Fertilizing Tobosa on Flood Plains in the Semidesert Grassland

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Tobosa (*Hilaria mutica* (Buckl.) Benth.), a drought resistant grass of the arid Southwest, occurs primarily on heavier textured soils, but is not limited to them. It is relatively unpalatable to livestock during the dormant season but is readily grazed during the growing season. Therefore, where possible, tobosa flood plains should be fenced separately and grazed during the growing season while the upland pastures are deferred. These flood plains supporting tobosa in high density and receiving additional water as run-in from adjacent mountains can produce several times the herbage of upland sites. On ranches where the area of tobosa flood plains is limited, increased yields of tobosa will enable the operator to defer the upland pastures more completely and for a longer time in the growing season. The objective of this study was to determine tobosa herbage yields and quality on flood plains as influenced by fertilizer treatments in relation to the effects of available moisture.

Literature Review

There have been a limited number of fertilizer trials on the arid grazing lands of the Southwest but none on tobosa flood plains as far as the author can determine. Freeman and Humphrey (1956) reported on a 1954 fertilizer trial on typical semidesert grassland in Southeastern Arizona. The major species on the study area were curly mesquite (*Hilaria belangeri* (Steud.) Nash) and sprucetop grama (*Bouteloua chondrosioides* (H.-B.K.) Benth. ex S. Wats.). Plots were fertilized with 100, 200, and 400 pounds per acre of superphosphate (0-8.7[2]-0), ammonium phosphate (16-8.7-0), and ammonium nitrate (32-0-0). Production on the check plots averaged 1283 pounds of air-dry herbage per acre. There were very small increases with the two lower rates of superphosphate. The higher rate of superphosphate and all the rates of ammonium phosphate and ammonium nitrate increased yields 23 to 43 percent. The striking point was that addition of phosphorus with nitrogen gave increased yields over the addition of nitrogen alone and increased both soil nitrate and soil phosphate. Freeman and Humphrey (1956) also found that nitrogen fertilizer increased crude protein and phosphorus fertilizer increased phosphorus content of the herbage of the two major species. An additional benefit of fertilization with nitrogen was that the herbage remained green longer in the year of application and greened earlier the following spring. They concluded, however, that fertilization was not economically feasible under present conditions.

Holt and Wilson (1961) reported on a 1958 fertilizer trial on semidesert grassland on the Santa Rita Experimental Range near Tucson, Arizona. The dominant species were Lehmann lovegrass (*Eragrostis lehmanniana* Ness) and Santa Rita threeawn (*Aristida glabrata* (Vasey) Hitchc.). Plots were fertilized with 25, 50, and 100 pounds of nitrogen per acre in the form of ammonium phosphate and ammonium nitrate. Summer precipitation for 1958 was about 50 percent above average. Check plots yielded an average of 2475 pounds of air-dry herbage per acre. Fertilizer increased yields 66 to 158 percent. Again phosphorus contributed to a small increase in yield. Holt and Wilson (1961) also found that cattle preferred the fertilized forage and exhibited no preference for grass species. On unfertilized areas, cattle showed marked species preferences. The fertilizer extended the green-feed period up to six weeks. They concluded that fertilization has a definite place in managing southern Arizona ranges, but that conclusion was based on a year with precipitation considerably above average.

The Study Area

The Jornada Experimental Range in south-central New Mexico is typical of the more arid portions of the semidesert grassland. The average annual precipitation is 8.98 inches (1915-61). About 55 percent occurs during the growing season (July-September). The winters and springs are often rather dry. The average frost-free period is 196 days, but lack of soil moisture in April, May, and June limits the average growing season to about 100 days.

The fertilizer plots were located on a $\bar{3}21/A$ soil. This soil is a deep (48″), slowly permeable silt loam with well-developed textural B horizon and strong C_{ca} horizon. This unit receives additional water from adjacent slopes but since it is a gentle slope (1 percent), the water does

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[2] *In this paper, phosphorus always means elemental phosphorus.*

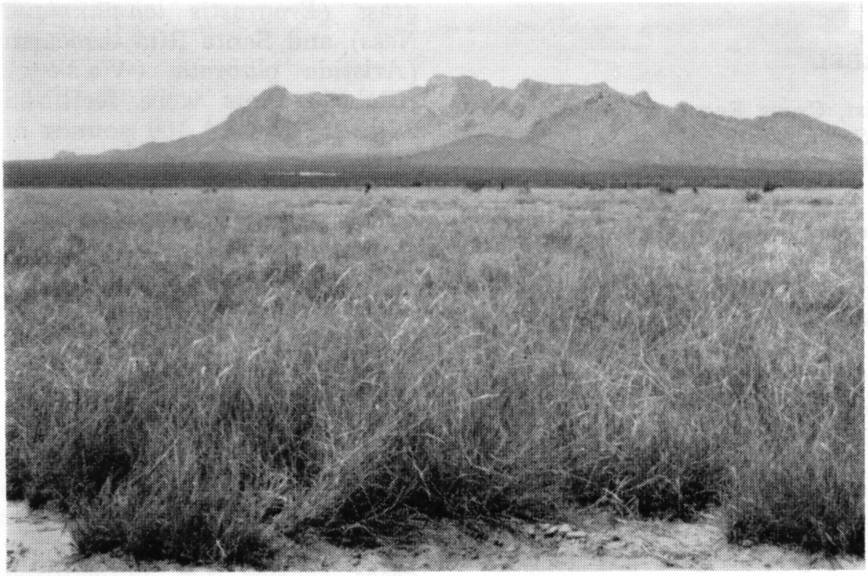

FIGURE 1. Tobosa flood plain. The area receives run-in from the mountains and foothills in the background.

not stand on the area. The range site is a clayey bottomland. The area has a dense, essentially pure, stand of tobosa (Figure 1).

Methods

This study was conducted for five years, 1957-61. In 1957 three replications of eight plots 20.87 feet square were established. The treatments for 1957 were 0, 20, 40, and 60 pounds of nitrogen per acre and 0 and 13.1 pounds of phosphorus per acre in a 4 x 2 x 3 factorial. For the 1958-61 treatments a different set of plots, three replications of twelve 20- x 30-foot plots, were used. The treatments for 1958-61 were 0, 30, 60, and 90 pounds of nitrogen per acre and 0, 13.1, and 26.2 pounds of phosphorus per acre in a 4 x 3 x 3 factorial. The fertilizer sources were ammonium nitrate (33.5-0-0) and treble superphosphate (0-19.7-0). The fertilizers were applied each year in early July before any effective precipitation for that growing season.

Five clipping samples were taken from each plot at the close of the growing season. The 1957 samples were from a 1- x 9.6-foot area, while the 1958-61 samples were from a 1- x 4.8-foot area. Clippings were made at a one-inch height and old herbage was separated from current year's growth at the time of clipping. Yield estimates are therefore of current year's production. The samples were uniformly air-dried and weighed. After weighing, a composite sample was obtained for each plot and retained for chemical analyses. In 1957 chemical analyses consisted of crude protein and phosphorus, while only crude protein was determined for 1958-61. Soil nitrates and soil phosphorus were determined at the close of the 1958 growing season on the plots established in 1958. Clippings were also made at the close of the 1958 growing season on the plots fertilized in 1957. On plots established in 1958, a rotation system was used within the plot to prevent any area being clipped twice in the four years these plots were used.

Soil moisture was measured by use of gypsum electrical resistance blocks. The blocks were placed at depths of 4, 10, and 16 inches for the 1957 and 1958 trials and at depths of 4, 10, 16, 24, 36, and 48 inches for the 1959-61 trials. The blocks were located on an untreated area adjacent to the plots. Electrical resistance was converted to atmospheres of suction corrected to a standard temperature of 60 degrees F. In this paper soil moisture suction below 5 atmospheres is considered as readily available for plant use, soil moisture between 5 and 15 atmospheres is considered as slowly available to the plant, and soil moisture suction greater than 15 atmospheres is considered below the wilting point. Precipitation was recorded in near proximity of the fertilizer plots.

Results

Soil Moisture and Precipitation

Table 1 presents precipitation and soil moisture data for the growing seasons of 1957-61. Soil moisture is given as; readily available (0-5 atm.), slowly avail-

Table 1. Precipitation and soil moisture for the growing seasons (July-September) of 1957-61.

		Number of days soil moisture;																	
		Readily available (0-5 atm.)						Slowly available (5-15 atm.)						Below wilting point (above 15 atm.)					
Growing season	Precipitation	Depth (inches)						Depth (inches)						Depth (inches)					
		4	10	16	24	36	48	4	10	16	24	36	48	4	10	16	24	36	48
	(inches)																		
1957	4.60	25	28	26	*	*	*	28	12	14	*	*	*	39	52	52	*	*	*
1958	6.20	30	30	32	*	*	*	17	5	2	*	*	*	45	57	58	*	*	*
1959	7.83	57	60	72	72	73	45	10	5	1	1	0	0	25	27	19	19	19	47
1960	3.55	35	43	46	47	0	0	15	7	23	15	61	34	42	42	23	30	31	58
1961	7.03	62	68	73	72	61	43	12	6	10	8	19	49	18	18	9	12	12	0
Average 1915-61	4.87																		

* Not sampled

Table 2. 1957 and 1958 herbage per acre and 1957 protein and phosphorus contents of herbage on plots fertilized in 1957.

Treatment	1957 Herbage	1957 Crude protein	1957 Phosphorus	1958 Herbage
	(Pounds)	(Percent)	(Percent)	(Pounds)
Check	2207	4.4	.127	3685
13.1# P/a.	2227	4.7	.123	2956
20# N/a.	2423	5.1	.117	4065
20# N + 13.1# P/a.	2753	5.3	.119	3575
40# N/a.	2705	6.0	.109	3391
40# N + 13.1# P/a.	2342	5.6	.117	3268
60# N/a.	2696	6.1	.112	3821
60# N + 13.1# P/a.	3511	5.4	.113	4047
LSD (5%)	NS	0.96	NS	NS
Standard error of mean:	75.0	0.15	.0023	100.0

able (5-15 atm.), and below the wilting point (greater than 15 atm.). Following the drought year of 1956, the growing season (July-September) precipitation of 1957 was nearly average. On 28 days soil moisture was readily available at the 10-inch depth. There were two distinct periods of available soil moisture, July 24-August 5 and August 28-September 13.

The growing season precipitation of 1958 was 27 percent above average, but available soil moisture was about the same as for 1957. At the two deeper depths (10 and 16 inches) measured in 1958, there was available soil moisture during July 28-August 29. In addition, there were two short periods of available moisture at the 4-inch depth in September.

In 1959 the growing season precipitation was 7.83 inches, or 61 percent above average. In addition, it was so well distributed that there was one long period of available soil moisture, July 20-September 18.

The growing season precipitation of droughty 1960 was 27 percent below average. For this year alone, only part of the fertilizer plots received flood water. The soil moisture observations are valid for only the plots receiving flood water. There were two periods of available soil moisture on the flooded plots, mid-July and mid-August.

In 1961 the growing season precipitation was 7.03 inches, or 44 percent above average. There were two periods of available soil moisture, July 1-22 and August 12-September 30.

Herbage Yields and Chemical Analyses

In 1957 fertilizer was applied on July 1. Table 2 lists the treatments as well as the herbage yields, crude protein, and phosphorus at the close of the growing season. Also presented are the yields obtained at the close of the 1958 growing season on the same plots. The only significant factor was a treatment-by-replication interaction in the 1957 yields, even though plots fertilized with 60 pounds nitrogen plus 13.1 pounds phosphorus per acre yielded 1304 pounds above the yields of the check plots. There was an apparent linear relationship with the various increments of nitrogen and also phosphorus. There were significant differences among treatment means in the crude protein content. All the herbage collected from plots fertilized with 40 or 60 pounds of nitrogen per acre had significantly more crude protein than the herbage from the check plots. There were no significant differences in phosphorus content of the herbage. There were no significant differences among treatments of the 1957 fertilizer plots clipped at the close of the 1958 growing season. The yields of the check plots in 1958 were about intermediate to the other treatments. The average of the 1958 yields was 38 percent higher than the average of the 1957 yields. Protein analyses of the herbage from the 1957 fertilizer plots clipped in 1958 showed treatments to be remarkably similar with about 4 percent crude protein.

Table 3 presents the treatments, yields, and crude protein of the herbage from the 1958-61 fertilizer plots. Each plot was

Table 3. Pounds per acre, and crude protein content (percent) of herbage on fertilized plots, 1958-61.

Treatment	1958 Herbage	1958 Crude protein	1959 Herbage	1959 Crude protein	1960 Herbage	1960 Crude protein	1961 Herbage	1961 Crude protein
Check	2071	4.23	2791	4.82	1489	4.00	4381	4.81
13.1# P/a.	2891	3.90	4333	5.55	2020	3.55	4051	4.97
26.2# P/a.	1795	4.42	3059	5.29	1472	4.28	2992	6.13
30# N/a.	2845	4.62	4992	4.73	1231	4.61	3700	6.84
30# N + 13.1# P/a.	3108	4.57	5555	5.50	1712	4.12	3513	7.11
30# N + 26.2# P/a.	2797	4.74	4671	5.10	2177	3.84	5212	4.70
60# N/a.	3308	4.80	5528	5.96	1905	4.36	3741	7.56
60# N + 13.1# P/a.	2873	5.00	6363	5.58	2175	4.13	4105	6.51
60# N + 26.2# P/a.	2881	5.67	6813	5.79	1981	4.71	4941	6.77
90# N/a.	2740	5.58	6955	6.77	1677	4.79	4077	7.85
90# N + 13.1# P/a.	3013	5.94	7115	6.10	2409	4.82	4556	7.83
90# N + 26.2# P/a.	3167	5.14	6045	5.44	1955	4.81	4524	7.19
LSD (5%)	353	1.00	1427	1.05	NS	0.81	NS	NS
Standard error of mean	77.6	0.13	146.2	0.15	95.2	0.10	116.8	0.28

given the same treatment each year. In 1958 the plots were fertilized on July 9. The 1958 herbage yields on all the plots fertilized with nitrogen and also the plots treated at the rate of 13.1 pounds of phosphorus per acre were significantly higher than those on the check plots. The plots receiving 60 pounds of nitrogen per acre had the highest yields, 3308 pounds of air-dry herbage per acre, or 60 percent higher than the check. An individual degree of freedom variance analysis using orthogonal polynomials showed the factor for nitrogen linear to be highly significant and the factor for nitrogen quadratic to be significant. The crude protein contents of the herbage from plots treated at the rate of 60 pounds nitrogen plus 26.2 pounds phosphorus per acre, 90 pounds nitrogen per acre, and 90 pounds nitrogen plus 13.1 pounds phosphorus per acre were significantly higher than the check. Nitrogen linear was the only significant factor in the variance analysis of the crude protein data. Soil samples were taken from the surface six inches to determine whether there was any carry-over effect of the fertilizer treatment. Soil nitrates on the various plots varied from 2.3 to 12.5 ppm and soil phosphorus varied 1.5 to 7.6 ppm. All the soil nitrates and soil phosphorus values were low and unrelated to the fertilizer treatments.

In 1959 the plots were fertilized on July 1 and 90 pounds nitrogen plus 13.1 pounds phosphorus per acre gave the highest yield (Table 3), but it was not significantly greater than that from plots receiving either 90 pounds nitrogen per acre, 60 pounds nitrogen plus 26.2 pounds phosphorus per acre, 60 pounds nitrogen plus 13.1 pounds phosphorus per acre, or 90 pounds nitrogen plus 26.2 pounds phosphorus per acre. The check plots had significantly less production than any of the other plots except those treated with 26.2 pounds phosphorus per acre but with no nitrogen. An individual degree of freedom variance analysis showed the factor for nitrogen linear to be highly significant and the factor for phosphorus quadratic to be significant. The remaining factors were non-significant. The crude protein content of the herbage taken from plots treated with 60 pounds nitrogen per acre, 90 pounds nitrogen per acre, and 90 pounds nitrogen plus 13.1 pounds phosphorus per acre were significantly higher than the check. The factor for nitrogen linear was highly significant.

In 1960 the plots were fertilized on June 28. There were no significant differences among treatments in yields at the close of this droughty growing season (Table 3). However there was a striking difference in yields on plots that were flooded and those that were not flooded. The flooded plots produced 2,586 pounds of air-dry herbage per acre with the check plots averaging 1,489 pounds and the plots fertilized with 60 pounds nitrogen plus 13.1 pounds phosphorus per acre averaging 4,068 pounds. The unflooded plots averaged only 707 pounds of air-dry herbage per acre with little difference among treatments. The crude protein content of the herbage taken from plots treated with 90 pounds nitrogen plus 13.1 pounds phosphorus per acre and 90 pounds nitrogen plus 26.2 pounds phosphorus per acre was significantly higher than the check. The factor for nitrogen linear was highly significant. The crude protein content of herbage from flooded plots averaged 11 percent higher than that from the unflooded plots.

In 1961 the fertilizer was applied to the plots on July 4. There were no significant differences among treatments in yields or protein content of the herbage clipped at the close of the 1961 growing season (Table 3). When phosphorus fertilization is disregarded, all plots receiving 0 nitrogen averaged 3,808 pounds of air-dry herbage per acre with 5.3 percent protein, all plots receiving 30 pounds of nitrogen per acre yielded 4,142 pounds per acre with 6.2 percent protein, all plots treated with 60 pounds of nitrogen per acre yielded 4,263 pounds per acre with 7.0 percent protein, and all plots treated with 90 pounds of nitrogen per acre yielded an average of 4,386 pounds per acre with 7.6 percent protein. When nitrogen is disregarded, all plots receiving 0 phosphorus yielded an average of 3,975 pounds of air-dry herbage per acre with 6.8 percent protein, all plots treated with 13.1 pounds of phosphorus per acre yielded 4,056 pounds per acre with 6.6 percent protein, and 26.2 pounds of phosphorus per acre yielded an average of 4,417 pounds per acre with 6.2 percent protein. The major factor affecting the 1961 response to fertilizer was whether the plots received flood water in droughty 1960. The plots receiving run-in in 1960 had an average of 55 percent higher yields in 1961 than did the plots not receiving run-in in 1960. However, the crude protein content of herbage from plots in 1961 not flooded in 1960 was 33 percent higher than that from the flooded plots.

Discussion and Conclusions

Moisture conditions during the 1957 growing season were slightly below average and there were no statistically significant responses in yield to the fertilizer treatment even though the treatment of 60 pounds nitrogen plus 13.1 pounds phosphorus per acre resulted in an additional 1,304 pounds of air-dry herbage per acre. There were significantly higher protein values with both 40 and 60 pounds of nitrogen per acre. Using costs of $86.00 per ton of 33.5 percent ammonium nitrate, $81.50 per ton of 19.7 percent treble superphosphate, and $1.25 per acre for broadcast application, the increased herbage production from the 60 pounds of nitrogen plus 13.1 pounds of phosphorus per acre would cost $17.91 per ton.

The growing season precipitation in 1958 was 27 percent above average, but soil moisture conditions were similar to 1957. All treatments except 26.2 pounds of phosphorus gave significantly higher yields than the checks. Sixty pounds of nitrogen per acre increased yields 1,237 pounds. Using the above production costs each additional ton of herbage would cost $14.47. Some of the higher nitrogen treatments also resulted in significantly higher protein content.

The 1959 growing season precipitation was 61 percent above average. In addition, it was so well distributed that there was a single 60-day period of available soil moisture. There was a large response to fertilization in 1959 and all the treatments except 26.2 pounds of phosphorus per acre gave significantly higher yields than the check. Ninety pounds of nitrogen per acre increased yields 4,164 pounds of air-dry herbage per acre with production costs of $6.16 per ton. The protein content of the herbage was also significantly higher as a result of the higher levels of fertilization.

In droughty 1960, only part of the plots received run-in water. The gypsum blocks measuring soil moisture were on the part of the area getting some additional moisture from run-in. When the entire fertilized area is considered there were no significant differences in yields but some of the high treatments of nitrogen resulted in significantly higher protein. Even in this droughty year on plots receiving flood water 60 pounds of nitrogen plus 13.1 pounds of phosphorus per acre increased yields 2,579 pounds of air-dry herbage per acre above the check at a production cost of $9.04 per ton of additional herbage.

The 1961 growing season precipitation was 44 percent above average but a 21-day dry period occurred between two periods of available soil moisture. There were no significant differences in yields or protein content. The tobosa on plots not receiving run-in in 1960 had reduced vigor and was not able to take advantage of the excellent moisture conditions in 1961. This was also a factor in the 1957 trial, since the 1958 yields on that area were considerably higher than the 1957 yields. The year 1956 was very droughty. It follows then that little benefits are to be expected from fertilizing tobosa following a year of drought stress.

There is no apparent carryover of fertilizer effects from one year to the next. The plots fertilized in 1957 only were clipped after the 1958 growing season and neither the yields nor the protein content reflected any effects of fertilizer. Soil analyses on plots fertilized in 1958 also indicated no carry-over of fertilizer.

The greatest yields were obtained in 1959, when tobosa growth was uninterrupted. Observations on this study as well as other unpublished studies on the Jornada Experimental Range indicate that yields are reduced when growth is interrupted by a dry period.

When statistical analyses indicated a significant difference in yield or protein content, individual degrees of freedom were separated by use of orthogonal polynomials. In all cases linear effects of nitrogen accounted for the major portion of the variability. This would indicate that yield and protein content were linearly related to the various increments of nitrogen fertilizer. On the 1958 and and 1959 yield data, a negative quadratic effect of phosphorus was also significant. This would indicate that the first increment of phosphorus, 13.1 pounds per acre, gave some increase in yields but the second increment, 26.2 pounds per acre, was little better than no phosphorus.

Under present economic conditions fertilizing tobosa on flood plains generally would be uneconomical. However, ranching units having a limited amount of tobosa could well fertilize in some years to obtain additional summer forage to defer their upland areas for winter-spring grazing. Fertilized tobosa flood plains would also give higher forage yields and higher quality hay. Areas to be fertilized should have dense stands of tobosa and be so situated that they would be most likely to be flooded even in droughty years. The best rates would be 60 or 90 pounds of nitrogen per acre plus zero or 13.1 pounds of phosphorus per acre.

Summary

The 5-year study reported was concerned with the effects of nitrogen and phosphorus fertilizers on tobosa on a heavy flood plains range site in southern New Mexico. Under all but the best moisture conditions fertilization appears to be generally uneconomical at present. During 1959, the year having available soil moisture for a continuous 60-day period, fertilization with 90 pounds of nitrogen per acre increased herbage production 4,164 pounds per acre. During one other year (1958) with above-average moisture, yields were somewhat increased but not as strikingly as in 1959. Herbage yields were unaffected by fertilization during another year (1961) of above-average precipitation because it followed droughty 1960. Even in 1960, when production as a whole

was reduced, plots receiving run-in markedly responded to fertilization. Moisture conditions in 1957 were about average but yields were probably reduced by the droughty conditions in 1956. Protein content of the herbage at the close of the growing season was generally 20 to 35 percent higher with some of the higher levels of fertilization than with checks.

Even under present economic conditions ranchers with a limited amount of tobosa could profitably fertilize flood plain sites with 60 or 90 pounds of nitrogen plus 0 or 13.1 pounds of phosphorus per acre. The additional herbage could be used to give longer growing season deferment to upland pastures.

Tobosa apparently has the genetic capability of high production, 7,000 pounds plus of air-dry herbage per acre, under high levels of available soil moisture and with fertilization.

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