Influence of Supplemental Run-off Water and Fertilizer on Production and Chemical Composition of Native Forage[1]

H. R. COSPER AND J. R. THOMAS[2]

Soil Scientists, Western Soil and Water Management Research Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A., Newell, South Dakota and Weslaco, Texas, Respectively

Utilization of run-off water to produce additional forage is essential in a balanced range management program. This is especially true in the northern Great Plains where limited and erratic precipitation results in frequent drought periods. The use of water spreading systems to collect and distribute run-off water over "run-in" range sites has generally resulted in greater forage production (Mooney and Martin, 1956). However, the extra moisture received on several "run-in" range sites on the heavy clay soils of western South Dakota has failed to produce forage in proportion to the amount of moisture available. Poor grazing management and/or low fertility could nullify the benefits expected from the additional moisture.

Increased efficiency of moisture can be obtained by balancing the moisture supply with the soil fertility level. Thomas and Osenbrug (1959) found that yields of crested wheatgrass-bromegrass hay increased from 86 pounds per inch of precipitation for non-fertilized grass to 187 pounds per inch of precipitation for grass fertilized with 255 pounds of nitrogen. Moisture use efficiency increased with further additions of nitrogen. The effect of moisture on the use of nitrogen fertilizer by grasses native to central North Dakota was reported by Rogler and Lorenz (1957). Forage yields decreased from 44.9 to 9.7 pounds per pound of nitrogen added as the annual precipitation changed from 21.76 to 10.25 inches, respectively. As the same area was fertilized annually for several years the values included the effects of residual nitrogen.

This study was planned to further investigate the relationships between forage production, soil fertility and moisture. The effects of nitrogen and phosphorus fertilization on the chemical composition of the forage were also investigated.

Experimental Area

The soil in the experimental area was classified as Orman clay loam. It is slightly calcareous having a pH of 7.5, low in available $NaHCO_3$ soluble phosphorus (6.5 ppm P), relatively high in total nitrogen (0.107 percent) and mineralizable nitrogen (46.2 ppm N), and has a cation exchange capacity of 24.6 me./100 gm, in the surface six inches.

Principal grasses are western wheatgrass *(Agropyon smithii)*, green needle grass *(Stipa viridula)*, and downy brome *(Bromis tectorum)*. These grasses comprised 65 percent of the total plant population. Other plant species present included sunflower *(Helianthus spec.)*, wild carrot *(Leplolania multifida)*, American vetch *(Vicia (Americana) augustifolia)*, and tansy mustard *(Sophia incisa)*.

The water collecting and spreading systems were constructed in 1944. Water was collected from a watershed of approximately 1400 acres, concentrated in a small reservoir and distributed over a "run-in" range site of approximately 140 acres by means of spreader ditches. In years of normal precipitation the system could be expected to produce one acre foot of water per 35 acres of watershed. Water was spread on the experimental area in 1958. Moisture carried over from the 1958 season influenced yields in 1959. Precipita-

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tion data for the experimental area for the period 1957 through 1959 and from surrounding areas for a longer period are given in Table 1.

The field in which the experimental sites were located was not grazed by livestock. Instead, hay was cut and stacked each year and hauled to the livestock as needed.

Table 1. Annual and seasonal precipitation, 1957-1959

Year	Annual	April 1-June 30
	Inches	Inches
1957	18.94	12.63
1958	16.09	12.71
1959	13.54	7.52
Mean	16.19	10.95
15 year Mean	15.12	9.49

Methods

In order to determine the effect of supplemental water on forage response to fertilizer, one set of fertilizer treatments was located in the water spreading area and another identical set of treatments was located in an adjacent area outside of the water spreading area. Each fertilizer treatment was applied to an area 5 feet wide and 24 feet long. The treatments included applications of nitrogen as ammonium nitrate (33.5 percent N) at rates of 0, 40, 80 and 160 pounds N per acre and applications of phosphorus as treble superphosphate (43 percent P_2O_5) at rates of 0, 80, and 160 pounds P_2O_5 per acre in a 4 x 3 factorial design replicated three times.

The fertilizer was placed in bands 10 inches apart to a depth of two to three inches by means of small inch-wide chisels. A new area was fertilized by this method each year. Response to residual fertilizer was determined by the Kjeldahl method mined on the areas previously fertilized.

Yields were determined by clipping the forage at the end of the growing season, which normally extends from mid-April through June depending on the amount of available moisture. The forage from an area three feet wide and twenty feet long from each fertilizer treatment was clipped to a height of one inch above the ground level. All forage yields are reported on an oven-dried basis (65° C).

Total nitrogen content of the plant material was determined by the Kjeldahl method and converted to crude protein values by means of the factor 6.25. Total plant phosphorus was determined by the methods of Bolin and Stamberg (1944) and Barton (1948).

Results and Discussion

Forage Production

Forage yields on the dry range site (outside of the water spreading system) were significantly increased by the application of nitrogen and phosphorus fertilizer. The degree of response was related to the annual precipitation (Figure 1). In 1957 with above normal precipitation (18.9 inches) the largest yields was obtained with the 160 pound N- 160 pound P_2O_5 fertilizer addition. As the amount of precipitation decreased the quantity of nitrogen and phosphorus fertilizer required for maximum production also decreased. In 1958 and 1959 the respective maximum yields were obtained with the 160 pound N-80 pound P_2O_5 and the 80 pound N-80 pound P_2O_5 fertilizer combinations. Yields decreased with the application of larger amounts of nitrogen or phosphorus. Precipitation in 1958 and 1959 was 16.1 and 13.5 inches, respectively. The ripping action of the chisels on the grass sod reduced forage yields slightly in the year follow-

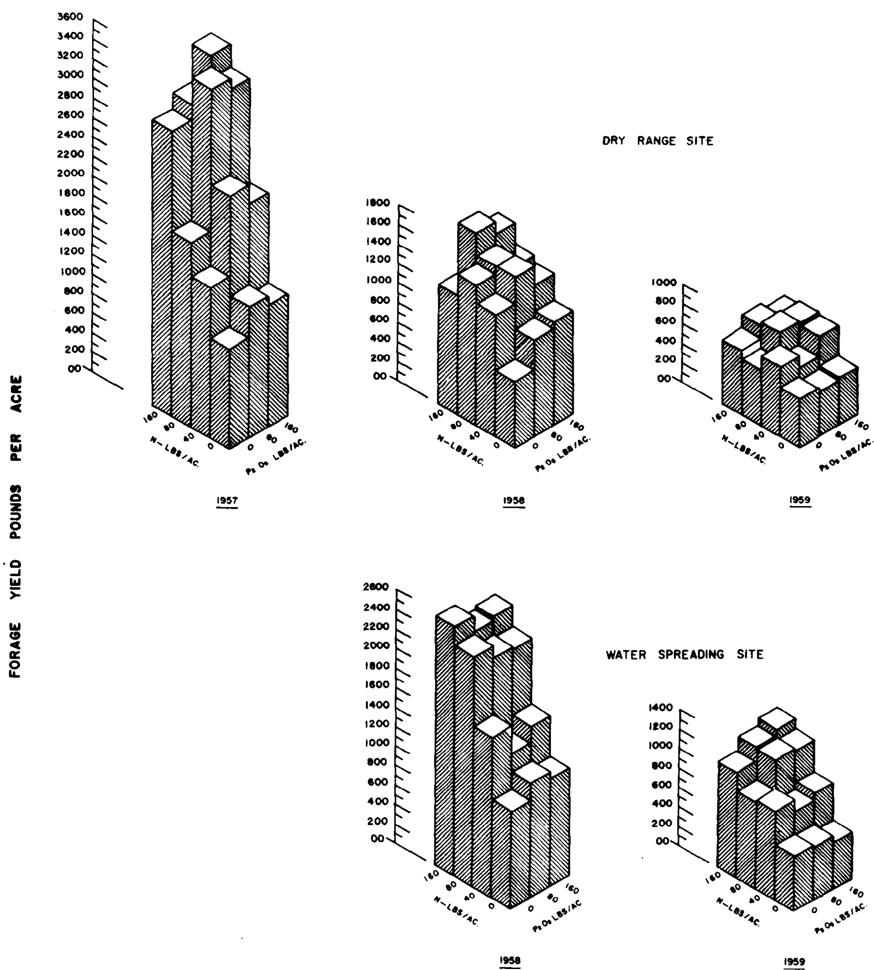

FIGURE 1. Effect of nitrogen and phosphorus fertilizer combination on forage yields on a dry range and water spreading site.

Table 2. Total yield of forage from a dryland and water spreading range site with various rates of applied fertilizer.

Fertilizer Applied		Total Yield Dryland Range Site[1]		Total Yield Water Spreading Range Site[1]
N	P_2O_5	1958-59[2]	1957-58-59[3]	1958-59[2]
		(Pounds Per Acre)		
0	0	1094	2527	1566
40	0	1908	3157	2559
80	0	2213	3631	3207
160	0	2084	4833	3711
0	80	1652	2938	1812
40	80	2355	4457	2082
80	80	2312	5357	3268
160	80	2607	5269	3532
0	160	1612	3095	1718
40	160	2008	3710	2372
80	160	2206	4979	3303
160	160	2535	5846	3568
L.S.D. .05		266	541	290
L.S.D. .01		360	723	393

[1]Oven dry basis.
[2]Fertilizer applied fall 1957.
[3]Fertilizer applied fall 1956.

ing the fertilizer application, but no effect occurred the second year.

Hay yields with supplemental water increased significantly with the use of nitrogen fertilizer (Figure 1). The largest yield of 2660 pounds per acre was obtained in 1958 with the 160 pound of N-0 pound P_2O_5 application. Phosphorus fertilizer alone or in combination with nitrogen did not significantly change forage production in 1958. However, in the drier year of 1959, the largest yield of hay was obtained with the 160 pound N-160 pound P_2O_5 fertilizer addition. The interaction between the high rates of nitrogen and phosphorus was statistically significant at the 5 percent level of probability. The apparent decrease in hay yields with the application of phosphorus fertilizer alone in 1959 was not significant.

Supplemental water increased mean forage production in 1958 on the water spreading site by 16.3, 10.1, 58.1 and 63.3 percent over forage yields on the dry range site for the 0, 40, 80, and 160 pound nitrogen additions, respectively. Yield response to phosphorus fertilizers was also enhanced by the additional moisture. Mean forage yield with supplemental water were 38.6, 21.2 and 25.7 percent greater than yields on the dry range site with the application of 0, 80 and 160 pounds of phosphorus, respectively.

The application of fertilizer to range land may create a serious problem in control of non-grass species, especially if the range condition is poor. On both range sites the non-grasses, mainly sunflower, responded markedly to both nitrogen and phosphorus. The grasses responded principally to nitrogen. Western wheatgrass accounted for most of the yield increase.

The differential response of grasses and nongrasses to fertilization points out the possibility for improving range conditions with nitrogen fertilizer additions. Rogler and Lorenz (1957) found that nitrogen fertilization and deferred grazing for two years improve range condition and production to greater extent than six years of deferred grazing.

Residual effects of nitrogen and phosphorus fertilizers applied in the fall of 1956 on the dry range site were apparent for two growing seasons (Figure 2). Significant increases in forage yields from residual fertilizer were obtained only from the 160 pound nitrogen applications alone or with phosphorus. The total yields for a three year period from the 1956 fertilizer applications are listed in Table 2. Total production increased linearly with the application of nitrogen and phosphorus fertilizer.

Significant increases in hay production were obtained from residual nitrogen at all levels of nitrogen fertilizer applied on the water spreading site in the fall of 1957. Residual phosphorus did not significantly effect yields. Table 2 shows the total forage yields for a two year period from the 1957 fertilizer application.

Fertilizer combinations that produced the largest hay yields did so with the least efficient use of the nitrogen fertilizer. Also, those combinations that produced the largest hay yields resulted in the least profitable return on a cost basis. From a physical standpoint use efficiency is defined as the increase in pounds of forage produced per pound of nitrogen applied and was influenced by the amount and ration of nitrogen and phosphorus and by the amount of

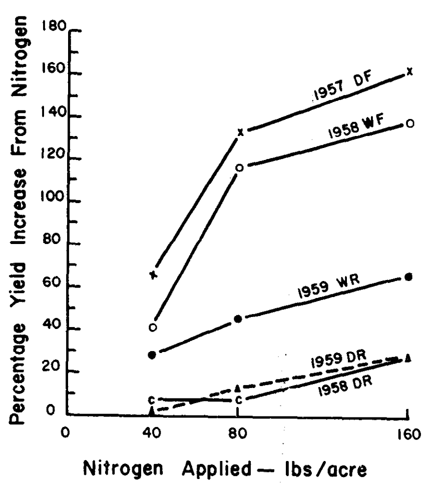

FIGURE 2. Relative yield response to fertilizer nitrogen (F), applied in the fall of 1956 on dry range (D) and 1957 on water spreading (W) site, and residual nitrogen (R).

Table 3. The mean nitrogen and phosphorus content, and the percentage of fertilizer recovered on a dryland and a water spreading range site.

Fertilizer Applied		Dryland Range Site				Water Spreading Range Site		
		Mean content of		Recovery of N		Mean content of		Recovery of N
N	P_2O_5	N	P	3 years[2]	2 years[1]	N	P	2 years[1]
(Percent)								
0	0	1.46	0.126	......	......	1.25	0.149	......
40	0	1.47	0.118	27.8	24.2	1.27	0.127	31.2
80	0	1.58	0.124	31.9	22.4	1.43	0.137	28.4
160	0	1.78	0.132	36.5	13.3	1.61	0.133	23.7
0	80	1.48	0.161	......	......	1.25	0.185	......
40	80	1.46	0.146	57.0	23.8	1.20	0.167	5.5
80	80	1.58	0.158	61.1	11.1	1.39	0.164	25.6
160	80	1.83	0.141	34.4	11.6	1.58	0.165	20.0
0	160	1.50	0.174	......	......	1.28	0.176	......
40	160	1.54	0.171	35.0	12.5	1.28	0.178	19.0
80	160	1.57	0.163	53.5	14.5	1.39	0.167	27.3
160	160	1.71	0.166	43.1	13.3	1.57	0.166	20.2
L.S.D.	.05	0.32	0.027			0.17	0.028	
L.S.D.	.01	0.44	0.036			0.24	0.040	

[1]Fertilizer applied fall 1957.
[2]Fertilizer applied fall 1956.

available moisture (Table 4). In general the efficiency of use of nitrogen fertilizer decreased as the amount of fertilizer nitrogen applied increased and as the supply of available moisture decreased. In a year of above normal rainfall (1957) the highest efficiencies were obtained with 40 and 80 pounds of nitrogen in combination with 80 and 160 pounds of phosphorus. Considering both initial and residual yields on the dry range site, the 40 pound N — 80 pound P_2O_5 fertilizer combination was most efficient. This 1:2 ratio was equally as efficient at the higher nitrogen-phosphorus level. With supplemental water phosphorus had very little effect on the efficiency of use of nitrogen fertilizer. The 40 pound N application was most efficient over a two year period. Comparison of the 1958 and 1959 yield changes on the dry range with those on a water spreading site show that supplemental water more than doubled the nitrogen use efficiency in several cases. In 1958 the respective mean efficiencies for all phosphorus levels were 7.5 and 12.1 pounds of forage per pound of. nitrogen on the dry range and water spreading sites.

Nitrogen Content of Forage

The nitrogen content of the forage was significantly increased by the addition of nitrogen fertilizer but decreased with the use of supplemental water and as precipitation increased. The mean nitrogen percentage of forage receiving supplemental water in 1958 was 1.04, 1.05, 1.16, and 1.41 for the 0, 40, 80 and 160 pounds of applied nitrogen, respectively, compared to percent nitrogen values of 1.14, 1.16, 1.29 and 1.46 for similar nitrogen applications on the dry range site.

The effects of a single application of nitrogen or phosphorus fertilizer, alone and in combination, on the mean nitrogen content of forage for a three year period and on the percent nitrogen recovery on the dry range site are shown in Table 3. The application of 80 and 160 pounds of nitrogen significantly increased the mean nitrogen content of the forage from 1.48 percent for the nonfertilized forage to 1.58 and 1.78 percent, respectively. The application of 40 pounds of nitrogen had no effect on the nitrogen percentage. Residual response from the 160 pound N applications significantly increased the nitrogen content of the forage for one year.

The quantity of nitrogen recovered in the forage over a three year period varied from 27.8 percent for the 40 pound N application to 61.1 percent for the 80 pound N — 80 pound P_2O_5 fertilizer additions (Table 3). The application of phosphorus fertilizer also increased the uptake of fertilizer nitrogen on the dry range during this period. The mean recovery of nitrogen with the addition of 0, 80 and 160 pounds of phosphorus for all levels of fertilizer nitrogen was 32.0, 50.8 and 43.8 percent, respectively. The effect of phosphorus fertilizer on nitrogen recovery was apparently related to the precipitation. In 1958 with 16.1 inches of precipitation the fall application in 1957 of 80 and 160 pounds of phosphorus decreased the mean nitrogen recovery for all levels of fertilizer nitrogen from 19.9 percent for the nonphosphorus-fertilized forage to 15.5 and 13.4 percent, respectively. The ratio of the amount of soil-applied nitrogen to phosphorus determined the quantity of fertilizer nitrogen utilized by the forage on the dry range. Mean nitrogen recovery was 55.2, 52.1, 35.0 and 34.4 percent for N: P_2O_5 fertilizer ratios of 1:2, 1:1, 1:4 and 2:1, respectively.

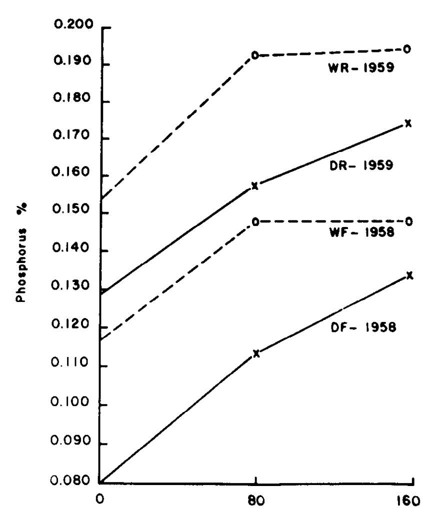

FIGURE 3. The effect of residual (R) and fertilizer (F) phosphorus applied in the fall of 1957 on the phosphorus content of forage on dry range (D) and water spreading (W) sites.

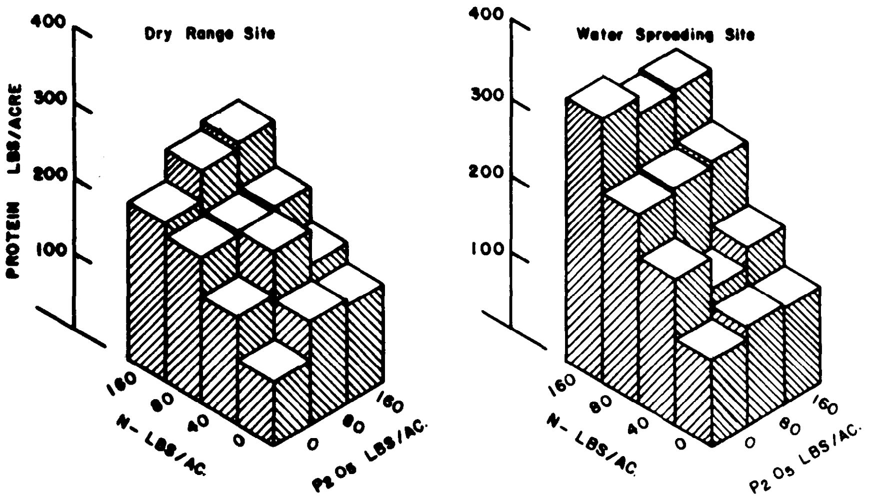

FIGURE 4. Total yield of crude protein for two year period 1958-1959 as effected by supplemental water and nitrogen and phosphorus fertilizer. Fertilizer applied fall of 1957.

The mean nitrogen content and percent nitrogen recovery in two years on the water spreading site are given in Table 3. The application of 80 and 160 pounds of nitrogen significantly increased the mean nitrogen content of the forage from 1.25 percent for the check treatment to 1.43 and 1.61 percent, respectively. The application of 40 pounds of nitrogen had no effect on the nitrogen content of the forage on the water spreading site. Residual responses were obtained from 80 and 160 pound rates of nitrogen previously applied on the water spreading system.

The quantity of nitrogen recovered in the forage for the two year period varied from 5.5 percent for a 40 pound N — 80 pound P_2O_5 fertilizer application to 31.2 percent for the 40 pound N addition. The mean recovery of nitrogen decreased from 27.7 percent to 17.0 and 22.1 percent with the application of 0, 80 and 160 pounds of phosphorus for all levels of nitrogen fertilizer during this period.

Phosphorus Content of Forage

The phosphorus percentage of the forage increased with the application of fertilizer phosphorus and with the use of supplemental water (Figure 3). Fertilizer was applied in the fall of 1957 and forage harvested in 1958 and 1959. Comparison of the phosphorus content of nonfertilized forage on the dry range and water spreading sites show that with the additional water the phosphorus percentage increased from 0.080 to 0.117 percent. Similar increases were noted in the phosphorus fertilized forage. Greater root activity and increased solubility of the soil and fertilizer phosphorus could account for the greater uptake of phosphorus by the forage (Power, et. al., 1961). A significant increase in the phosphorus content of the forage two years after fertilizer was applied was noted on both sites (Figure 3, R 1959).

The addition of nitrogen fertilizer by greatly increasing forage production decreased the mean phosphorus content of the forage (Table 3). Considering all levels of applied phosphorus, the addition of 0, 40, 80 and 160 pounds of nitrogen forage containing 0.153, 0.145, 0.148 and 0.146 percent phosphorus, respectively, on the dry range site and 0.170, 0.157, 0.156 and 0.154 percent phosphorus, respectively on the water spreading site. The effect of nitrogen fertilizer on the phosphorus percentage of forage also accounts for the high phosphorus content of forage on residual fertilizer (compare immediate and residual curves, Figure 3).

The effects of one fertilizer application and supplemental water on the total yield of crude protein for the two year period 1958 and 1959 are illustrated in Figure 4. Crude protein production increased with the application of nitrogen fertilizer and with the use of supplemental water. The increase in forage yields by the application of fertilizer was significantly correlated with the increase in percent crude protein (r=0.889). Fertilizer applied on the dry range site increased forage yields and crude protein. Yield increases were significantly correlated with increases

Table 4. Effect of different years in applying nitrogen and phosphorus fertilizer and supplemental water on the increase in pounds of forage per pound of nitrogen.

Fertilizer applied		Dry range site[1]				Water spreading site[1]		
N	P_2O_5	1957	1957	1959	Total[2]	1958	1959	Total[3]
(Pounds per acre)		— — —	— — —	— —	(Pounds)	— — —	— — —	— —
40	0	13.2	14.0	4.9	15.7	16.3	7.9	24.8
80	0	10.9	9.5	1.4	13.8	17.6	3.8	20.5
160	0	12.0	3.5	0.9	14.4	10.4	3.5	13.4
40	80	25.2	13.8	3.4	37.9	5.0	11.9	6.7
80	80	25.5	6.8	5.0	30.2	14.3	8.1	18.2
160	80	10.1	4.9	2.3	14.5	8.2	4.0	10.7
40	160	23.3	6.9	8.2	15.3	12.7	15.0	16.3
80	160	25.1	4.6	4.7	23.5	15.8	8.3	19.8
160	160	15.3	3.6	1.8	17.1	9.4	4.9	11.5

[1]A new area was fertilized each fall.
[2]Based on 3 year forage yields from fertilizer applied 1956.
[3]Based on 2 year forage yields from fertilizer applied 1957.

in percent crude protein (r=0.625). When fertilizer was applied to the dry range and the water spreading site the "r" values for correlation indicate better correlation was obtained between yield increases and percent crude protein increases on the water spreading site. This would emphasize more efficient use of applied fertilizer where supplemental water was used. Phosphorus fertilizer increased the yield of crude protein only on the dry range site.

Summary

The effects of supplemental water and the nitrogen-phosphorus fertilizer ratio on the yield and chemical composition of forage native to western South Dakota were investigated.

Nitrogen fertilizer increased the production of forage and crude protein on both the dry land and water spreading sites. The supplemental water received on the water spreading site increased the efficiency of use of the applied nitrogen.

Increases in forage yields on the dry range and water spreading site were significantly correlated with increases in percent crude protein.

Phosphorus fertilizer increased forage and crude protein yields on the dry range site but had little influence on yields where supplemental water was used.

The percentage nitrogen of the forage was significantly increased by the application of nitrogen fertilizer but decreased with the use of supplemental water.

Recovery of applied nitrogen was enhanced by the additional water received on the water spreading site.

Phosphorus content of the forage increased with the addition of phosphorus fertilizer and with the use of supplemental water.

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