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Yield, Yield-Trend, and Response to Nitrogen of Introduced Grasses On the Oregon High Desert

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CONTENTS

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YIELD, YIELD-TREND, AND RESPONSE TO NITROGEN OF INTRODUCED GRASSES ON THE OREGON HIGH DESERT

Forrest A. Sneva and D. N. Hyder

At the end of the sixth growing season, Cooper and Hyder (1958) summarized the results of a varietal adaptability trial of eleven grasses on a sagebrush-bunchgrass soil of the Oregon high desert. The following conclusions were made at that time: (1) big bluegrass, because of its earliness and high yielding ability, could readily replace crested wheatgrass for range seeding if a strain could be developed which had a stronger root system; and (2) Siberian wheatgrass showed considerable promise. Other observations were: (1) tall wheatgrass yielded well but was a poor performer in dry years and was believed not adapted to the area; (2) Whitmar wheatgrass was well adapted; (3) there were no significant differences among strains of crested or fairway wheatgrass; (4) hard fescue was a low yielder; and (5) in one year of response to nitrogen, varieties varied considerably.

This paper presents 9 years of yield data of these 11 grasses from 1953 to 1961, 5 years of yield response to nitrogen fertilization, 1 year of response to residual nitrogen in 1962, and concludes the adaptability trial of these grasses.

EXPERIMENTAL AREA AND PROCEDURE

The range unit of Squaw Butte lies approximately 42 miles west of Burns, Oregon, at an elevation of 4,600 feet. Extreme temperatures and low, but variable, precipitation amounts within and between years produce a harsh climate. These climatic conditions limit cropping to drought-resistant forage species.

The study area was classified by Eckert (1957) as the *Artemisia tridentata* - *Agropyron spicatum* habitat type, *Stipa thurberiana* phase. This habitat type is extensive in eastern Oregon.

The soils of the nursery area are an uncorrelated series representing the Brown great soil group. The texture varies from loam in the A horizon to a sandy clay loam in the B horizon. A platy structure is found in the A horizon, while the primary structural units in the B horizon are moderate prisms, breaking into sub-angular blocks. The soils are nonsaline throughout and vary in pH from 6.0 to 7.0, except in the calcium-carbonate pan where the pH increases to about 8.0. The organic matter content is low:

2.0 to 2.2% in the A_1, but decreasing to less than 1% in the surface 6 inches. A moisture content of 17.0 to 20.0% was measured at a tension of 1/3 atmosphere in the surface 6 inches, and this decreased at 8 to 11% at 15 atmospheres of tension.

Twelve grasses (Table 1) were seeded in May 1952, and were sprinkle-irrigated only to insure stand establishment in that year. Stands of sheep fescue were inadequate and yields from those plots were not presented in the earlier paper. By 1957 sheep fescue had thickened up, and yields since that date have been used in this report.

Ammonium nitrate (30 pounds of elemental nitrogen per acre) was broadcast on the soil surface in late fall of the calendar years 1956, 1957, 1958, 1959, and 1960. Herbage yield samples were obtained each year after the grasses had matured. They were oven dried and reported on an oven-dry basis plus 10% moisture. Dry matter and crude protein concentration at the time of harvest were also obtained from the harvested samples in some years. Details of the study design, seeding, and harvesting procedures were presented by Cooper and Hyder in 1958.

LITERATURE REVIEW

Despite the vast number of varietal trials that were initiated in the 1930's and 1940's, there is a paucity of published data that present continuous yield records of tested grasses over a period of years. In this report, only that literature pertaining to the semi-arid region of the Pacific Northwest and Great Basin areas has been recorded.

Production records of fairway and standard crested wheatgrass show some advantage for the latter (Knowles, 1958; Klages and Stark, 1949; Jackman, 1951; Gates and Harris, 1959; Cooper and Hyder, 1958. However, differences are small and Hafenrichter, et al. (1949) considered the two wheatgrasses alike for use on these ranges. Eckert, et al. (1961) concluded from a study in Nevada that standard crested wheatgrass was better adapted to the more zeric sites than was fairway.

Siberian wheatgrass has recently been suggested as a replacement for the standard type currently being used. Hafenrichter, et al. (1949) and Hafenrichter (1958) indicated that Siberian wheatgrass had more drought resistance, a longer growing season, and greater production than the standard type. Production records as published by Cornelius and Williams (1961) and Hyder and Sneva (1963), indicated no yield advantage for Siberian wheatgrass. Schwendiman and Douglas (1960), concluded that on the better range soils there was no difference in yield, but that Siberian wheatgrass was the more productive on tough sites and under low precipitation.

Table 1. Mean yields and relative rank* of grasses on August 1 in each of nine years and crop-year precipitation amounts

Species	1953	1954	1955	1956	1957	1958	1959	1960	1961	Mean
					lb./A (air dry)					
Sherman big bluegrass	1,421[7/]	1,336[1/]	715[1/]	1,997[1/]	1,394[1/]	1,106[2/]	732[4/]	993[1/]	635[1/]	1,148[1/]
Poa ampla Merr.										
Siberian wheatgrass	1,129[1/]	820[2/]	487[2/]	1,991[2/]	1,116[5/]	786[9/]	793[1/]	716[7/]	493[6/]	1,037[2/]
Agropyron sibiricum (Willd.)Beauv.)										
Tall wheatgrass	2,119[2/]	499[5/]	241[11/]	1,630[3/]	1,069[6/]	877[5/]	730[5/]	457[11/]	211[11/]	870[4/]
Agropyron elongatum (Host)Beauv.)										
Whitmar wheatgrass	1,551[4/]	582[3/]	405[3/]	1,315[5/]	912[8/]	811[8/]	690[9/]	543[10/]	469[8/]	808[7/]
Agropyron inerme (Scribn. and Smith)Rydb.										
Crested wheatgrass										
Agropyron desertorum (Fisch.)Schult.)										
Standard	1,492[6/]	406[7/]	317[9/]	1,368[4/]	955[7/]	731[11/]	588[11/]	735[5/]	420[9/]	779[8/]
Mandan 571	1,579[3/]	403[8/]	321[8/]	1,258[9/]	1,168[3/]	868[6/]	694[8/]	763[4/]	486[7/]	838[5/]
Nebraska-10	1,506[5/]	453[6/]	341[5/]	1,296[6/]	1,260[2/]	1,144[1/]	744[2/]	884[2/]	609[2/]	915[3/]
Utah-42-1	1,408[8/]	371[9/]	338[6/]	1,260[8/]	1,126[4/]	829[7/]	742[3/]	799[3/]	515[4/]	820[6/]
Fairway wheatgrass										
Agropyron cristatum (L.) Baertn.										
Standard	1,386[9/]	319[10/]	344[4/]	1,163[10/]	858[10/]	942[3/]	697[7/]	621[8/]	578[3/]	767[9/]
A-1770	1,276[10/]	252[11/]	270[10/]	1,266[7/]	906[9/]	903[4/]	642[10/]	571[9/]	505[5/]	732[10]
Hard fescue	1,107[11/]	509[4/]	332[7/]	1,043[11/]	701[11/]	748[10/]	721[6/]	730[6/]	325[10/]	691[11]
Festuca ovina L. var. *duriuscula* (L.) Koch.										
Sheep fescue**	-----	-----	-----	-----	907	1,080	744	581	384	-----
Festuca ovina L.										
Mean	1,543	541	374	1,417	1,042	886	706	710	477	855
L.S.D.	629	310	180	431	296	-----	-----	238	192	221
Probability level	5%	5%	5%	5%	5%	N.S.	N.S.	5%	5%	10%
Crop-year precipitation Sept. 1 to June 30, incl.	14.00	8.44	5.88	14.29	13.14	16.25	6.13	9.74	7.17	

* Denoted within the table by the superscripts.

** Yields of sheep fescue are not included in the year means, nor considered in the ranking of yield.

Sherman big bluegrass, an ecotype of Poa ampla, Merr., has been shown to be widely adapted within the semi-arid region and generally produces as much or more herbage than the crested wheatgrass types (Cooper and Hyder, 1958; Klages and Stark, 1949; Hafenrichter, et al. 1949; and Gates and Harris, 1959). Perhaps more important than its higher productivity is its early season growth characteristics which surpass those of crested wheatgrass. Difficulty in establishment due to small seed size and insufficient rooting strength in the initial establishment years have deterred wide acceptance of this grass.

Cooper and Hyder (1958) considered tall wheatgrass to be poorly adapted to the Squaw Butte range soils. Stark, et al. (1946) considered it as being equal in production to crested wheatgrass in Idaho. Bennett, et al. (1954) in Utah and Cornelius and Talbot (1955) in California obtained higher production from tall wheatgrass than from crested wheatgrass. The latter named trial was in an area receiving 18 inches of precipitation annually.

Later curing is the primary asset of Whitmar wheatgrass, and Whitmar is now being used on semi-arid soils. Its productivity has generally been shown to equal that of crested wheatgrass types (Cooper and Hyder, 1958; Gates and Harris, 1959). However, greater yields of Whitmar in dry years have been reported by Hafenrichter, et al. (1949), but, significantly lower yields were reported by Hyder and Sneva (1963). Schwendiman (1958) reported greater yields of Whitmar than for standard crested wheatgrass were realized when the former was properly managed.

Sheep and hard fescue, although low producing (Cooper and Hyder, 1958; Gates and Harris, 1959; Klages and Stark, 1949), have been shown to be well adapted on these sites; both species are presently recommended where forage is of secondary importance.

Matthews and Cole (1938) were among the first to suggest that nitrogen may limit continuous crop production in the semi-arid parts of the Intermountain Region. Sneva, et al. (1958) found that a shortage of available soil nitrogen limited production of crested wheatgrass in favorable moisture years. The many recorded increases in herbage production from nitrogen fertilization on rangeland attest to its importance (Sneva, et al., 1958; Hyder and Sneva, 1961; Eckert, et al., 1961; Patterson and Youngman, 1960; Klages and Stark, 1949; Cosper and Thomas, 1961; and Mason and Miltimore, 1959).

RESULTS AND DISCUSSION

Mean yield

The additional four years of yield data strengthen the conclusions made at the end of the sixth growing season of these grasses. The nine-year mean yield of big bluegrass (1,148 lb./A) was significantly greater at the 10% level than that of all other grasses tested except that of Siberian wheatgrass (1,037 lb./A, Table 1).

Mean yields of tall, Whitmar, standard crested, and fairway wheatgrass were alike; yet there were year and trend differences that will be considered later in this report.

The two fescues were generally the lowest producing, but in this trial the mean yield of hard fescue was not significantly different from that of crested wheatgrass.

Relative yield rank and adjusted yield trends

Species yield rank each year is presented with yield in Table 1. Such ranking does not indicate whether the increase in rank of a grass is due to a real increase in yield of that specific grass or a reduction in yield in some or all of the other grasses. Nevertheless, it is of interest to note that: (1) big bluegrass ranked high in all years; (2) Siberian wheatgrass rank was high in the first four years but ranked low in the last five years except in the extremely dry year of 1959; (3) tall wheatgrass varied considerably during the test years and was lowest in rank in the last two years; (4) Whitmar wheatgrass yields ranked higher in the first half of the study than in the last half; (5) among standard crested wheatgrass selections, Neb.-10 and Utah-42-1 yields increased in rank as the stands aged; and (6) low yield rank was a general characteristic of hard fescue.

Herbage yields were adjusted by crop-year precipitation amount following procedures derived from precipitation-herbage-yield studies at this station and published elsewhere (Sneva and Hyder, 1962). Adjusted yields (median-year yield estimates) remove a large portion of yield variation due to year difference and offer opportunity to examine yield trend across years.

Figures 1, 2, and 3 present these median-year estimates plotted over their respective calendar years.

Only one specie (big bluegrass) failed to reach peak production by the second growing season, as is indicated by the decreasing adjusted yield in 1954 of all grasses other than big bluegrass (Figures 1, 2, and 3).

In this trial, other than the decrease in adjusted yields following peak production, the generally accepted decreasing yield trend in time is not strikingly evident. This is due in part to the wet years of 1956, 1957, and 1958 that caused nitrogen deficiency and interferred with yield response to precipitation in 1958 (Hyder and Sneva, 1963). Low median-year yields were estimated in 1958. In 1959, a dry year, high median-year yields suggest beneficial carryover (possibly of soil moisture) from 1958, an extremely wet year.

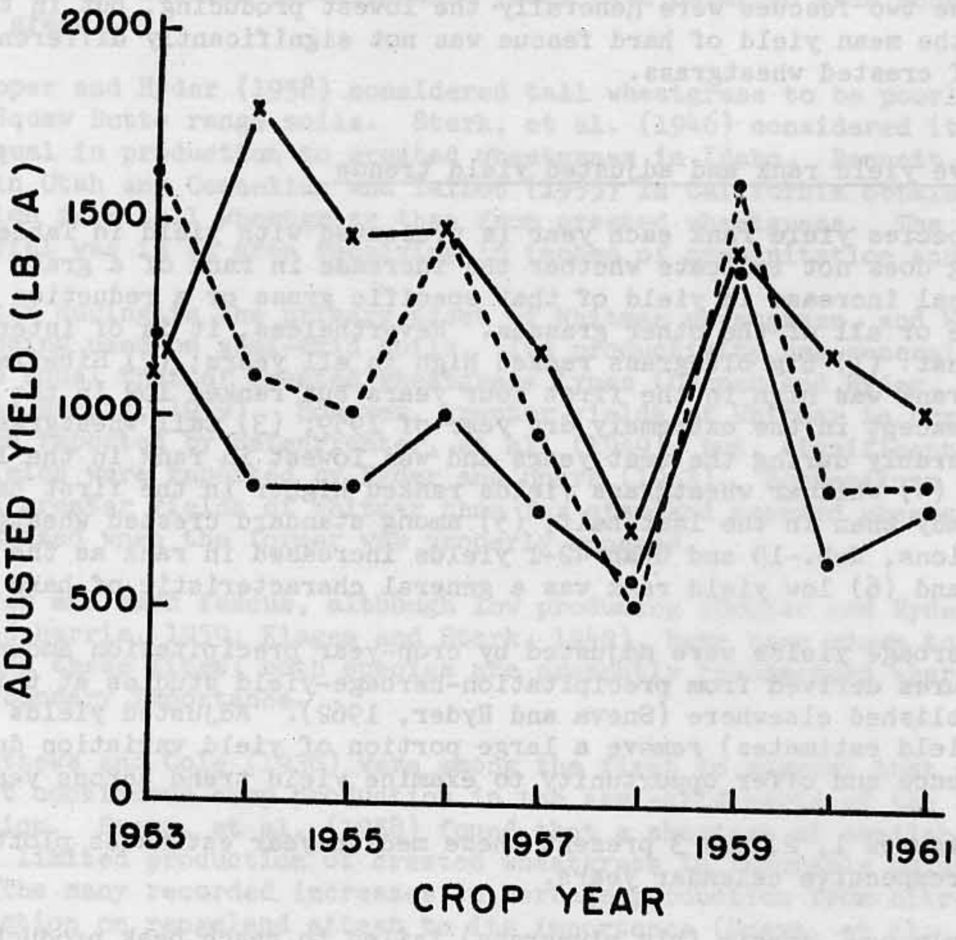

Figure 1. Adjusted herbage yields of Sherman big bluegrass (X——X), Siberian wheatgrass (.----.), and Whitmar wheatgrass (.——.).

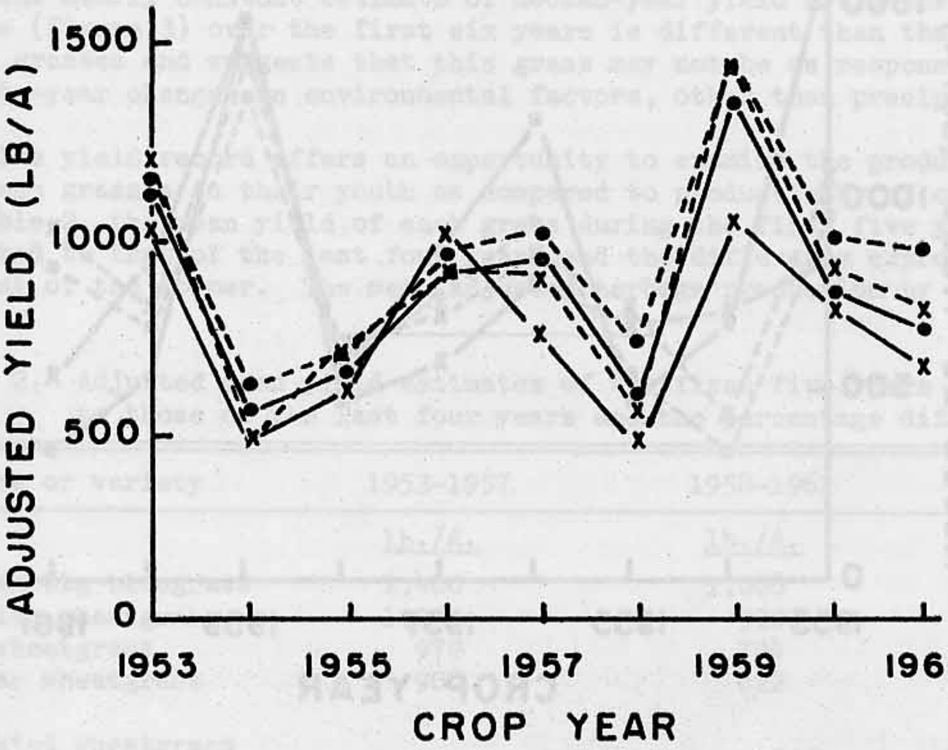

Figure 2. Adjusted herbage yield of four selections of crested wheatgrass: Nebraska-10 (.----.), Utah-42-1 (X--,-X), Mandan 571 (.——.), and Standard (X——X).

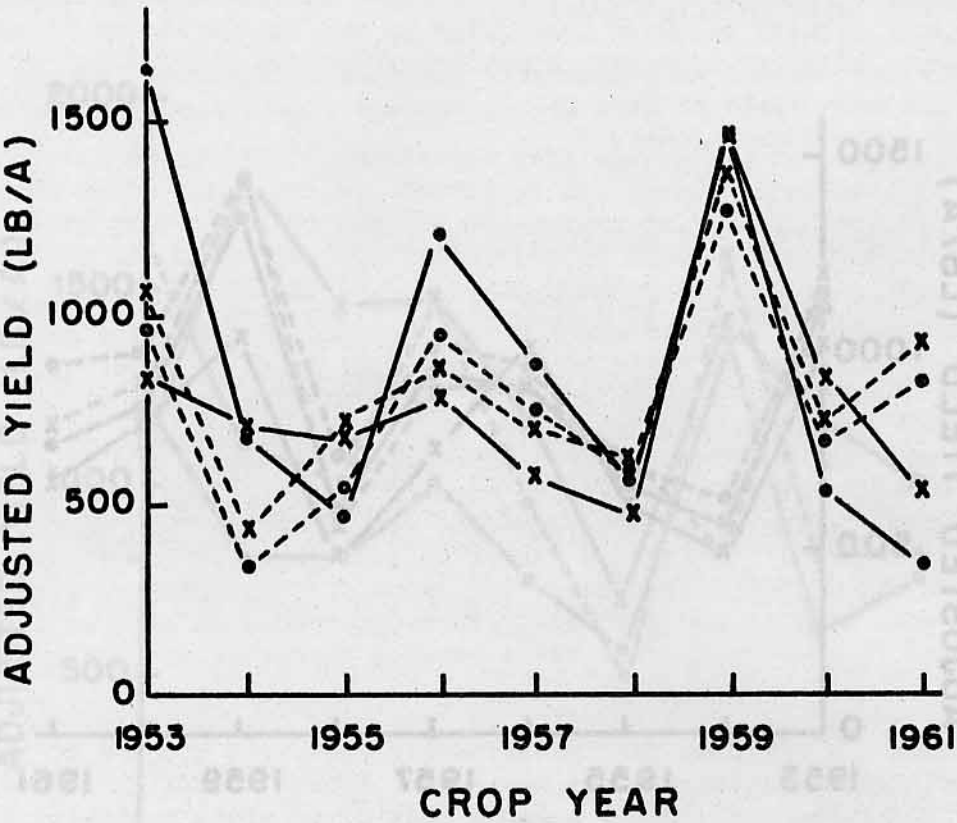

Figure 3. Adjusted herbage yield of two Fairway wheatgrasses (Standard, X---X) and (A-1770, .---.), hard fescue (X——X), and tall wheatgrass (.——.).

Selections of crested wheatgrass were markedly consistent in production during the first four years (Figure 2). In 1957, differences in yield began and continued throughout the remaining years with Neb.-10 consistently producing at the highest level. Utah-42-1 and Man. 571 also increased in yield in the latter years as compared to standard crested wheatgrass. In California, Neb.-10 was also reported as being the highest producer of crested wheatgrass selections (Cornelius and Williams, 1961).

The nearly constant estimate of median-year yield estimates of hard fescue (Figure 3) over the first six years is different than that of the other grasses and suggests that this grass may not be as responsive to year-to-year changes in environmental factors, other than precipitation.

The yield record offers an opportunity to examine the productivity of these grasses in their youth as compared to productivity of older plants. In Table 2, the mean yield of each grass during the first five years is compared to that of the last four years and the difference expressed in percent of the former. The mean adjusted herbage production by species and

Table 2. Adjusted mean yield estimates of the first five years compared to those of the last four years and the percentage difference

Species or variety	1953-1957	1958-1961	Difference
	lb./A.	lb./A.	%
Sherman big bluegrass	1,400	1,088	-22
Siberian wheatgrass	1,230	930	-24
Tall wheatgrass	979	724	-26
Whitmar wheatgrass	908	822	-9
Crested wheatgrass			
Standard	831	794	-5
Mandan 571	864	904	+5
Nebraska-10	895	1,058	+18
Utah-42-1	829	943	+14
Fairway wheatgrass			
Standard	755	914	+21
A-1770	713	836	+17
Hard fescue	715	824	+15

varieties during the last four years varied from 26% less to 21% more. The highest-producing grasses during the first five years generally showed the greatest reduction during the last four years, while those grasses that were lower in early production increased.

Nitrogen response

Cooper and Hyder (1958) found a wide range in response to nitrogen fertilization. The continuance of fertilization at 30 pounds of nitrogen per acre for an additional four years did little to improve upon that result. All sources of variation, except replications and the second order interactions, were highly significant in the yield analysis.

Response to nitrogen was greatest in years of favorable moisture (Table 3). The greatest response was made in 1958 when 30 pounds of nitrogen per acre increased the mean yield by 155%; this was in a year when unfertilized grasses were limited in production by a factor other than moisture. Nitrogen increased herbage yields 31% in 1961 as compared to a 65% increase in 1959; yet, 1 inch more of precipitation was received in the 1961 crop year. It is suggested that the higher response in 1959 resulted from beneficial soil moisture carryover from 1958. Low nitrogen response in 1961 may also have been caused by a build up of soil nitrogen during the dry years of 1959 and 1960 and subsequently greater than normal yields on unfertilized plots.

The mean yield of fertilized big bluegrass was 2,118 pounds per acre, highest of all grasses tested. This was an increase in yield of 104%. Siberian wheatgrass responded most strongly to nitrogen, increasing its mean yield 143% and producing 1,972 pounds per acre. Results of trials elsewhere indicate Siberian wheatgrass to be better adapted than crested wheatgrass to the tougher sites. Nitrogen fertilization of crested wheatgrass has caused earlier and more rapid depletion of soil moisture (Sneva, et al., 1958). Although a shorter growing season brought about by a more rapid depletion of soil moisture does not make a site more zeric, it does extend the drought period to which the plants are exposed.

The low response to nitrogen by tall wheatgrass was attributed to its late-season growth habit when soil moisture in the surface foot of soil is rapidly being depleted (Cooper and Hyder, 1958).

The mean response of crested wheatgrass selections varied quite widely and somewhat interestingly. Standard crested wheatgrass, the lowest yielding selection unfertilized, made a mean yield increase in the presence of nitrogen of 135%. Nebraska-10, the highest yielding selection unfertilized, made the lowest response in the presence of nitrogen (52%). Mean responses to nitrogen among crested wheatgrass selections were in reverse order to those of unfertilized yields.

Mean yields for crested, fairway, and Whitmar wheatgrasses were alike in the presence of nitrogen.

Low responses to nitrogen by the two fescues (54 and 65%) support the earlier conclusions of Cooper and Hyder (1958) that hard fescue was not responsive to fertilization. None or small responses to nitrogen by fescues have been reported in the literature (Gomm, 1961; Patterson and Youngman, 1960; and Gates, 1961). The large response to nitrogen in 1958

Table 3. Mean yields of grasses fertilized with thirty pounds of nitrogen annually in each of five years and percent yield increase.

Species	1957	1958	1959	1960	1961	Mean		1957	1958	1959	1960	1961	Mean
	lb./A (air dry)					30 lbs.N/A	0 lbs.N/A	Percent yield increase 2/					
Sherman big bluegrass	3,319	3,339	1,311	1,957	666	2,118	972	138	202	79	97	5	104
Siberian wheatgrass	3,599	2,292	1,201	1,799	967	1,972	781	223	192	51	151	96	143
Tall wheatgrass	1,792	1,852	848	507	199	1,040	669	168	111	16	11	-6	60
Whitmar wheatgrass	2,239	2,639	1,083	1,455	754	1,634	685	146	225	57	168	61	131
Crested wheatgrass													
Standard	2,591	2,455	1,190	1,477	683	1,679	686	171	236	102	101	63	135
Mandan 571	2,769	2,027	1,233	1,197	616	1,568	796	137	134	78	57	27	86
Nebraska-10	2,689	1,840	1,059	1,242	623	1,491	928	113	61	42	40	2	52
Utah-42-1	3,111	2,087	1,168	1,323	682	1,674	802	176	152	57	66	32	97
Fairway wheatgrass													
Standard	2,673	2,392	1,450	1,192	813	1,704	739	212	154	108	92	41	121
A-1770	2,710	1,781	1,102	943	661	1,439	705	199	97	72	65	31	93
Hard fescue	900	2,247	1,123	941	358	1,114	645	28	200	56	29	10	65
Sheep fescue	1,688	2,098	1,232	664	424	1,221	739	86	94	66	14	10	54
	2,507	2,254	1,167	1,225	620	1,554	762	141	155	65	74	31	93

1/ Obtained from comparable years in Table 1.

2/ Computed by $\left(\frac{\text{fertilized yield}}{\text{unfertilized yield}} \times 100\right) - 100$.

by hard fescue suggests that with sufficient moisture this grass might show a greater nitrogen response than that measured in this trial.

Nitrogen efficiency

In Table 4, the efficiency of a pound of nitrogen to produce additional herbage is presented. If the cost of a pound of nitrogen per acre applied is figured at 15¢ and a ton of grass herbage valued at $20, then a return of 15 pounds of herbage per pound of nitrogen would return the investment (not accounting for interest on the investment and increased costs of managing the extra herbage). The efficiency values computed suggest that all but three grasses (tall wheatgrass, sheep fescue, and hard fescue) returned somewhat more than 15 pounds of herbage per pound of nitrogen. The mean efficiency values for the crested wheatgrasses (28) were higher than that obtained (21) over a four-year period that included both first and residual year yield of an old stand of crested wheatgrass fertilized anew each year (Sneva, et al., 1958).

It would be erroneous to accept these efficiency values as an index to animal response; however, if grazed after their peak in yield, the carrying capacity is dependent upon the herbage yield. Grazing prior to peak production would seriously reduce the total effectiveness of the fertilizer (Hyder and Sneva, 1961; Rumburg, 1961).

Since crested wheatgrasses are grown primarily for spring pasture, yield increases due to nitrogen are of little practical value. This is not true for Whitmar wheatgrass which is recommended for late season grazing (Hyder and Sneva, 1963). The 32 pounds of herbage returned per pound of nitrogen can be viewed favorably. Whether or not annual nitrogen fertilization of late maturing grasses is more economical than enlarging the area of that seeded species is questionable.

The high return of Sherman big bluegrass herbage per pound of nitrogen cannot be overlooked. This grass is not now recommended for this area because of low seeding success, slow establishment, and susceptibility to "pull-up". However, should research be able to overcome these disadvantages, the opportunity for yield increases through a nitrogen fertility program appears quite realistic.

Residual response

The mean yield response of the 12 grasses in 1962 to residual nitrogen was 46% (Table 4). This was 15% greater than the first-year response in 1961 and just approached being significant at the 5% level. Varieties and the variety by nitrogen interaction were both significant in the yield analysis. Yields of tall wheatgrass decreased 16%, while yields of Siberian wheatgrass increased 110% in the presence of residual nitrogen. This extreme deviation was perhaps due to: (1) decreasing plant vigor in the case of tall wheatgrass, and (2) residual soil nitrogen from the previous dry years.

Table 4. Mean nitrogen efficiency, residual response, crude protein, and dry matter content of twelve grasses

Species	Nitrogen efficiency2/	Residual response in 1962			Crude protein content1/		Dry matter content1/	
		Unfertilized	Fertilized	Yield increase	Unfertilized	Fertilized	Unfertilized	Fertilized
	lb.	lb./A	lb./A	%	%	%	%	%
Sherman big bluegrass	38	564	555	-2	5.8	7.8	61	62
Siberian wheatgrass	40	483	1,014	110	6.6	9.1	59	63
Tall wheatgrass	12	90	90	0	6.9	9.2	52	67
Whitmar wheatgrass	32	415	583	40	6.9	9.4	64	69
Crested wheatgrass								
Standard	33	396	683	72	5.4	8.8	60	69
Mandan 571	29	334	540	62	6.9	8.8	61	69
Nebraska-10	19	362	633	75	6.4	8.7	61	69
Utah-42-1	29	401	647	61	6.8	9.1	61	69
Fairway wheatgrass								
Standard	32	398	611	54	5.4	8.8	64	72
A-1770	24	431	602	40	7.0	7.7	63	70
Hard fescue	16	286	240	-16	6.8	9.8	60	64
Sheep fescue	16	258	273	6	5.4	8.6	69	72
Mean	27	368	539	46	6.4	8.9	61	68

1/ 1961 data.

2/ Fertilized yield-unfertilized yield = N efficiency, 5-year mean.

A positive yield response to residual nitrogen by crested wheatgrass following application in a dry year was also reported in earlier investigations (Sneva, et al., 1958). In that work it was found that response to residual nitrogen did not occur after a year of favorable moisture.

Crude protein content

Mean crude protein contents were significantly increased 2.5% in the presence of 30 pounds of nitrogen per acre in 1961, one of the dry years (Table 4). Sneva, et al., 1958, also reported significant herbage crude protein content increases from fertilizer rates of 40 or less pounds of nitrogen per acre; but, only in the dry years.

Varieties also differed significantly in their crude protein concentrations. Big bluegrass, sheep fescue, and standard fairway wheatgrass had significantly lower crude protein contents than all other grasses except Nebraska-10.

Herbage dry matter content

In the last three years, herbage dry matter contents at the time of harvest were determined (only that of 1961 is presented in Table 4). Main effects of nitrogen and varieties were significant sources of variation each year.

Nitrogen increased the mean dry matter content at harvest time by 7% in 1960 and 1961. Residual nitrogen in 1962 caused a significant mean increase in herbage dry matter contents at the time of harvest of 4%. This is surprising because crude protein content and dry matter yield increases due to residual nitrogen were not significant.

Tall wheatgrass in all years contained the least dry matter content at the time of harvest. This is not unrealistic, for this grass does have a later growth period than the other grasses tested and also "greens up" in the presence of summer showers. Big bluegrass develops early but is not summer dormant; it too "greens up" with summer rains. Dry matter content of big bluegrass when harvested on August 1 generally was lower than that of most other grasses. Siberian wheatgrass, which was recognized by Douglas et al., (1960) as remaining green longer than crested wheatgrass, generally had lower dry matter content than did the crested wheatgrass selections in this trial. Both fescues contained significantly higher dry matter content than the other grasses. In 1962, the fescues were harvested with 88% dry matter.

The influence upon cattle preference in late summer of species or varieties differing in dry matter content is not recorded in the literature. The range in dry matter content of 17% among unfertilized grasses in 1961 is sufficiently large to suggest possible influence upon preference by cattle.

CONCLUSIONS

The additional years of yield data substantiate the observations drawn at the end of the sixth growing season:

1. Big bluegrass can provide an earlier and greater forage supply than crested wheatgrass on these soils. However, slow establishment and a weak root system deter recommending this grass at the present time.

2. Siberian wheatgrass production was greater than that of standard crested wheatgrass, but not significantly. If other forage characteristics are acceptable, this grass could be used wherever standard crested wheatgrass is now recommended.

3. Whitmar wheatgrass production was equal to that of standard crested wheatgrass, and the specie was well adapted.

4. Tall wheatgrass, the third highest yield producing grass in the first five years, was an extremely poor performer in the later study years. It is not well adapted to these soils.

5. The two fairway and four crested wheatgrass selections produced similar yields.

The additional years of data also revealed that the yield trend between these grasses differs. In general, grasses producing at a high level during the first five years produced at a lower level the last four years; the reverse held true for those that had low yields during the early part of the study.

Yield differences among crested wheatgrass selections began in the sixth growing season; subsequent differences in yield were consistent, with Neb.-10 increasing its yield by the greatest amount.

Grasses exhibited considerable variation in their response to nitrogen. Siberian wheatgrass responded most to fertilization, a 143% increase. The greatest 5-year mean yield in the presence of nitrogen was produced by big bluegrass (2,118 lb./A.). Hard and sheep fescues were, with one exception, low responders to applied nitrogen. Crested and fairway wheatgrasses responded in the same way.

Both Sherman big bluegrass and Whitmar wheatgrass returned high amounts (38 and 32 lb./A.) of additional herbage per pound of nitrogen applied. When used as a late season forage supply, fertilization of these two grasses may be economical, depending upon grazing performance of animals on the fertilized forage. The above statement may also be valid for crested wheatgrasses; however, these grasses are recommended for early season grazing.

Greater herbage response to nitrogen was made in the more favorable moisture years and response to residual nitrogen in 1962 was quite high. Response in 1962 was partially attributed to the preceding dry years which may have accumulated and retained unused soil and fertilizer nitrogen. Crude protein in grasses in a dry year were increased an average of 2.5% in the presence of 30 pounds of nitrogen per acre. Significant differences in crude protein content among grasses also occurred.

Herbage dry matter content at the time of harvest of unfertilized grasses varied from 52 to 69% and that of tall and Siberian wheatgrass and big bluegrass was generally lower than that of the others. Nitrogen fertilization increased herbage dry matter content when determined on August 1.

SUMMARY

The performance of 12 introduced grasses from establishment in 1952 through 1962 with nitrogen treatments applied in the last 5 years on a semi-arid soil in eastern Oregon was presented and discussed. It was found that: (1) Big bluegrass was the highest yielding in the presence and absence of nitrogen. When disadvantages of slow establishment and "pull-up" can be overcome, this grass should be used extensively in this area. (2) Siberian wheatgrass produced as well as crested wheatgrass and increased its yield 143% in the presence of nitrogen, the largest increase of all grasses tested. If found comparable in other forage qualities, Siberian wheatgrass can be used in lieu of crested wheatgrass. (3) Tall wheatgrass yields in dry years were low and stands were deteriorating in the ninth and tenth years of this study. (4) Hard and sheep fescues were consistently low producers and made poor responses to nitrogen in most years. (5) Fairway and crested wheatgrass performed in a similar manner. (6) Grasses ranking high in production for the first five years showed decreases in production in the last four years. Grasses ranking low in the first five years generally exhibited increased production in the last four years. (7) Greater herbage yield response to nitrogen was found in the more favorable years and a response to residual nitrogen was measured following a dry year. (8) High response to nitrogen by big bluegrass and Whitmar wheatgrass suggest the opportunity of increasing fall herbage supply of these two grasses by fertilization. (9) Nitrogen significantly increased the crude protein content of the grasses in a dry year and dry matter content of the herbage in 1960, 1961, and 1962.

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