Time of Fertilizer Application on Desert Grasslands[1]

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Highlight

In most fertilization studies on desert grasslands, little attention has been paid to soil moisture conditions at the time of application. Results have been highly variable and fertilization has not been accepted as an economical management practice. These studies were designed to determine if the time of application could be adjusted to soil moisture conditions in order to insure maximum response to fertilizaton. In general, fertilization of desert grasslands after the start of the summer rainy season gave best results in three of four sites studied. Applying fertilizer after soil moisture is present helps prevent fertilizer losses during a dry season. Maximum response to the fertilizer is assured because application is just prior to the time of the greatest demand for nutrients.

In southern Arizona, lack of rainfall is usually considered to be the limiting factor in range production. Many studies during the past several years (e.g. Freeman and Humphrey, 1956; Holt and Wilson, 1961; Stroehlein et al., 1964) have shown that during seasons of adequate moisture, low soil fertility, especially nitrogen, limits grass growth. However, many fertilizer studies on desert grassland have not been successful because of a deficiency of summer rainfall and usually have not been reported. Except for the work of Jones (1960) on California annual range which has a long season of winter rainfall, little attention has been paid to the proper timing of range fertilization. In one study in Arizona, Honnas et al. (1959) applied ammonium phosphate in early summer. Due to a deficiency of summer rainfall, six months elapsed before enough rain fell to move the material into the soil. Some response was found the following summer, but they concluded that adequate precipitation immediately following application of fertilizer is essential to obtaining optimum benefits from range fertilization.

Dyer (1958) obtained good results by fertilizing after four inches of rain had fallen. In 1964, Stroehlein et al. (1965) obtained good response to fertilization on three of four sites. The one which failed to show a response was near the Kitt Peak site described in this paper. At this site, adequate levels of fertilizers were applied long before a better than average rainy season. The three sites which responded well were fertilized after the summer rains. The lack of response may have been caused by fertilizer loss from the hot dry soil surface by volatilization, erosion by wind or water, or by leaching during the first rain.

On native range in Arizona, July and August rains produce the bulk of the perennial grass forage (Humphrey, 1962). Here about 60% of the annual rainfall comes between July 1 and September 30 with no effective rainfall expected in April, May, or June (Martin, 1966). The purpose of studies reported here was to determine the proper time to fertilize semiarid grassland in Arizona in relation to summer rainfall patterns with respect to forage production and quality.

Experimental Sites and Methods

Studies were conducted in 1965 and 1966. In 1965 one site was located on the Williams Ranch near Benson, Arizona at 4,400 ft elevation. The dominant grass was black grama (*Bouteloua eriopoda* Torr.). The soil is a Hathaway sandy loam which is alkaline (pH 7.6) and is derived

[1] Contribution of the University of Arizona Agricultural Experiment Station as Technical Paper No. 1226.

from shallow mixed alluvial materials over limestone bedrock.

A second site, used in 1965 and 1966, was located near Kitt Peak on the Papago Indian Reservation at 4,400 ft. These plots were located near the site of a 1964 study where growth response was not obtained following application of up to 200 lb N/acre and good summer rainfall. The soil is Comoro gravelly sandy loam derived from granite and is slightly acid (pH 6.5). The individual sites were close together but varied slightly in grass composition between 1965 and 1966. The 1965 site contained mainly grama grasses (*B. filiformis* (Fourn.) Griffiths, *B. hirsuta* Lag., *B. rothrockii* Vasey) with some threeawns (*Aristida* spp.). The site in 1966 contained a larger proportion of *Aristida* and less *Bouteloua*.

A third site used in 1966, was located on the Santa Rita Experimental Range in southeastern Pima County, near the plots of Holt and Wilson (1961). This site contained an excellent stand of Lehmann lovegrass (*Eragrostis lehmanniana* Nees) at 4,100 ft elevation. The soil is classified as Whitehouse sandy loam. This site was selected because Holt and Wilson previously obtained excellent growth response as well as an increase in palatability with fertilization. Also Lehmann lovegrass has proved to be well adapted for reseeding southern Arizona ranges (Humphrey, 1960), and a good stand of grass is a prerequisite for economic returns from fertilization.

Plots size was 20 × 20 ft for the first three sites and 20 × 10 ft for those at the Santa Rita site. The design for all studies was completely random, and treatments were replicated five times. Treatment dates varied but were arranged so that fertilizer would be applied well before the first summer rain and at regular intervals after onset of the rains until near the end of the rainy season (Tables 1, 2, and 3). Fertilizers were 16-16-8 (N-P_2O_5-K_2O) at a rate of 75 lb N/acre and 30-10-0 at a rate of 50 lb N/acre for 1965 and 1966, respectively. The nitrogen was almost equally divided between the ammonium and nitrate forms in each material. This combination provided a readily available nitrate source as well as an ammonium source to resist leaching by heavy rains.

The plots were harvested in September or October after the plants were mature. In 1965, three 9.6 ft² subplots were clipped by hand from each plot. In 1966, two strips were cut through each plot with a power mower. Subsamples were saved from each plot for moisture determinations and nitrogen and total phosphorus analyses. Nitrogen was determined by the Kjeldahl procedure and converted to protein by multiplying by 6.25. Soil samples were taken from two replicates of the Williams study at harvest time

Table 1. Influence of dates of fertilization and rainfall distribution on oven-dry herbage production and nutrient content of black grama grass[1] and soil tests at harvest time, Williams Ranch, 1965.

Date of application	Herbage (lb/A)	Nutrient content: Protein (%)	Nutrient content: P (%)	Soil test at harvest: NO_3-N (ppm)	Soil test at harvest: PO_4 (ppm)	Rainfall between treatments (in.)
Mar. 27	1380	4.94	0.64	48	32	—
June 2	1350	5.06	0.62	20	7	0.02
June 26	1220	5.19	0.59	21	9	none
July 9	1340	5.69	0.66	32	10	2.50
July 23	1450	5.25	0.54	46	7	0.38
Aug. 7	1770	4.63	0.51	62	5	2.00
Check	1230	4.31	0.51	6	2	0.35[2]
Significance	NS	NS	NS			

[1] Harvested Oct. 6, 1965.
[2] Between Aug. 7 and harvest on Oct. 6.

Table 2. Influence of various dates of fertilization and rainfall distribution on oven-dry herbage production and nutrient content of native range grasses, Kitt Peak, 1965 and 1966.

Date of application	Herbage (lb/A)	Protein (%)	P (%)	Rainfall between treatments (in.)
Harvested September 23, 1965				
June 1, 1965	1580ab[1]	8.19a	0.20	—
July 3, 1965	1740b	8.19a	0.18	0.66
July 16, 1965	2020b	7.88a	0.18	0.53
July 31, 1965	1750b	8.50a	0.21	1.35
August 14, 1965	1840b	8.50a	0.18	1.05
Check	1180a	4.69b	0.18	3.75[2]
Significance	**	**	NS	
Harvested September 17, 1966				
June 8, 1966	710b	4.94a	0.23	
July 9, 1966	715b	5.44a	0.23	0.30
July 30, 1966	810b	6.19a	0.22	2.85[3]
August 20, 1966	420a	6.38a	0.24	0.32
Check	525a	4.56b	0.23	2.00[4]
Significance	**	**	NS	

[1] Values followed by the same letter are not significantly different at the .05 level.
[2] Between Aug. 14 and harvest on Sept. 23.
[3] Includes 1.50 inch between July 9 and July 22.
[4] Between Aug. 20 and harvest on Sept. 17, including 0.32 inch before Aug. 31.

Table 3. Influence of various dates of fertilization and rainfall distribution on oven-dry herbage production, nutrient content, and utilization of Lehmann lovegrass,[1] Santa Rita Range, 1966.

Date of application	Herbage (lb/A)	Nutrient content: Protein (%)	Nutrient content: P (%)	Utilization Jan. 6, 1967 (%)	Rainfall between treatments (in.)
June 15	1870b[2]	3.49a	0.21a	18a	—
July 7	1700b	3.54a	0.19a	11a	0.16
July 28	1820b	5.12a	0.19a	23a	2.62
August 18	1610b	6.32b	0.24a	51b	3.38
Check	1060a	2.96a	0.28b	16a	5.94[3]
Significance	**	**	**	**	

[1] Harvested Oct. 5, 1966.
[2] Values followed by the same letter are not significantly different at the .05 level.
[3] Between Aug. 18 and harvest on Oct. 5.

and analyzed for nitrate and carbonic acid extractable phosphate.

Results and Discussion

Williams Ranch Study, 1965.—Visual differences among treatments were noted in the field at the time of the last fertilizer application, but dry matter production was variable and statistically significant differences were not found at the October harvest (Table 1). The nutrient content of the grass also was variable and differences were nonsignificant although the protein content tended to increase with later fertilization. Extensive damage by grasshoppers during July and August accounted for a portion of the variability and poor results. Attempts at control were temporary, as the plots were continually invaded from the surrounding area. Black grama has also been found to respond poorly to nitrogen fertilization (Burkholder, 1967).

Analyses of soil samples taken at harvest time gave variable results, although important trends were found. The fertilized plots had higher nitrate and phosphate than the unfertilized plots (Table 1). These fertility levels indicate that the plants could have responded later, although differences were not observed during the 1966 growing season.

Kitt Peak, 1965.—Forage density and height differences were observed during the growing season as a result of all fertilizer applications. The plots fertilized last remained green about two weeks longer than the others. The plots were harvested on September 23. Fertilizer applications from July 3 to August 14 significantly increased herbage yields (Table 2). The herbage yield from the June 1 treatment was higher although not significantly different from the check. Fertilization before the rainy season was not as successful as later applications. An early application of fertilizer at the Kitt Peak site did not increase herbage production in 1964 (Stroehlein et al., 1965). The protein content of the plants harvested September 23, 1965 was significantly increased by all fertilizer treatments with only a slight trend toward higher protein with later fertilizer application. The phosphorus content of the plants was not affected by fertilization.

Response of sixweeks fescue (*Festuca octoflora* Walt.) on fertilized plots was observed in the spring of 1966 but harvest data were not collected. Spring annuals can benefit from fertilization the previous summer and may reduce residual response by perennials the following summer. Bales (1965) pointed out that redstem filaree (*Erodium cicutarium* (L.) L'Her.) was able to utilize nitrogen applied in January before most grasses begin growth.

Kitt Peak, 1966.—Response to fertilization was easily observed during late July and August. A significant increase in production was obtained at harvest on September 17 from the first three applications (Table 2). Low rainfall in early August helps account for poor response to the August 20 application. There was an increase in plant protein with each delay in fertilizer application. The last two applications produced significantly higher protein content but the phosphorus content was not affected by the different treatments. Slightly lower rainfall and the different species composition on the new site probably account for the lower production in 1966.

Santa Rita Range, 1966.—Response was shown by Lehmann lovegrass to each fertilizer treatment throughout the rainy season. The plots were harvested on October 6. At this time, the unfertilized grass was yellow with a few short seed stalks. Fertilization on June 15 increased tillering and produced tall coarse seed stalks. The July 7 application resulted in numerous coarse seed stalks and greener color than the June 15 treatment when evaluated in October. The July 28 treatment was similar but was greener than the July 7 application in October. The late applications yielded more green leaves and fewer seed stalks than earlier fertilizer applications when evaluated in October. All treatments gave significantly higher dry weight than the unfertilized grass, although the last application was lower than the other fertilizer treatments. Total rainfall (Table 3) as measured by a recording rain gauge from the first rain on June 20 through October 4 was 12.10 inches, with 7.96 inches occurring in July and August and 3.82 inches in September. The July and August rainfall was 1.90 inches less than the 1952–1958 year average and 4.98 inches less than the excellent 1958 season of Holt and Wilson (1961). Martin (1966) reported averages of about 4.5 inches for July, 4.8 for August, and 2.0 for September for this elevation on the Santa Rita Range. If rainfall had been average for September in this study, significant increases in production may not have resulted from the August 18 fertilizer application.

As with the 1966 Kitt Peak study, the protein content increased with late fertilization for grass harvested in October. Application of fertilizer on August 8 resulted in 6.3% protein compared to 3.5% for the June 15 application. The phosphorus content of the grass at harvest was significantly lower for fertilized as compared to unfertilized plots (Table 3), but total phosphorus uptake was higher for all fertilized plots (0.32 to 0.39 lb/acre) than the check (0.30 lb/acre). In October, the moisture content of plant samples from the last date of fertilizer application was 58%, a significant increase over the check and the other dates of application which averaged 50% moisture.

Plant samples also were collected January 4, 1967 and analyzed for protein and phosphorus but statistically significant differences were not found. The trends were the same as with the October samples, although the protein content was lower. The protein content had dropped to 1.8% for the unfertilized check and 2.5% for the August 18 treatment. The phosphorus remained at about the same level as in the October samples.

On January 6 and 25, 1967, utilization estimates were made (Table 3). Cattle grazing on the plots between harvest on October 6 and January 6 showed a significant preference for the grass fertilized on August 18, but there was no difference between the other treatments. The utilization estimates showed good agreement between the other treatments. The utilization estimates showed good agreement between the two dates as there was little additional grazing between January 6 and 25. Previous studies have shown that cattle prefer fertilized range grasses, but information on the effect of time of fertilizer application on palatability has not been previously reported.

Total nitrogen uptake was greatest with the mid- to late-season applications. The reason for lower efficiency of fertilizer nitrogen use with earlier application dates is not known. Nitrates can move readily in moist soil and as such, could be moved into and possibly through the root zone by rainfall. Ammonium movement is limited except in very sandy soils but is susceptible to volatilization from a hot soil surface. Fertilizers applied to dry soils remain on the surface and would be susceptible to wind and water erosion. When applied to moist soils the fertilizer dissolves immediately. Thus, in moist soils which are slightly acid, nitrogen loss is more likely when applied prior to summer rains. It is apparent that additional work on the fate of nitrogen fertilizer forms applied to range soils would be helpful for development of fertilizer management practices.

Conclusions

In general, highest grass production on three desert grassland sites in southern Arizona was obtained when fertilizer was applied during the summer rainy season. Fertilizer applications prior to the rainy season increased production in two studies, although poorer quality forage for fall utilization was produced on one site compared to forage from later fertilizer applications. Fertilization during the latter part of the rainy season (mid-August) increased production compared to non-fertilized grass in two of the four studies, but yields were not as good as earlier fertilization dates. Fertilizer treatments generally increased the protein content of the grass. On two sites, however, protein was increased more by later applications as compared to earlier applications. Fertilizing later when nutrient needs are greatest may lose some advantage by delaying the start of the green feed period; although the extension of the green feed period, increased protein, and better production should more than balance any disadvantage. The difference in utilization and the extension of the green feed period with Lehmann lovegrass in the Santa Rita study are evidence of the advantage of delaying fertilizer application as long as possible for extra forage quality in late fall and early winter. If earlier production is desired, then the application should be made as soon as adequate soil moisture is available for good grass growth. It is apparent from these results that fertilization should be delayed until after the start of summer rains for best grass production and quality.

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