TECHNICAL BULLETIN 84 JUNE 1965

Seasonal Yield and Chemical Content of Forage Mixtures on a Pine Woodland Meadow Site in Northeastern Oregon

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The authors acknowledge the contribution of John L. Schwendiman, plant materials specialist of the Soil Conservation Service at Pullman, Washington. He provided the seed for the experimental nursery and gave valuable suggestions on which species to use.

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Introduction

What forage species or mixture to plant is a question common to both agronomists and livestock workers. Too often this question has had to be answered by either a single-yield figure commonly taken at the hay stage or by actual grazing experience from a large trial or demonstration area. A method is needed to evaluate more effectively the performance of promising forages. The experimental trial on which this report is based was designed to assist both technicians and livestock producers in making more enlightened decisions as to the best forage or mixture to use in improving meadows in the Blue Mountains of northeastern Oregon.

Numerous publications contain data on forage evaluation. Few studies, however, have been comprehensive enough to measure more than one or two factors influencing adaptability, productivity, and use of the more important species. Thomas, Hayes, and Schmid (1949) report 10 years of results from testing forage grasses in Minnesota. In their opinion, none of the new introductions performed as well as timothy and bromegrass. They reported, as have most workers, that legume mixtures were markedly superior to grasses sown alone.

Richards and Hawk (1945), working with sheep at the Eastern Oregon Experiment Station, were able to classify species on the basis of both production and palatability into hay and pasture grasses. In this study, crested wheatgrass, big bluegrass, meadow foxtail, and timothy were all regarded as hay species; meadow foxtail and crested wheatgrass, from the standpoint of palatability, were considered to be good pasture plants as well. When Richards and Hawk considered both yield and palatability of species used in this trial, they ranked tall wheatgrass first, followed in order by timothy, crested wheatgrass, big bluegrass, and meadow foxtail.

Vogel (1957) studied forage crop species response in Montana to varying soil moisture stress during germination. Using a fine sandy loam soil, he reported that three wheatgrasses—crested, tall, and intermediate—all exhibited germination at 15 atmospheres tension. Whitmar wheatgrass, birdsfoot trefoil, and Kentucky bluegrass gave no germination at $12\frac{1}{2}$ atmospheres tension, whereas meadow foxtail, big bluegrass, timothy, and ladak alfalfa exhibited limited germination at this level.

Recognizing these differences in moisture zone adaptability, the Oregon Interagency Report (1964) classifies a wide range of adapted grasses and legumes in Oregon for planting in precipitation zones from under 9 inches to over 25 inches. Up to 15 inches, crested wheatgrass and Whitmar wheatgrass are the best adapted. Most of the species used in this experiment fall into the 12- to 18-inch zone; tall wheatgrass is listed for 18 inches; and timothy, meadow foxtail, and Granger birdsfoot trefoil, for 18 to over 25 inches.

In variance with current recommendations for keeping pasture mixtures simple, Bateman and Keller (1956), studying grass-legume mixtures in Utah for irrigated pastures for dairy cows, reported that under their conditions yields increase as the number of productive species in the mixture is increased. Palatability, in their opinion, is considered to be important for two reasons only: (1) the forage must be sufficiently palatable to be acceptable to the grazing animal; and (2) the various components of a mixture must be utilized to such an extent that they can be maintained in proper balance with one another throughout the life of the pasture.

Hafenrichter, *et al.* (1949) classified grasses and legumes for soil conservation in the Pacific Northwest into several groups. Those categories, including the species studied in this experiment, are: (1) late-maturing—intermediate wheatgrass, pubescent wheatgrass, and tall wheatgrass; (2) drought-tolerant, long-lived bunchgrasses—crested wheatgrass and Whitmar beardless wheatgrass; (3) vernal dominant, dryland grasses—big bluegrass; (4) understory grasses with heavy root production—hard fescue; and (5) wet-meadowland grasses—meadow foxtail.

Seasonal development and nutritive value are important considerations in selecting forage varieties for range improvement. Under English conditions, Beddows (1956) reported that strains already available provide grass from mid-April to mid-October when appropriately managed. However, there is now a demand for strains with quite different growth rhythms to be grown in special leys.

A major problem facing forage breeders is the evaluation of their potential new strains before going through the rigorous process of selection and release only to find that the strains do not produce the most palatable and nutritious grazing desired. To avoid costly multiplication of promising genetic material that is needed to evaluate livestock performance by conventional methods, new evaluation techniques have been devised. For example, Bowden and Church (1962) report on correlations between *in vitro* and *in vivo* measures of digestibility and chemical components of forages. They found correlations between *in vitro* dry matter digestibility and *in vivo* dry matter digestibility were highly significant. Based on pooled correlations that are all high for *in vitro* dry matter digestibility with crude protein in the forage ($r = 0.68$), *in vitro* cellulose digestibility with crude protein content ($r = 0.66$), and *in vivo* dry matter digestibility with crude protein content ($r = 0.79$), a close relationship apparently exists between digestibility of a forage either *in vivo* or *in vitro* and its crude protein content. Accordingly, crude protein was chosen as the single best indicator of forage value in this study.

Most management recommendations for forage species have, historically, been based on clipping experiments. In general, different frequencies and heights have been used on grass stands as compared with legumes. Grass-legume mixtures generally respond best to cutting regimes which compromise the fairly frequent, high clipping requirements for grass; the less frequent but lower stubble height is best suited for legumes.

In this study, as near as possible, a ground-level clipping height was selected for use on temporary plots, and about a 2-inch stubble height for permanent quadrats 9.6 square feet in area. Four clipping times were used and these were adjusted to the growth stage of the native bluegrass: (1) *range readiness,* as indicated by 6 to 8 inches of leaf elongation; (2) *emergent,* when the seed heads were visible; (3) *hay stage,* or late flowering; and (4) *late summer,* when most of the foliage had lost its green color. At the last cutting, regrowth was taken on one-half of the plots cut at the range readiness and emergent stages. Results of this trial should permit extension of these findings to other remote nursery areas where clipping is more difficult and harvesting at the hay stage is all the yield data that can be obtained.

Experimental Area

The nursery is located on the Hall Ranch, a part of the Eastern Oregon Experiment Station. The ranch lies astride Catherine Creek in Township 5 South, Range 41 East, of the Willamette Meridian some 12 miles southeast of Union, Oregon. The elevation of the Hall Ranch nursery site is 3,500 feet. The nursery is located on a sloping bench on the lower one-third of the 2,000 foot escarpment which forms the west wall of Catherine Creek canyon.

Geology

Information on geology has been reported by Wagner (1955), who records that the Hall Ranch rests on the lava plateau which partially surrounds the west slope of the granitic Wallowa Mountains core. Flows in the Hall Ranch area consist of basalt and basaltic andesite with minor amounts of interbedded sediments and pyroclastics. The Wallowa upthrust has influenced this lower area through associated structural faulting. In recent times, ash from volcanic activity in the high Cascades was deposited on the area (Williams, 1942). This volcanic ash has greatly influenced some of the soils of the area.

Soils

The nursery site is located on the Couse series which consists of moderately well drained fine-textured Prairie-like or Prairie intergrading to Gray Brown Podzolic soils. These soils have developed in loess influenced by volcanic ash which overlays old fine-textured alluvium of varied mineralogy. An important characteristic of Couse soils is the abrupt horizon boundary from the A2 to the buried B2 horizon. The nursery plot has a slope gradient of 2 to 4%, and these soils normally occur on nearly level to sloping uplands. Surface runoff is fairly rapid, internal drainage is slow, and the permeability of the buried B2 is slow. During periods of high runoff, a water table moves laterally through the A2 horizon. The entire profile is slightly acid. A Couse series profile described at the Hall Ranch nursery site is given in the Appendix.

Appendix Tables 1 and 2 contain figures on moisture tension and selected chemical tests from soil samples taken at different depths in the profile on the Hall Ranch nursery. These soil test values indicate that the moisture-holding capacity of the upper 2 feet of the profile is good and that fertility and pH values are suitable for deep-rooted species such as legumes and grasses.

Climate

Climatic data are available from the Hall Ranch only from June to November, 1963, and for all of 1964. Precipitation at the nursery site for June through August was 3.8 inches in 1963 and 6.6 inches for the same period in 1964. The nearest stations with lengthy records are Union, Cove, and Elgin, Oregon, all reasonably close to the Hall Ranch geographically, but mountainous topography and differing storm tracks combine to make variation in climatic data between the stations extreme. Mean annual precipitation figures in inches for the stations are: Union, 13; Cove, 23; and Elgin, 26. Considering the precipitation records of the closest stations and the brief records from the nursery site, the bulk of the Hall Ranch is in the *Pinus ponderosa/Calamagrostis rubescens* type ecologically; a rough estimate of the precipitation received annually is 16 to 20 inches. Ten years of growing season precipitation data from Union are included in Table 1.

In general, the area receives the bulk of its precipitation as rain and snow during the cold winter months. Fall and spring months are

TABLE 1. MEAN TEMPERATURE AND GROWING SEASON PRECIPITATION AT EASTERN OREGON EXPERIMENT STATION, UNION, OREGON, FROM 1955 THROUGH 1964 AND FOR THE EXPERIMENTAL SITE IN 1963 AND 1964

	April		May		June		July		August	
	Ppt.	Temp.	Ppt.	Temp.	Ppt.	Temp.	Ppt.	Temp.	Ppt.	Temp.
	in.	° *F.*	*in.*	° *F.*	*in.*	° *F.*	*in.*	° *F.*	*in.*	° *F.*
1955	1.2	43	1.2	50	.5	61	.7	65	T	65
1956	.2	48	3.7	55	1.8	60	.8	67	1.1	64
1957	1.9	46	2.0	55	1.1	61	.3	65	.2	63
1958	2.1	45	1.9	59	4.1	61	1.3	67	.9	68
1959	1.2	47	1.8	49	.8	60	.3	66	.9	63
1960	1.3	47	4.1	50	.3	60	.6	70	2.2	62
1961	1.1	46	2.0	52	.4	65	T	69	.7	71
1962	1.0	49	2.4	50	.3	58	.2	64	.2	63
1963	1.5	44	1.3	54	2.3	60	.4	64	.6	66
1964	1.2	43	0.6	51	2.9	58	1.2	66	.5	62
					Experimental Area (precipitation only)					
1963	....		....		1.7		1.5		0.6	
1964	1.6		0.6		3.5		0.9		2.2	

cool and frequently moist. July and August are very dry and warm, although infrequent showers do occur.

Mean monthly temperature for January is about 30° F., and for July about 60° F., but again these are rough estimates based on Union, Cove, and Elgin climatic data.

Land-use history

Settlement started along Catherine Creek in the Union area by the mid 1860's. Catherine Creek, which flows through the Hall Ranch, offered a natural path from these early settlements to the high mountain ranges of the west slope of the Wallowas. By location, the Hall Ranch became used as spring-fall range for cattle and sheep. Bands of horses also wintered in more open areas of the ranch. Experiment Station records indicate the Hall Ranch was rather heavily used by both sheep and cattle from 1936 to 1956. A range survey in 1956 indicated the nursery site was in poor range condition. The original owner of the Hall Ranch cut hay and cultivated parts of some of the meadows on the ranch. The meadow where the nursery is located probably has been plowed at one time and, undoubtedly, occasional hay crops have been harvested. During the last 25 years, it was neither cultivated or harvested other than by grazing animals.

Vegetation

The vegetation on the Hall Ranch is predominantly ponderosa pine (*Pinus ponderosa* Dougl.) with a pinegrass (*Calamagrostis* *rubescens* Buckl.) and elk sedge (*Carex geyeri* Boott.) understory. On shallow soils and south slopes, the pine stands become quite open with a bunchgrass understory of bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Sm.) and Idaho fescue (*Festuca idahoensis* Elmer.). On deeper soils with higher volcanic ash content, considerable Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco.) and western larch (*Larix occidentalis* Hook.) become mixed with the ponderosa pine. As Douglas-fir and western larch increase, a considerable shrub layer of ninebark (*Physocarpos malvaceus* (Greene) Kuntze) and ocean spray (*Holodiscus discolor* (Pursh) Maxim.) develops. North slopes with rather deep, pure ash soils are occupied by dense stands of grand fir (*Abies grandis* Lindl.), Douglas-fir, and western larch.

Interspersed through the timber are infrequent open benches with meadow vegetation. Wet meadows occur in basins and on soils with rather restricted drainage. Their vegetation is composed of tufted hairgrass (*Deschampsia caespitosa* L.), redtop (*Agrostis palustris* Huds), Kentucky bluegrass (*Poa pratensis* L.), and Canada bluegrass (*Poa compressa* L.). Several dry meadows occur on the Hall Ranch, with vegetation consisting originally of about 75% Idaho fescue, 5% Kentucky or Canada bluegrass, and a variety of perennial grasses and forbs (Anderson, 1959). Currently the drier meadows on the Hall Ranch are occupied by sod bluegrasses and perennial and annual forbs (Appendix Table 3).

The original vegetation of the site of the Hall Ranch nursery is difficult to reconstruct. Currently the meadow outside the nursery exclosure is a sod of Canada and Kentucky bluegrass with such forbs as cinquefoil (*Potentilla glandulosa* Lindl.), yarrow (*Achillea lanulosa* Nutt.), silver lupine (*Lupinus leucophyllus* Dougl.), and Canadian thistle (*Cirsium arvense* Scop.). Little, if any, Idaho fescue or tufted hairgrass is present. The site appears too moist for the characteristic dry meadow and too dry for the usual wet meadow. The nursery "meadow" may originally have been a rather open woodland with large meadow-like openings; its present appearance has been altered by clearing and plowing. The Couse series soils are usually associated with open ponderosa pine/pinegrass woodlands. Bordering the nursery meadow, Couse series soils support an open ponderosa pine woodland with a snowberry (*Symphoricarpos albus* (L.) Blake), elk sedge, pinegrass understory beneath the pine canopy. The larger openings, between the pine stands, with good soil depth support a vegetation similar to that presently found on the nursery site.

Experimental Design and Procedures

Based on results of a nursery established on the same site in the 1940's, a formerly undisturbed part of the study area was summer-fallowed shallowly as soon as the soil dried in 1954. It was plowed in the fall and seeding was accomplished on May 18, 1955, so that 20 viable seeds were supplied per foot of row. Rows were spaced 8 inches apart.

The 13 mixtures listed in Table 2 were used in a randomized block design with four replications. Plot size was 22 feet by 40 feet, or about 1/50 of an acre in area. These were later split into two, 1/100-acre plots for evaluating fertilizer responses. The area was mowed in the summer of 1955 to control weeds and sampled in late August to obtain an average stand count per foot of row. The first yield samples were taken from permanently located 9.6-square-foot plots established in late July of 1956.

In 1957, a sampling design was employed to obtain yields on 4.8-square-foot randomized plots. The four stages of plant development and approximate dates at which harvests were taken are as follows:

1. Range readiness—about June 1.
2. Emergent stage—about June 20-25.
3. Hay stage—about July 15-25.
4. Late summer—about August 15-25.

One-half of the plots clipped at the range readiness and emergent stages were reclipped in August to measure regrowth.

In 1958, complete data were taken on all plots and an electronic computer program was designed to summarize both forage and nutrient yield analyses. In April of 1959, one-half of each plot (that portion without the permanent 9.6-square-foot quadrat) was fertilized with 60 pounds of nitrogen and 40 pounds of P_2O_5 in the form of ammonium nitrate and single superphosphate. Both the 1959 and 1960 analyses involved the fertilizer variable—immediate response in 1959 and residual effects in 1960.

Stand evaluation based on ground cover was made on May 4, 1963. Plots were rated according to the following classes:

1. Over 75% ground cover, excellent stand.
2. 50 to 75% ground cover, good stand.
3. 25 to 50% ground cover, fair stand.
4. 5 to 25% ground cover, poor stand.
5. Less than 5% ground cover, very poor stand.

In July 1963, all permanent 9.6-square-foot plots, together with two randomly located 4.8-square-foot plots, were clipped at the hay stage to provide a check on stand compositional changes by weight which occurred during the experimental period from 1956 to 1963 inclusive. Randomly located temporary plots were included in this last harvest to check on the possible cumulative effects of yearly clipping on the species in permanent quadrats.

In September 1963 and June 1964, the plots were grazed by 20 cows with calves for one-day periods to record seasonal grazing preferences in both fall and spring.

Results

An 8-year summary of forage yields from permanent plots on species and mixture comparisons at the Hall Ranch is presented in Table 2. On the basis of these data, it is not difficult to pick out the most productive, long-lived species based on single harvests taken at the hay stage. The most consistent high producer has been intermediate wheatgrass. The only other consistent producer, although significantly lower in production, has been hard fescue. Tall wheatgrass had the greatest variability in yields and was hurt measurably by continual close clipping.

Figure 1 shows the marked superiority of intermediate and tall wheatgrasses in comparison with the other three wheatgrasses used on this site. Data in Figure 2 indicate that meadow foxtail and hard fescue are the only other grass species of those tested to qualify as suitable long-lived forages for seeding on this meadow area. Based on recommendations in the Interagency seeding report (1964), intermediate and tall wheatgrasses, meadow foxtail, and timothy should be the heaviest producers when well managed in this zone of effective moisture. Under poorer grazing management, pubescent wheatgrass and hard fescue could be expected to excel.

At the conclusion of the study in 1963, the only treatments producing more than one ton of hay per acre were the grass-legume mixtures (Table 2, Figure 3). Because of rodent damage to the nomad alfalfa, Granger birdsfoot trefoil is now producing as much or more dry matter per acre, but the protein yield from the grass-alfalfa mixture has been superior to that of the grass-trefoil combination until the last couple of years. Data in Figure 4 show that since 1959 nomad alfalfa has decreased in production in comparison with Granger birdsfoot trefoil as an important legume component in mixture with intermediate wheatgrass. Two reasons have probably contributed to this decline. One is the relatively better adaptation of nomad alfalfa to grazing, where it takes on a more prostrate growth habit, rather than cutting for hay; and the other is the concentrated rodent activity, primarily pocket gophers, on the alfalfa plots. Temporary samples were necessary to evaluate the alfalfa-intermediate treatments in 1963, since rodent activity had interfered with relocating the permanent plot markers in both 1962 and 1963.

TABLE 2. SUMMARY OF HAY STAGE HERBAGE YIELDS IN POUNDS PER ACRE AIR DRY WEIGHT OVER EIGHT-YEAR PERIOD (1956-1963) FROM PERMANENT 9.6-SQUARE-FOOT PLOTS IN HALL RANCH STUDY AREA

Species	Year of harvest 1956	1957	1958	1959	1960	1961	1962	1963	1963[1]	Ground cover[2]
	pounds per acre									%
Whitmar wheatgrass	3,270	1,690	1,240	490	290	750	620	880	800	50
Total	3,770	2,040	1,480	680	610	1,050	620	940	1,330	
Tall wheatgrass	5,490	1,680	1,710	600	280	460	370	630	1,570	70
Granger birdsfoot trefoil	130	170	760	620	420	630	210	340	340	10
Total	5,720	2,010	2,810	1,420	970	1,280	570	1,200	2,470	
Intermediate wheatgrass	2,910	1,320	1,860	750	860	1,150	880	1,410	1,470	90
Total	3,190	1,330	1,910	790	920	1,230	880	1,470	1,560	
Crested wheatgrass	3,180	980	1,280	720	350	420	270	240	540	65
Total	3,330	1,140	1,420	920	410	670	340	680	970	
Pubescent wheatgrass	3,040	1,270	1,580	780	480	500	260	340	1,000	80
Total	3,160	1,320	1,630	860	590	680	260	730	1,120	
Meadow foxtail	2,170	1,020	1,170	740	640	630	530	710	1,080	90
Total	2,400	1,140	1,350	880	700	780	530	960	1,120	
Hard fescue	840	950	1,070	950	1,000	910	700	890	890	90
Total	1,420	1,120	1,290	1,000	1,050	960	700	1,000	990	
Timothy	3,530	1,350	1,910	730	620	650	80	330	420	15
Total	3,790	1,520	2,160	880	850	880	490	750	980	
Sherman big bluegrass	2,280	1,050	780	220	360	190	40	......	310	40
Total	2,780	1,270	1,410	750	710	830	280	750	990	
Crested wheatgrass	2,390	1,050	1,260	470	220	270	130	30	70	5
Hard fescue	....	110	260	500	410	680	640	850	750	90
Total	2,600	1,610	1,830	1,290	760	1,150	790	930	1,110	
Whitmar wheatgrass	1,630	170	560	270	350	270	220	370	790	30
Hard fescue	680	800	370	440	380	470	660	360	340	70
Total	3,030	1,150	1,100	850	920	840	880	790	1,350	
Intermediate wheatgrass	2,820	2,080	2,720	1,240	750	790	420	580	1,940	70
Nomad alfalfa	680	110	1,520	1,110	440	650	50	330	310	50
Total	3,800	2,230	4,270	2,370	1,260	1,600	520	1,090	2,500	
Intermediate wheatgrass	4,390	2,050	2,430	1,000	810	850	580	1,160	1,210	75
Granger birdsfoot trefoil	....	20	130	240	440	770	230	680	610	15
Total	4,520	2,130	2,640	1,390	1,450	1,790	810	1,890	2,180	

[1] In 1963, yields were taken also from randomly located temporary plots to check on possible cumulative effects of clipping on yields from permanent quadrats.

[2] Stand ratings were obtained in May 1963 by estimating percent ground cover to the nearest 5% for each species per plot. Figures given are means of estimates from four plots and because of foliage layers may add to more than 100%.

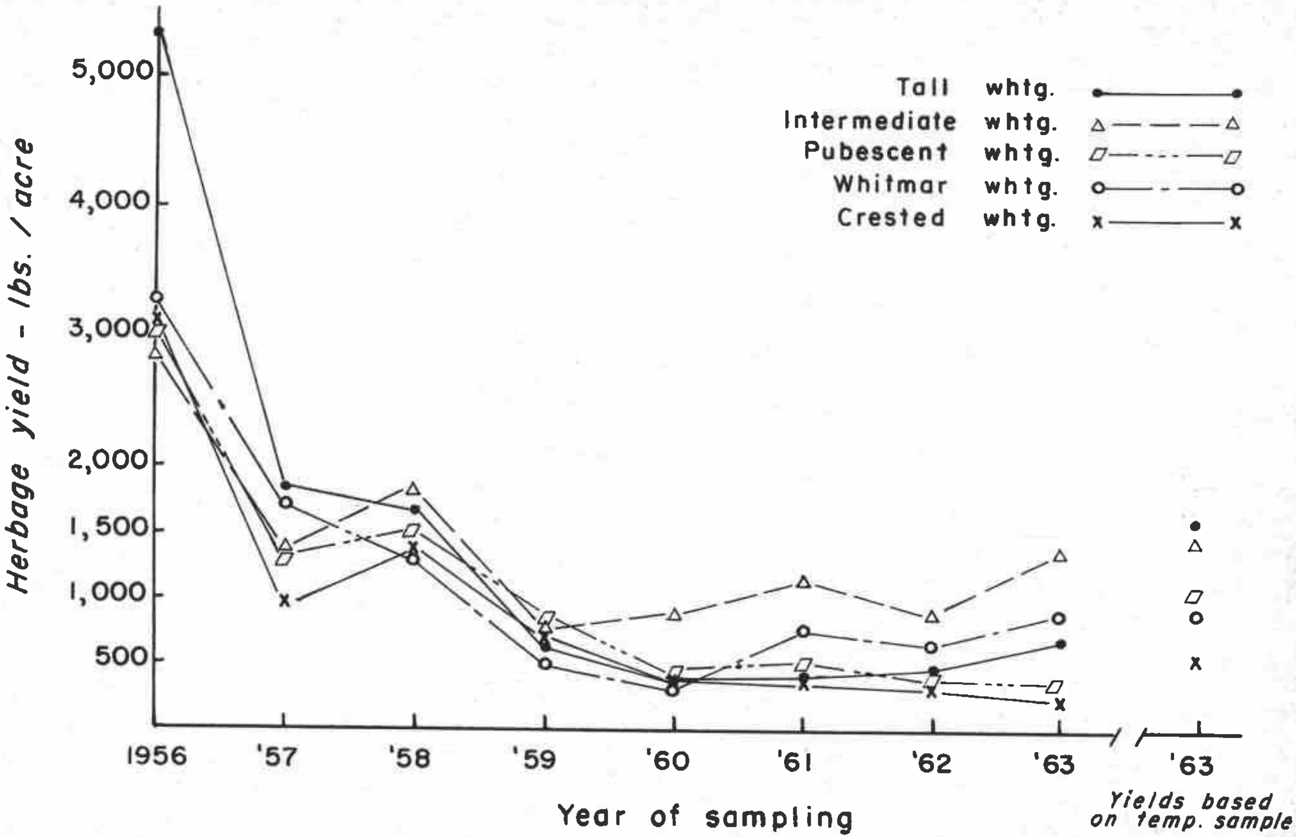

Figure 1. Production of all wheatgrasses in trials on Hall Ranch nursery. Harvests at hay stage from permanent 9.6-square-foot plots, except for temporary sampling in 1963.

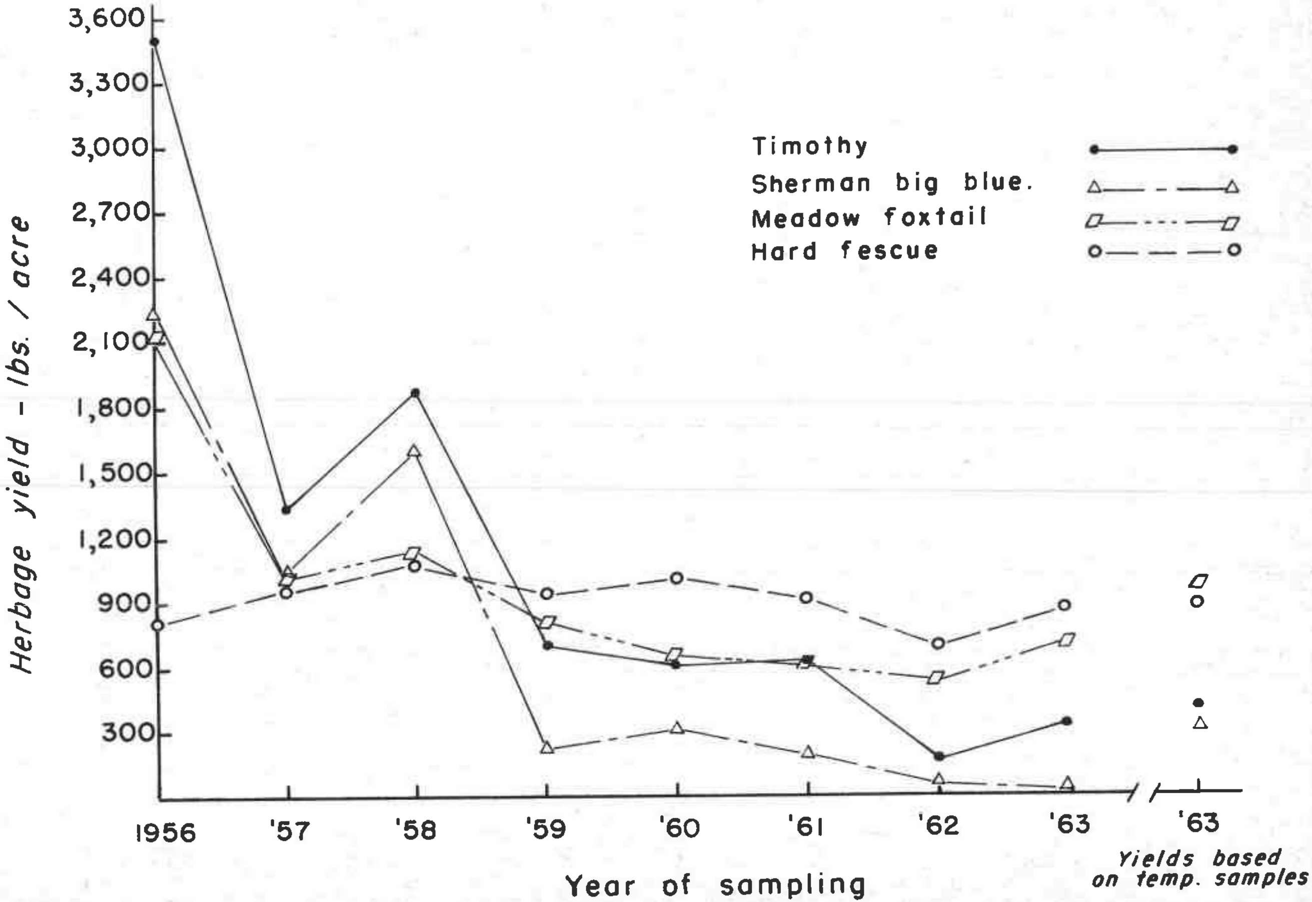

Figure 2. Yields of grasses other than wheatgrasses used in trials on Hall Ranch. All data are comparable to those in Figure 1.

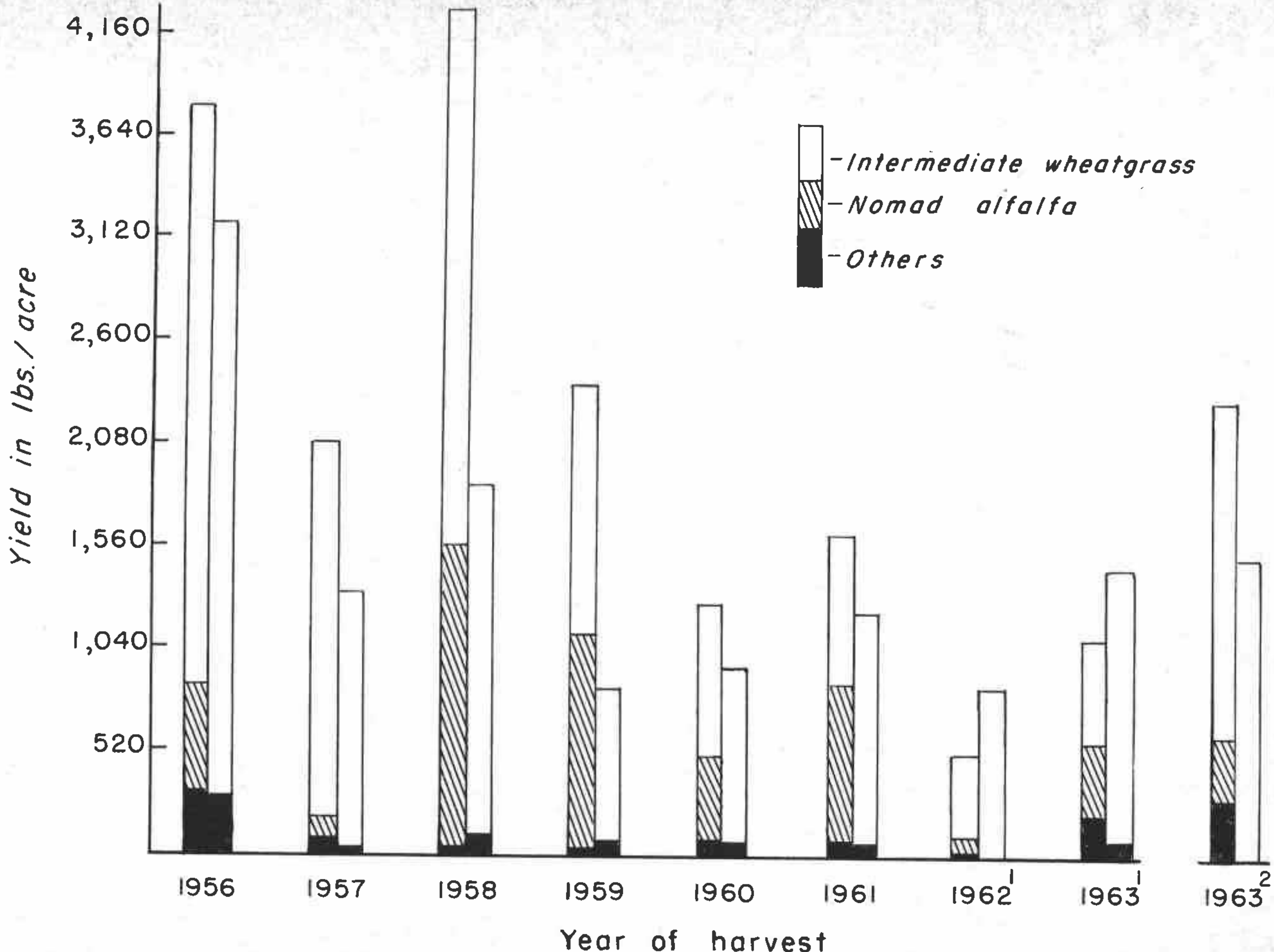

Figure 3. Comparison of yields from alfalfa-intermediate wheatgrass mixture with intermediate wheatgrass alone.

[1]Low yields in alfalfa-grass mixture in 1962 and 1963 were caused by failure to relocate stakes of permanent plots which were disturbed by excessive rodent activity. [2]Relative yields from temporary plots in 1963 were similar to those on permanent plots prior to 1962.

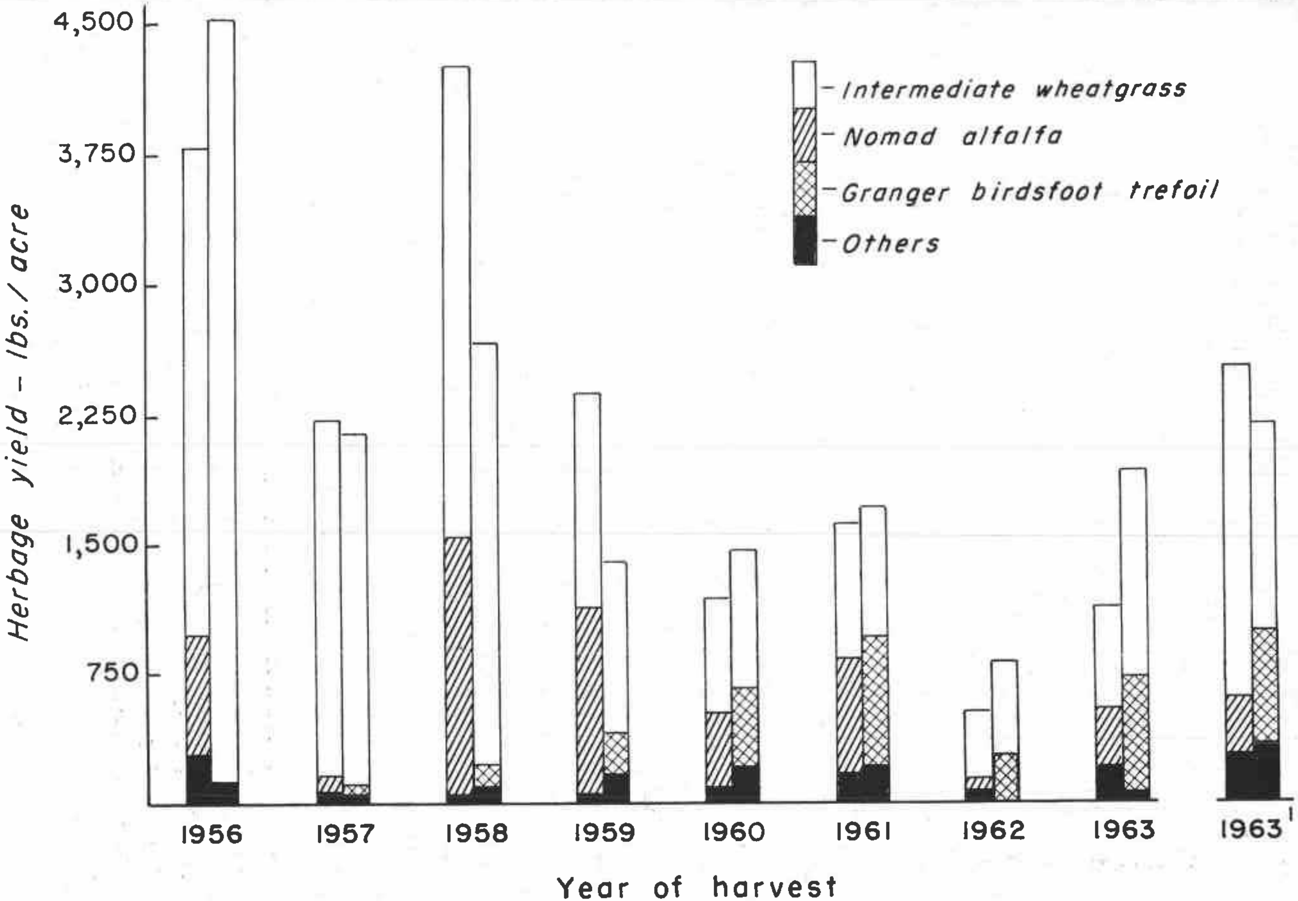

Figure 4. Yields of mixtures containing intermediate wheatgrass plus nomad alfalfa or Granger birdsfoot trefoil.
[1]Temporary plot samples in 1963.

Table 2 includes stand ratings 8 years after seeding. These data further support the value of intermediate wheatgrass alone and in mixtures for this and similar sites in the Blue Mountain area. Cover ratings on intermediate wheatgrass-nomad alfalfa plots are higher than those from intermediate-trefoil treatments and help to explain the greater complementary effect of the legume on grass yields taken from temporary plots in 1963. Reference to yields from these randomly located plots in 1963 to check on cumulative effects of clipping revealed little difference between permanent and temporary plot yields for: Whitmar and intermediate wheatgrasses, hard fescue, timothy, and intermediate wheatgrasses in combination with Granger birdsfoot trefoil. Marked differences were apparent for: tall wheatgrass, pubescent wheatgrass, crested wheatgrass, Sherman big bluegrass, meadow foxtail, and intermediate wheatgrass in combination with nomad alfalfa. The difference in intermediate wheatgrass-alfalfa yields has already been explained largely on the basis that all but one permanent plot marker was obscured by rodent activity.

Figures 5 and 6 illustrate the condition of stands of intermediate wheatgrass, intermediate wheatgrass plus nomad alfalfa, and hard fescue in July 1963. Although the stand of intermediate wheatgrass alone is good, the general vigor and height of the grass-legume mixture is superior. The stand of hard fescue is characterized by an abundance of fine basal leafage.

1958-1960 intensive clipping design

Complete analyses of variance for yields taken from 1958 through 1960 are shown in Table 3. Limited precipitation for both 1959 and June and July in 1960 (Table 1) removed a significant potential site difference attributable to replications in 1958. Otherwise, treatments, cuttings, and the treatment x cutting interaction were all significant throughout the 3-year period. In 1960, residual effects of fertilizer exhibited a significant cutting x fertilizer interaction. This differential response of fertilizers among cuttings could not be measured in 1959, since complete harvests the year of application were taken only on the fertilized portion of the plot.

Yields in 1960 of unfertilized treatments and residual effects of fertilization by cutting stages are shown in Table 4. Limited data on hay stage and late summer production are available from 1959 and indicate that yields from all fertilized treatments were at least doubled and some of them trebled in 1959 (Table 5). As expected, pure grass stands responded better to fertilizer containing nitrogen than grass-legume mixtures did. Most of the residual benefit of fertilizer in 1960 came from the emergent stage clipping plus regrowth. This delay in the first harvest until late June enabled all species to receive maximum

Table 3. Analyses of variance of yields taken from Hall Ranch nursery mixtures for three consecutive years

1958 yields

Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	983,540	4.15**
Treatments	12	7,164,835	30.20**
Cuttings	3	29,347,342	123.72**
Treatments x cuttings	36	785,975	3.31**
Error	153	237,215	

1959 yields

Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	95,467	.40
Treatments	12	7,204,517	29.96**
Cuttings	3	55,985,850	232.87**
Treatments x cuttings	36	703,506	2.93**
Error	153	240,420	

1960 yields

Source of variation	Degrees of freedom	Mean square	F
Total	415		
Replications	3	143,637	2.05
Treatments	12	2,340,133	33.46**
Cuttings	7	11,599,877	165.87**
Fertilizer	1	772,820	11.05**
Cutting stage	3	24,873,922	355.69**
Cutting x fertilizer	3	491,244	7.02**
Treatment x cutting	84	176,352	2.52**
Treatment x fertilizer	12	89,306	1.28
Treatment x cutting	36	303,489	4.34**
Treatment x fertilizer x cutting	36	660,252	.95
Error	309	69,932	

** Indicates significance at .01 level of probability.

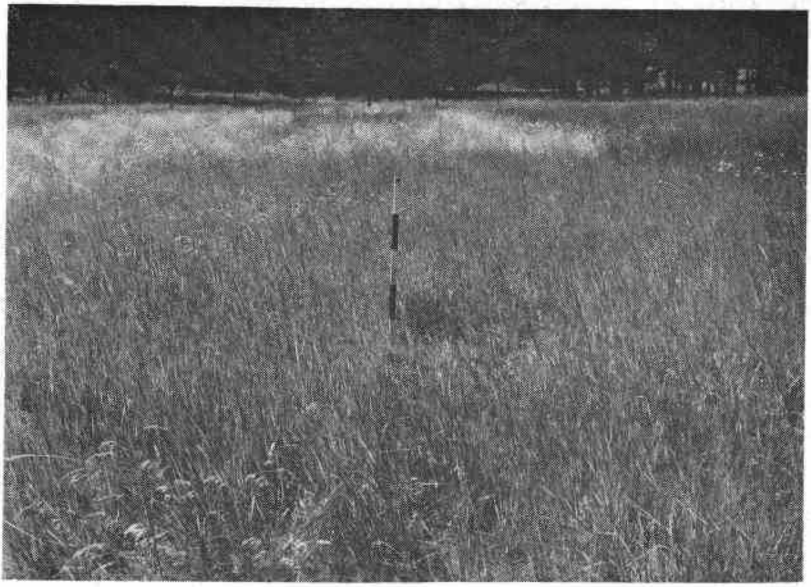

Figure 5a. Stand of pure intermediate wheatgrass photographed July 25, 1963, eight years after seeding.

Figure 5b. Plot of intermediate wheatgrass plus nomad alfalfa which exhibits a generally taller and more vigorous growth than the grass alone (Figure 5a).

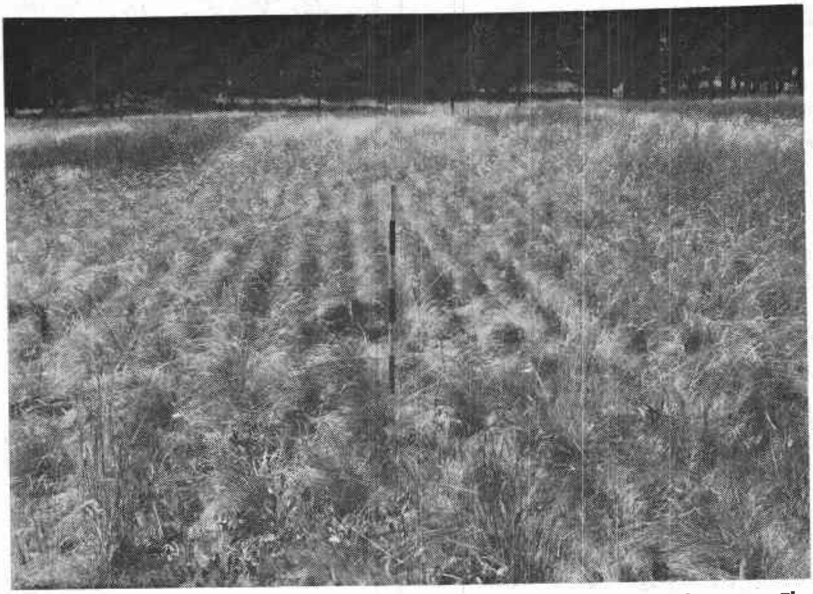

Figure 6. Hard fescue planting which clearly illustrates the original seeded rows. The abundant basal leafage on this species furnishes excellent late summer or early fall forage.

benefit from fertilizer applied in 1959. In fact, hard fescue was the only species not reflecting a net increase in yield from the emergent stage clipping plus regrowth in late August. Reference to regrowth yields in Tables 6 and 7 indicates that only a small proportion of the total, generally less than 15%, was produced after the first clipping on June 23, whereas about 20 to 40% of the total was obtained as regrowth after clippings on June 7. This difference of only two weeks in cutting dates is particularly crucial from the standpoint of regrowth in years with low June precipitation (Table 7). However, even in 1958 with abundant June moisture, regrowth from a late June cutting was still only one-third that for early June (Table 6).

Forage values based on regrowth after early clipping or grazing vary tremendously among species and mixtures. In 1960, with low June precipitation, Sherman big bluegrass and the grass-legume mixtures were superior. In 1958, with abundant late spring moisture, meadow foxtail and hard fescue together with Sherman big bluegrass were outstanding grasses, and Granger birdsfoot trefoil in both intermediate and tall wheatgrass mixtures was better than alfalfa with intermediate wheatgrass. Mean production figures in 1958 and 1960 were remarkably similar, 1,500 to 1,200 pounds per acre, but grasses alone yielded relatively more in the poor year than the grass-legume mixtures. For example, in 1960 with low precipitation and a residual

TABLE 4. EFFECT OF FERTILIZER BY CUTTING DATES ON HERBAGE YIELDS IN POUNDS PER ACRE IN 1960

Species	Range readiness and regrowth			Emergent stage and regrowth			4.8 hay stage			Late summer		
	Fert.	Unfert.	Diff.	Fert.	Unfert.	Diff.	Fert.	Unfert.	Diff.	Fert.	Unfert.	Diff.
	pounds per acre			*pounds per acre*			*pounds per acre*			*pounds per acre*		
Crested wheatgrass	560	560	— 0	920	640	+280	760	760	....	850	790	+ 60
Sherman big bluegrass	850	680	+170	850	810	+ 40	720	690	+ 30	800	600	+200
Pubescent wheatgrass	660	740	— 80	950	590	+360	880	920	— 40	880	820	+ 60
Whitmar wheatgrass	890	1,160	—270	1,300	800	+500	1,340	690	+650	960	900	+ 60
Timothy	840	680	+160	1,150	950	+200	1,140	980	+160	1,080	900	+180
Crested wheatgrass and hard fescue	940	1,140	—200	1,150	1,080	+ 70	940	780	+160	800	910	—110
Meadow foxtail	1,040	1,190	—150	1,750	980	+770	1,540	1,180	+360	1,250	990	+260
Whitmar wheatgrass and hard fescue	1,430	1,240	+190	1,390	1,250	+140	1,000	1,190	—190	1,350	860	+490
Hard fescue	1,350	880	+470	1,770	1,800	— 30	950	1,030	— 80	1,140	1,110	+ 30
Tall wheatgrass and Granger lotus	1,060	980	+ 80	1,240	1,090	+150	1,180	1,520	—340	1,180	1,420	—240
Intermediate wheatgrass	940	1,050	—110	1,290	1,170	+120	1,890	1,750	+140	1,260	1,640	—380
Intermediate wheatgrass and Granger lotus	1,060	1,040	+ 20	1,640	1,470	+170	1,770	1,750	+ 20	1,740	1,500	+240
Intermediate wheatgrass and nomad alfalfa	1,630	1,540	+190	2,390	1,950	+440	1,910	2,110	—200	1,850	1,990	—140
Mean	1,160	1,130		1,370	1,120		1,230	1,180		1,160	1,110	

TABLE 5. INFLUENCE OF FERTILIZER ON HAY STAGE AND LATE SUMMER YIELDS IN POUNDS PER ACRE OF MIXTURES IN HALL RANCH NURSERY THE YEAR OF APPLICATION, 1959

Species	Hay stage Unfert.	Hay stage Fert.	Late summer Unfert.	Late summer Fert.
	pounds per acre		*pounds per acre*	
Sherman big bluegrass	530	1,910	730	1,600
Whitmar wheatgrass	860	2,060	990	1,960
Hard fescue	900	2,150	880	1,800
Pubescent wheatgrass	970	2,190	800	2,160
Whitmar wheatgrass and hard fescue	990	2,060	1,060	2,260
Crested wheatgrass and hard fescue	1,020	2,560	1,280	2,820
Timothy	1,060	3,260	1,420	3,410
Crested wheatgrass	1,220	2,910	1,140	3,040
Meadow foxtail	1,250	3,200	900	2,940
Intermediate wheatgrass and Granger birdsfoot trefoil	1,670	3,760	1,600	3,860
Tall wheatgrass and Granger lotus	1,770	3,300	1,610	3,080
Intermediate wheatgrass	1,780	4,090	1,510	3,800
Intermediate wheatgrass and nomad alfalfa	3,140	4,450	2,290	3,840
Mean	1,320	2,920	1,240	2,810

response from nitrogen and phosphate fertilizer, three grass plantings —meadow foxtail, hard fescue, and hard fescue-Whitmar wheatgrass —were ranked next to intermediate wheatgrass and alfalfa. In contrast, in 1958 all grass-legume mixtures outyielded grass alone at least $1\frac{1}{2}$ to 2 times.

Analyses of 1958-1960 yield data

These variations in regrowth and response to nitrogen fertilizer are similar to those reported by Sneva, *et al.* (1958) on crested wheatgrass in the Oregon high desert. Examination of data on fertilized yields in 1959 supports Hyder and Sneva's (1961) contention that nitrogen fertilization should not be employed prior to early grazing. Range readiness clippings on June 2, 1959, plus regrowth cut on August 27, yielded less than one-half the amounts obtained by waiting until June 25. These data indicate that if greater quantities of early spring grazing are desired, one might profitably fertilize creeping meadow foxtail or more economically use a mixture of intermediate wheatgrass and nomad alfalfa.

TABLE 6. INITIAL AND REGROWTH YIELDS AND REGROWTH PERCENT OF TOTAL YIELDS IN POUNDS PER ACRE FROM HALL RANCH NURSERY MIXTURES WHEN CUT AT RANGE READINESS (JUNE 2) AND EMERGENT (JUNE 20) STAGES IN 1958

Species	Range readiness	Regrowth	Total	Regrowth percent of total	Emergent stage	Regrowth	Total	Regrowth percent of total
	pounds per acre			%	*pounds per acre*			%
Crested wheatgrass and hard fescue	590	310	900	35	260	130	390	33
Pubescent wheatgrass	600	230	830	27	1,050	70	1,120	6
Whitmar wheatgrass and hard fescue	680	340	1,020	33	1,030	170	1,100	16
Sherman big bluegrass	410	350	760	46	1,110	320	1,430	22
Whitmar wheatgrass	690	250	940	27	1,280	100	1,380	7
Meadow foxtail	670	430	1,100	39	980	280	1,260	22
Crested wheatgrass	1,790	420	2,210	19	60	150	210	71
Timothy	590	430	1,020	42	1,490	210	1,700	12
Hard fescue	800	550	1,350	42	1,470	200	1,670	12
Intermediate wheatgrass	1,030	600	1,630	37	1,500	60	1,560	4
Intermediate wheatgrass and Granger lotus	1,000	860	1,860	47	2,400	440	2,840	16
Intermediate wheatgrass and nomad alfalfa	1,710	490	2,200	22	3,020	160	3,180	5
Tall wheatgrass and Granger lotus	1,260	1,600	2,860	56	2,400	440	2,840	16
Mean	910	530	1,430	37	1,390	210	1,590	13

Table 7. Initial and regrowth yields and regrowth percent of total yields in pounds per acre from Hall Ranch nursery mixtures when cut at range readiness (June 7) and emergent (June 23) stages in 1960

Species	Range readiness	Regrowth	Total	Regrowth percent of total	Emergent stage	Regrowth	Total	Regrowth percent of total
		pounds per acre				*pounds per acre*		
Crested wheatgrass	440	120	560	21	890	30	920	3
Pubescent wheatgrass	510	150	660	22	950	....	950	0
Sherman big bluegrass	590	260	850	31	760	90	850	11
Timothy	700	140	840	17	1,150	....	1,150	0
Crested wheatgrass and hard fescue	710	230	940	25	1,140	20	1,160	13
Whitmar wheatgrass	730	160	890	18	1,230	70	1,300	5
Intermediate wheatgrass	680	260	940	27	1,290	....	1,290	0
Tall wheatgrass and Granger lotus	630	430	1,060	41	1,180	60	1,240	5
Intermediate wheatgrass and Granger lotus	650	410	1,060	38	1,600	40	1,640	2
Meadow foxtail	850	190	1,040	18	1,720	25	1,750	1
Whitmar wheatgrass and hard fescue	1,160	280	1,430	19	1,250	140	1,390	10
Hard fescue	1,110	240	1,350	17	1,620	150	1,770	9
Intermediate wheatgrass and nomad alfalfa	1,120	520	1,640	32	2,290	100	2,390	4
Mean	760	260	1,020	25	1,310	60	1,370	4

Tables 8 and 9 include mean yield data from unfertilized treatments for three years, 1958 through 1960, and fertilizer responses in 1959 and 1960. Since the mixtures in each analysis have been arranged in order of increasing magnitude of yield, differences among species in yield trends and fertilizer responses are easily observed. Crested, pubescent, and Whitmar wheatgrasses, together with Sherman big bluegrass, fall generally into a low group, whereas creeping meadow foxtail, intermediate wheatgrass, and intermediate wheatgrass and legume mixtures are high. Some species, such as timothy, start as good stands and decline rather quickly in contrast to other stands; for example, hard fescue, which is intermediate in magnitude, continued to increase during the course of the experiment.

Although there was no significant fertilizer treatment interaction in 1960, a comparison of unfertilized and fertilized yields for meadow foxtail in 1959 shows a better than average first-year response to fertilizer. Whereas the yield of most grass species was doubled by fertilization, production on meadow foxtail was nearly $2\frac{1}{2}$ times as great as that on the check plot. These data clearly show the advisability of using nitrogen on pure grass stands of improved species, whereas grass-legume mixtures responded poorly to a complete fertilizer and would be more economically served by non-nitrogen amendments.

The significant cutting stage x fertilizer interaction is apparent in Figures 7 and 8. Even though residual fertilizer responses were generally low in 1960, it is obvious that all fertilized mixtures yielded most when cut at the emergent stage of growth. This difference for a grass species responsive to fertilizer, such as creeping meadow foxtail, is similar to that for a grass-legume mixture, e.g., intermediate wheatgrass and nomad alfalfa, even though fertilizer might be economical in the case of the pure grass stand and definitely not recommended for the grass-legume mixture. Table 3 and Figures 7 and 8 illustrate clearly the point many researchers have made about the importance of properly timed cuttings or grazing when managing non-irrigated fertilized stands of forage. If cutting or grazing comes too early, the photosynthetic capacity is reduced below the critical minimum to make efficient use of the added nutrients, and if cut too late the opportunity for regrowth is impaired, thus reducing the efficiency of nutrient uptake.

Analyses of 1958-1960 nutrient yields

Crude protein. Analyses of variance for protein yields are included in Table 10. These results are similar to those for herbage yields except that replications were not significant in any year and there was no residual response of fertilizer in 1960 on protein yield.

TABLE 8. MULTIPLE RANGE TEST OF UNFERTILIZED YIELDS[1] IN POUNDS PER ACRE OF HALL RANCH NURSERY MIXTURES FOR 1958, 1959, AND 1960

1958		1959		1960	
Mixture	Yield	Mixture	Yield	Mixture	Yield
	lb./A.		*lb./A.*		*lb./A.*
Sherman big bluegrass	1,200	Sherman big bluegrass	670	Crested wheatgrass	690
Meadow foxtail	1,240	Whitmar wheatgrass	840	Sherman big bluegrass	700
Whitmar wheatgrass and hard fescue	1,240	Pubescent wheatgrass	880	Pubescent wheatgrass	760
Crested wheatgrass and hard fescue	1,270	Hard fescue	920	Whitmar wheatgrass	870
Whitmar wheatgrass	1,290	Whitmar wheatgrass and hard fescue	960	Timothy	880
Hard fescue	1,340	Meadow foxtail	1,010	Crested wheatgrass and hard fescue	980
Pubescent wheatgrass	1,350	Crested wheatgrass	1,090	Meadow foxtail	1,080
Crested wheatgrass	1,550	Timothy	1,120	Whitmar wheatgrass and hard fescue	1,130
Timothy	1,830	Crested wheatgrass and hard fescue	1,190	Hard fescue	1,200
Intermediate wheatgrass	2,080	Intermediate wheatgrass	1,420	Tall wheatgrass and Granger lotus	1,250
Intermediate wheatgrass and Granger lotus	2,290	Intermediate wheatgrass and Granger lotus	1,550	Intermediate wheatgrass	1,400
Tall wheatgrass and Granger lotus	2,840	Tall wheatgrass and Granger lotus	1,600	Intermediate wheatgrass and Granger lotus	1,440
Intermediate wheatgrass and nomad alfalfa	3,360	Intermediate wheatgrass and nomad alfalfa	2,600	Intermediate wheatgrass and nomad alfalfa	1,900

[1] Mean yields not covered by the same line are significantly different.

TABLE 9. MULTIPLE RANGE TEST OF BOTH UNFERTILIZED AND FERTILIZED YIELDS[1] IN POUNDS PER ACRE OF HALL RANCH NURSERY MIXTURES FOR 1959 AND 1960

1959				1960			
Unfertilized		Fertilized		Unfertilized		Fertilized	
Mixture	Yield	Mixture	Yield	Mixture	Yield	Mixture	Yield
	lb./A.		*lb./A.*		*lb./A.*		*lb./A.*
Sherman big bluegrass	670	Sherman big bluegrass	1,430	Crested wheatgrass	690	Crested wheatgrass	770
Whitmar wheatgrass	840	Whitmar wheatgrass	1,560	Sherman big bluegrass	700	Sherman big bluegrass	800
Pubescent wheatgrass	880	Whitmar wheatgrass and hard fescue	1,650	Pubescent wheatgrass	760	Pubescent wheatgrass	840
Hard fescue	920	Hard fescue	1,760	Whitmar wheatgrass	870	Crested wheatgrass and hard fescue	950
Whitmar wheatgrass and hard fescue	960	Crested wheatgrass and hard fescue	1,960	Timothy	880	Timothy	1,050
Meadow foxtail	1,010	Pubescent wheatgrass	2,040	Crested wheatgrass and hard fescue	980	Whitmar wheatgrass	1,130
Crested wheatgrass	1,090	Crested wheatgrass	2,130	Meadow foxtail	1,080	Tall wheatgrass and Granger lotus	1,160
Timothy	1,120	Tall wheatgrass and Granger lotus	2,200	Whitmar wheatgrass and hard fescue	1,130	Whitmar wheatgrass and hard fescue	1,290
Crested wheatgrass and hard fescue	1,190	Timothy	2,440	Hard fescue	1,200	Intermediate wheatgrass	1,290
Intermediate wheatgrass	1,420	Meadow foxtail	2,590	Tall wheatgrass and Granger lotus	1,250	Hard fescue	1,300
Intermediate wheatgrass and Granger lotus	1,550	Intermediate wheatgrass and Granger lotus	2,710	Intermediate wheatgrass	1,400	Meadow foxtail	1,390
Tall wheatgrass and Granger lotus	1,600	Intermediate wheatgrass	2,890	Intermediate wheatgrass and Granger lotus	1,440	Intermediate wheatgrass and Granger lotus	1,550
Intermediate wheatgrass and nomad alfalfa	2,600	Intermediate wheatgrass and nomad alfalfa	3,250	Intermediate wheatgrass and nomad alfalfa	1,900	Intermediate whtg. and nomad alfalfa	1,950

[1] Mean yields not covered by the same line are significantly different.

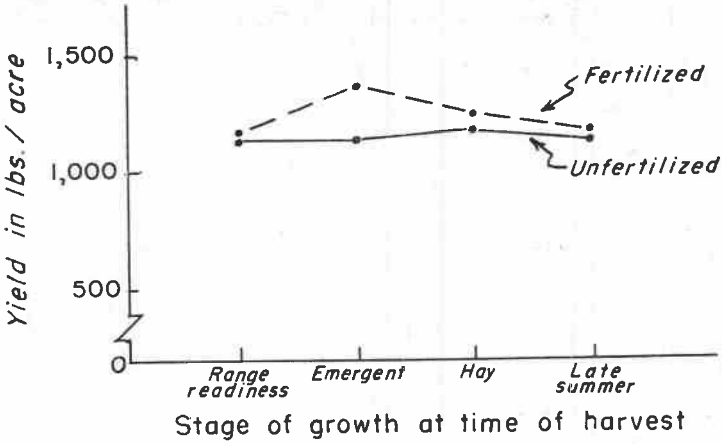

Figure 7. Cutting stage x fertilizer interaction averaged over all mixtures in 1960.

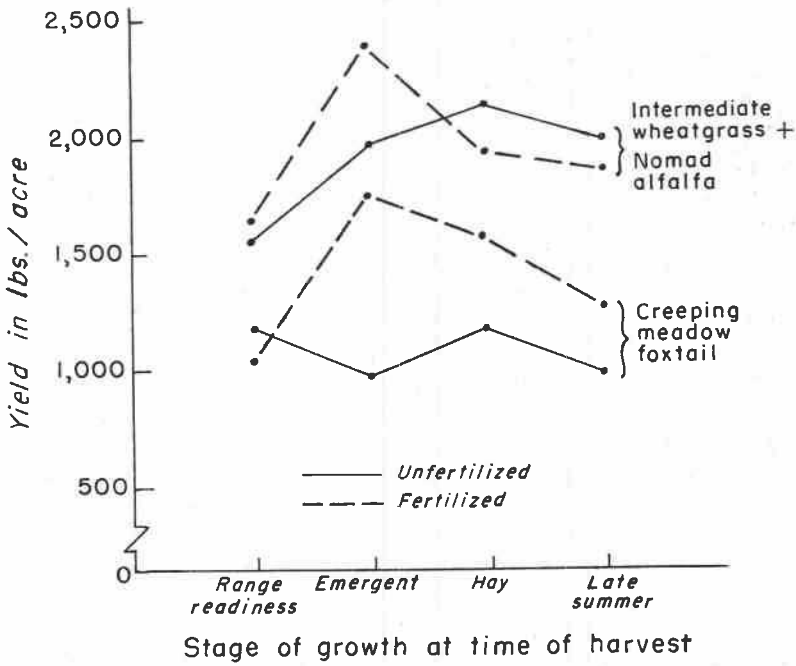

Figure 8. Cutting stage x fertilizer interaction of two mixtures in 1960.

TABLE 10. ANALYSES OF VARIANCE OF PROTEIN YIELDS TAKEN FROM HALL RANCH NURSERY MIXTURES FOR THREE CONSECUTIVE YEARS

1958 protein

Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	353.16	.19
Treatments	12	50,572.05	27.54**
Cuttings	3	85,999.98	46.83**
Treatments x cuttings	36	4,595.01	2.50**
Error	153	1,836.53	

1959 protein

Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	1,664.20	.86
Treatments	12	62,753.55	32.52**
Cuttings	3	475,118.74	246.23**
Treatments x cuttings	36	6,192.86	3.21**
Error	153	1,929.58	

1960 protein

Source of variation	Degrees of freedom	Mean square	F
Total	415		
Replications	3	766.47	1.26
Treatments	12	26,198.48	42.90**
Cuttings	7	56,527.90	92.57**
Fertilizer	1	1,808.40	2.96
Cutting stage	3	121,734.98	199.36**
Cutting x fertilizer	3	2,264.74	3.71**
Treatment x cutting	84	1,554.33	2.55**
Treatment x fertilizer	12	1,202.65	1.97*
Treatment x cutting	36	2,672.46	4.38**
Treatment x fertilizer x cutting	36	506.53	.83
Error	309	610.62	

* Indicates significance at .05 level of probability.

** Indicates significance at .01 level of probability.

However, crude protein yields for hay stage and late summer in 1959 (Table 11), the year fertilizer was applied, show a marked response of most mixtures the first year. As one would expect, the grasses show the greatest increase in protein from fertilizer, and grass-legume mixtures show the least. The three-fold increase from hard fescue at both the hay and late summer stages of cutting is surprising in view of its short height growth. In fact, hard fescue is superior to all other grasses except intermediate wheatgrass. In view of its palatability in the late summer and fall, hard fescue would rank along

TABLE 11. INFLUENCE OF FERTILIZER ON HAY STAGE AND LATE SUMMER PROTEIN (N x 6.25) YIELDS IN POUNDS PER ACRE OF MIXTURES IN HALL RANCH NURSERY THE YEAR OF APPLICATION, 1959

Species	Hay stage		Late summer	
	Unfert.	Fert.	Unfert.	Fert.
	pounds per acre			
Sherman big bluegrass	40	125	35	50
Hard fescue	70	245	40	115
Whitmar wheatgrass	75	190	40	75
Crested wheatgrass and hard fescue	80	195	50	70
Pubescent wheatgrass	80	175	30	60
Whitmar wheatgrass and hard fescue	85	190	45	70
Crested wheatgrass	95	220	40	55
Timothy	95	175	45	50
Meadow foxtail	110	215	40	45
Intermediate wheatgrass	150	310	50	115
Intermediate wheatgrass and Granger lotus	175	295	70	90
Tall wheatgrass and Granger lotus	195	315	85	110
Intermediate wheatgrass and nomad alfalfa	335	405	135	145

with the grass-legume mixtures to supply protein needed by growing or lactating animals late in the grazing season.

Residual fertilizer response, as measured by protein yields from initial and regrowth clippings, is included in Table 12. Even though overall fertilizer effects were not significant in 1960, the treatment x fertilizer interaction was significant as evidenced by meadow foxtail and hard fescue, both outproducing all other grasses in protein in 1960. The value of legumes in protein production is further exemplified by all grass-legume mixtures rating higher than grass alone in 1960. Reference to Table 13 illustrates that the unfertilized mixture of intermediate wheatgrass and alfalfa produced as much protein as fertilized intermediate wheatgrass. If phosphorus had been used on the grass-legume mixtures, yields from these treatments would no doubt have exceeded that of grasses receiving 60 pounds of nitrogen per acre. Some benefit of grass association with legumes is evident when herbage yield data in Table 9 are compared with protein yields in Table 13. In other words, nearly all grass-legume mixtures were superior in protein yield even though mixtures were occasionally inferior to herbage yields of fertilized grasses.

TABLE 12. INITIAL AND REGROWTH PROTEIN YIELDS IN POUNDS PER ACRE REPRESENTING RESIDUAL FERTILIZER RESPONSE FROM HALL RANCH NURSERY MIXTURES AT DIFFERENT CUTTING DATES IN 1960

1960 Mixture	Range readiness	Regrowth	Total	Emergent stage	Regrowth	Total	Hay stage	Late summer	Mean
	pounds per acre			*pounds per acre*			*pounds per acre*		
Pubescent wheatgrass	50	10	60	70	....	70	45	35	50
Crested wheatgrass	45	10	55	70	5	75	45	35	50
Sherman big bluegrass	45	15	60	60	10	70	40	40	55
Crested wheatgrass and hard fescue	65	15	80	85	0	85	50	40	65
Timothy	80	10	90	95	....	95	60	35	70
Whitmar wheatgrass	65	15	80	105	5	110	40	55	70
Intermediate wheatgrass	60	10	70	95	....	95	75	45	70
Hard fescue	90	15	105	110	10	120	50	65	85
Meadow foxtail	70	10	80	115	0	115	95	50	85
Whitmar wheatgrass and hard fescue	100	20	120	105	15	120	65	55	90
Intermediate wheatgrass and Granger lotus	60	25	85	125	10	135	100	75	100
Tall wheatgrass and Granger lotus	70	35	105	105	5	110	120	65	100
Intermediate wheatgrass and nomad alfalfa	150	30	180	265	15	280	170	110	185

TABLE 13. MULTIPLE RANGE TEST OF BOTH UNFERTILIZED AND FERTILIZED PROTEIN YIELDS[1] IN POUNDS PER ACRE OF HALL RANCH NURSERY MIXTURES

1959				1960			
Unfertilized		Fertilized		Unfertilized		Fertilized	
Mixture	Yield	Mixture	Yield	Mixture	Yield	Mixture	Yield
	lb./A.		*lb./A.*		*lb./A.*		*lb./A.*
Sherman big bluegrass	45	Sherman big bluegrass	145	Crested wheatgrass	45	Pubescent wheatgrass	50
Whitmar wheatgrass	60	Whitmar wheatgrass	180	Sherman big bluegrass	45	Crested wheatgrass	50
Pubescent wheatgrass	60	Crested wheatgrass and hard fescue	195	Pubescent wheatgrass	45	Sherman big bluegrass	55
Hard fescue	60	Whitmar wheatgrass and hard fescue	200	Timothy	55	Crested wheatgrass and hard fescue	65
Whitmar wheatgrass and hard fescue	65	Pubescent wheatgrass	200	Hard fescue	60	Timothy	70
Crested wheatgrass	70	Crested wheatgrass	200	Crested wheatgrass and hard fescue	60	Whitmar wheatgrass	70
Timothy	75	Hard fescue	225	Whitmar wheatgrass and hard fescue	70	Intermediate wheatgrass	70
Meadow foxtail	75	Tall wheatgrass and Granger lotus	230	Whitmar wheatgrass	70	Hard fescue	85
Crested wheatgrass and hard fescue	80	Timothy	230	Meadow foxtail	75	Meadow foxtail	85
Intermediate wheatgrass	95	Meadow foxtail	235	Intermediate wheatgrass	85	Whitmar wheatgrass and hard fescue	90
Intermediate wheatgrass and Granger lotus	125	Intermediate wheatgrass	255	Tall wheatgrass and Granger lotus	95	Intermediate wheatgrass and Granger lotus	100
Tall wheatgrass and Granger lotus	125	Intermediate wheatgrass and Granger lotus	270	Intermediate wheatgrass and Granger lotus	115	Tall wheatgrass and Granger lotus	100
Intermediate wheatgrass and nomad alfalfa	250	Intermediate wheatgrass and nomad alfalfa	370	Intermediate wheatgrass and nomad alfalfa	175	Intermediate wheatgrass and nomad alfalfa	185

[1] Mean yields not covered by the same line are significantly different.

Phosphorus. Analyses of variance for this important mineral constituent of improved forages appear to parallel closely those for herbage and protein (Table 14), except that the significant residual fertilizer response in 1960 is negative rather than positive. This apparent anomaly is more easily observed in Table 15 where both unfertilized and fertilized yields of phosphorus are given for 1959, the year fertilizer was applied, and for 1960, the second growing season after application of 60 pounds of nitrogen and 40 pounds of P_2O_5 per acre.

TABLE 14. ANALYSIS OF VARIANCE OF PHOSPHORUS YIELDS TAKEN FROM HALL RANCH NURSERY MIXTURES FOR THREE CONSECUTIVE YEARS

1958 phosphorus			
Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	6.257	1.94
Treatments	12	112.998	34.94**
Cuttings	3	443.309	137.09**
Treatments x cuttings	36	20.075	6.21**
Error	153	3.234	
1959 phosphorus			
Source of variation	Degrees of freedom	Mean square	F
Total	207		
Replications	3	1.364	.72
Treatments	12	65.757	34.66**
Cuttings	3	650.173	342.74**
Treatments x cuttings	36	11.552	6.09**
Error	153	1.897	
1960 phosphorus			
Source of variation	Degrees of freedom	Mean square	F
Total	415		
Replications	3	1.029	2.10
Treatments	12	20.335	41.45**
Cuttings	7	64.348	131.16**
Fertilizer	1	8.273	16.86**
Cutting stage	3	136.971	279.19**
Cutting x fertilizer	3	2.940	5.99**
Treatment x cutting	84	1.587	3.24**
Treatment x fertilizer	12	1.464	2.99**
Treatment x cutting	36	2.507	5.11**
Treatment x fertilizer x cutting	36	.692	1.41*
Error	309	491	

* Indicates significance at .05 level of probability.
** Indicates significance at .01 level of probability.

TABLE 15. MULTIPLE RANGE TEST OF BOTH UNFERTILIZED AND FERTILIZED PHOSPHORUS YIELDS[1] IN POUNDS PER ACRE OF HALL RANCH MIXTURES

1959				1960			
Unfertilized		Fertilized		Unfertilized		Fertilized	
Mixture	Yield	Mixture	Yield	Mixture	Yield	Mixture	Yield
	lb./A.		*lb./A.*		*lb./A.*		*lb./A.*
Sherman big bluegrass	1.9	Whitmar wheatgrass	4.8	Sherman big bluegrass	2.0	Crested wheatgrass	1.8
Whitmar wheatgrass	2.0	Sherman big bluegrass	5.6	Pubescent wheatgrass	2.2	Sherman big bluegrass	2.0
Hard fescue	2.1	Crested wheatgrass and hard fescue	6.0	Whitmar wheatgrass	2.3	Crested wheatgrass and hard fescue	2.1
Whitmar wheatgrass and hard fescue	2.2	Whitmar wheatgrass and hard fescue	6.1	Hard fescue	2.5	Pubescent wheatgrass	2.4
Pubescent wheatgrass	2.3	Crested wheatgrass	6.3	Timothy	2.5	Whitmar wheatgrass	2.5
Timothy	2.5	Hard fescue	6.6	Crested wheatgrass	2.6	Timothy	2.5
Meadow foxtail	2.6	Pubescent wheatgrass	7.7	Crested wheatgrass and hard fescue	2.7	Hard fescue	2.6
Crested wheatgrass	2.6	Intermediate wheatgrass	8.1	Whitmar wheatgrass and hard fescue	2.8	Whitmar wheatgrass and hard fescue	2.7
Crested wheatgrass and hard fescue	2.9	Tall wheatgrass and Granger lotus	8.2	Meadow foxtail	2.8	Tall wheatgrass and Granger lotus	2.8
Intermediate wheatgrass	3.4	Intermediate wheatgrass and Granger lotus	9.0	Tall wheatgrass and Granger lotus	4.0	Intermediate wheatgrass	2.9
Intermediate wheatgrass and Granger lotus	4.0	Meadow foxtail	9.1	Intermediate wheatgrass	4.1	Meadow foxtail	3.0
Tall wheatgrass and Granger lotus	5.0	Timothy	10.4	Intermediate wheatgrass and Granger lotus	4.4	Intermediate wheatgrass and Granger lotus	3.5
Intermediate wheatgrass and nomad alfalfa	7.2	Intermediate wheatgrass and nomad alfalfa	14.3	Intermediate wheatgrass and nomad alfalfa	6.0	Intermediate wheatgrass and nomad alfalfa	4.8

[1] Mean yields not covered by the same line are significantly different.

Most research data on fertilization of forages have indicated percentage increases of the mineral constituent in the plant; e.g., Stitt (1958), Fisher and Caldwell (1959), and Riewe and Smith (1955). Ward (1959), in his review of the effect of fertility upon the yield and nutritive value of forages, reported that the phosphorus content of phosphate-fertilized forage was not always altered, and that concurrent nitrogen and phosphate fertilization and heavy rainfall after phosphate application both resulted in decreased content of phosphorus in the forage. Comparable protein and phosphorus percentages in the forage cut at hay and late summer stages for 1958 through 1960 are presented in Table 16. Since phosphorus contents are generally above livestock nutritional requirements, no serious problems should be encountered with any of the mixtures used. Intermediate wheatgrass and grass-legume mixtures were high in phosphorus on both fertilized and unfertilized treatments.

TABLE 16. AVERAGE PERCENTAGE OF CRUDE PROTEIN AND PHOSPHORUS BY YEARS AND FERTILIZER TREATMENT FOR HAY AND LATE SUMMER GROWTH STAGES OF ALL MIXTURES IN HALL RANCH TRIAL

	1958		1959		1960	
	Crude protein	Phos.	Crude protein	Phos.	Crude protein	Phos.
	%	%	%	%	%	%
Hay stage						
Unfertilized	12.7	.34	9.3	.27	6.3	.26
Fertilized			9.4	.25	6.5	.23
Late summer						
Unfertilized	6.2	.30	4.5	.20	5.3	.28
Fertilized			4.6	.16	5.2	.20

Utilization of Forage Mixtures by Cattle

Some measure of utilization by cattle, in addition to the intensive agronomic and chemical analyses data, was obtained by undertaking two, one-day grazing trials with cows and calves. About 20 head of cows plus calves were turned into an enclosure on the Hall Ranch in early September of 1963 and again in late June of 1964. Relative degrees of utilization recorded at these two seasons are summarized in Table 17.

Data from the several grass species grazed in a single unit reflect greater selectivity than when animals are restricted to one species or a simple mixture. Nevertheless, even limited grazing trials do help in arranging forages into groups based on cattle preference in dif-

TABLE 17. UTILIZATION OF FORAGE MIXTURES ON HALL RANCH BY CATTLE IN EARLY FALL AND LATE SPRING

Mixture	Degree of utilization Sept. 1963	 June 1964
Whitmar wheatgrass	Light to heavy	Very light
Pubescent wheatgrass	Moderate	Very light
Timothy	Moderate	Stand too poor to test
Intermediate wheatgrass and Granger birdsfoot trefoil	Light	Heavy
Intermediate wheatgrass	Moderate	Heavy
Tall wheatgrass and Granger birdsfoot trefoil	Moderate to heavy on trefoil Moderate on tall wheatgrass	Moderate on trefoil Light on tall wheatgrass
Intermediate wheatgrass and nomad alfalfa	Heavy on alfalfa	Very heavy on alfalfa and intermediate wheatgrass
Meadow foxtail	Heavy	Very heavy
Hard fescue	Heavy	Very light
Sherman big bluegrass	Heavy	Stand too poor to test
Crested wheatgrass	Heavy	Stand too poor to test

ferent seasons. For example, it is readily apparent that creeping meadow foxtail and intermediate wheatgrass and alfalfa are heavily used in both spring and fall. In contrast, hard fescue is good for fall use, but poor in the spring. In general, the grass-legume mixtures are superior to any single species for season-long grazing.

Application of Results to Management

All species in this trial appear to be well adapted to a pine woodland meadow site and long-lived, with the exception of timothy, Sherman big bluegrass, and crested wheatgrass. Under conditions of limited fertility, intermediate wheatgrass—alone and in grass-legume mixtures—was a top producer of palatable forage. With nitrogen and phosphorus fertilizer added, creeping meadow foxtail becomes relatively more productive, particularly at the emergent stage of growth in late spring.

If meadows similar to this are to be improved, it will be essential to fence and graze them separately from adjoining native range land. Concurrent research by Young (1965) indicates that traditional patterns of grazing timbered ranges late in the season in the foothills of the Blue Mountains may not be making the most effective use of the principal forage species, pinegrass and Cusick's vetch, both of which are most palatable and nutritious in mid-spring to late spring. If grazing tests planned for 1965 and 1966 on the Hall Ranch support this contention, many livestock operators in northeastern Oregon may advantageously turn cattle out in the timbered range and utilize meadow areas later in the season.

Under actual grazing conditions, it is more difficult to maintain some of these species than was true in this experiment, where the only method of forage removal was seasonal clipping or mowing. In recognizing this difficulty in grazing management, some extension workers are currently recommending species that are more resistant to grazing use, e.g., tall fescue. Before making any range seedings, it is essential for the operator and range administrator to weigh both production advantages and management difficulties in reaching a sound decision on range improvement programs in foothill areas of the Blue Mountains.

The most urgent need for additional research is the translation of these agronomic results into realistic livestock production data applicable to similar sites and ranch operations in the Blue Mountain area. In brief, grazing results are needed on seedings of intermediate wheatgrass, intermediate wheatgrass plus alfalfa, intermediate wheatgrass plus Granger lotus, creeping meadow foxtail and Whitmar wheatgrass-hard fescue mixtures with and without applications of appropriate fertilizers. Since stands of tall fescue are being used in these areas by some operators, this grass in mixture with appropriate legumes should be included in grazing evaluations.

Summary

Data on the seasonal production and chemical content of eleven forage species and five mixtures were obtained on a pine woodland meadow site in the Wallowa Mountain foothills in northeastern Oregon. Yields from permanent plots were plotted for an 8-year period to evaluate trends in production over time. Comprehensive statistical analyses for three years, 1958-1960, provided a quantitative comparison of performance, including the addition of nitrogen and phosphate fertilizer.

The experimental area is located on the Hall Ranch, a part of the Eastern Oregon Experiment Station, about 12 miles southeast of Union, Oregon. Soil parent materials are of basalt and basaltic andesite with minor amounts of interbedded sediments and pyroclastics. The Couse series consists of moderately well drained fine-textured Prairie-like or Prairie intergrading to Gray Brown Podzolic soils. These soils have developed in loess influenced by volcanic ash which overlay old fine-textured alluvium of varied mineralogy.

Since only limited climatic data are available from the experimental site, an average annual precipitation of 16 to 20 inches has

been inferred from the ponderosa pine-pinegrass association which predominates in the surrounding area. The bulk of the precipitation falls as rain and snow during the cold winter months. Fall and spring months are cool and frequently moist, whereas July and August are dry and warm with infrequent showers.

Although not cultivated or cut for hay in the past 25 years, the site of the nursery has been influenced by past grazing and possibly by farming practices prior to the 1940's. The original vegetation is difficult to reconstruct, but the aspect was probably a meadow-like opening in a pine woodland. If this were so, the predominant grasses would have been Idaho fescue on the dry part and tufted hairgrass in the more moist portions.

Plots were seeded in 1955 after plowing and summer fallowing in 1954. Yield samples were first taken in 1956, and the last in 1963. For a 3-year period, 1958 through 1960, plant development stages were sampled at range readiness, emergent, hay, and late summer. One-half of the plots clipped at the first two dates were reclipped in late summer to measure regrowth. These data were summarized by using an IBM program for both forage and nutrient yields. In the fall of 1963 and spring of 1964 short grazing tests were made to evaluate seasonal preferences by cows and calves.

Based on an 8-year summary of hay yields, intermediate wheatgrass and hard fescue were found to be the most consistent producers of all single species. Tall wheatgrass exhibited the greatest variability in yields and was hurt measurably by continual close clipping. Meadow foxtail was the only other grass species of those tested to qualify as a suitable long-lived forage for seeding in this area. Grass-legume mixtures were far superior to grasses alone, and in 1963 they were the only treatments producing more than one ton of hay per acre. Although nomad alfalfa appeared to be losing some of its earlier superiority over Granger birdsfoot trefoil by 1963, the results might have been different under a grazing regime; a grazing alfalfa such as nomad would probably excel birdsfoot trefoil where livestock were used to harvest the forage crop.

Statistical analyses of yields for the years 1958 through 1960 revealed that treatments (species and mixtures), cuttings (stage of growth), and the treatment x cutting interaction were all significant during the 3-year period. The significant cutting times fertilizer interaction in 1960 indicated the importance of delaying the first harvest until mid or late June to receive maximum benefit from fertilizer applications.

Regrowth yields varied among species and years. In seasons of high precipitation, meadow foxtail among grasses and birdsfoot trefoil of the two legumes gave the best results. In poorer years, hard fescue and hard fescue-Whitmar wheatgrass, together with meadow foxtail, were ranked next to intermediate wheatgrass and alfalfa in yield.

Based on mean yields over 3 years for unfertilized treatments and 2 years of fertilizer responses, crested, pubescent and Whitmar wheatgrasses, together with Sherman big bluegrass, fall generally into a low group, whereas creeping meadow foxtail, intermediate wheatgrass, and intermediate wheatgrass and legume mixtures are high. These data clearly show the advisability of using nitrogen on pure grass stands of improved species, such as creeping meadow foxtail, whereas only non-nitrogen amendments should generally be applied to grass-legume mixtures.

Nutrient yield analyses were similar to those for herbage except that there was no residual response of fertilizer in 1960 on protein yield. As expected, the grasses show the greatest increase in protein from fertilizer, and grass-legume mixtures show the least. Hard fescue and intermediate wheatgrass were top producers of protein among the grasses, and hard fescue was equal to grass-legume mixtures for the late grazing season. Some benefit of grass association with legumes is evident when you consider that grass-legume mixtures were superior in protein yield even though mixtures were occasionally inferior to herbage yields of fertilized grasses.

Analyses of variance for phosphorus were similar to those of herbage yields and protein, except that a significant residual response in 1960 was negative rather than positive. Similar results have been noted by other workers and, since all contents are generally above livestock nutritional requirements, no serious problems should be encountered with any of the mixtures used.

Limited grazing trials indicated that cattle prefer creeping meadow foxtail and a mixture of intermediate wheatgrass and alfalfa in both spring and fall. In contrast, hard fescue is good in the fall, but poor in the spring. In general, the grass-legume mixtures are superior to any single species for season-long grazing.

All species used in this trial, with exception of timothy, Sherman big bluegrass, and crested wheatgrass, are long-lived and well adapted to this foothill meadow site. Under conditions of limited fertility, intermediate wheatgrass, alone and in grass-legume mixtures, was the highest producer. When fertilized, creeping meadow foxtail became relatively more productive during the emergent or late spring growth stage.

When integrated into a complete range improvement program, improved species on meadow sites should be grazed separately from adjoining range and used to supplement effectively the forested ranges. Before range improvement is undertaken, the operator or administrator needs to weigh both production advantages and management difficulties of each mixture in order to reach a sound decision on what to plant on these pine woodland meadow sites. The most urgent research need is to translate these agronomic results into realistic livestock production data applicable to similar sites in the Blue Mountain area.

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Appendix

Description of Couse Soil on Hall Ranch

Prepared by Grant Lindsay and Howard Vance,
SCS Soil Scientists (December 1963)

The Couse soil on the nursery plot of the Hall Ranch Experiment Station has a slope gradient of 2 to 4%. The soil is moderately well drained, medium textured in the upper solum, and moderately fine textured in the lower solum. An A2 horizon separates the upper B horizon from the lower buried B2tb horizon. The range in depth to the buried B2tb horizon is 22 to 48 inches. Parent material consists of loess and volcanic ash over moderately fine textured old alluvium of mixed mineralogy. The series is tentatively classified as Prairie-like or Prairie intergrading to Gray Brown Podzolic.

The following description was taken in the deer enclosure.

A_{11}	0-3″	Dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; weak thin and medium platy breaking to fine and medium granular structure; slightly hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium continuous, tubular inped pores; slightly acid pH 6.4; gradual smooth boundary. 3 inches thick.
A_{12}	0-10″	Dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; weak medium prismatic structure; slightly hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium continuous tubular pores; slightly acid pH 6.4; abrupt wavy boundary. 4 to 10 inches thick.
B_2	10-17″	Brown to dark brown (10YR 4/3) silt loam, dark brown (10YR 3/3) when moist; weak medium prismatic structure; slightly hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium continuous tubular pores; slightly acid pH 6.4; gradual wavy boundary. 6 to 10 inches thick.
A_{21}	17-24″	Pale brown (10YR 6/3) silt loam, brown to dark brown (10YR 4/3) when moist; weak medium prismatic breaking to weak fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium tubular pores; few fine, faint mottles; slightly acid pH 6.4; gradual wavy boundary. 6 to 8 inches thick.

A_{22}	24-34"	Pale brown (10YR 6/3) silt loam, brown to dark brown (10YR 4/3) when moist; weak fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium continuous tubular pores; few fine, faint mottles; slightly acid pH 6.4; gradual wavy boundary. 3 to 6 inches thick.
A_{23}	34-38"	Very pale brown (10YR 7/3) silt loam, brown (10YR 5/3) when moist; massive; hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine and medium continuous tubular pores; few fine, distinct mottles; slightly acid pH 6.4; abrupt smooth boundary. 3 to 6 inches thick.
IIB_{21tb}	38-46"	Dark brown (7.5YR 3/2) and brown to dark brown (7.5YR 4/3 crushed) moist, heavy silty clay loam, strong medium prismatic to breaking to medium subangular blocky structure; very hard, very firm, very sticky and very plastic; few roots, thick continuous clay films; slightly acid pH 6.4; gradual smooth boundary. 10 to 15 inches thick.
IIB_{22tb}	46-60"	Dark brown (7.5YR 4/3) moist, silty clay loam; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few roots; medium continuous clay films; slightly acid pH 6.4.

Appendix Table 1. Points on soil moisture tension curve for three major horizons in the Hall Ranch nursery soil

Horizon	Approximate depth in feet	.10 bar	.5 bar	5 bars	10 bars	15 bars
A	0-1	30.26	27.32	17.22	13.70	13.09
B	1-2	26.18	22.23	13.76	11.12	10.82
C	2-3½	33.12	30.87	28.20	24.32	24.26

Appendix Table 2. Summary of soil tests by six-inch depths made on the nursery site

Soil depth	pH	Organic matter	Total nitrogen	P	K	Total salts	Cation exchange capacity	Boron
inches		*%*	*%*	*ppm*	*me/100g*	*ppm*	*me/100g*	*ppm*
0-6	6.4	4.23	0.19	27	1.02	135	23.4	0.80
6-12	6.5	2.23		10	0.75			
12-18	6.6	0.94		7	0.58			
18-24	6.8	0.51		5	0.46			
24-30	6.8	0.31		4	0.38		17.5	
30-36	6.9	0.27		4	0.44			
36-42	7.0	0.26		4	0.46			

Appendix Table 3. Species list from Hall Ranch meadow site

Scientific name	Common name
Native species	
Abies grandis Lindl.	Grand fir
Larix occidentalis Hook.	Western larch
Pinus ponderosa Dougl.	Ponderosa pine
Pseudotsuga menziesii	Douglas-fir
Holodiscus discolor (Pursh) Maxim.	Oceanspray
Physocarpos malvaceus (Greene) Kuntze	Ninebark
Symphoricarpos albus (L.) Blake	Snowberry
Agrostis palustris Huds.	Red top
Calamagrostis rubescens Buckl.	Pinegrass
Carex geyeri Boott.	Elk sedge
Deschampsia caespitosa L.	Tufted hairgrass
Poa compressa L.	Canadian bluegrass
Poa pratensis L.	Kentucky bluegrass
Achillea lanulosa Nutt.	Yarrow
Cirsium arvense Scop.	Canada thistle
Lupinus leucophyllus Dougl.	Silver lupine
Potentilla glandulosa Lindl.	Cinquefoil
Seeded species	
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron elongatum (Host) Beauv.	Tall wheatgrass
Agropyron inerme (Scribn. & Smith) Rydb.	Whitmar beardless wheatgrass
Agropyron intermedium (Host) Beauv.	Intermediate wheatgrass
Agropyron trichophorum (Link) Richt.	Pubescent wheatgrass
Alopecurus arundinaceus Poir	Creeping meadow foxtail
Festuca ovina var. *duriuscula* (L.) Koch	Hard fescue
Phleum pratense L.	Timothy
Poa ampla Merr.	Sherman big bluegrass
Lotus corniculatus L.	Granger birdsfoot trefoil
Medicago sp.	Nomad alfalfa