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Influence of Nitrogen on Seasonal Production of Dry-Matter and Nitrogen Accumulation From Meadows[1]

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SYNOPSIS. Difference in dry-matter yields among plots given different levels of N fertilizer gradually increased to a maximum at time of maximum yield. The time of maximum yield occurred later in the growing season on plots fertilized with N than on unfertilized plots. During early stages of growth the internal concentration of N in herbage increased with each increment of applied N. The rate of dilution of internal N increased with increasing levels of applied N.

OPPORTUNITIES for increasing dry-matter production from grass swards with N fertilizer have been amply illustrated (5, 9, 13, 14). Native meadows respond to N in much the same manner as pure grass stands (2, 10, 11, 17), but they may contain appreciable quantities of rushes (*Juncus* spp.) and sedges (*Carex* spp.) in association with native grasses.

The N content of herbage has generally been found to increase with increasing levels of N fertilizer (5, 9, 14, 17). But hay from eastern Oregon meadows fertilized with N usually has a N content comparable to herbage from unfertilized meadows or slightly less. This was true even at high levels of application, such as 600 pounds of N per acre (11).

The low N content in herbage from fertilized meadows was inferred to be the result of late harvesting relative to maturity of the herbage because the N content is known to decrease when harvest is delayed beyond maturity (1, 3, 7, 8). Workers in South Africa attributed this to the translocation of N to the roots (15). However, if the N content in herbage increases with increasing levels of applied N before maturity, the previous hypothesis implies that the rate of decrease of N content after maturity is greater with increasing concentrations of N in the forage. Verification of this implication could not be found in the literature.

The percent of applied N recovered in the harvested herbage varies widely (9, 12, 14). Recoveries of 50 to 70% are common for a single harvest, and values of over 100% have been reported for multiple harvest during the same growing season (4). N recovery from native meadows usually ranges from 20 to 33%. The low recovery is partly a reflection of the low N concentrations in the herbage at time of harvest.

The objective of these studies was to determine the effects of level of N fertilizer on seasonal patterns of dry-matter production and N accumulation from meadows.

METHODS AND PROCEDURE

The Squaw Butte experimental meadows lie in the flood plain of the Silvies River at an elevation of 4200 feet. They are irrigated by diverting water from natural or artifical channels and flooding it across the fields. Water is usually on the meadows for 8 to 12 weeks but the flooding period varies widely from year to year. There is little downward movement of water through the soil horizon during the irrigation season because of a high water table. Often the water table is above the soil surface. The experimental plots were located on areas with shallow depths of surface water to facilitate harvesting. Surface water disappeared in early June.

Vegetation on the experimental sites was composed largely of rushes (*Juncus* spp.), sedges (*Carex* spp.), meadow barley (*Hordeum brachyantherum* Nevski), Nevada bluegrass (*Poa nevadensis* Vasey ex Schribn.), and beardless wild-rye (*Elymus triticoides* Buck.). Experimental locations were moved each year to eliminate cumulative effects of clipping and fertilizer. Mineral elements other than N appear to be adequate for maximum yields from rush-sedge-grass meadows.

On April 12, 1960, 0, 80, 160, 240, 320, and 400 pounds of N per acre as ammonium nitrate were broadcast on plots 3 feet wide and 80 feet long. Six dates of harvest (May 4, May 18, June 6, June 15, June 29, and July 13) were assigned at random to 3 by 13-feet subplots in strips across all N levels. With 4 replications this required 144 plots. The experimental design was a strip-plot variation of the split-plot. Herbage samples were obtained from a strip through the center of each subplot with a 20-inch sickle-bar mower designed to be carried from the shoulder. Individual plots were 1/2000 of an acre and the height of cut was approximately 1 inch above the soil surface. When the quantity of herbage present was sufficient to be sampled, regrowth was harvested on July 13 (the last harvest date) from previously clipped plots.

On April 15, 1961, 0, 80, 160, and 240 pounds of N per acre as ammonium nitrate were applied to 6- by 20-feet plots in factorial combination with 12 dates of harvest (weekly intervals beginning May 10 and ending July 26). With 4 replications this required 192 plots. Herbage samples were obtained by harvesting a strip of forage 38 inches wide through the center of the plot with a sickle-bar plot mower. Height of cut was about 1½ inches above the soil surface. When the quantity of herbage present was sufficient to be sampled, regrowth was harvested on July 26, the last harvest date, from previously clipped plots.

Subsamples were removed from yield samples in 1960 and 1961, dried in forced air ovens at approximately 160° F. for dry matter determination. The samples, after equilibrating with the moisture in the air, were ground and analyzed for N content by the standard Kjeldahl method. Yields were reported on a dry-matter basis. N content was reported from samples which were 95% dry-matter when dried at 105° C.

The clipped herbage from all plots was carefully raked by hand and weighed. It was thought that this procedure would adequately collect any plant parts that might have shattered and fallen before clipping with the exception of seed and small plant fragments.

RESULTS

Dry-Matter Production

Initial crop. Yields of dry-matter in 1960 were significantly affected by date of harvest and level of N fertilizer. The date of harvest × level of N interaction was significant. Dry matter increased with time throughout the growing season and increased with increasing levels of applied N up to 240 lb. N/acre (Table 1). Fertilizer had not increased yields of dry matter on May 4 and May 18, but yields were significantly higher from fertilized plots by June 6. As the season progressed the difference in yields among levels of N became progressively larger.

The 1960 data were neither extensive enough to include the entire seasonal production of dry matter nor intensive enough to adequately measure growth patterns at each level of N. More thorough sampling in 1961 showed again that yields were significantly affected by date of harvest, level of N fertilizer, and the date of harvest by level of N interaction (Table 2). Yields, averaged for level of N, increased

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Table 1. Seasonal production of dry matter from meadows fertilized with 6 levels of N, 1960.

Date of harvest	Yield, lb./acre						
	Pounds of N applied per acre						Mean
	0	80	160	240	320	400	
May 4	660	820	980	980	860	800	860
May 18	2000	2260	2580	2740	2580	2820	2500
June 6	2860	3960^{a}	4660^{ab}	5280^{bc}	6000^{c}	5340^{bc}	4680
June 15	3200	5060	5460	6380	6760	7360	5700
June 29	3880	4980	6140	7280	7440	7280	6160
July 13	5020	5860	7220	8120	8540	9240	7320
Mean	2940	3820	4500	5120	5360	5480	

Values underscored by the same line or designated by the same superscript letter are not significantly different from each other at 5% level.

with time until July 12, decreased slightly on July 19, and showed no further change on July 26.

N fertilizer had no significant effect on yields until May 24 but thereafter differences in yields among levels of N became progressively larger.

Fertilizer also extended the period of production later into the season. Dry-matter production ceased on June 28 without N but continued until about July 12 with 160 and 240 lb. N/acre (Table 2).

Regrowth. Dry-matter yields of regrowth herbage were significantly affected by date of harvest of the initial crop, level of N fertilizer, and the date of harvest by level of N interaction. The 1961 data are shown in Table 3.

N fertilizer increased yields when the initial crop was harvested early, but the effect of N on yields gradually diminished with each successive week of delay of the initial harvest. Regrowth yields decreased at the rate of 488 lb./acre/week of delay of the intial harvest when averaged for levels of N. This rate of decrease was nearly linear until late in the growing season. Little regrowth was produced when the initial clipping was June 15 or later.

Total dry-matter production. Total yields (initial crop+regrowth) were greatest with a single harvest at time of maximum production (Figure 1). However, this was not true at all levels of N in 1961, which resulted in a significant ($P=.05$) date of harvest by level of N interaction (this interaction was significant at $P=.25$ in 1960). Without fertilizer, several of the 2-harvest combinations yielded as much as a single harvest at the time of maximum yields (Figure 1). Averaged for all levels of N, yields declined with each harvest date of the initial crop prior to maximum yields.

Yields obtained in 1960 were considerably higher than those in 1961. This was attributed to a lower height of cut in 1960, higher levels of N application and location.

Nitrogen Content

Initial crop. The N content of the herbage followed similar patterns in both 1960 and 1961. Therefore, only the 1961 data were presented because they encompassed more of the growing season.

N content of the herbage increased with increasing levels of N fertilizer early in the season; however, it was impossible to distinguish statistically any difference in N content of herbage harvested June 14 or later regardless of fertility treatment (Figure 2). After June 21 the N content was actually lower in herbage from fertilized plots than in that from unfertilized plots (Figure 2). Averaged for all levels of N, the rate of decline in N content was 0.13% N/week.

Regrowth. The concentration of N in regrowth herbage harvested in 1960 was not measured. In 1961 N concentration in regrowth herbage harvested July 26 increased

Table 2. Seasonal production of dry matter from meadows fertilized with 4 levels of N, 1961.

Date of harvest	Yield, lb./acre				
	Pounds of N applied per acre				Mean
	0	80	160	240	
May 10	80	89	114	123	102^{a}
May 17	163	253	366	414	299^{a}
May 24	507	884	1160	1310	965
May 31	791	1270	1910	1920	1470
June 7	947	1560	2240	2820	1890
June 14	1420	2130	2620	2990	2290
June 21	1960	2330	3120	3510	2730
June 28	2020	2720	3380	3830	2990^{b}
July 5	1860	2980	3400	4640	3220^{bc}
July 12	2010	2710	3960	4770	3360^{c}
July 19	1980	2600	3540	4550	3170^{bc}
July 26	1980	2550	3860	4360	3190^{bc}
Mean	1310	1840	2470	2940	

Values underscored by the same line or designated by the same superscript letter are not significantly different from each other at 5% level.

Table 3. Effect of level of spring-applied N and date of harvest of the initial crop on yields of regrowth harvested July 26, 1961.

Date of harvest of initial crop	Yield, lb./acre				
	Pounds of N applied per acre				Mean
	0	80	160	240	
May 10	1760	2350	3420	3960	2872
May 17	1460	2180	2500	2980	2280
May 24	1350	1770	1990	2740	1962
May 31	920	1330	1570	1590	1352
June 7	712	621	849	774	739
June 14	457	364	498	447	442^{a}
June 21	198	200	184	306	222^{a}
June 28	43	88	93	89	78^{a}
Mean	862	1113	1388	1611	

Values designated by the same superscript letter are not significantly different from each other at the 5% level. $s_{\bar{x}}$ for levels of N at each date = 75 lb./acre.

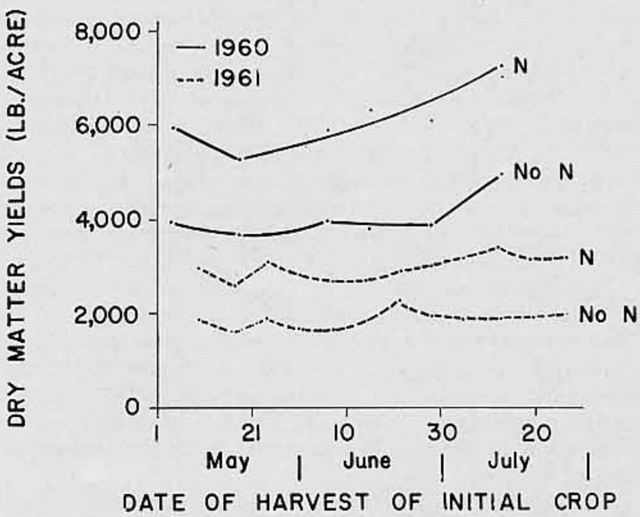

Figure 1. Total production of dry matter (initial crop + regrowth) without N and averaged for all levels of N, 1960 and 1961.

from 1.09% when the initial crop was harvested May 10 to 1.79% when it was harvested June 21.

N fertilizer did not significantly increase N content in regrowth herbage (5% level), but there was a definite trend toward high N content in herbage from fertilized plots when the initial harvest was delayed until late in the growing season, i.e., when the regrowth was in an early stage of development.

Nitrogen Yields

Initial crop. N yields showed that the initial crop of herbage continued to accumulate N until July 5, one week before the time of maximum dry-matter production (Figure 3). There was a substantial decrease in N yields after

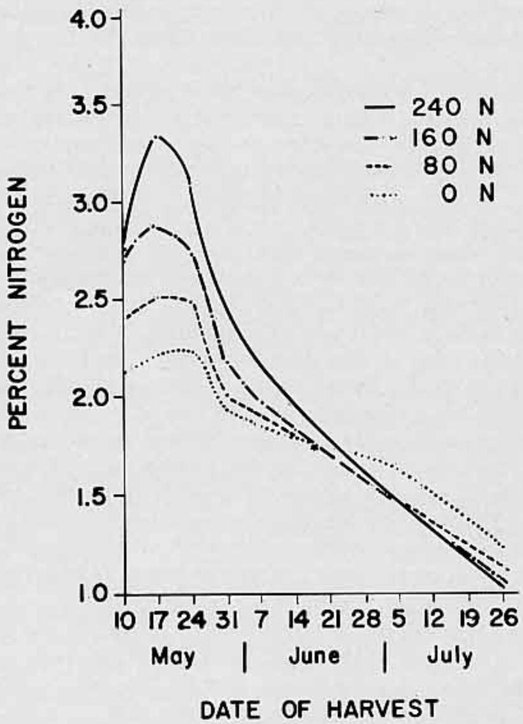

Figure 2. N content of the initial crop of herbage during the growing season with 4 levels of N fertilizer, 1961.

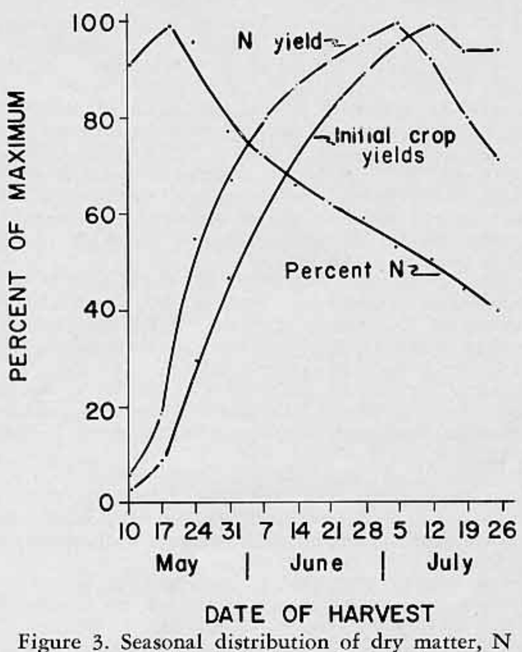

Figure 3. Seasonal distribution of dry matter, N content, and N yields from the initial crop of herbage when averaged for 4 levels of N fertilization, 1961.

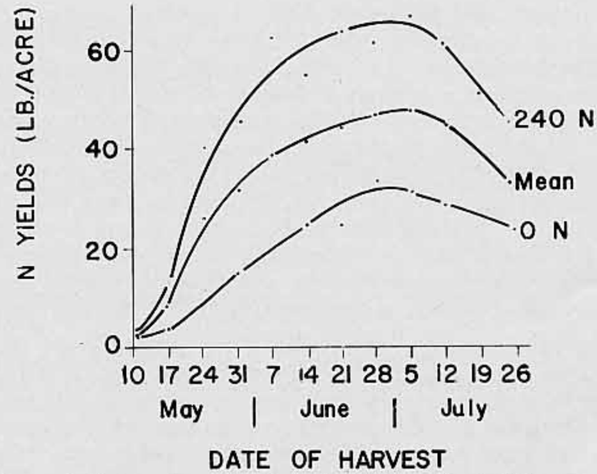

Figure 4. Seasonal production of N from the initial crop of herbage at 2 levels of N and when averaged for 0, 80, 160, and 240 lb. N/acre, 1961.

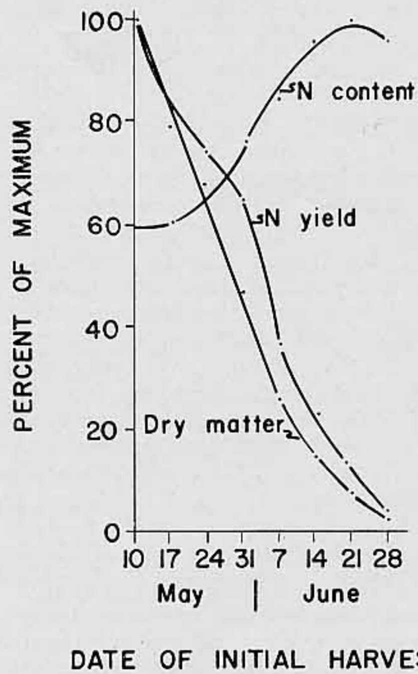

Figure 5. Seasonal distribution of dry matter, N content, and N yields from regrowth herbage clipped July 26, 1961 (averaged for 4 levels of N).

July 5 which represented an actual loss of N that could not be accounted for in the herbage. The loss of N increased with increasing levels of N fertilizer (Figure 4).

The highest rate of N accumulation (14 lb. N/acre/week) in the herbage from plots treated with 240 lb. N/acre occurred during the 3-week period from May 17 until June 7. On unfertilized plots, herbage accumulated N at a steady rate of 4.8 lb. N/acre/week during a 6-week period from May 17 to June 28 (Figure 4).

The percent of applied N recovered in the initial crop depended on the harvest date used for the calculations. When calculated for July 5, the point of maximum N yield, only 13, 12, and 14% of applied N was recovered in the herbage with 80, 160, and 240 lb. N/acre, respectively. N lost from July 5 to July 26 amounted to 33% (21 lb. N/acre) and 24% (8 lb. N/acre) with fertilizer levels of 240 and 0 lb. N/acre, respectively.

Regrowth. The N yields from regrowth herbage decreased with each week's delay in harvest of the initial crop (Figure 5).

DISCUSSION

The production of dry matter during the growing season resulted in a continual decrease (dilution) of the N concentration in the herbage. This was a dilution because N yields showed that herbage accumulated N until July 5.

The most rapid rate of N dilution occurred during early stages of growth. The rate of dilution of N concentration in the herbage increased with increasing levels of N fertilizer resulting in herbage with lower N content from fertilized plots compared with the N content of herbage from unfertilized plots. Furthermore, the dilution of N in herbage from fertilized plots continued for a longer period of time, relative to the time when the herbage ceased to accumulate N. This difference in N content among levels of N fertilizer at each date after June 28 was not statistically significant but may have been real since it persisted over a substantial portion of the season in both 1960 and 1961.

It was impossible to account for the loss in N that occurred after July 5. This loss may have been an actual loss in plant parts that were not recovered in the yield samples since a slight decrease in yield was noted after the time of maximum yield. However, it would appear that this is not the only process responsible for N loss. The average loss in dry matter was 180 lb./acre which contained an average of 1.25% N. This accounts for only 2.25 lb. N/acre, whereas the actual loss was 14 lb. N/acre. Furthermore, the beginning of N loss preceded by one week the beginning of dry matter losses and was continuous whereas dry matter losses were not.

The meadows used in these studies contained a mixture of species and it was impossible to associate the time of harvest—calendar date—with any particular stage of development. But it is possible that grass stands containing a single species progress through similar stages during a growth cycle. Any inherent or environmental condition which increases the rate of dry-matter production or prolongs the period of production relative to N absorption and accumulation would dilute the N concentration in the herbage. Gregory (6), working with barley, proposed that the larger the final size the lower the final internal concentration of N. In his inverse-yield nitrogen law, Wilcox (16) stated that yields of all agrotypes were inversely proportional to the percent N contained in the aboveground dry matter. The N concentration of meadow or grass herbage may be inversely related to dry-matter yields but this would only be evident when the time of sampling nearly coincides with the time of maximum dry-matter production.

The percent N in herbage dry-matter at any particular time depends on the level of fertilizer and stage of development. Because of this and the loss of N from herbage after maturity, caution must be exercised in selecting the harvest date if N recovery values are to be calculated, especially if species which differ in their date of maturity are to be compared.

Clipping the initial crop any time before maximum production—which varied with level of N—tended to reduce total yields (initial crop + regrowth) from fertilized plots but not from unfertilized plots. Therefore, if maximum yield increases are to be obtained from N fertilizer, it must be with a single harvest at time of maximum production. However, the time of maximum dry-matter production may not necessarily be the best time to harvest with respect to the quality of the herbage for feeding livestock.

SUMMARY AND CONCLUSIONS

The influence of N fertilizer on seasonal production of dry-matter and N accumulation in herbage from native meadows was studied in 1960 and 1961.

Increasing levels of N fertilizer increased yields and extended the period of production later into the growing season.

During early stages of growth the internal concentration of N increased with increasing levels of N application. However, the N concentration was continuously diluted by an increase in dry matter until the time of maximum yield. The rate of dilution increased with increasing levels of applied N. As a result, the N concentration in the herbage was about the same after June 21 at all levels of N. Actually, the N content was lower in herbage from fertilized plots than from unfertilized plots late in the season.

The herbage continued to accumulate N until one week before the time of maximum dry-matter production. After reaching a peak, N was actually lost in that it was not accounted for in the herbage. The loss of N increased with increasing levels of N fertilizer. N recovery values depend upon the time of harvest relative to the stage of maturity. Yields of regrowth decreased sharply with each week's delay in harvest of the initial crop. However, N concentration in regrowth herbage increased with delayed harvest of the initial crop (when the regrowth was in an early stage of development).

LITERATURE CITED

1. Bird, J. N. Stage of cutting; I. Grasses. J. Am. Soc. Agron. 35:845–861. 1943.
2. Cooper, Clee S. The effect of source, rate, and time of nitrogen application upon the yields, vegetative composition, and crude-protein content of native flood-meadow hay in eastern Oregon. Agron. J. 48:543–545. 1956.
3. ———. The effect of time and height of cutting on the yield, crude-protein content and vegetative composition of a native flood meadow in eastern Oregon. Agron. J. 48:257–258. 1956.
4. ———, Klages, Murry G., and Schulz-Schaeffer, Jurgen. Performance of six species under different irrigation and nitrogen treatments. Agron. J. 54:283–288. 1962.
5. Dotzenko, A. S. Effect of different nitrogen levels on the yields, total nitrogen content and nitrogen recovery of six grasses grown under irrigation. Agron. J. 53:131–133. 1961.
6. Gregory, F. G. Mineral nutrition of plants. Annual Review of Biochemistry 6:557–578. 1937.
7. Miller, D. E., and Amemiya, M. Better quality mountain meadow hay. Colorado Agr. Exp. Sta. Bul. 434-A. 1945.
8. Philips, T. G., Sullivan, J. T., Loughlin, M. E., and Sprague, V. G. Chemical composition of some forage grasses: I. Changes with plant maturity. Agron. J. 46:361–369. 1954.
9. Ramage, Carroll H., Eby, Claude, Mather, Robert E., and Purvis, Ernest R. Yield and chemical composition of grasses fertilized heavily with nitrogen. Agron. J. 58:59–62. 1958.
10. Rumburg, C. B. Fertilization of wet meadows—A progress report. Oregon Agr. Exp. Sta. Misc. Paper 116. 1961.
11. ———, and Cooper, C. S. Fertilizer-induced changes in botanical composition, yield and quality of native meadow hay. Agron. J. 53:255–258. 1961.
12. Schumaker, Gilbert, and Davis, Sterling. Nitrogen applications and irrigation frequencies for western wheatgrass production on clay soil. Agron. J. 53:168–170. 1961.
13. Sneva, Forrest A., Hyder, Donald H., and Cooper, C. S. The influence of ammonium nitrate on the growth and yield of crested wheatgrass on the Oregon High Desert. Agron. J. 50:40–44. 1958.
14. Wagner, R. E. Legume nitrogen versus fertilizer nitrogen in protein production of forage. Agron. J. 46:233–237. 1954.
15. Weinman, H. Seasonal chemical changes in the roots of some South African highveld grasses. J. South Afr. Bot. 6:131–145. 1940.
16. Wilcox, O. W. Quantitative agrobiology: I. The inverse yield-nitrogen law. Agron. J. 46:315–320. 1954.
17. Willhite, Forrest N., Rouse, Hayden K., and Miller, David E. High altitude meadows in Colorado: III. The effect of nitrogen fertilization on crude protein production. Agron. J. 47:117–121. 1955.