Precipitation, Temperature, and Herbage Relationships for a Pine Woodland Site in Northeastern Oregon

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Abstract

Nine years of herbage yield data from nonfertilized and nitrogen (N) fertilized plots of introduced grasses on a foothill, woodland meadow were correlated with monthly precipitation and temperature. Herbage yields from nonfertilized plots were poorly correlated with monthly precipitation or combinations of monthly precipitation. Fifty-five and 71% of the year-to-year variations in yields of N fertilized grass stands were associated with April and April-through-May precipitation, respectively. Yields from N fertilized stands were nearly 2,000 kg/ha larger than yields from nonfertilized stands. Mean monthly temperature were not well correlated with yields.

Anticipating herbage production requires an understanding of the relationships between numerous environmental factors and their effects on plant growth. Mathematical models have been developed from research data to evaluate environment-plant responses and to establish relationships. One of the prime objectives of such work has been to develop predictive equations which will reliably forecast forage yields several months in advance. Such forecasts are of great value to livestock grazing operations and range resource management.

Precipitation in arid and semiarid areas is the principal environmental factor influencing plant growth. Sneva and Hyder (1962) developed a linear herbage response equation that was dependent on the quantity of crop year precipitation. Annual herbage production could be forecast by April 1. These authors concluded that the effects of several other phenomena affecting plant growth contributed less than 25% of the year-to-year yield variation. Sneva (1977) found that 64% of the variation in mature yields of unfertilized crested wheatgrass (*Agropyron desertorum*) was associated with July through June precipitation and the mean March through May temperature. Slightly higher correlations were obtained using yields of nitrogen (N) fertilized crested wheatgrass. Blaisdell (1965) from work on the arid Upper Snake River Plains of Idaho developed a regression equation that predicted herbage yields of grasses, forbs, and shrubs based on the precipitation during the 9 months preceding the growing season. Mean monthly temperatures and yield were negatively correlated. Predictions of forage production suggested by the above authors can be made early enough to provide an opportunity to adjust livestock numbers to expected forage production prior to the start of the grazing season.

Murphy (1970) working in humid northern California with a wet winter-dry summer precipitation cycle found November precipitation to be a fair indicator of subsequent

forage yields on annual grasslands. However, in central California, Duncan and Woodmansee (1975) worked in an area with a similar precipitation cycle but concluded that data for early season precipitation were of little value for predicting yields.

Herbage yields in semihumid southwestern Montana mountain grasslands were positively and significantly correlated with May precipitation (Mueggler 1972). Precipitation adequately distributed throughout the growing season was also important. Production was negatively correlated with maximum June and July shaded soil temperatures and positively correlated with minimum June air temperatures. Stitt (1958) working in Montana found a correlation coefficient of 0.88 between the yields of several cool-season introduced grasses and April-through-May precipitation. The correlation coefficient between April through June precipitation and yield was only 0.54.

Large herbage yield increases resulting from fertilization have been associated with introduced grasses more so than with native grasses and forbs (Bowns 1975, Cook 1965, Pumphrey 1971, Sneva 1977, Stitt 1958). Larger responses to nitrogen fertilizer have been reported than for other fertilizers. Sulfur, in addition to nitrogen, has been shown to be deficient in ash-derived soils in northeast Oregon (Geist 1976, Pumphrey 1973).

The purpose of the work reported in this paper was to determine if precipitation and air temperatures might be of value for early forecasting of herbage production from introduced grasses growing on foothills in northeastern Oregon. Simple correlations between monthly precipitation and monthly mean air temperatures were examined. The more meaningful simple correlations and stepwise multiple regression relationships with nonfertilized and N fertilized herbage yields are presented.

Experimental Site

The grass nursery used in this study was established in an open meadow in the ponderosa pine (*Pinus ponderosa*) woodland foothills of the Wallowa Mountains of northeastern Oregon and was managed by the Eastern Oregon Experiment Station. The nursery was located on soil belonging to the Couse series. The Couse series consists of moderately well-drained soils that formed in loess and some volcanic ash overlaying older soils formed in loess and residuum weathered basalt. Volcanic ash materials have relatively high water storage capacity and yield this water to plants at low moisture tensions (0.1 to 1.0 bar) Geist and Strickler 1978). Rooting depth is over 150 cm. Soil analysis results indicated the surface soil was well supplied with available phosphorus and potassium. The Couse series is a member of the fine-silty, mixed, frigid family of typic Halploxerolls (Soil Survey Staff 1960).

Most precipitation occurs as rain and snow from November

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Table 1. Mean, range, standard deviation (S.D.), and coefficient of variation (C.V.) of precipitation, temperature, and herbage yields for 1967 through 1973.

Months	Precipitation (mm)		S.D.	C.V. (%)
	Mean	Range		
September	34	0-69	21.26	62
October	40	5-91	23.81	60
November	48	23-91	20.58	43
December	91	20-152	36.10	40
January	71	38-145	31.50	45
February	46	33-69	11.40	25
March	60	18-102	27.45	46
April	50	13-97	27.93	56
May	49	25-64	15.43	32
June	51	15-94	22.97	45
Sept.-Oct. ¹	74	23-157	39.04	53
Sept.-Nov.	122	59-191	42.04	34
Sept.-Dec.	213	98-287	55.81	26
Sept.-Dec. + April	263	111-374	77.17	29
Sept.-Dec. + April-May	312	141-430	83.30	27
Sept.-Dec. + April-June	363	182-496	93.47	26
April-May	99	43-158	37.02	37
April-June	150	73-219	47.56	32
Sept.-June	540	350-659	111.83	21

Months	Temperature (C°)		S.D.	C.V. (%)
	Mean	Range		
April	6.9	5.0-9.0	1.25	18
May	11.9	10.3-13.2	0.96	8
June	16.0	14.1-19.2	1.43	9

Fertility	Herbage yield (kg/ha)		S.D.	C.V. (%)
	Mean	Range		
No N fertilizer	1375	588-2357	776.06	56
67 kg/ha N	3364	1533-5159	1153.59	34

¹September through October precipitation.

through June with December being the wettest month (Table 1). Extremes in crop-year precipitation which occurred from September through June were 350 and 659 mm, with a mean of 540 mm. July and August are warm and dry, but summer showers do occur some years. Pan evaporation exceeds precipitation from May until the arrival of damp, cool weather in late fall. A snow cover from December into March is common.

Most grasses and forbs begin growth in April or early May and mature in late spring and early summer. Summer dormancy is common and fall regrowth is dependent on timing and quantity of fall precipitation.

The nursery was fenced to exclude cattle, deer, and elk.

Materials and Methods

Results of growth studies published by Hedrick et al. (1965) showed that yields stabilized during the last few years of their work at levels that appeared to express some relationship between mature stand production and annual precipitation. A year after the completion of these studies, four replications of the most promising forage producers were utilized in a fertilizer experiment. The three entries used were creeping meadow foxtail (*Alopecurus arundinaceus*), intermediate wheatgrass (*Agropyron intermedium*), and intermediate wheatgrass plus alfalfa (*Medicago sativa* var. Nomad). Alfalfa contributed an estimated 15 to 30% of the yield of the grass-alfalfa entry. Forage main plots were divided into subplots for fertilizer treatments. Each subplot was fertilized in early spring with the same fertilizer treatment for nine consecutive years. Fertilizer treatments were none, 34, 67, and 101 kg/ha nitrogen (N); 67 N + 11 phosphorus (P₂O₅) + 12 kg/ha sulfur (S); and 11 P₂O₅ + 12 kg/ha S.

Herbage yields were determined each year when intermediate

wheatgrass reached the hay (late blooming) stage of growth, which was mid to late July. Yields were sampled by a 0.9 × 6.1 m plot mowed in the center of each subplot. Green herbage was weighed immediately and subsamples were oven dried for dry matter content.

Analysis of variance of herbage yields indicated that the three forages responded similarly to the applied fertilizers. Large and highly significant herbage yield increases were measured when N fertilizer was applied. No significant yield response was measured where P₂O₅ + S were applied either with or without N. Therefore, yields from the no fertilizer and the P₂O₅ + S treatments for each of the three forages were pooled to represent yield data not receiving N fertilizer (n=54). Likewise, the 67 kg/ha N and the 67 kg/ha N + P₂O₅ + S yield data were pooled (n=54) for analysis.

Precipitation was measured monthly at the nursery site with a collecting rain gauge. Monthly mean temperatures were calculated from maximum and minimum daily air temperatures measured at the Eastern Oregon Experiment Station, Union, Oregon.

Nine years of monthly precipitation from September through June and combinations of precipitation for several months (independent variables); mean air temperatures for April, May, and June (independent variables); and corresponding herbage yields from no N and N fertilized plots (dependent variables) were subjected to simple correlation analysis. Stepwise multiple regression was utilized to establish the relative influence of independent variables alone and in combination with herbage yields.

Results and Discussion

Simple Relations

Climatic Relations

The amount of precipitation received in any one month varied greatly between years as indicated by the monthly precipitation range, standard deviation, and coefficient of variation (Table 1). Precipitation in September and October was more variable than in any of the following 8 months. The large variability in September and October precipitation indicated the possibility for large differences between years in fall green-up and fall growth. The coefficient of variation decreased with an increase of length of time for precipitation accumulation. This indicated greater stability in rainfall over longer seasonal periods compared with shorter periods.

Simple correlation coefficients obtained between monthly precipitation, combinations of monthly precipitation, mean monthly temperatures, and precipitation and temperature revealed no helpful relationships or trends. Low correlations and the range of precipitation and temperature are typical of the climatic variability experienced in this region of the Pacific Northwest (Meteorology Committee, Pacific Northwest River Basins Commission 1969).

Herbage Yields

Nitrogen-fertilized herbage plots yielded nearly 2,000 kg/ha more herbage than did the nonfertilized plots (Table 1). Although a larger range and standard deviation were found for yields from the fertilized plots, yields from nonfertilized plots were so variable that they had a larger coefficient of variation. The kilograms per hectare of herbage produced per millimeter of precipitation occurring from September through December plus April and May were 5.1 for the nonfertilized grass and 11.9 for the fertilized grass.

Precipitation, Temperature, and Herbage Yield Relationships.

Herbage yields were positively correlated ($P=.01$ or $.05$) with the precipitation for individual fall and spring months except November (Table 2). April precipitation was corre-

Table 2. Simple correlation coefficients (*r*) of yields with precipitation and temperature as influenced by nitrogen (N) fertilization.

Climatic variates	Forage yield variates	
	O N	67 kg/ha N
Precipitation		
September	0.37**	0.52
October	0.30*	0.44**
November	0.14	0.20
December	0.27*	0.39**
January	0.17	0.28*
February	-0.03	-0.22
March	0.05	0.13
April	0.42**	0.74**
May	0.35*	0.67**
June	0.39**	0.36**
September-October ¹	0.39**	0.55**
September-November	0.43**	0.61**
September-December	0.50**	0.72**
September-January	0.48**	0.71**
September-March	0.47**	0.69**
September-April	0.50**	0.77**
September-May	0.52**	0.83**
September-June	0.54**	0.80**
Sept.-Dec. + April	0.51**	0.79**
Sept.-Dec. + April-May	0.54**	0.85**
Sept.-Dec. + April-June	0.58**	0.85**
April-May	0.46**	0.84**
April-June	0.55**	0.83**
Monthly mean temperature		
April	-0.02	-0.08
May	-0.04	-0.24
June	0.30*	0.47**

¹September through October precipitation.

* = $P < 0.05$

** = $P < 0.01$

lated more closely with yield than was any other monthly precipitation. Precipitation in September and October was significantly and positively correlated with subsequent herbage yields. Precipitation during the winter months and yields were poorly correlated. The snow that usually accumulated during January, February, and March had less effect on herbage production than fall and spring precipitation.

Table 3. Correlation coefficients (*r*) and partial *F* values from stepwise multiple regression analysis of yields with precipitation (ppt) and temperature (temp) as influenced by nitrogen fertilization.

Precipitation & temperature variable	No nitrogen		Precipitation & temperature variable	67 kg/ha Nitrogen	
	Correlation coefficient (<i>r</i>)	Partial <i>F</i>		Correlation coefficient (<i>r</i>)	Partial <i>F</i>
April ppt	0.42	11.45**	April ppt	0.74	64.09**
June ppt	0.54	7.61*	May ppt	0.85	29.00**
April temp	0.56	2.28	December ppt	0.88	11.94**
May ppt	0.60	3.07	May temp	0.92	27.00**
February ppt	0.62	2.06	June temp	0.95	19.49**
November ppt	0.64	2.13	November ppt	0.95	2.22
April-June ppt ¹	0.55	22.96**	April-June ppt	0.83	117.48**
Sept.-Dec. ppt	0.59	3.03	Sept.-Dec. ppt	0.87	13.32**
Jan.-March ppt	0.60	1.57	Jan.-March ppt	0.88	3.19
Sept.-Dec. ppt	0.50	17.59**	April-May ppt	0.84	125.06**
April-May ppt	0.55	3.22	Sept.-Dec. ppt	0.88	18.07**
April temp	0.55	0.70	April temp	0.90	5.09*
May temp	0.55	1.55	May temp	0.90	2.15
Jan.-March ppt	0.55	1.70	Jan.-March ppt	0.90	0.92

¹April through June precipitation.

* = $P < 0.05$

** = $P < 0.01$

Winter snow accumulation and melting patterns, sublimation, precipitation while the accumulated snow was melting, soil permeability, and soil water holding capacity are some of the factors which could explain why overwinter precipitation was less associated with yield variations than reported by other authors (Sneva 1977, Duncan and Woodmansee 1975, Blaisdell 1965). Increasing the length of the precipitation period improved the relationship between yield and precipitation providing the winter months were not included (Table 2).

Much stronger correlations existed between herbage yields from N fertilized plots and precipitation than between yields from nonfertilized plots and precipitation (Table 2). Reducing the nitrogen deficiency allowed the grass to be more responsive to precipitation.

Yields from fertilized plots were not as well correlated with precipitation in 1972 as in the other eight years. A serious grasshopper infestation occurred in 1972 and is assumed to have caused the relatively lower yield. This is an example of one of the many potential confounding factors which may occur while trying to develop or apply apparently simple relationships to a dynamic plant-environment complex.

Herbage yields were not significantly related to April or May mean temperatures (Table 2). Mean June temperature were positively and significantly correlated with herbage yields. Yields from fertilized plots were correlated more closely with mean June temperatures than were yields from nonfertilized plots.

Stepwise Multiple Regression of Climate-Yield Relations Nonfertilized

April precipitation was the monthly precipitation most closely associated with yields from nonfertilized plots, $r=0.42$ (Table 3). June precipitation, second most important, increased the r value to 0.54. Other monthly precipitation and temperature variables did not have any additional significant influence on yield.

Testing for the relative importance of fall, winter, and spring precipitation indicated a highly significant relationship between spring precipitation and yields from nonfertil-

ized plots, $r=0.55$ (Table 3). Even though the relationship was highly significant, spring precipitation accounted for only 30% of the year-to-year yield variation. Fall and winter precipitation did not significantly influence yields.

June precipitation was omitted from the spring multiple-north precipitation in the last analysis reported in Table 3 to test the potential of a yield estimate based on precipitation and temperature data available at the end of May. Omitting June precipitation reversed the relative importance of fall and spring precipitation on yields from nonfertilized plots. September through December precipitation was associated with 28% ($r=0.50$) of the yield variations. April through May precipitation, over-winter precipitation, and spring monthly mean temperatures were of insignificant value in improving the estimate of herbage yields.

Fertilized

April precipitation was the variable most closely associated with yields from N fertilized plots, $r=0.74$ (Table 3). Adding May as a second variable increased the r value to 0.85. Adding three more variables, December precipitation and May and June mean monthly temperatures, increased the r value to 0.95. Each of these climatic factors had a highly significant effect. Conspicuously absent on influencing fertilized yield was June precipitation. This is in contrast to the significant effect June precipitation had on herbage yields from nonfertilized plots.

Spring and fall precipitation each had a highly significant influence on yields from fertilized plots (Table 3); however, the spring precipitation ($r=0.83$) was much more influential than the fall precipitation in accounting for variability in yields. Over-winter precipitation was not significantly related to yields.

Omitting June precipitation from the spring precipitation did not adversely affect correlations with herbage yields. The April through May and fall precipitation periods accounted for 77%, $r=0.88$, of the yield variations of fertilized herbage (Table 3). Adding April mean temperature accounted for 4% more of the yield variations. Over-winter precipitation was of insignificant value in explaining variations from year-to-year in yield from fertilized plots.

Conclusions

Herbage yields of nonfertilized established stands of introduced grasses in a foothill meadow in northeast Oregon were positively but poorly correlated with monthly, seasonal, or crop year precipitation. Increasing the length of the precipitation period improved the relationships between yields and precipitation. However, these correlations explained only 30 to 35% of the variation in yield among years.

Established stands of introduced grasses that were fertilized with nitrogen were much more responsive to precipitation than nonfertilized stands. Over 75% of the yield variation between years was positively associated with Sep-

tember through December plus April and May precipitation.

Spring precipitation influenced yields more than did fall precipitation. Over-winter precipitation was of insignificant value in accounting for variability in herbage production. Including spring monthly mean temperatures did not significantly improve correlations.

September through December plus April-through-May precipitation would be a useful measurement for a range manager to use in estimating future herbage production where moisture is the primary limiting factor. Using September through December plus April precipitation would have approximately 10% less reliability than including May precipitation.

The much greater responsiveness of the fertilized grass stands to precipitation re-emphasizes the need to be aware of those factors which limit yield when trying to relate a climatic factor to a response from a biological system.

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