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Productivity of *Cenchrus ciliaris* in relation to rainfall and fertilization

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Abstract

Forage for livestock is always in short supply in the arid zone of India. *Cenchrus ciliaris* L. is one of the major forage grasses cultivated in this region. We studied its productivity in relation to rainfall and nitrogen (N) and phosphorus (P) fertilization in the Indian arid zone at Jodhpur during 1983 to 1992. Factorial combinations of 4 rates of N (0, 20, 40, and 60 kg ha^{-1}) and 3 rates of P (0, 15, and 30 kg ha^{-1}) were applied annually. Twenty kg N ha^{-1} was the most effective fertilizer treatment, increasing average annual forage yields from 942 to 1,785 kg ha^{-1} over the 10-year study with significant yield increases occurring in 7 of the 10 years. Yield responses to N rates greater than 20 kg ha^{-1} occurred only during the last 3 years of the study and then only at the 60 kg ha^{-1} rate with either 15 or 30 kg P ha^{-1}. Yields reached maximum levels on both the nonfertilized and fertilized plots with between 180 and 250 mm of growing-season rainfall.

Key Words: nitrogen, phosphorus, Indian arid zone, forage production

The Indian arid region in Northwest India is characterized by low and variable rainfall. Arable farming is possible in only 1 of every 3 years. Hence, the main economy of this region is dependent on forage production to support its 23 × 10^6 head of livestock. Several studies have shown that available forage supplies are inadequate to maintain the livestock population in good condition and prevent overuse and degradation of the rangeland. Shankarnarayan et al. (1985) reported that only 44% of the animals' fodder requirements are met during normal-rainfall years leaving a deficit of 56%. Ahuja and Mann (1975) estimated a fodder deficit of 35% based on the land available for grass production. Shankarnarayan and Kalla (1985) estimated the demand for the grazing forage in the northwest arid zone of India was 233 × 10^7 kg and the supply was only 172 × 10^7 kg.

Of the 7 major pasture types available in the Indian arid zone, *C. ciliaris* is one of the most important grass types. Known locally as Anjan, *C. ciliaris* is a perennial, nutritious, highly preferred grass that performs better in low rainfall-conditions than other predominant grasses like *Lasiarus sindicus* Henr. and *C. setigerus* Vahl. Because of the large deficit of forage supplies, there is considerable need to increase forage production in this arid region. The coarse-textured soils of the Indian arid zone are very low in organic matter content with subsequent deficiences in nitrogen (N) and often other essential plant nutrients. This study was conducted to determine the effects of N and phosphorus (P) fertilization on the productivity of *C. ciliaris* with varying annual rainfall.

Methods and Procedure

The study site was located at the Central Arid Zone Research Institute in Jodhpur (26° 18' N; 73° 01' E, elevation above MSL 224 m). The average annual rainfall of 360 mm is highly variable (coefficient of variation = 60%) and usually occurs within a 75-day period (Table 1). Mean annual air temperature is 26.7°C. The normal crop growing period is between July and September and is dependent on the southwest monsoon rains. Soils at the experimental site are loamy sand, mixed hyperthermic Camborthids low in organic matter (0.4%) and have a mechanical composition of 80–90% sand and 8% clay. Field capacity of the soils is between 0.12 and 0.135 cm^3 cm^{-3} and wilting point is between 0.055 and 0.065 cm^3 cm^{-3}. Bulk density is 1.12 to 1.56 g cm^{-3}, and the hydraulic conductivity is 15 cm hour^{-1}. The soil depth varies between 90 and 100 cm. Olsen extractable soil P (12–15 kg ha^{-1}) and soil pH (8.0) values from a nearby experiment (Singh and Aggarwal 1988) would be good estimates of the intial values for this experiment. The 12–15 kg P ha^{-1} test value is considered in the medium range.

Cenchrus ciliaris (c.v. 358) was established on the study site in July 1983. The inter- and intra-row spacings were 75 and 25 cm, respectively. Fertilizer treatments consisted of 4 levels of N (0, 20, 40, and 60 kg ha^{-1}) in combination with 3 levels of P (0, 15, and 30 kg ha^{-1}) for a total of 12 treatments. Plot size was 7.5 m × 10.0 m. Half of the N and all of the P of each treatment were side-dressed in deep bands at the time of seeding. The remaining N was top-dressed one month later following good soaking rains. Fertilization treatments were repeated annually at the onset of the rainy season. Urea and single superphosphate were the N and P sources, respectively. Treatments were replicated 3 times in a randomized complete block design with a factorial arrangement

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Table 1. Monthly precipitation Jodhpur, India. 1983–1992.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.	Growing Season[1]
							(mm)							
1983	1	1	0	31	38	32	77	88	11	33	0	0	512	409
1984	0	0	0	4	0	7	45	86	90	0	0	0	232	219
1985	0	0	0	21	41	1	63	72	5	9	0	0	212	152
1986	0	1	0	0	55	0	142	42	0	10	0	0	250	183
1987	6	6	5	0	28	33	18	14	0	0	0	8	118	70
1988	5	0	0	0	0	16	106	96	47	0	0	0	270	257
1989	4	0	5	0	0	12	52	139	18	0	0	0	230	210
1990	0	36	0	0	31	3	516	180	78	1	0	0	845	775
1991	0	0	0	11	0	10	75	96	11	0	0	1	204	193
1992	27	0	4	0	5	4	85	101	196	0	0	0	422	393
Mean	4	4	2	7	20	12	138	91	46	5	0	0	330	286

[1]The growing season depends on monsoon rains and usually occurs between July and September.

of treatments. Above-average rainfall resulted in the establishment of a good stand of grass.

All of the forage in each plot was harvested annually when the grass reached maturity. Yields were recorded on an air-dry basis. Percent moisture in air-dry forage in this dry climate is generally lower than the 10–12% usually reported for air-dry forage in the literature. Analyses of variance were used to evaluate fertilizer treatments on an annual basis and over periods of years. Statistically significant differences in treatment effects were established at $P \leq 0.05$.

Results and Discussion

Annual yields of *C. Ciliaris* varied over a wide range during the 10-year study period (Fig. 1). As would be expected, there was a significant year by fertilizer treatment interaction due to the high variation in growing season rainfall. Because of the treatment by year interaction, each year's yield data were analyzed separately (Fig. 1). Combining the low- production years—1985, 1987, and 1989—and the remaining 7 years (high-production years) into 2 separate groups for analyses also eliminated the fertilizer treatment by year interaction and allowed comparison of fertilizer treatments averaged over several years (Fig. 2). For the 3 low-production years, there were no significant yield responses to N, P, or N-P combinations.

Based on the single-year analyses of variance, there was a significant yield response to N in all but 3 years of the 10-year study (Fig. 1). There were only 3 years—1990, 1991 and 1992—in which N rates greater than 20 kg ha^{-1} were measureably effective, and then only at the 60 kg N ha^{-1} rate applied with P. Phosphorus applied with N significantly enhanced yields only during the last 3 years of the study suggesting that increased production on the N fertilized plots the previous years was depleting the reservoir of available soil P. Thus to maintain maximum long-term yield responses to N, applications of P may be necessary. Averaged over the high production years, there was no significant yield response beyond the 20 kg N ha^{-1} rate (Fig. 2).

Yield responses to P were inconsistent and difficult to interpret. In 7 of the 10 years, P had no measureable effect on yields. Significant N by P interactions occurred in 1983, 1991, and 1992 and were the result of positive yield responses to P at the 0 and 60 kg N ha^{-1} rate and negative yield responses to P at the 20 kg N ha^{-1} rate (Fig. 1). The same interactions were evident in the high-production years analysis (Fig. 2). It seems unreasonable that applications of P fertilizer would actually decrease forage yields when applied with 20 kg N ha^{-1}; have no effect at the 40 kg N ha^{-1} rate; and have positive effects at the 0 and 60 kg N ha^{-1} rates. There is no known explanation for this combination of yield responses, especially the yield reductions, unless it is due to a lack of homogeneity in the experimental plots. Such a combination of responses tended to obscure the role of P in the production of *C. Ciliaris* in this study. However, the response to P at the high N rate after several years of high productivity does seem logical and to be a true P effect. In a 4-year study reported by Wiedenfeld et al. (1985), yield increases on the fertilized plots

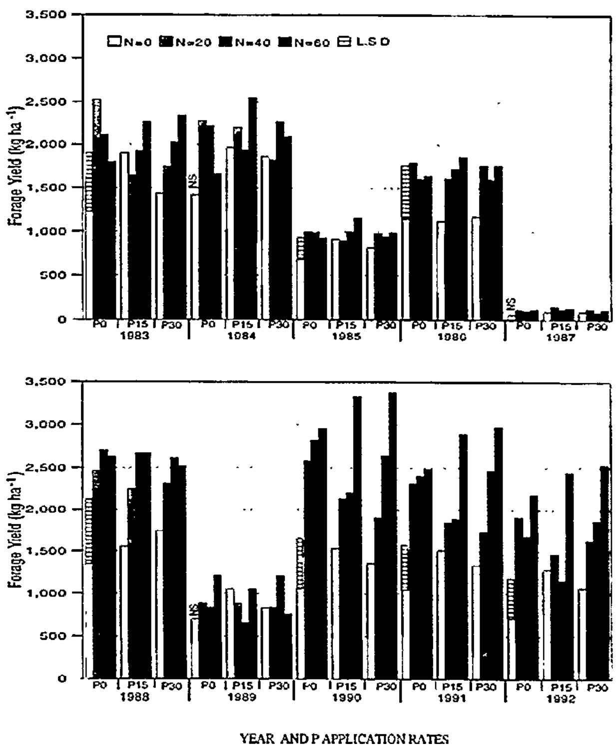

Fig. 1. The effect of nitrogen and phosphorus fertilization on forage yields of *C. ciliaris*. Jodhpur, India. 1983–1992. (L.S.D.'s can be used for within year comparisons among all 12 fertilization treatments.)

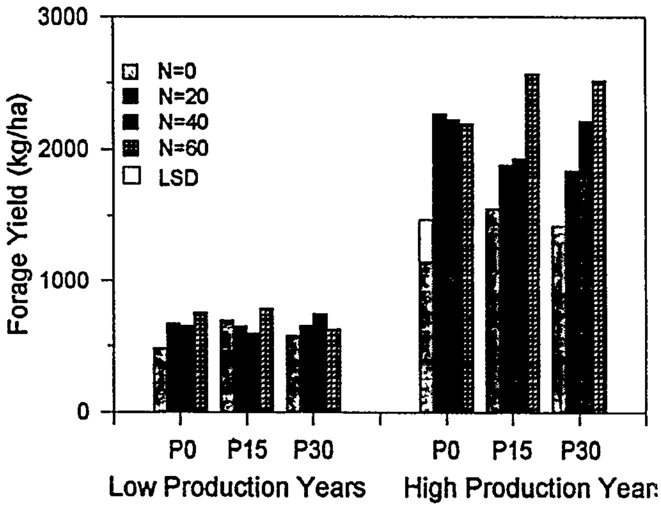

Fig. 2. The effect of nitrogen and phosphorus fertilization on forage yields of *C. ciliaris* averaged over the three low-production years and the seven high-production years. Jodhpur, India. 1983–1992.

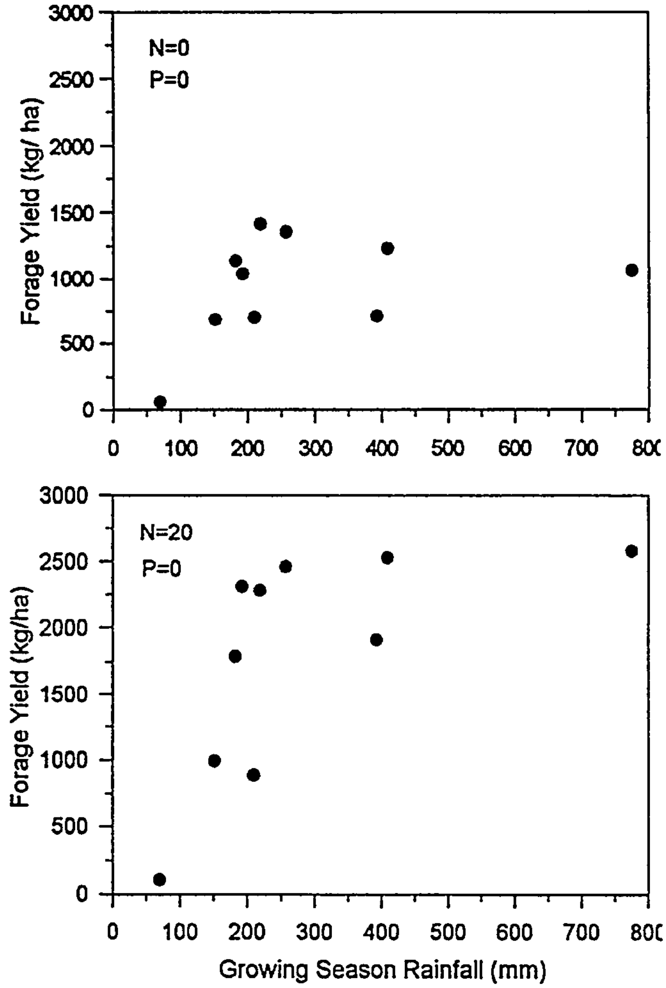

Fig. 3. Relationship of forage yields of *C. ciliaris* to growing season rainfall. Jodhpur, India. 1983–1992.

were due primarily to N with some additional response to P only at the high N rates during 2 of 4 years.

There was no significant correlation between yield and growing-season rainfall (Fig. 3). No measurable yield increases occurred with additions of rainfall above 250 mm. Distribution of rainfall during the growing-season also affected plant response, thus further affecting the correlation between growing-season or annual rainfall and forage yields.

Forage yields of both the nonfertilized and fertilized plots tended to reach maximum levels with between 180 and 250 mm of growing season rainfall suggesting that *C. Ciliaris* reaches its genetic productivity potential at these rainfall levels. On a site near Kingsville, Tex. with an average annual precipitation of 640 mm, maximum, single-harvest annual yields of *C. Ciliaris* on plots receiving 156 and 44 or more kg ha^{-1} N and P, respectively, were maximized near 3000 kg ha^{-1} (Mutz and Drawe 1983), about the same as the maximum yields in this study.

It is significant to note that maximum yield responses to N fertilization occurred with between 180 and 250 mm of growing-season rainfall. For this 10-year study, the growing- season rainfall represented 86% of the total annual rainfall. Using this relationship between growing-season and annual rainfall, the long-term growing-season rainfall for this location would be 0.86 × 360 or 311 mm. Assuming a variability in growing season rainfall similar to that for total annual rainfall, which has a 60% coefficient of variation, the standard deviation for growing season rainfall would be 187 mm. Thus one would expect rainfall adequate to maximize yield responses to the 20 kg N ha^{-1} treatment in at least 70% of the growing seasons. In this study where the average annual rainfall was 330 mm (30 mm below the long-term average), yield responses to fertilization were maximum or near maximum in 7 of the 10 years.

In terms of increased forage production and treatment costs, annual applications of 20 kg N ha^{-1} was the most practical fertilizer treatment (Fig. 2). Over the 10-year study, the average annual yield of the 20 kg N ha^{-1} treatment was 843 kg ha^{-1} more than that of the nonfertilized treatment. This translates to a N-use efficiency of 42 kg of additional forage for every kg of N applied. Nitrogen-use efficiency is the units of forage produced per unit of N applied and is calculated as the difference in forage production between the fertilized (1785 kg ha^{-1} for 20 kg ha^{-1} N treatment) and the nonfertilized (942 kg ha^{-1}) plots. For the 7 high- production years, N-use efficiency was 57 units.

Data from the National Research Council (1970) indicate that a normal growing yearling steer should gain 1 kg for every 10.5 kg of forage intake. Using this relationship, the 20-kg N ha^{-1} treatment should produce an additional 80 kg of beef ha^{-1} or 4 kg beef kg^{-1} N. In the northern Great Plains of America, annual applications of about 40 kg N ha^{-1} to native range, crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) and Russian wildrye (*Elymus junceus* Fishc.) produced 1.0, 1.7 and 2.2 kg beef kg^{-1} N, respectively (Wight 1976). Information such as this can be used to help make economic evaluations.

This study shows that *C. ciliaris* can perform well even at relatively low levels of rainfall and that annual applications of 20 kg N ha^{-1} will more than double forage yields 7 years out of 10. No economic interpretations have been made, but an N-use efficiency of 42 kg of forage kg^{-1} of N applied suggests that N fertilization may be a viable option for increasing forage production in this forage-deficient region.

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