of fertilizer on plant response if vigor and sustained production are to be maintained. Change in growth habit of the plants must be considered in evaluating the effects of grazing pressure on fertilized mixed prairie. The combination of cool-season and warm-season species provides more nutritious forage for season-long grazing than does either type alone. Therefore, management practices which will allow use of fertilizer to increase production without the loss of blue grama must be developed.

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