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J. J. Jurinak

D. W. James

A. Van Luik

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

J. J. Jurinak (Project Leader),
D. W. James and R. L. Evans
Utah State University

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Ecology Center, Utah State University, Logan, Utah 84322

ABSTRACT

Field studies were conducted 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) and *Artemisia tridentata* (sagebrush). The phosphorus was added as treble superphosphate and the nitrogen as either $Ca(NO_3)_2$ or NH_4NO_3. The crested wheatgrass study involved spring and fall applications, both surface and subsurface, of nitrogen and phosphorus at various rates. The experimental design consisted of 32 treatment plots replicated eight times. No response to treatment was noted in the yield of crested wheatgrass to the application of nutrients. This was considered due to the abnormally low soil moisture content during the growing season. The protein percentage in the plant material was significantly increased by nitrogen treatment. Exploratory studies on sagebrush response to nitrogen and phosphorus application were also conducted. Treatments consisted of nitrogen and phosphorus applications at four levels applied either on the surface or in the subsurface. The treatments were replicated 10 times. The close association of *Atriplex confertifolia* (shadscale) within the sagebrush plots allowed observations to be made concerning the response of shadscale to nutrient application. Contrary to crested wheatgrass, both species responded significantly to fertilizer application. However, differences between fertilizer levels were not significant. The differences between surface and subsurface application were also nonsignificant. Fertilizer response for both shadscale and sagebrush was measured by an increase in the terminal vegetative growth.

INTRODUCTION

Research conducted in 1974 was concerned with the effect of nitrogen and phosphorus on the biomass production of *Agropyron desertorum* and *Artemisia tridentata* at the Curlew Valley site.

Previous research suggested that, under controlled growth-chamber conditions, the nutrient status of the soil is a potential factor in biomass production of *Agropyron desertorum* (crested wheatgrass). Significant nitrogen times phosphorus interaction as well as a response to Fe treatment was observed. The current studies were the application of these findings to the field to note the response to nutrient application under natural conditions.

In addition, an exploratory study involving *Artemisia tridentata* (sagebrush) was initiated to observe if biomass production of native vegetation would benefit from nutrient application. The close association of *Atriplex confertifolia* (shadscale) within the sagebrush plots allowed data to be collected concerning the response of shadscale to nutrient application although the plots were specifically selected for sagebrush.

OBJECTIVES

The objectives of the crested wheatgrass study initiated in 1974 were to:

1. Determine if the observed N x P interaction on biomass production of crested wheatgrass, as documented under growth-chamber conditions, is manifested at the field level where the critical factor of soil moisture is introduced.
2. Determine the response difference for biomass production of crested wheatgrass between surface and subsurface soil fertilizer treatment applications.
3. Determine the response difference for biomass production of crested wheatgrass between surface fertilizer treatments applied to the soil in fall and those applied in the spring.

The sagebrush study was considered exploratory. The objectives of this study were to:

1. Measure the response of sagebrush and shadscale, as determined by the seasonal, terminal growth of vegetative shoots, to levels of N and P fertilizer applications.
2. Determine the response difference for growth of sagebrush and shadscale between surface and subsurface fertilizer treatment applications.

METHODS

Nitrogen Times Phosphorus -- Crested Wheatgrass Study

The crested wheatgrass study involving fall and spring fertilizer applications, both surface and subsurface, of N and P at various rates was conducted adjacent to and east of the Desert Biome site at Curlew Valley, Utah. The natural vegetation on the site had originally been sagebrush-dominated, but the area had been cleared and crested wheatgrass (*Agropyron desertorum*) introduced to increase its grazing potential for cattle. Chemical characterization of the Thiokol silt loam soil, a typic calciorthid, can be found in 1971 and 1973 Desert Biome project reports (Jurinak and Griffin 1972, Jurinak and Evans 1974), and in data bank DSCODES A3UJD01, 02, 06 and 07.

The fall treatment, applied October 16, 1973, was designed as an incomplete block of N x P applied as both surface and subsurface (shanked to about 8 cm) treatments. In addition, two forms of N, $(NH_4)_2SO_4$ and $Ca(NO_3)_2$, were applied to the surface treatment plots. NH_4NO_3 was the source of N for the subsurface treatment.

In the fall subsurface treatments (treatments 1-4), nitrogen was added at rates of 28, 56, 112 and 224 kg/ha; phosphorus, added as treble superphosphate, was applied at rates of 11.2, 22.4, 44.8 and 67.2 kg/ha.

In the fall surface treatments (15-18), nitrogen was added as either $(NH_4)_2SO_4$ or $Ca(NO_3)_2$ at a rate of either 28 or 56 kg/ha. Phosphorus, added as treble superphosphate, was applied at a rate of 22.4 kg/ha.

In the spring treatments (19-22), applied April 2, 1974, the surface treatments of N and P were identical to those used in the fall. The plots remaining untreated (23-32) were left as additional checks and available for further treatment in the fall of 1974, if deemed necessary.

The experimental design consisted originally of 32 treatment plots replicated eight times. The replications were randomized within each block. Each plot was 2.4 x 12.1 m. The study site area was 7614.4 m^2. The total site area, which included a buffer zone or perimeter, was about 1 ha and was mowed prior to treatment. The design of this experiment is recorded in DSCODE A3UJJ02.

Sampling and harvest were carried out on all plots on July 2-3, 1974. There was no rainfall at the site during the period of April 2 to July 2. The crested wheatgrass was cut approximately 2 cm above the ground using hand sickles with serrated edges. The sampling area within each plot was determined using a portable, rectangular frame of light metal chain and wood which, when extended, was 2 m^2 in area. The frame was placed within the plot with the corners at right angles and all crested wheatgrass plants harvested within the frame. If the frame fell upon a plant, that part of the plant which was inside the perimeter of the frame was harvested. The frame was placed so that the perimeter was at least 25 cm from the plot boundary. The samples were placed in paper bags which were then labeled and sealed.

The samples were air dried in open paper bags, weighed to the nearest gram, ground in a Wiley mill and subsampled for P and N analyses. Plant tissue P content was determined as μg P/g of dry plant material by the ascorbic acid method of Murphy and Riley (1962) as reported by Watnabe and Olsen (1965) following digestion of a 2-g sample by perchloric acid (800 ml HNO_3 + 120 ml $HClO_3$ + 80 ml H_2SO_4). The standard Kjeldahl method with the Winkler modification was used to analyze N as NH_3 as caught in an excess of boric acid (Blaedel and Meloche 1963). The N was measured by titration 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. The data found for the yield, P concentration and protein content by percentage are documented in A3UJJ02.

Soil moisture measurements were made at the beginning (April 2, 1974) and at the end (July 1, preceding the harvest of the crested wheatgrass) of the growing season at four sites within the study area and at five depth increments to 76 cm and reported as percentage of the soil dry weight. Plant-available P or labile P was found for the soil by sodium bicarbonate extraction from samples taken before fall fertilization from four replicates of three selected treatment plots to note the possibility of a P gradient at the site. The mean value was found to be 16.82 μg P/g soil. No gradient was observed.

Nitrogen Times Phosphorus -- Sagebrush Study

The sagebrush study involving fall fertilizer applications of N and P was conducted at a site just north of hectare 6 of the Desert Biome site at Curlew Valley, Utah. The natural vegetation around the site was representative of the sagebrush-dominated complex common to the area. Specifically, the study was concerned with measuring the vegetative shoot growth of sagebrush (*Artemisia tridentata*) and shadscale (*Atriplex confertifolia*) over a single growing season. Chemical characterization of the Thiokol silt loam soil has been documented.

The experimental design consisted of four treatments replicated ten times. The arrangement of all 40 plots was random except that each sagebrush plant selected was between 50-60 cm in height. Each treatment replication was a circular plot of 0.001 ha (a millihectare). The plot contained not only a tagged sagebrush plant, to be measured for vegetative shoot growth, but also a shadscale community that could be measured for biomass response as well. The treatments used for this experiment were 1) check; 2) surface application of 67.2 kg/ha N; 3) subsurface application of 67.2 kg/ha N; and 4) subsurface application of 67.2 kg/ha N and 33.6 kg/ha P. Subsurface application was done with a hand soil auger to a depth of 8-10 cm, at 20-25 random sites within each plot. Nitrogen was added as $(NH_4)_2NO_3$ and P added as treble superphosphate. Treatment was applied only in fall (November 1, 1973).

Data were collected by measuring the vegetative shoot growth of sagebrush and shadscale on September 3-4, 1974. The vegetative shoots of sagebrush were randomly selected for measurement using the technique of Smith and Doell (1968). Within each plot, 20 vegetative shoots of the tagged sagebrush and five shoots of four shadscale plants were measured.

The shadscale plants were not previously selected or tagged. At the time of measurement, four plants were selected at random within each millihectare plot. The shoots measured for growth were selected randomly.

Each shoot for sagebrush and shadscale was measured for new growth using clear, plastic engineering rulers. Measurements were made to the nearest 0.1 cm. The shoots were laid flat against the rulers during measurement. The data collected for sagebrush and shadscale growth are recorded in A3UJJ01.

RESULTS AND DISCUSSION

Crested Wheatgrass Study

Figure 1 shows the mean soil moisture profiles taken in the field at the crested wheatgrass site on April 2 and July 1, 1974, respectively. On each date, soil moisture was measured in percent dry weight at five depth increments to 76 cm at four locations. However, the locations selected on each occasion were not the same.

The depletion of moisture from the soil is quite evident when the two profiles are compared. Overall, the soil water fell from 22 to 13 % from April to July. The greatest depletion among depth increments was the surface 0-15 cm increment, where soil water was reduced from 17 to 4 %. Increments 15-30, 30-45 and 45-60 were reduced by a difference of 12, 13 and 7 %, respectively, to moisture contents of 9, 13 and 18 %. The deepest increment measured showed a negligible change in soil water content, remaining at about 23 %.

The distribution of water in the soil profile also changed from April to July. In April, depth increments 30-45 and 45-60 had the greatest percentages of soil moisture, 26 and 25 %, respectively. In July, the percentages progressively increased from the surface to the 60-75 increment, where the moisture content was greatest; 23 %.

A high variability was noted in both April and July between samples at several of the depth increments. For both months, the standard deviation from the mean moisture percentage ($SD_{\bar{x}}$) at each depth increased from the surface to the 45-60 increment, and then decreased slightly for the 60-75. For April, the $SD_{\bar{x}}$ ranged from 0.50 to 3.76; for July, from 0.19 to 2.29. Under dryland conditions, the variability in soil water from site to site is not uncommon. This uneven distribution of soil water probably caused some of the exceptionally large yield variations discussed later in this report.

Table 1 is a summary of the treatment means for the three variables of yield, tissue P concentration and protein percentage for the crested wheatgrass study. The table provides not only the means of the 14 treatments for the incomplete block design, but also the means for the eight supplementary treatments. The treatment means of the model have been summed over increasing N rates and down increasing P rates to provide additional means that help show the effect due either solely to N or to P applications. Overall means are given for the treatments of the model and for all treatments of the study.

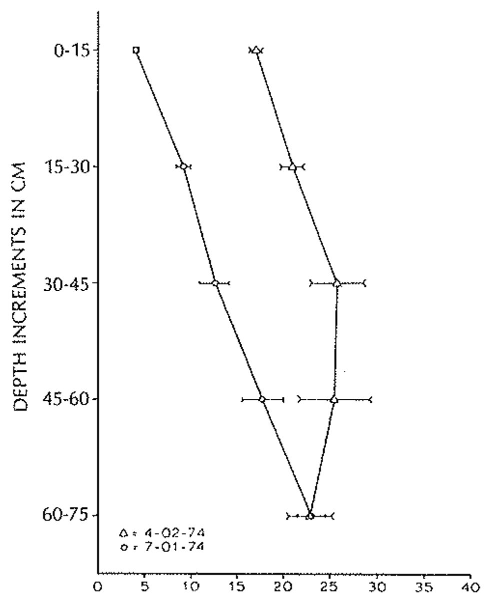

Figure 1. Moisture distribution in the profile of the Curlew Valley crested wheatgrass site sampled April 2, 1974, and July 1, 1974.

Yield appeared slightly affected by N fertilizer rates. For example, the unfertilized plots produced a mean yield lower than any other treatment in the model (213 g). Outside the model, several treatments with 28 and 56 kg/ha N applied had lower yields than did the check, and all treatment means were lower than treatments with equivalent nutrient applications within the model. There was an indication that protein content did not increase as yield increased. Overall, the mean yield within the model was 280 g. The mean for all treatments of the study was 251 g.

Generally, an increase was noted in tissue P concentration with increasing rates of N application among treatments of the model. In the supplementary treatments, P concentrations in crested wheatgrass increased dramatically over those of the model. Overall, the mean concentration within the

Table 1. Treatment means for yield, tissue P content and protein percentage for crested wheatgrass (DSCODE A3UJJ02)

Overall mean for 22 treatments: Yield or Variable (1) = 251 g
Tissue P or Variable (2) = 1023 ppm
Protein or Variable (3) = 8.83%

I. MODEL: nutrients applied shank in fall, N as NH_4NO_3

		N (kg/ha)					
		0	28	56	112	224	
P (kg/ha)	0	(1) = 213 (2) = 912 (3) = 7.02		274 992 8.90			244 952 7.96
	11.2		222 990 8.43	287 1014 8.64		361 938 9.79	290 981 8.95
	22.4	245 942 6.88	277 937 7.76	268 932 8.64	270 988 10.04	412 945 9.88	294 949 8.64
	44.8			301 985 8.30			301 985 8.30
	67.2		242 997 8.21	243 1032 9.42		311 975 9.51	265 1001 9.05
		229 927 6.95+	247 975 8.13+	275 991 8.78+	270 988 10.04+	361 953 9.73+	

Overall means for treatments of the model: Yield = 280 g
Tissue P = 970 ppm
Protein = 8.67%

II. SUPPLEMENTAL TREATMENTS

		broadcast fall		broadcast spring	
		$Ca(NO_3)_2$-N	$(NH_4)_2SO_4$-N	$Ca(NO_3)_2$-N	$(NH_4)_2SO_4$-N
N,P (kg/ha)	28,22.4	207 1092 9.56	190 1192 9.56	184 1043 7.50	176 1065 8.12
	56,22.4	217 1186 11.60	222 1189 9.75	226 1110 8.25	164 1052 8.57

model was 970 ppm P. The mean for all treatments of the study was 1023 ppm P.

With the exception of a single fertilized treatment ($N_0P_{22.4}$), with a protein content of 6.8%, the check had the lowest mean (7.02%) of protein of any treatment, either inside the model or among all treatments. The highest treatment means in the model, where nutrients were shanked into the soil and N was in the form of NH_4NO_3, were 1) $N_{112}P_{22.4}$ (10.04%); 2) $N_{224}P_{22.4}$ (9.88%); 3) $N_{224}P_{11.2}$ (9.79%); and 4) $N_{224}P_{67.2}$ (9.51%). No other treatments in the model had more than 56 kg/ha N added, and the range among those treatment means was from 6.88 to 9.42% protein. Outside the model (among broadcast fall and broadcast spring plots) with either $(NH_4)_2SO_4$-N or $Ca(NO_3)_2$-N applications, the following observations were made: 1) when two treatments whose only difference was the amount of N applied were compared, the higher N level produced the greater percentage of protein in all four cases; and 2) fall broadcast treatments were higher in protein content than were the spring broadcasts at the same level and type of N application. Overall, the mean protein content within the model was 8.67%. The mean for all treatments of the study was 8.83%.

Table 2 shows the analysis of variance of the incomplete block portion of the experimental design. Treatment effects were found to be significant for yield (dry weight) and protein content. The analysis of variance was also determined for all the treatments of the design, the 14 treatments of the incomplete block and eight supplemental treatments prepared to test type, method and time of fertilizer application. Treatments were found to be significant at the 5% level for all three variables measured. High variability among replicates was noted in the analyses. This may be attributed to the uneven distribution of soil water in the field. Although growth may be affected by such conditions, other variables, such as the tissue and protein, are not necessarily affected in the same manner.

Table 2 also gives F ratios for the main, quadratic and interaction effects of N and P on yield, P and protein, as

Table 2. Analyses of variance for yield, P content and protein percentage for crested wheatgrass (A3UJJ02)

	F Ratio		
	Dry Weight (g)	Tissue P (ug/g)	Protein (%)
Treatments	3.72*	1.61	7.77**
Replicates	79.37**	3.00	1.16
N	1.24	6.95**	49.71**
P	2.44	0.86	1.23
N^2	0.20	7.22**	25.96**
P^2	2.15	2.11	2.20
N x P	1.56	0.11	1.46

*Significant at the 5% level
**Significant at the 1% level

found by placing the data collected for the incomplete block model into the regression equation below:

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

where X represents the variable of yield, tissue P concentration, or protein percentage, and b values are the regression coefficients for main, quadratic and interaction effects. Interaction between N and P proved nonsignificant for all three variables. The R value for protein (.691) indicated some measure of agreement between predicted and actual percentages, but no response surface was calculated from the regression coefficients because the effects of P on protein content were nonsignificant. Instead, the main and quadratic coefficients for N were used to plot the predicted effect of N on protein, shown in Figure 2. The regression equation used for that prediction is given in the figure. In addition to the predicted effect, actual data are plotted on the same graph for comparison. The values plotted are the means of model treatment means as summed down each N application level over P rates. Each of these values is denoted by a plus mark (+) in Table 1.

Both the analysis of variance and the model regression equation for the 14 treatments of the incomplete block provided a mean square error term needed to test pairs of treatments (two treatments differing from each other only in the rate of N application) against other pairs to determine if the type of N applied or the method or time of application had any significant effect on yield, P or protein values. None of these variables had a significant effect on yield. Significance was found at the 5% level for the following comparisons: 1) NH_4NO_3 -- shanked fall vs. $Ca(NO_3)_2$ -- broadcast fall, for P and protein; 2) NH_4NO_3 -- shanked fall vs. $(NH_4)_2SO_4$ -- broadcast fall, for P; 3) NH_4NO_3 -- shanked fall vs. $Ca(NO_3)_2$ -- broadcast spring, for P.

The exact cause of significance above cannot be determined without further evidence, for in each case more than one variable differentiates between the pairs of treatments tested. Therefore, pairs of treatments were tested where the two sets differed in only one respect. These tests were 1) broadcast fall vs. broadcast spring (both sets with $(NH_4)_2SO_4$-N); 2) broadcast fall vs. broadcast spring (both with $Ca(NO_3)_2$); 3) $Ca(NO_3)_2$-N vs. $(NH_4)_2SO_4$-N (both broadcast fall); and 4) $Ca(NO_3)_2$-N vs. $(NH_4)_2SO_4$-N (both broadcast spring).

In each of these four cases, the comparisons were found to be nonsignificant. It can be concluded that there is neither a significant difference between the application of N fertilizer broadcast fall and spring, nor between N sources ammonia ($(NH_4)_2SO_4$) and nitrate ($Ca(NO_3)_2$). If the latter is true, there is probably no reason to expect that an equivalent N concentration in the form of ammonium nitrate (NH_4-NO_3) should produce significant results in yield, P or protein over treatments of ammonium sulfate or calcium nitrate. It must be concluded that the significance involved in the three cases discussed must result from the method of application; broadcast over shanking, manifested in three cases with increased concentrations of P in crested wheatgrass and in a single case with increased protein content. Such a conclusion should be considered speculative, for soil moisture conditions of this particular growing season may have grossly influenced the relationships between fertilizer applications and the variables measured.

Sagebrush Study

The results of the sagebrush study are given in two bar graphs in Figure 3. The bar graphs show mean vegetative shoot growth (as length in centimeters) for sagebrush and shadscale. The four treatments are identified by N and P fertilizer application rates (kg/ha) and by their method of application in the upper left corner of the figure. The analyses of variance for four treatments and 10 replicates (with 3 and 36 degrees of freedom) found treatment significance at the 2.5% level (F = 3.63) for sagebrush and at the 1% level (F = 7.36) for shadscale. Mean square error terms for sagebrush and shadscale were used to test various treatment pairs to determine if the level of nutrient addition or the method of nutrient application to the soil resulted in meaningful effects upon yield. Statistically, significant increases were found for the following: 1) sagebrush, from nutrient addition levels of N_0P_0 (3.1 cm) to $N_{67.2}P_{33.6}$(4.4 cm); 2) shadscale, from N_0P_0 (4.3 cm) to $N_{67.2}P_{33.6}$ (6.5 cm); and 3) shadscale, from N_0P_0 (4.3 cm) to $N_{67.2}P_0$ (6.0 cm).

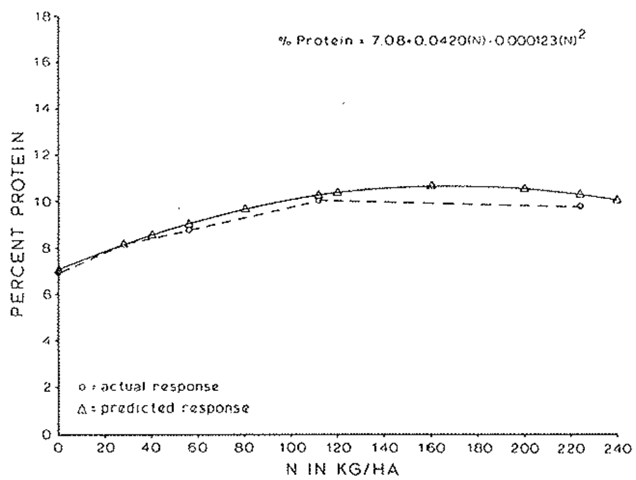

Figure 2. The predicted effect of N on protein content of crested wheatgrass (A3UJJ02).

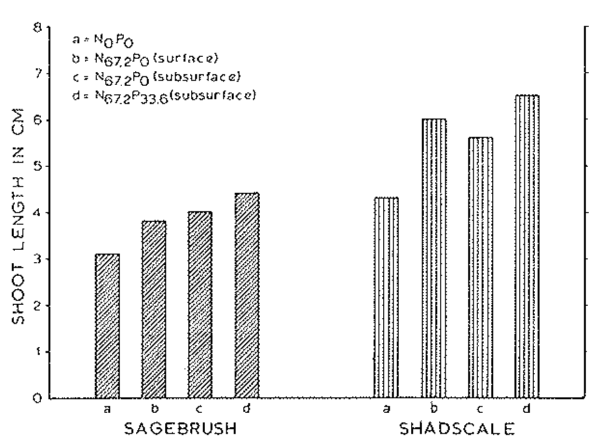

Figure 3. Mean vegetative shoot lengths for sagebrush and shadscale plants (A3UJJ01).

Although other comparisons between fertilizer levels in terms of increased yield for sagebrush and shadscale proved nonsignificant, Figure 3 clearly demonstrates that increases in yield due to increased N and P fertilizer rates are suggested overall for both plant species. The factor of limiting water in the desert during this growing season (1974), discussed previously with respect to the nominal fertility response of crested wheatgrass, may account for the lack of significance between levels of fertilizer application. In addition, in both the sagebrush and shadscale data, it was found that the difference between surface and subsurface fertilizer application -- compared at the $N_{67.2}P_0$ level -- was nonsignificant. For sagebrush, the surface-applied treatment had a mean shoot length of 3.8 cm and the subsurface treatment 4.0 cm. For shadscale, the mean shoot lengths were 6.0 cm and 5.6 cm, respectively.

EXPECTATIONS

The 1975 study will be directed toward the residual effect of N and P applied during fall 1973 and spring 1974, particularly with respect to crested wheatgrass sites. To establish a reference base for the residual effect, two surface treatments will be applied in the fall of 1974. It is anticipated that because of the adverse soil moisture conditions and the resulting lack of growth response during the 1974 growing season, the residual effect of the previously added nutrients should be significant if soil moisture conditions are normal.

The sagebrush study will be continued with additional N and P treatments applied to expand and verify growth response information obtained this year on natural vegetation. The terminal vegetative shoot growth will be harvested and analyzed for phosphorus and protein. The response of shadscale associated with the sagebrush plots will be studied similarly. A growth response of the sagebrush and shadscale is expected as soil fertility is increased.

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