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Nitrogen and Phosphorus Constraints on Primary Production in the Great Basin Desert

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NITROGEN AND PHOSPHORUS CONSTRAINTS ON PRIMARY PRODUCTION IN THE GREAT BASIN DESERT

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ABSTRACT

Field studies conducted in 1974 adjacent to the Curlew Valley, Utah, site to observe the effect of nitrogen and phosphorus application on the biomass production of *Agropyron desertorum* (crested wheatgrass), *Artemisia tridentata* (sagebrush) and *Atriplex confertifolia* (shadscale) were continued in 1975 and expanded for the latter two species. The crested wheatgrass study consisted of 24 treatments replicated eight times. Crop yield and protein content responded significantly to nitrogen additions. Phosphorus content did not respond to nitrogen or phosphorus additions, and was generally higher for the lower yielding plots. The natural vegetation studies of 1974, consisting of four treatments replicated ten times, were expanded with six additional treatments also replicated ten times. Shadscale was a better indicator of soil nitrogen and phosphorus status than sagebrush. Shoot length was more sensitive to nutrient additions than was shoot weight in both shadscale and sagebrush. Protein content in both native vegetation species was increased by nitrogen additions. No significant differences were demonstrated between responses to surface and subsurface methods of nutrient application in these studies.

INTRODUCTION

Research conducted in 1975 concerned the effect of nitrogen and phosphorus application on the biomass production of *Agropyron desertorum* (crested wheatgrass), *Artemisia tridentata* (sagebrush) and *Atriplex confertifolia* (shadscale) at the Curlew Valley Validation Site.

Previous field studies (Jurinak et al. 1975) at the Curlew Valley site indicated that both *Artemisia tridentata* and *Atriplex confertifolia* responded significantly in terms of vegetative shoot growth to the application of N and P; this, in spite of the insignificant rainfall recorded during the 1974 growing season. The N and P treatments on *Agropyron desertorum* failed to produce any significant biomass increase. The protein content, however, was found to be related significantly to nitrogen application.

This year's study was directed toward residual effects of nutrients applied during the fall of 1973 and the spring of 1974, particularly with regards to the *Agropyron desertorum* plots. In addition, N and P treatments were applied to the *Artemisia tridentata* plots to further verify and expand information obtained during 1974 on response of natural vegetation to increased soil fertility.

OBJECTIVES

1. Continue the study of *Agropyron desertorum* to determine the residual response to N and P application.
2. Continue the study of *Artemisia tridentata* and associated *Atriplex confertifolia* to evaluate the residual response to N and P application.
3. Determine the effect of N rates on *Artemisia tridentata* with respect to yield and protein content of terminal shoot growth.
4. Estimate the water use efficiency of *Agropyron desertorum*.

SITE DESCRIPTION

The crested wheatgrass study was conducted adjacent to and east of the Desert Biome site at Curlew Valley, Utah. The natural vegetation on the site was originally sagebrush-dominated, but the area had been cleared and crested wheatgrass (*Agropyron desertorum*) introduced to increase its grazing potential for cattle. The sagebrush study was conducted at a site just north of hectare 6 of the same site. Chemical characterization of the Thiokol silt loam soil, a typic calciorthid, is recorded in 1971 and 1973 project reports (Jurinak and Griffin 1972; Jurinak and Evans 1974), and in DSCODES A3UJD01, 02, 06 and 07.

METHODS

Experimental: Crested Wheatgrass Study

Sampling Procedure

The study was designed to determine if the greenhouse-observed N x P interaction on biomass production of crested wheatgrass is manifested at the field level where soil moisture is the critical factor. Adverse soil moisture conditions during the 1974 growing season resulted in a lack of growth response. In the 1975 growing season, improved soil moisture conditions were expected. Thus, two additional surface treatments of N were applied in the fall of 1974 to establish a reference base for the residual fertilizer effect. The following general statements can be made concerning the experimental design (some of which are given in the specification for the coding forms of this experiment):

1. The experimental design originally consisted of 32 treatments replicated eight times. The arrangement of the replications was a randomized complete block.

2. Each plot was 2.44 x 12.2 m and the total site was 29.8 m^2. The entire site, which included a buffer zone or perimeter, was approximately 1 ha and was cut prior to plot staking and nutrient addition in 1973.

3. Among the treaments was an incomplete factorial design (treatments 1-14) of N x P. These treatments were established in the fall of 1973, and the fertilizer was shanked (drilled) into the soil. At the same time, treatments 15-18

were applied to compare the type of N applied and the method of application (subsurface vs. surface). Treatments 19-22 were applied in the spring of 1974, duplicating treatments 15-18, to evaluate time of application. Treatment Plot 23 was used as an additional check in 1974. Treatments 25 and 26 were added in the fall of 1974. Treatments 23, 24 and 27-32 were not sampled. Biomass sampling for the study was done during August 3-5, 1975. The crested wheatgrass was cut approximately 2 cm above the ground by hand. Sampling within each plot was done with a 1 x 3 m (or 3-m^2) frame. The frame was placed within the plot and all crested wheatgrass plants within the frame were harvested. If the frame fell across the crown of a plant, the part of the plant inside the frame was harvested. The grass samples were placed in paper bags and the bags were labeled and sealed.

Plant Sample Analyses

The grass samples were air-dried, weighed to the nearest gram, ground in a Wiley Mill and subsampled for P and N analyses.

Experimental: Native Vegetation Site

Sampling Procedure

This study is a continuation of previous field studies (1974) which indicated that both *Artemisia tridentata* and *Atriplex confertifolia* responded to N and P application. The following summarizes the field design for this experiment:

1. The experimental design consisted of two separate but adjacent experimental locations. One location received four treatments, replicated 10 times, in November 1973. The other location received six treatments, replicated eight times, in November 1974. The treatment design was completely randomized for both trials.

2. Each treatment covered a circular plot of 0.001 ha (a millihectare). The plot contained a tagged sagebrush plant, and four or more shadscale plants.

3. The fall 1973 treatments were: 1) a check, or zero N and P; 2) 67.2 kg/ha N with no P, applied broadcast on the surface; 3) 67.2 kg/ha N and no P, applied at a depth of 8 cm with a soil auger at 25 random points within the plot (subsurface application); and 4) 67.2 kg/ha N and 33.6 kg/ha P, applied subsurface. The fall 1974 treatments were: 1) a check; 2) 33.6 kg/ha N and no P, applied broadcast; 3) 67.2 kg/ha N and no P, applied broadcast on the sagebrush; 4) 134.4 kg/ha N and applied broadcast; 5) 134.4 kg/ha N and no P, applied subsurface; and 6) 134.4 kg/ha N and 33.6 kg/ha P, applied subsurface.

New shoot growth was harvested from all plots on September 16, 1975. Twenty vegetative shoots were collected from each tagged sagebrush plant. Five shoots were collected from each of four shadscale plants within each millihectare plot. Shadscale shoots were chosen randomly. The vegetative shoots on the sagebrush plants were selected using the equipment and procedure described in Jurinak et al. (1975).

Sample Treatment

Selected shoots included only new growth. Each harvested shoot was subsequently measured for length, air-dried and weighed for dry-matter production, finely ground in a Wiley Mill, mixed and subsampled for tissue analysis for P and N.

N and P Analyses

Plant tissue P content was determined by the ascorbic acid method of Murphy and Riley (see Watanabe and Olsen 1965) following digestion of a 1-g sample in perchloric acid. The standard Kjeldahl method with the Winkler modification was used to analyze N as NH_3 (Blaedel and Meloche 1963). The N was measured by titration of the boric acid trap with H_2SO_4 to the bromocresol green endpoint. A factor of 6.25 was used to convert the concentration of N into percent crude protein.

RESULTS AND DISCUSSION

Crested Wheatgrass

Soil Moisture and Climatology

Soil sampling done before and after the growing season, both in 1975 and in 1974, showed a soil moisture distribution as shown in Figure 1. Moisture percentage is on the weight basis. Using approximate figures for bulk densities, the soil-water depletion for 1975 was about 8.0 cm, and for 1974 was 8.7 cm. Note that the data show more moisture in the soil before and after the 1975 growing season. An average 3-m^2 yield of 730 g in 1975 corresponds

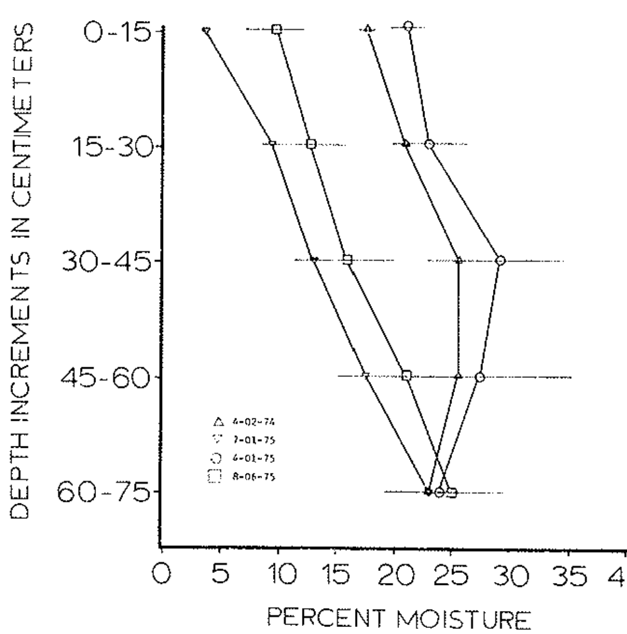

Figure 1. Moisture distribution in the profile of the Curlew Valley crested wheatgrass site sampled April 2 and July 1, 1974, and April 1 and August 6, 1975.

Table 1. Monthly climatological summaries for the 1974 and 1975 growing seasons of the Desert Biome site at Curlew Valley, Utah

I. The 1974 study. Total precipitation during Jan and Feb = 9.07 cm.

MONTH	MAR	APR	MAY	JUN	JUL	AUG
PPTN. (CM)	0.28	2.34	0.51	0.00	0.64	0.76

II. The 1975 study. Total precipitation during Jan and Feb = 3.58 cm.

MONTH	MAR	APR	MAY	JUN	JUL	AUG
PPTN. (CM)	4.24	5.31	3.05	0.86	3.02	0.64
AVG DAILY RADIATION (LY/DAY)	3379	(est) 5600	6112	6101	6250	5956
TEMP (°C)	3.35	4.56	10.24	15.30	20.74	16.60
R. H. (%)	72	68	67	62	60	55
AVG WIND SPEED @ 2 M (MI/DAY)	26.0	29.5	28.9	20.1	25.7	25.3

to a 2433 kg/ha crested wheatgrass yield. Using Tr/Pc = -301 (metric conversion of data in Briggs and Shantz 1914), for crested wheatgrass (where Tr is transpiration in centimeters of water and Pc is yield in kilograms per hectare), the transpiration water required for the 1975 yield was 7.8 cm. Correspondingly, only 3.0 cm of water was used to produce the low 1974 yields.

Using the data of Table 1, and the method of Christiansen and Hargreaves (1969), the average potential free water surface evapotranspiration, $\overline{E}tp$, for the 1975 season was calculated as —2.64 cm/day.

The Table 1 data further illustrate the impact of timely spring precipitation. In the 1974 study, a wet winter was followed by an extremely dry spring and summer, allowing the crop, in competition with evaporation, to use only about 23% of the nearly 13 cm of water which was the combined season total of precipitation and soil-moisture depletion. In the 1975 study, however, a relatively dry winter was followed by a wet spring, and the crop was able to use about 37% of the nearly 21-cm combined season total of precipitation and soil-moisture depletion.

Nitrogen and Phosphorus Treatments

Table 2 summarizes the treatment means for the three measured variables of yield (g), tissue P concentration (ppm) and protein content (%) for both the crested wheatgrass study of 1974 and the residual study of 1975. The means for the two treatments added in the fall of 1974 are included also.

A comparison of the overall means for the 22 treatments of the 1974 study and of the 1975 residual study showed that yield increased an average of 280%, phosphorus concentration increased an average of 307% and protein content decreased an average of 28%.

Hotelling and Pabst's Spearman rank-order correlation test (as in Bradley 1968) showed both yield and protein percentages for the 1974 study to be significantly correlated with the same variables for the same treatments in the 1975 residual study (at the 99.9% confidence level). This result suggests that information sought from the 1974 study may be found in the corresponding residual study, and/or that field effects or genetic effects may also be significant.

Two-way analysis of variance for yields showed both treatment and field effects significant at the 99% confidence level. Similar analyses for the phosphorus and protein content variables demonstrated significant differences due to treatments at the 95 and 99% confidence levels, respectively, and no significant field effects.

Yields increased with increased N application rates with few exceptions. That these exceptions demonstrate field effects follows from their presence for the same treatments in both the 1974 and the residual studies, and the correlation and variance analyses cited.

Specifically, at the 95% confidence level, the following treatment pairs were found to be significantly different in mean yield using Duncan's multiple range test after two-way analysis of variance:

1. 56 kg NH_4NO_3 — N/ha + 0 kg P/ha, shanked, fall 1973, vs. the check plot.

2. 56 kg NH_4NO_3 — N/ha + 11.2 kg P/ha, shanked, fall 1973, vs. 28 kg NH_4NO_3 — N/ha + 11.2 kg P/ha, shanked, fall 1973.

3. 224 kg NH_4NO_3 — N/ha + 22.4 kg — P/ha, shanked, fall 1973, vs. 0, 28, 56 and 112 kg NH_4NO_3 — N/ha + 22.4 kg — P/ha, shanked, fall 1973.

Table 2. Treatment means for yield, tissue P content and protein percentage for crested wheatgrass (DSCODE A3UJJ02)

I. THE INCOMPLETE BLOCK MODEL. Nutrients applied shank in fall 1973, N as NH_4NO_3. Means for the 1974 and 1975 residual study. Yield (1), tissue P content (2), and protein % (3).

	N (kg/ha)									
	0		28		56		112		224	
Harvest	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975
P (kg/ha) 0	1) 213 2) 912 3) 7.02	537 3765 4.96			274 992 8.90	724 3088 6.55				
11.2			222 990 8.43	671 2659 5.87	287 1014 8.64	887 2851 6.24			361 938 9.79	797 2841 7.88
22.4	245 942 6.88	616 3694 5.26	277 937 7.76	715 2988 5.58	268 932 8.64	662 2578 6.51	270 988 10.04	741 3294 7.65	412 945 9.88	940 2973 8.00
44.8					301 985 8.30	716 2661 6.23				
67.2			242 997 8.21	670 3293 5.74	243 1032 9.42	699 3096 6.43			311 975 9.51	843 3085 7.84

Overall means for the 14 treatments of the model:

1974: Yield = 280 g Tissue P = 970 ppm Protein = 8.67%
1975: Yield = 730 g Tissue P = 3062 ppm Protein = 6.48%

II. SUPPLEMENTAL TREATMENTS

Overall means for the 22 treatments of the 1974 study: Yield = 251 g
Tissue P = 1023 ppm
Protein = 8.83%

Overall means for the corresponding 22 treatments of the 1975 residual study:
Yield = 702 g
Tissue P = 3138 ppm
Protein = 6.39%

Broadcast Fall 1974 NH_4NO_3-N	
56 kg/ha	112 kg/ha
739 2295 6.57	890 3020 7.51

	Broadcast Fall 1973				Broadcast Spring 1974			
	$Ca(NO_3)_2$-N		$(NH_4)_2SO_4$-N		$Ca(NO_3)_2$-N		$(NH_4)_2SO_4$-N	
Harvest	1974	1975	1974	1975	1974	1975	1974	1975
N,P(kg/ha) 28,22.4	207 1092 9.56	554 3704 6.03	190 1192 9.56	661 3884 5.74	184 1043 7.50	621 3411 5.62	176 1065 8.12	661 3211 6.46
56,22.4	217 1186 11.60	659 3089 6.50	222 1189 9.75	664 3340 6.30	226 1110 8.25	643 2643 6.47	164 1052 8.57	760 2895 6.81

4. 224 kg NH_4NO_3 — N/ha + 67.2 kg — P/ha, shanked, fall 1973, vs. 28 kg NH_4NO_3 — N/ha + 67.2 kg — P/ha, shanked, fall 1973.

5. 112 kg NH_4NO_3 — N/ha + 0 kg — P/ha, broadcast, fall 1974, vs. 56 kg NH_4NO_3 — N/ha + 0 kg P/ha, broadcast, fall 1974.

Yields were not significantly affected by P application rate changes. Type of nitrogen, method of application or time of application did not affect yield in the residual study. The one fall 1974 treatment which could be compared with a fall 1973 treatment, confounding only application method, showed no significant difference in yield. This suggests that the low soil moisture conditions prevailing throughout the 1974 growing season, with resulting low yields, prevented the normal reduction in the availability of the added nitrogen by plant uptake.

Phosphorus content results from the residual study conflicted with corresponding results from the 1974 study. In 1974, a general increase of tissue P was noted with increasing rates of N application. In the 1975 residual study, higher P content generally corresponded to the lower N application rates. The only two treatments in the incomplete block two-way analysis of variance which differed significantly in mean P content (95% confidence level) were the treatment receiving 0 kg — N/ha + 22.4 kg — P/ha, which had a higher P content than the treatment receiving 56 kg — N/ha + 22.4 kg — P/ha. The check plots had an average P content greater than either of these two treatments, suggesting that P uptake was generally unaffected by P application rates, which is also corroborated by the lack of significant differences in treatments varying only in P application rates.

It was considered that the increased yields affected the P content of the plant. In order to adjust these phosphorus results for this dilution effect by yield, analysis of covariance was performed using yield as the independent variable and P content as a dependent variable. The resulting adjusted treatment means showed the following treatments to be significantly different at the 95% confidence level (the higher P content treatment is listed first):

1. 0 kg — P/ha + 0 kg — N/ha, check plots, vs. 0 kg — P/ha + 56 kg NH_4NO_3 — N/ha, shanked, fall 1973.

2. 22.4 kg — P/ha + 0 kg — N/ha, shanked, fall 1973, vs. 22.4 kg — P/ha + 28 and 56 kg NH_4NO_3 — N/ha, shanked, fall 1973.

3. 22.4 kg — P/ha + 112 kg NH_4NO_3 — N/ha, shanked, fall 1973, vs. 22.4 kg — P/ha + 56 kg NH_4NO_3 — N/ha, shanked, fall 1973.

4. 67.2 kg — P/ha + 28 kg NH_4NO_3 — N/ha, shanked, fall 1973, vs. 11.2 kg — P/ha + 28 kg NH_4NO_3 — N/ha, shanked, fall 1973.

5. 22.4 kg — P/ha + 28 kg $Ca(NO_3)_2$ — N/ha broadcast, fall 1973, vs. 22.4 kg — P/ha + 56 kg $Ca(NO_3)_2$ — N/ha, broadcast, fall 1973.

6. 22.4 kg — P/ha + 28 kg $Ca(NO_3)_2$ — N/ha, broadcast, spring 1974, vs. 22.4 kg — P/ha + 56 kg $Ca(NO_3)_2$ — N/ha, broadcast, spring 1974.

7. 22.4 kg — P/ha + 28 kg $(NH_4)_2SO_4$ — N/ha, broadcast, fall 1973, vs. 22.4 kg — P/ha + 28 kg $(NH_4)_2SO_4$ — N/ha, broadcast, spring 1974.

8. 0 kg — P/ha + 112 kg NH_4NO_3 — N/ha, broadcast, fall 1974, vs. 0 kg — P/ha + 56 NH_4NO_3 — N/ha, broadcast, fall 1974.

Except for the current-season (fall 1974) applications, the general trend for the previous-season (fall 1973 and spring 1974) applications was one of decreasing tissue P with increasing N rates. With a single exception, the 11 contrasting treatment pairs which differed only in P application rate showed no significant differences in tissue P content.

Previous research on the phosphorus cycle in the desert ecosystem (Jurinak and Griffin 1973) showed that the soil of the study site has an unusually high phosphorus adsorption capacity and bonds phosphorus more tenaciously than soil with lower capacities. Furthermore, the Curlew Valley soil was shown to be highly unsaturated with respect to adsorbed phosphorus. With low soil moisture, therefore, or over a relatively short time interval, it is speculated that less of the added phosphate-P was adsorbed than with higher soil moisture or a longer time interval. Hence, current-season applications showed response to added P while residual effects were diminished by the adsorption or fixation of the added P in the calcareous soil. It appears that P release to the plant was controlled by the desorption rate of P from the soil as well as the diffusion rate of P in the soil solution.

Protein content in the 1975 wheatgrass study was reduced from that of the 1974 study. It should be noted, however, that, on the average, there was 2.02 times as much protein harvested in the 1975 residual harvest as compared with the 1974 harvest. This general decrease in protein content is considered a dilution effect due to the increased dry matter production.

Protein percentage was significantly correlated with the N application rate. For example, the five treatments receiving 22.4 kg — P/ha and 0, 28, 56, 112 and 224 kg NH_4NO_3 — N/ha, respectively, provided the following relationship (confidence level = 98%):

$$\text{Protein \%} = 5.47\ g + 0.0135\ (\text{kg — N/ha applied})$$

$$r = .936$$

$$df = 3$$

Data from the incomplete block model were used in the regression equation:

$$Y = b_0 + b_1N + b_2P + b_{11}N^2 + b_{22}P^2 + b_{12}NP$$

where Y represents the dependent variables and b values are the regression coefficients. The independent variables N, P, N^2, P^2 and NP represent the main, quadratic and interaction effects of the N and P applications. Protein percentage was the only one of the three dependent variables (phosphorus, yield and protein percentage) which gave a reasonable correlation coefficient. Discarding nonsignificant variables, the regression equation gave (significant at 99% confidence level):

$$Y = 5.072 + .0298\,(N) - 0.000762\,(N)^2$$

$$r = .749$$

A corresponding equation was derived in the 1974 study. When the value of N = 100 kg/ha was substituted in the 1974 equation, a 10.05% protein content was predicted. When the same N value was entered in the above relation, a 7.29% protein percentage was predicted, indicating a decrease of 27.5%, which closely corresponded to the overall observed decrease of 28% in the protein content.

In the 1974 study, type of nitrogen, method of application and time of application were tested for significant effects on yield, P content and protein content. Repeating these tests on the 1975 residual data gave no new information. This year's study provided no evidence to contradict the conclusions of previous studies that no signficant differences were due to sources of N used (nitrate vs. ammonia), time of application (fall vs. spring) or method of application (shanked vs. broadcast).

Natural Vegetation Study

Sagebrush

The results of the sagebrush study appear in Table 3. In comparison to the 1974 sagebrush study results, the average vegetative shoot length in 1975 was 176% greater than in 1974.

Statistical analysis of the 1975 residual experiment revealed that only the shoot protein content was significantly different among the four treatments. Average shoot weight, shoot length and P content were not influenced by previous treatments.

Similar analysis of the 1975 current-season sagebrush experiment showed that both shoot length and protein percentage were affected by treatments at the 95% confidence level. This result supports the choice of shoot-length sampling to evaluate fertilizer response in sagebrush.

Certain general trends appear in Table 3. In both the residual and the expanded study, for example, both the average shoot weight and length generally increased with the surface and the subsurface treatments. The same trend as observed in the crested wheatgrass (namely the highest P content appearing in the check plots), also appears in Table 3 for sagebrush.

The significant response in the sagebrush was, for the residual study (at the 95% confidence level):

Protein percentage for the 67.2 kg N/ha, broadcast, fall 1973 treatment.

For the expanded 1975 study, the 95% significance level responses were:

1. Shoot lengths were greater for 134.4 kg N/ha surface-applied treatment and the 134.4 kg N/ha + 33.6 P/ha subsurface treatment than for the check plots.

2. Protein contents were greater in the 67.2 kg N/ha surface, 134.4 kg N/ha surface, 134.4 kg N/ha subsurface and the 134.4 kg N/ha + 33.6 kg P/ha subsurface treatments than in the check plots.

3. Protein content was greater in the 134.4 kg N/ha surface treatment than in the 33.6 kg N/ha surface treatment.

A shoot-length and protein content response to nitrogen was thus indicated, but no difference between surface and subsurface treatments and no P responses were observed in the sagebrush.

Shadscale

Results for the shadscale appear in Table 4. Comparing the residual study shoot lengths with the 1974 shoot lengths indicated a 214% average length increase in 1975 over 1974.

Analysis of variance on the results of the residual shadscale study revealed shoot weight to be significantly affected by treatment at the 95% level of significance, and both shoot length and protein percentage to be treatment-dependent at the 1% significance level.

The expanded 1975 shadscale study indicated also that shoot length and protein percentage were significant at the 1% level. But shoot weight was not signficant. Specifically, in the residual shadscale study, both of the subsurface treatments had average shoot weights significantly greater than the check.

Shoot lengths, for both the residual and expanded shadscale studies, differed significantly for the following treatment cases: 1) for all treatments of the residual study as compared with the check; 2) for the subsurface treatment with added P, as compared to the subsurface treatment without added P, in the residual study; 3) for the two higher surface treatments and the subsurface treatment with added P, as compared to the check, in the expanded study.

Table 3. Treatment means for the sagebrush studies*

Residual Sagebrush Study*

P (kg/ha)	N (kg/ha): 0, 1974	0, 1975	Surface 67.2, 1974	Surface 67.2, 1975	Subsurface 67.2, 1974	Subsurface 67.2, 1975
0	1) 2) 3.2 3) 4)	.1395 6.03 8130 11.08	3.8	.1498 6.76 7530 11.92	4.0	.1549 6.86 7284 11.53
33.6					4.4	.1534 7.43 6853 11.61

Overall means for this study:

	1974	1975
1)		.1494 gm
2)	3.85 cm	6.77 cm
3)		7449 ppm
4)		11.54%

Expanded 1975 Sagebrush Study*

P (kg/ha)	N (kg/ha): 0	Surface 33.6	Surface 67.2	Surface 134.4	Subsurface 134.4
0	.1413 6.20 7409 10.99	.1726 7.31 6564 11.49	.1726 7.26 5182 11.85	.1865 7.50 6887 12.51	.1588 7.18 6738 11.92
33.6					.2087 7.98 6419 12.04

Overall means for this study:
1) .1734 gm
2) 7.24 cm
3) 6533 ppm
4) 11.80%

*Order of data is as follows:
1) shoot weight in g
2) shoot length in cm
3) tissue P in ppm
4) tissue protein percentage

Table 4. Treatment means for the shadscale studies*

Residual Shadscale Study*

		N (kg/ha) 0		Surface 67.2		Subsurface 67.2	
Harvest		1974	1975	1974	1975	1974	1975
P (kg/ha)	0	4.3	.5691 9.26 2799 6.69	6.0	.6964 12.63 2587 10.45	5.6	.9033 11.58 2857 9.79
	33.6					6.4	1.049 14.30 2742 9.45

Overall means for this study:

	1974	1975
1)		.8045 gm
2)	5.58 cm	11.94 cm
3)		2746 ppm
4)		9.10%

Expanded 1975 Shadscale Study*

		N (kg/ha) 0	Surface 33.6	Surface 67.2	Surface 134.4	Subsurface 134.4
P (kg/ha)	0	.6003 10.26 2721 7.96	.9147 11.86 2770 7.96	.7712 12.75 3012 8.77	.8213 12.24 2524 10.07	.6834 11.66 2471 9.90
	33.6					1.012 13.38 2905 10.20

Overall means for this study: 1) .8005 gm
2) 12.03 cm
3) 2734 ppm
4) 9.14 %

*Order of data is as follows:

1) shoot weight in g
2) shoot length in cm
3) tissue P in ppm
4) tissue protein percentage

Phosphorus contents were not significantly affected by treatments in either of the shadscale studies. Using both shoot weight and shoot length as a composite index of shoot quality, an analysis of covariance was performed with P content as dependent variable. The regression analysis was significant at the 5% level for the residual check plots. For treated plots, there was no significant correlation between P content and shoot quality. There was one treatment where protein percentage was positively correlated (at the 95% confidence level) with the shoot quality index. This was where shoot length showed a significant response to added P as compared to the corresponding treatment without P. The data suggest that, with shadscale, there is a N x P interaction.

Protein percentage in the residual study was significantly higher for all treatments as compared to the check. However, no significant difference in protein existed among treatments.

In the expanded shadscale study, the three treatments receiving 134.4 kg N/ha had protein contents significantly greater than the check plots. Again, no significant differences were found among treatment plots; hence no differences can be demonstrated between the surface and subsurface nutrient treatments.

SUMMARY AND CONCLUSIONS

The 1975 crested wheatgrass residual fertilizer study was a continuation of the 1974 study. In 1974 there was a lack of growth response due to poor soil-moisture conditions. The 1975 growing season soil moisture was more favorable, and crested wheatgrass yielded, on the average, 280% more, contained 307% more phosphorus and 28% less protein than in 1974. Statistical analysis showed that crop yield and protein content responded significantly to nitrogen additions. Phosphorus content was generally highest in the check plots and with the lower rates of nitrogen addition, suggesting a dilution effect on this element with increased vegetative growth. Nitrogen source was a nonsignificant factor in determining nitrogen response in crested wheatgrass.

The sagebrush residual studies of the plots fertilized in the fall of 1973 showed no significant changes in yield or phosphorus content with fertilization; added nitrogen, however, did increase the protein content significantly. The corresponding shadscale residual study inferred significant yield and protein increases with added nitrogen, and also that shoot length responded to phosphorus addition.

The 1975 sagebrush and shadscale studies, in which treatments were applied in the fall of 1974, gave the same general results, with some increase in shoot length, but no shoot weight increase of statistical significance with added nitrogen. Protein content in both sagebrush and shadscale increased significantly by nitrogen additions. There were no significant responses to phosphorus additions for either sagebrush or shadscale in these expanded trials.

Shoot length was found to be a more sensitive physical indicator of fertility response than shoot weight in the sagebrush and shadscale studies.

Shadscale was more responsive to the soil N and P fertility status than sagebrush.

No significant differences were demonstrated between the surface and subsurface methods of nutrient application in either the crested wheatgrass or the natural vegetation studies.

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