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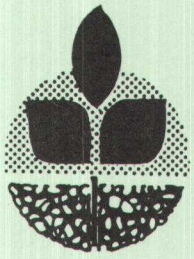
Seasonal Responses of Perennial Forage Grasses to Nitrogen Applications



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Abstract

Nitrogen fertilizers were applied at four rates (0, 15, 30, and 45 pounds per acre) after each of six harvests per season and at doubled rates during the winter to nine cool-season perennial grass species. Forage yields were measured over a five-year period.

Maximum five-year average yield was produced by Alta tall fescue at 6.91 tons of air-dry forage per acre followed closely by reed canarygrass at 6.38 tons per acre. Maximum yields of rescuegrass, hardinggrass, and orchardgrass were closely grouped at 5.99, 5.92, and 5.83 tons per acre, respectively. Manawa ryegrass and Linn perennial ryegrass averaged 5.07 and 4.17 tons per acre, respectively, with neither being very productive during July and August.

Orchargrass and rescuegrass were the most responsive species to N fertilization, and they maintained the most uniform distribution of production during the season. Alta tall fescue was nearly as N-responsive, but most of the other grasses were less responsive to N applications.

Nitrogen fertilization tended to promote a more uniform seasonal distribution of production than when none was applied. Crude protein percentages and crude protein production were increased by N fertilization. Soil pH at the 0 to 4-inch depth was reduced more than one pH unit over the five-year period at the highest N rate. Soil pH changes were minor at soil depths greater than eight inches.

Frequent close-clipping weakened the stands in reed canarygrass plots by the fourth year, but no stand reductions because of N applications were seen.

KEY WORDS: grass species, nitrogen response, crude protein production.

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Seasonal Responses of Perennial Forage Grasses to Nitrogen Applications

Summary

J. A. Yungen, T. L. Jackson, and W. S. McGuire

Ten perennial grasses comprising nine species were seeded in April, 1960, at the Southern Oregon Experiment Station, Medford, in an experiment designed to obtain basic information on the seasonal trends of forage production as affected by species and nitrogen fertilizer rates. The grasses were Alta and a Mediterranean selection of tall fescue called 'winter fescue 1000,' reed canarygrass, hardinggrass, rescuegrass, orchardgrass, Manawa ryegrass, Linn perennial ryegrass, smoth bromegrass, and intermediate wheatgrass.

From 1961 through 1965, nitrogen fertilizers were applied at 0, 15, 30, and 45 pounds per acre after each harvest and at doubled rates during the winter, giving annual rates of 0, 105, 210, and 315 pounds of nitrogen (N) per acre. The grasses were harvested six times per season (eight harvests were made in 1962) over the five-year period.

Maximum five-year average air-dry forage yields of 6.91 tons per acre were produced by Alta fescue followed by reed canarygrass with 6.38 tons per acre. Maximum forage yields of rescuegrass, hardinggrass, and orchardgrass were closely grouped at 5.99, 5.92, and 5.83 tons per acre, respectively. The winter fescue 1000 selection of tall fescue was less productive than Alta fescue, especially during the summer months. Smooth bromegrass was moderately productive, while intermediate wheatgrass was lowest in forage production; both became very winter-dormant.

Manawa ryegrass had a maximum production of 5.07 tons of forage per acre compared to Linn perennial ryegrass with 4.17 tons per acre. Linn perennial ryegrass had a relatively low growth rate during the summer, approaching dormancy during July and August.

Orchardgrass and rescuegrass were highly responsive to N applications, producing 31.7 and 26.8 pounds of air-dry forage for each pound of N applied when 15 pounds of N per acre were applied per growth cycle. Alta fescue was nearly as N-responsive as the orchardgrass and rescuegrass. The other grasses were less responsive to N fertilization.

Rescuegrass and orchardgrass had the most uniform distribution of production during the season, and both were more productive than Alta fescue during the summer. Nitrogen applications helped maintain higher production levels with most of the grasses during the summer than where no N was applied.

Crude protein contents of the grasses were increased by N applications. Reed canarygrass produced the most crude protein at the highest N rate, 2,476 pounds per acre as an average for the 1964 and 1965 seasons. Alta fescue, hardinggrass, rescuegrass, and smooth bromegrass were nearly equal in crude protein production per season, averaging 1,891, 1,957, 1,906, and 1,939 pounds per acre, respectively, at the highest annual N rate of 315 pounds per acre, compared to 1,669 pounds of crude protein per acre for orchardgrass.

The soil pH was reduced from 7.2 to 5.6 at the highest N rate in the 0 to 4-inch depth after five years, but reductions were slight at depths greater than eight inches.

Introduction

Most cool-season grasses generally produce good forage yields in their first or spring harvest cycles but yields usually decline during the warm part of the season. Nitrogen fertilizer, in combination with supplemental irrigation in areas of low summer rainfall, is commonly used to increase forage yields and to help maintain a more uniform seasonal distribution of production. In areas with adequate summer rainfall, it can be accomplished with adequate fertilizer and proper management.

Grass species can differ in total production, seasonal distribution of production, response to applied N, and crude protein content. Several investigators have reported increases in forage yields with single and multiple N applications on grasses (2,3,4,5,7,8,9). George et al. (4) found orchardgrass (*Dactylis glomerata* L.) was very responsive to N and superior in summer production to timothy (*Phleum pratense* L.) and smooth bromegrass (*Bromus inermis* Leyss.). Schmidt and Tenpas (8) also found midsummer production of orchardgrass to be higher than timothy and smooth bromegrass when N was applied four times during the season.

Orchardgrass was shown to have a high N requirement during 14 annual applications by Singh et al. (9) in Virginia. Split applications totaling 240 pounds of N per acre produced greater yield increases than a single application on orchardgrass by Alexander and McCloud (2) in Virginia, and they reported stand thinning with N rates above 240 pounds per acre. Hallock et al. (5) applied N at weekly intervals from May through August with rates as high as 50 pounds per acre to tall fescue (*Festuca arundinacea* Schreb.). Forage yield and N uptake were highest at the weekly N rate of 35 pounds per acre with the highest yield occuring in May, followed in order by June, September, July, and August in Virginia. The highest yield and highest crude protein content of reed canarygrass (*Phalaris arundinacea* L.) were obtained by Niehaus (7) in Ohio with N at 535 pounds per acre as a split application in March and May although the yields were low in the summer months. Yields of orchardgrass and smooth bromegrass were lower than intermediate wheatgrass (*Agropyron intermedium* Host.) when N rates were applied in April over a three-year period in Colorado by Dotzenko (3). Early bloom of the two grasses before they could more fully utilize the N for forage production was responsible for the lower yields. Crude protein contents of the orchardgrass and smooth bromegrass were higher than for the intermediate wheatgrass.

Prolonged use of high N rates will cause marked reductions in soil pH values. Three annual applications of 400 pounds of N per acre as ammonium nitrate to bermudagrass (*Cynodon dactylon* L. Pers.) lowered soil pH from 5.3 to 4.7 in the 0 to 6-inch depth in experiments by Adams et al. (1) in Georgia.

Soil type, temperature, and available soil moisture as well as species and fertilizers influence forage production and its seasonal distribution (3,4,8).

This experiment was designed to provide basic information on the yield and seasonal distribution of forage production of nine grass species as affected by multiple applications of nitrogen over a five-year period.

Materials and Methods

Ten perennial grasses comprising nine species were broadcast-seeded in April, 1960. They included two tall fescues (*Festuca arundinacea* Schreb.) cv. Alta and a selection from a Mediterranean introduction, winter fescue 1000, perennial ryegrass (*Lolium perenne* L.) cv. Linn, annual and perennial ryegrass cross (*Lolium hybridum*) cv. Manawa (formerly known as H-1), reed canarygrass (*Phalaris arundinacea* L.) selection P-2369, hardinggrass (*Phalaris aquatica* L.) of California origin, rescuegrass (*Bromus catharticus* Vahl.) cv. Prairie Brome, smooth bromegrass (*Bromus inermis* Leyss.) cv. Manchar, orchardgrass (*Dactylis glomerata* L.) cv. S-143, and intermediate wheatgrass (*Agropyron intermedium* Host.) cv. Greenar.

The grasses were uniformly fertilized during the establishment year. Phosphorus, potassium, and sulfur were applied annually in the fall or early spring in adequate amounts. The soil was Central Point sandy loam, a member of the coarse-loamy, mixed, mesic, Pachic Haploxerolls. Soil analyses values at the start of the experiment, in the surface eight inches, were: pH 6.3, phosphorus 6.1 ppm, potassium 134 ppm, calcium 11.3 milli-equivalents per 100 grams, magnesium 2.0 milli-equivalents per 100 grams, cation exchange capacity 13.42 milli-equivalents per 100 grams, and organic matter 3.62 percent.

Beginning in 1961 and continuing through 1965, N was applied at 0, 15, 30, and 45 pounds per acre after each harvest and at doubled rates during the winter, resulting in seasonal N totals of 0, 105, 210, and 315 pounds per acre. Over the five-year period, ammonium sulfate was the N source for 28 applications and ammonium nitrate was applied twice. The experimental design was a randomized complete block with four replications. Plots were eight feet wide and 29 feet long. The harvest area was 39 inches wide and 25.75 feet in length.

The grasses were harvested six times per season except in 1962 when eight harvests were made. Average cutting dates for the six harvests per year were April 21, May 21, June 21, July 22, August 23, and September 29. Although a few heads usually had emerged at the first harvest, most of the grasses were at a pre-heading stage of maturity at the other harvests. The grasses were irrigated with overhead sprinklers applying about 24 inches of water per year. The long-term average precipitation at the location is 20.19 inches. Samples were air-dried to a constant weight for forage yield estimates and subsamples were taken for crude protein analysis.

Because weedy grasses, principally annual ryegrass (*Lolium multiflorum* L.) were invading some of the plots, diruon (Karmex) was applied at 2.4 pounds per acre in December, 1962, for weed control.

Soil samples were taken in January, 1966, at the 0-4, 4-8, 8-16, and 16-24 inch depths of the orchardgrass plots for pH determinations.

Results and Discussion

Forage yields differed among grass species and among the nitrogen rates applied. Yields of air-dry forage and N rates applied are shown in Table 1 as totals of six harvests per year, as the five-year mean, and as the increase in pounds of forage per pound of N applied.

Seasonal distributions of yields varied among the grasses and were influenced by N applications. The effects of N fertilization on distribution of yield during the season are presented in Table 2.

Table 1. The effect of N fertilization on forage yields of perennial grasses

Grass	N applied per year	Air-dry forage per season						Yield increase per lb of N
		1961	1962	1963	1964	1965	Mean	
	lbs/acre	tons per acre						
Alta tall fescue	0	5.10	3.46	3.55	3.37	2.74	3.64	—
	105	6.38	4.99	5.01	4.78	3.82	4.99	25.7
	210	6.78	6.05	5.75	5.76	5.00	5.87	21.2
	315	7.81	7.25	6.45	6.83	6.22	6.91	20.7
Winter fescue	0	5.45	3.24		2.39	2.12	3.20	—
1000 tall fescue	105	5.54	4.17		2.94	3.49	3.99	15.1
	210	6.22	5.35		3.47	4.22	4.71	14.4
	315	6.82	6.12		4.65	5.18	5.50	14.6
Reed canarygrass	0	5.09	3.97	3.27	3.23	3.58	3.83	—
	105	5.63	4.80	4.00	3.80	4.11	4.47	12.2
	210	5.80	5.46	3.81	4.66	4.46	4.84	9.6
	315	7.47	6.87	4.52	6.57	6.49	6.38	16.2
Hardinggrass	0	5.45	4.26	2.86	3.31	3.45	3.87	—
	105	5.73	4.85	3.60	3.68	3.52	4.23	7.8
	210	6.93	6.45	3.88	5.09	4.69	5.41	14.7
	315	7.27	6.97	3.88	5.62	5.84	5.92	13.0
Rescuegrass	0	4.87	1.97	2.06	1.66	1.10	2.33	—
	105	6.06	3.52	3.69	3.17	2.27	3.74	26.8
	210	6.44	5.27	5.06	4.62	3.55	4.99	25.3
	315	7.51	6.74	5.84	5.21	4.65	5.99	23.2
Orchardgrass	0	3.05	2.38	1.96	1.60	1.01	2.00	—
	105	4.39	4.06	3.87	3.36	2.66	3.67	31.7
	210	5.65	5.81	5.44	4.85	3.95	5.14	29.9
	315	6.43	6.62	5.91	5.48	4.69	5.83	24.3
Smooth	0	2.60		1.74	1.54	1.16	1.77	—
bromegrass	105	2.85		2.01	2.74	1.94	2.42	12.3
	210	4.13		3.44	4.21	3.38	3.89	20.2
	315	3.89		3.42	4.99	4.12	4.22	15.6
Manawa	0	4.00	2.61				2.62	—
ryegrass	105	4.29	3.75				3.38	14.4
	210	5.16	5.03				4.41	17.0
	315	5.79	5.80				5.07	15.5
Linn ryegrass	0	3.09	1.95				2.00	—
	105	3.45	2.72				2.59	11.3
	210	4.65	3.80				3.66	15.8
	315	5.03	4.50				4.17	13.2
Intermediate	0	2.45					1.63	—
wheatgrass	105	2.93					2.20	10.8
	210	3.44					2.86	11.7
	315	3.32					2.82	7.5
LSD, 5%		0.46	0.78	0.56	0.73	0.78	0.55	
C. V., %		6.2	10.1	10.3	12.4	15.0	8.3	

- N was broadcast at 0, 15, 30, and 45 pounds per acre after each harvest and at double rates during the winter.
- Weighted mean yields were calculated for those grasses harvested for less than five years.
- Yield data are totals of six harvests per year.

Table 2. Seasonal distribution of forage production as affected by N fertilization of perennial grasses, 1961-1965

Grass	Lbs N applied per cutting	Percent of seasonal forage production per harvest					
		April 21	May 21	June 21	July 22	Aug. 23	Sept. 29
Alta tall fescue	0	46.1	20.5	14.3	8.2	5.8	5.1
	15	42.7	18.2	13.9	10.5	8.2	6.5
	30	41.1	16.7	13.2	10.5	10.1	8.4
	45	37.9	15.2	13.3	12.0	11.4	10.2
Winter fescue	0	47.0	20.7	14.7	6.5	6.3	4.5
1000	15	46.2	18.7	14.7	9.7	4.5	6.2
tall fescue	30	44.0	16.9	15.8	8.8	6.6	7.9
	45	40.8	16.3	15.7	9.6	8.7	8.9
Reed canarygrass	0	30.4	14.7	17.4	14.5	13.3	9.7
	15	29.7	15.7	16.4	14.5	13.5	10.2
	30	26.1	14.3	16.4	17.1	14.9	11.2
	45	28.1	11.7	17.2	15.4	14.2	13.4
Hardinggrass	0	29.3	14.4	22.2	12.7	10.8	10.6
	15	28.8	14.8	19.6	14.2	11.0	11.6
	30	26.8	13.5	19.8	15.3	11.0	13.6
	45	25.7	12.5	19.6	15.4	11.3	15.5
Rescuegrass	0	27.9	20.7	17.9	11.9	11.9	9.7
	15	26.6	17.6	18.6	13.6	13.2	10.4
	30	27.7	17.3	14.7	14.2	14.5	11.6
	45	25.2	14.2	16.4	15.7	15.0	13.5
Orchardgrass	0	18.5	29.9	21.6	12.6	10.6	6.8
	15	24.0	24.4	17.8	14.7	12.0	7.1
	30	25.1	20.5	15.6	15.9	14.1	8.8
	45	24.2	18.7	15.7	16.3	14.3	10.8
Smooth bromegrass	0	25.5	30.5	16.4	13.7	9.4	4.5
	15	24.6	29.8	16.2	14.9	10.0	4.5
	30	26.9	22.7	15.2	16.7	11.8	6.7
	45	25.7	20.1	15.8	17.5	12.8	8.1
Manawa ryegrass	0	35.7	18.7	18.9	11.7	9.4	5.6
	15	36.6	19.4	15.5	12.9	8.7	6.9
	30	34.7	16.8	14.9	15.0	8.6	10.0
	45	32.3	16.5	15.4	14.7	10.9	10.2
Linn ryegrass	0	33.4	37.1	16.7	5.3	3.7	3.8
	15	29.3	35.0	15.5	7.5	4.4	8.3
	30	31.6	27.7	14.7	9.3	7.6	9.1
	45	30.3	26.9	13.6	10.1	8.9	10.2
Intermediate	0	44.1	33.9	14.8			7.2
wheatgrass	15	48.6	34.8	10.2			6.4
	30	44.7	28.2	15.8			11.3
	45	48.7	32.5	8.7			10.1

Air temperatures affected several of the grasses during parts of the growing season. Monthly maximum temperature means from April through September for the five-year period were 60.4, 70.0, 81.7, 89.8, 88.5, and 82.9 degrees Fahrenheit (15.8, 21.1, 27.6, 32.1, 31.4, and 28.3 degrees Celsius), respectively. Corresponding minimums were 38.7, 41.4, 47.7, 52.0, 53.2, and 45.1 (2.6, 5.2, 8.7, 11.1, 11.8, and 7.3 degrees Celsius), respectively.

Tall fescue. Alta fescue was one of the two most productive grasses in the experiment. Its forage yield was quite uniform over the five-year period with means of 3.64, 4.99, 5.87, and 6.91 tons per acre for the 0, 105, 210, and 315 pound N rates per year, respectively. It was quite responsive to N fertilization, with forage yield increases of 25.7, 21.2, and 20.7 pounds for each pound of N applied at the three highest rates, respectively.

Alta fescue produced a high percentage of its seasonal yield in the first harvest; this amounted to 46 percent when no N was applied (Table 2). Nitrogen applications reduced the percent of the seasonal total in the first harvest and resulted in greater percentages of the production in the last

three harvests. Figure 1 shows that the seasonal distribution of yield was quite uniform from harvests two through six. The grass remained vigorous and weedfree throughout the investigation. It can be included in most irrigated and some dryland pasture mixtures in southern Oregon to extend the grazing season and to increase total forage production.

Winter fescue 1000 selection was less productive than Alta fescue with average yields of 3.20, 3.99, 4.71, and 5.50 tons per acre for the 0, 105, 210, and 315 pound N rates per year, respectively. It produced high percentages of its seasonal yields in the first harvest and was much less responsive to N applications than Alta. It began spring growth about three weeks earlier than the other grasses except for Manawa ryegrass and rescuegrass. Its growth rate was slow during the summer months as shown in Figure 1b when maximum temperatures were above 82 degrees Fahrenheit. The selection sustained some injury from the diuron application of December, 1962, so yield data were not taken in 1963 while it was regaining its vigor. If this grass is released for production, it will be intended for non-irrigated pastures since its early season growth can utilize winter rainfall. Its summer production would not justify irrigation.

Reed canarygrass. Yields of reed canarygrass averaged 3.83, 4.47, 4.84, and 6.38 tons per acre for the 0, 105, 210, and 315 pound N rates per year, respectively, and were nearly equal to those of Alta fescue, but the percentages of seasonal production in the first harvest were lower than for the fescue. Seasonal distribution of yield was quite uniform from the second through the sixth harvests as shown in Figure 1c, but N responses were very small in the second harvest. There appeared to be a physiological shock from cutting the tall first crop growth to a two-inch stubble height. It was only moderately responsive to applied N. Niehaus

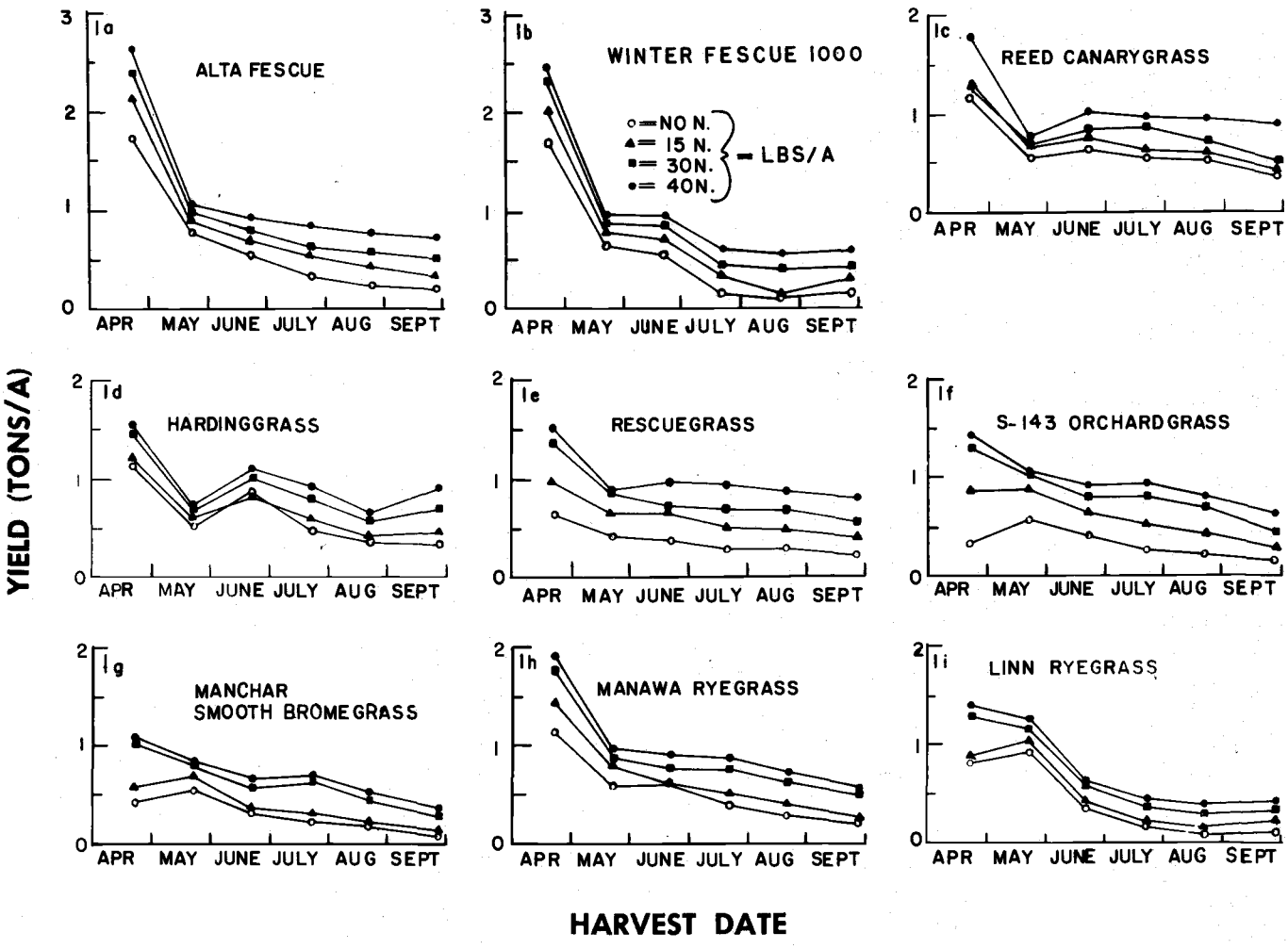

Figure 1. Air-dry forage responses of perennial grasses to different N rates applied after each harvest and at doubled rates in the winter, 1961-1965.

(7) reported low yields of reed canarygrass during the summer despite N application.

Yields were slightly reduced in 1963 from the effect of the diuron applied in December, 1962, but recovery was complete. The frequent close-clipping weakened the canarygrass by the fourth year, and a number of the plots became heavily infested with rescuegrass and orchardgrass. The stand life of reed canarygrass usually can be extended by allowing the grass to reach the heading stage of maturity at least once each growing season.

Hardinggrass. Hardinggrass yields closely matched those of reed canarygrass, averaging 3.87, 4.23, 5.41, and 5.92 tons per acre for the respective N rates. It started spring growth about 14 days earlier but had nearly the same percentages of its seasonal production in the first cutting. It appeared to suffer the same physiological shock as reed canarygrass from the removal of the tall growth of the first crop. Hardinggrass was only moderately responsive to N applications, and its growth rate slowed more than reed canarygrass, as shown in Figure 1d, when maximum temperatures reached 84 degrees Fahrenheit. The stands of hardinggrass remained satisfactory and relatively weedfree throughout the trial.

Hardinggrass has a place in irrigated pastures in southern Oregon. It has been observed performing well under dryland conditions on soils ranging from those of granitic origin to heavy clays where mean annual precipitation was at least 20 inches.

Rescuegrass. Rescuegrass started its growth in late winter, and its early season production could allow earlier grazing by cattle than for the other grasses in the trial. Its average yields were 2.33, 3.74, 4.99, and 5.99 tons per acre for the 0, 105, 210, and 315 pound N rates, respectively. It was very responsive to N applications during the summer. as shown in Figure 1e, and had the must uniform forage production of any of the grasses. Its mean increases in forage per pound of N applied, were 26.8, 25.3, and 23.2 pounds, respectively, for seasonal N totals of 105, 210, and 315 pounds per acre. It headed and produced viable seed between several of the harvests. Seeds shattered while cut forage was drying, and germinated, spreading the grass into less competitive species. In two later plantings, rescuegrass was the only grass that established a satisfactory stand in spring seedings in well-prepared seedbeds under dryland conditions on a Central Point sandy loam soil. The other grasses were Alta fescue, orchardgrass, reed canarygrass, intermediate wheatgrass, and hardinggrass.

Orchardgrass. Orchardgrass was the most responsive grass to N fertilization. For each pound of N applied, forage yields increased 31.7, 29.9, and 24.3 pounds for seasonal N totals of 105, 210, and 315 pounds per acre, respectively. Its average seasonal yield was 5.83 tons per acre for the 315 pound N rate which was slightly lower than that of Alta fescue and reed canarygrass, but its summer production was greater than that of Alta fescue and almost as uniform as that of rescuegrass, as shown in Figure 1f. It was winter-dormant and started spring growth later than most grasses in the trial. Its stand remained strong and weedfree throughout the study. It should be considered as a basic component for most irrigated pastures in southern Oregon.

Smooth bromegrass and intermediate wheatgrass. The yields of smooth bromegrass and intermediate wheatgrass were 4.22 and 2.82 tons per acre, respectively, for the 315-pound N rate, which were quite low in comparison with most of the other grasses in the experiment. Smooth bromegrass was moderately responsive to N fertilization as shown in Figure 1g, while intermediate wheatgrass gave the lowest response to applied N. Both grasses became very winter-dormant which allowed weedy grasses to become dominant after only one production year. No data were taken in 1962 when it appeared their stands were lost. The diuron applied in December, 1962, removed competing grasses and allowed the smooth bromegrass to grow as a pure stand in succeeding years. The wheatgrass made some recovery, but yield data were not taken after the first year.

Ryegrass. Manawa ryegrass (formerly known as H-1) was an active late-winter grower but was only moderately productive in midsummer. It was intermediate in response to N fertilization, as shown in Figure 1i, averaging 14.4-, 17.0-, and 15.5-pound increases in forage per pound of N applied at seasonal total rates of 105, 210, and 315 pounds per acre, respectively. Yields averaged 2.62, 3.38, 4.41, and 5.07 tons per acre for seasonal N totals of 0, 105, 210, and 315 pounds per acre.

Linn ryegrass was productive early in the season but approached a state of dormancy in July and August. When summer temperature maximums exceeded about 82° Fahrenheit, its production was low, even with N fertilization and irrigation. Its production averaged 2.00, 2.59, 3.66, and 4.17 tons per acre for seasonal N totals of 0, 105, 210, and 315 pounds per acre, respectively. It be-

gan spring growth later and its production was less than that of Manawa ryegrass. It was moderately responsive to N in the early part of the season, but its N responses were low during the summer as shown in Figure 1j.

Crude protein

The crude protein contents of the grasses were increased by N fertilization. Table 3 shows the mean crude protein values for the 1964-1965 crop years for six of the grasses. Values for the first cutting of Alta fescue were the lowest of the grasses although its yields were high.

Reed canarygrass produced more crude protein than the other grasses, ranging from 1,069 pounds per acre when no N applied, to 2,476 pounds per acre with 315 pounds of N per acre applied per season. Crude protein values for hardinggrass were slightly lower, but its patterns were similar. Data for crude protein production are presented in Table 4.

Crude protein production of Alta fescue was high, ranging from 732 pounds per acre without applied N to 1,891 pounds per acre for the highest N rate. The protein production for smooth bromegrass was quite high, ranging from 436 to 1,939 pounds per acre for the no N to the highest N rate, respectively.

Orchardgrass and rescuegrass, the two grasses most responsive to N fertilization, were low in crude protein production when no N was applied, but were quite high with the highest N rate. Orchardgrass ranged from 365 to 1,669 and rescuegrass ranged from 338 to 1,906 pounds of crude protein per acre at the no N and the 315 pound per acre total N rates, respectively.

Crude protein data from the experiment were in close agreement with findings of several other investigators. The N content of smooth bromegrass was higher than that of Alta fescue in Colorado while its yield was lower (3). The highest crude protein value obtained with tall fescue in Virginia was 24 percent when N was applied weekly at 35 pounds per acre, approximately three times the highest monthly rate used here (5). The maximum value obtained with Alta fescue was 18.51 percent in this experiment.

Table 3. Crude protein contents of perennial grasses as affected by N applications, 1964-1965

Grass	N per application[1]	Cutting number					
		1	2	3	4	5	6
	lb/a	% Crude protein					
Alta tall fescue	0	10.93	13.56	13.37	14.33	13.98	14.13
	15	9.61	13.76	14.06	13.67	14.59	14.43
	30	12.83	15.40	15.21	16.11	16.20	14.61
	45	14.05	16.96	17.40	17.50	17.69	17.80
Reed canarygrass	0	15.00	14.84	15.09	15.18	16.76	18.14
	15	13.83	14.70	15.84	15.48	15.60	18.19
	30	15.42	16.56	16.08	15.31	17.11	17.62
	45	20.14	19.71	17.65	16.98	18.46	20.67
Rescuegras	0	11.95	10.97	12.50	13.95	13.79	14.16
	15	13.98	11.47	15.01	15.00	14.50	17.36
	30	15.40	14.11	15.90	16.23	16.20	17.83
	45	17.36	15.53	16.40	15.98	20.36	19.26
Hardinggrass	0	13.60	16.61	12.79	14.32	15.01	16.89
	15	13.89	13.34	14.99	15.03	15.57	15.95
	30	16.89	18.06	13.96	16.15	15.23	18.80
	45	17.43	19.54	14.40	16.93	18.07	18.82
Orchardgrass	0	16.00	13.34	14.46	15.01	15.45	15.29
	15	15.50	13.50	14.85	16.44	15.82	14.82
	30	15.81	15.06	16.02	16.78	17.03	16.70
	45	16.68	16.65	15.38	16.04	18.83	16.95
Smooth bromegrass	0	14.31	15.41	17.34	19.42	18.89	15.83
	15	15.13	14.83	15.14	17.89	18.75	16.66
	30	20.25	17.73	19.53	21.57	21.70	18.32
	45	20.33	22.95	18.61	23.60	23.70	23.42

[1] N rates were applied after each harvest and at double rates in the winter.

Table 4 Crude protein production of perennial grasses as affected by N fertilization, 1964-1965 seasons[1]

Grass	N applied, per Treatment	N applied, per Season	Cutting number 1	2	3	4	5	6	Seasonal Total
	pounds per acre		crude protein, pounds per acre						
Alta tall fescue	0	0	361	141	87	53	51	39	732
	15	105	458	188	145	79	94	70	1,034
	30	210	657	251	200	130	146	109	1,493
	45	315	760	328	248	197	193	165	1,891
Reed canarygrass	0	0	354	147	174	135	161	98	1,069
	15	105	364	194	207	136	190	136	1,227
	30	210	474	204	259	189	220	136	1,482
	45	315	907	258	373	285	336	317	2,476
Hardinggrass	0	0	315	160	187	70	126	107	965
	15	105	324	137	215	110	138	107	1,031
	30	210	551	202	270	171	183	216	1,593
	45	315	641	224	350	166	262	314	1,957
Rescuegrass	0	0	49	103	46	47	53	40	338
	15	105	171	177	106	100	100	98	752
	30	210	344	250	158	166	186	156	1,260
	45	315	457	289	216	203	288	253	1,906
Orchardgrass	0	0	92	103	60	36	56	18	365
	15	105	255	184	155	123	122	37	876
	30	210	432	231	224	191	217	90	1,385
	45	315	499	292	264	210	268	136	1,669
Smooth bromegrass	0	0	126	122	80	52	41	15	436
	15	105	205	190	119	102	80	23	719
	30	210	471	304	252	214	162	60	1,463
	45	315	576	390	306	302	254	111	1,939

[1] Crude protein values are means of the 1964 and 1965 crop seasons.

N application and soil pH

At the conclusion of five years of production, the pH of the soil in the 0 to 4-inch depth was 7.2 where no N was applied and 5.6 with the highest cumulative N rate of 1,575 pounds per acre, applied mostly as ammonium sulfate. Table 5 presents soil pH data. It is not clear why the soil pH where no N was applied was higher at the conclusion than at the start of the experiment unless there was a seasonal time-of-sampling effect.

Lesser reductions in soil pH were found at greater depths. Changes in soil pH were minor below the eight-inch depth, even with the highest N rates.

Continued use of high rates of N with the subsequent lowering of soil pH might require that lime be applied to help maintain nutrient availability and to provide a favorable soil pH for the crop being grown and for crops that might follow in a rotation.

Table 5. The effect of five years of N fertilization on pH of soil samples from orchardgrass plots

Depth sampled (inches)	N applied, pounds per acre[1] 0	525	1,050	1,575
	pH			
0-4[2]	7.2	6.9	6.3	5.6
4-8	6.6	6.5	6.4	6.0
8-16	6.7	6.6	6.5	6.3
16-24	6.7	6.7	6.4	6.3

[1] Ammonium sulfate supplied 0, 480, 960, and 1,440 pounds of N; ammonium nitrate supplied 0, 45, 90, and 135 pounds of N.

[2] The soil pH was 6.3 for the 0 to 8-inch depth at planting. Seasonal differences in time of sampling could account for differences in soil pH.

1962 crop year

Eight harvests were made in 1962 while six were made in the other four years. The first harvest on March 29 was approximately three weeks earlier than the average date for other years. The eighth harvest on November 2 was nearly five weeks later than the average final harvest date. Yield data and increases in forage production per pound of N applied are shown in Table 6.

The data show the excellent early season production characteristics of the winter fescue 1000

Table 6. The effect of N fertilizers on forage yields of perennial grasses, 1962 season

Grass	N applied, lbs/a per Treatment	N applied, lbs/a per Season	Yield of air-dry forage, tons per acre, by cutting dates 3/29	4/23	5/28	6/29	7/27	8/27	9/27	11/2	Season Total	lbs forage per lb. N
Alta tall fescue	0	0	0.44	1.19	0.70	0.57	0.26	0.29	0.26	0.18	3.89	—
	15	135	0.80	1.44	0.92	0.89	0.46	0.48	0.37	0.26	5.62	25.3
	30	270	1.01	1.55	1.02	1.06	0.65	0.74	0.53	0.34	6.90	22.3
	45	405	1.16	1.62	1.15	1.30	0.92	1.10	0.83	0.49	8.57	23.0
Winter fescue 1000 tall fescue	0	0	1.00	0.92	0.68	0.42	0.08	0.14	0.20	0.31	3.75	—
	15	135	1.28	1.03	0.85	0.53	0.17	0.31	0.23	0.37	4.77	15.0
	30	270	1.50	1.08	1.15	0.79	0.30	0.54	0.51	0.64	6.51	20.3
	45	405	1.74	1.09	1.26	0.90	0.37	0.76	0.70	0.74	7.56	18.8
Reed canary-grass	0	0	0.51	0.78	0.71	0.88	0.46	0.62	0.34	0.23	4.53	—
	15	135	0.63	0.99	0.85	1.01	0.57	0.74	0.35	0.33	5.47	14.0
	30	270	0.82	0.99	0.93	1.20	0.65	0.87	0.32	0.45	6.23	12.6
	45	405	1.04	1.22	1.11	1.39	0.84	1.27	0.57	0.61	8.05	17.9
Hardinggrass	0	0	0.52	0.73	0.77	1.08	0.34	0.82	0.33	0.27	4.86	—
	15	135	0.73	0.82	0.93	1.13	0.35	0.89	0.31	0.36	5.52	9.7
	30	270	0.94	1.03	1.02	1.72	0.43	1.31	0.42	0.59	7.46	19.2
	45	405	0.94	1.03	0.92	1.96	0.47	1.66	0.52	0.59	8.09	15.9
Rescuegrass	0	0	0.32	0.29	0.61	0.23	0.18	0.33	0.20	0.17	2.33	—
	15	135	0.70	0.45	1.00	0.56	0.35	0.47	0.36	0.36	4.25	28.2
	30	270	1.08	0.74	1.17	0.86	0.59	0.83	0.43	0.43	6.13	28.0
	45	405	1.16	0.81	1.40	1.28	0.81	1.28	0.66	0.64	8.04	28.1
Orchardgrass	0	0	0.06	0.61	0.85	0.37	0.26	0.23	0.16	0.07	2.61	—
	15	135	0.23	1.01	1.05	0.75	0.49	0.53	0.24	0.16	4.46	27.2
	30	270	0.35	1.38	1.20	1.17	0.75	0.96	0.37	0.28	6.46	28.5
	45	405	0.52	1.35	1.26	1.33	0.92	1.25	0.51	0.35	7.49	24.0
Manawa ryegrass	0	0	0.56	0.55	0.55	0.46	0.29	0.21	0.14	0.16	2.92	—
	15	135	1.00	0.78	0.62	0.68	0.31	0.35	0.25	0.26	4.25	26.8
	30	270	1.15	0.89	0.86	1.07	0.35	0.71	0.32	0.48	5.83	21.6
	45	405	1.44	0.92	1.04	1.14	0.52	0.73	0.46	0.55	6.80	19.3
Linn ryegrass	0	0	0.17	0.94	0.52	0.17	0.06	0.09	0.13	0.13	2.21	—
	15	135	0.36	1.05	0.63	0.30	0.09	0.28	0.18	0.26	3.15	14.1
	30	270	0.64	1.23	0.77	0.52	0.21	0.43	0.32	0.43	4.55	17.3
	45	405	0.79	1.30	0.82	0.70	0.32	0.56	0.41	0.49	5.39	15.7
									LSD, 5%		0.78	
									C. V., %		10.1	

selection of tall fescue, Manawa ryegrass, and rescuegrass. Alta fescue and reed canarygrass also were quite productive at the first harvest on March 29. Forage yields of winter fescue 1000 and rescuegrass were higher than the other grasses at the highest N rate at the final harvest on November 2.

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