Effects of fallow and pigeon pea on yield and nitrogen response of the succeeding sorghum on a Vertisol

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The effect of a weed-free fallow and short- and medium-duration pigeon pea in the first year's growing season on yield and N response of a succeeding sorghum crop on a Vertisol under dryland conditions in India was examined. In the second year, a sorghum crop was grown on all the treatments with four rates of applied N (0, 30, 60, and 90 kg N ha^{-1} as urea). The response of sorghum to N depended on the preceding crop. Weed-free fallow gave the largest grain and straw yield of sorghum without applied N, which was significantly higher than the yields obtained from other treatments with no added N. Both short- and medium-duration pigeon pea had a non-significant residual N effect on the yield and N uptake of the succeeding sorghum crop. Mineral N accumulated in the weed-free fallow was significantly higher than that accumulated in the other preceding crop treatments, and this significantly influenced sorghum grain and straw yields, uptake of N, and response to zero and 30 kg N ha^{-1} applied in the succeeding season.

Keywords: Mineral nitrogen accumulation; Nitrogen uptake; Residual effects; Yield; Weed-free fallow

Fertilizer use in drylands is low and an integrated nutrient management strategy appears to be more suitable when chemical fertilizers are supplemented with grain legumes in the cropping systems. As an intercrop or in sequence before cereals, these legumes can improve soil fertility, especially soil N supply (Sen *et al.*, 1962; Kumar Rao *et al.*, 1983; Burford *et al.*, 198[illegible]).

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is an important grain legume commonly grown in the semiarid tropical regions of India. Recent studies have shown that long-duration pigeon pea can significantly improve the N supply to the succeeding cereal crop such as maize, when grown either as an intercrop or as a sequential crop (Kumar Rao *et al.*, 198[illegible]). Short-duration pigeon pea is becoming increasingly popular as a sole crop (Chauhan *et al.*, 1987) because it can be better accommodated in cropping systems. However, little information is available about the residual effects of short-duration pigeon pea on a succeeding cereal crop. The objective of this study, therefore, was to evaluate the residual effects of short- and medium-duration pigeon pea on the soil N supply to a succeeding sorghum crop.

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Materials and Methods

Experimental site and soil

Field experiments were conducted during the rainy seasons in 1985 and 1986 at the ICRISAT Center, Patancheru near Hyderabad, India (17.5° N, 78.5° E; 545 m altitude) on a deep Vertisol. The site receives an annual rainfall of about 750 mm, mainly during June to October. In 1985, rainfall during the growth of maize and short- and medium-duration pigeon pea was 256, 256, and 361 mm, respectively. In 1986, rainfall during the growth of sorghum (June–September) was 475 mm. Total rainfall during the rainy season in 1985 and 1986 was considerably lower than the normal 650 mm.

The Vertisol belongs to the Kasireddipalle series and is a Typic Pellusterts developed on basaltic alluvium. The soil is about 1.25 m deep and has a high water-holding capacity (>200 m). Some soil characteristics at the experimental site are given in Table 1. Soil samples were taken before initiating the experiment, air-dried, ground, and sieved through a 2-mm screen before analysis. Soil pH was measured by a glass electrode using a soil-to-water ratio of 1:2, and organic C and total N were determined as described by Walkley and Black (1934) and Dalal *et al.* (1984), respectively. Carbonate (expressed as $CaCO_3$) content was

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Table 1 Soil characteristics of the experimental site

Characteristic	Soil depth (cm) 0–15	15–30
pH (1:2 H_2O)	8.12	8.04
Organic C (%)	0.82	0.86
Total N (%)	0.0652	0.0673
Extractable P, 0.5M $NaHCO_3$ (mg kg^{-1})	1.0	0.8
Exchangeable K, 1N NH_4OAC (mg kg^{-1})	163	145
Extractable Zn, DTPA (mg kg^{-1})	2.1	1.0
Clay (%)	54	57
Silt (%)	25	24
Sand (%)	21	19
$CaCO_3$ (%)	5.2	6.1

determined as described by Allison and Moodie (1965) and particle-size analysis was determined by the hydrometer method of Gee and Bauder (1986). Extractable P (Olsen and Sommers, 1982), Zn (Lindsay and Norvell, 1978), and exchangeable K (Jackson, 1967) were also determined.

Field experiment

A split-plot design with three replicates was used, with the four main plot treatments consisting of short-duration pigeon pea (cv. ICPL 87), medium-duration pigeon pea (cv. ICPL 6), maize (Deccan 103), and a weed-free fallow in the first year (1985 growing season) and four N rates (0, 30, 60, and 90 kg N ha^{-1} as urea) applied to sorghum in the second year as subplots. Both pigeon pea and maize crops were grown on plots measuring 20 m × 3 m.

Before sowing in 1985, single superphosphate was applied uniformly to all the treatments to supply 20 kg P ha^{-1}. Fertilizer was incorporated in the top 3–4 cm soil layer. The crops were seeded on 24 July 1985. The short- and medium-duration pigeon pea were seeded at a spacing of 30 cm × 10 cm and 60 cm × 10 cm, respectively. The spacing used for maize was 60 cm × 25 cm. The maize crop was given basal N at a rate of 30 kg N ha^{-1} as urea which was applied along the row at a depth of about 5 cm and covered with the soil. The crops were grown under rainfed conditions. Two harvests were taken from both types of pigeon pea. The final harvests from the short- and medium-duration pigeon pea were carried out on 2 December 1985 and 12 March 1986, respectively. The maize crop was harvested on 24 October 1985.

All the harvested materials including grain and stalks were removed from the plots. No plant materials, except fallen materials from the pigeon pea crops, were returned to the plots. Fallen materials, consisting largely of leaves, were collected within replicates from the pigeon pea plots during the growing season and were incorporated, without any chopping, in the respective treatment plots before seeding the sorghum crop. A small sample of fallen pigeon pea leaves was used for chemical analysis of total N.

During the second year (1986 rainy season) soil samples were taken up to a depth of 45 cm from each preceding crop treatment including the fallow and were analysed for mineral N, i.e. NH_4 + NH_3 as described by Keeney and Nelson (1982). The plots were disc-ploughed (5–6 cm depth) and a basal rate of 20 kg P ha^{-1} as single superphosphate was applied. Each main plot of 1985 was divided into four subplots measuring 5 m × 3 m to accommodate the four rates of N (0, 30, 60, and 90 kg N ha^{-1}) applied as urea. Fertilizer was basally applied (at about 5 cm depth and covered with soil) at seeding of the sorghum crop on 12 June 1986. Sorghum (cv. CSH6) was seeded at a 50 cm × 20 cm spacing. The crop was harvested from a 15-m^2 area in each plot on 9 September 1986, leaving three rows on each side of the plots as borders. During the growing season the crops were hand-weeded twice. The pigeon pea crops were protected from pod borer (*Helicoverpa armigera*) infestation by spraying with 0.35% endosulfan (35% EC) at the pod-setting stage. The sorghum crop was protected from shoot fly (*Atherigone soccata*) at the seedling stage by spraying with 0.2% metasystox.

Harvested crops were separated into seeds and straw after drying at 60°C for 3–4 days. The separated parts were oven-dried at 60°C for moisture correction. Ten plants were randomly taken from each plot, dried, and ground for plant analysis.

Both grain and straw samples were analysed for N content. The plant samples were digested, using a digestion block, and N in the digest was determined by an autoanalyzer procedure (Technicon Industrial Systems, 1972).

The data were statistically analysed using analysis of variance procedures according to the SAS Institute, Inc. (1987) program.

Results and Discussion

The amount of rainfall (256–361 mm) received during the 1985 growing season was lower than the normal (650 mm) and this affected the performance of the crops which preceded sorghum, especially maize. Among the preceding crops, medium-duration pigeon pea, ICPL 6, gave the largest grain yield of 2.06 t ha^{-1} followed by short-duration pigeon pea, ICPL 87 (1.61 t ha^{-1}), but maize grain yield was low (0.61 t ha^{-1}) as a result of the low level of N (30 kg ha^{-1}) applied to the maize crop (Table 2).

The mineral N content of the top 45-cm soil profile under different treatments is given in Table 3 and shows that the fallow treatment accumulated the highest amount of mineral N (46.1 mg N kg^{-1} soil), which was significantly ($P < 0.05$) higher than the mineral N found under other treatments. Mineral N in the soil following maize was also significantly higher ($P < 0.05$) than in soil following short- and medium-duration pigeon pea. The preceding crop, however, did not significantly affect the distribution of soil N with depth. Higher accumulation of mineral N under maize than under pigeon pea might have been due to greater mineralization of soil N because the maize crop was harvested several weeks before the pigeon pea crops. Also, the soil, after the maize crop was harvested, was moist and kept weed-free. The preceding crop, fertilizer N, and interaction effects of the preceding crop with N significantly ($P < 0.05$) affected sorghum yield response. The response to increasing fertilizer N rates was linear in each of the preceding crop treatments, except for medium-duration pigeon pea which showed a quadratic response.

When no fertilizer N was applied, sorghum grain and straw yields were significantly larger ($P < 0.05$) in the plots kept fallow in the preceding season than those preceded by maize, and medium- and short-duration pigeon pea (Table 4). The response of sorghum to N depended on the preceding crop. Grain and straw yield of sorghum increased up to 30 kg ha^{-1} applied N in the fallow but it increased up to 90 kg ha^{-1} applied N in other treatments (Table 4). Yields were similar in all treatments at 90 kg ha^{-1} applied N indicating that the residual effects on yield were partly due to N. Short- and medium-duration pigeon pea had little residual N effect on the yield of the succeeding sorghum crop. The total N uptake by the sorghum crop (Table 5) under different treatments was similar to the yield response.

Short-duration pigeon pea produced 836 ± 32 kg fallen leaves ha^{-1}, leaf N 1.32%, and medium-duration pigeon pea produced 796 ± 57 kg fallen leaves ha^{-1}, leaf N 1.26%, (data not shown). Short-duration pigeon pea thus added 11 kg total N ha^{-1} while medium-duration pigeon pea added 10 kg total N ha^{-1} to the system through fallen leaves. These leaf materials would have contributed a small amount of N through mineralization. The contribution by fallen leaves in this study is much less than that reported by Sheldrake and Narayanan (1979), who found that 34 kg N

Table 2 Grain and straw yield and N uptake (±SE) of crops preceding sorghum

Parameter	Maize	Short-duration pigeon pea	Medium-duration pigeon pea
Grain yield (t ha^{-1})	0.61±0.197	1.61±0.286	2.06±0.199
Straw yield (t ha^{-1})	2.37±0.101	1.41±0.200	2.81±0.284
Total N uptake (kg ha^{-1})	18±2.2	58±11.0	87±7.6

SE, standard error

Table 3 Effect of fallowing and the crops preceding sorghum on mineral N content of soil

Soil depth (cm)	Bare fallow	Maize	Short-duration pigeon pea	Medium-duration pigeon pea
	$N_{NH_4 + NO_3}$ mg kg^{-1} soil			
0–15	17.1	14.6	10.7	9.0
15–30	15.9	12.8	11.2	10.4
30–45	13.1	10.6	9.6	9.9
0–45	46.1	38.0	31.5	29.3
SEM				
Preceding crop N effect			±0.43	
Soil depth			±0.37	
Preceding crop N effect × soil depth			±0.75	

SEM, standard error of the mean

Table 4 Effects of fallowing and preceding crops on sorghum grain (and straw) yield in response to increasing applications of N fertilizer

Preceding crop	Sorghum grain (and straw) yield (t ha^{-1}) at fertilizer N rate (kg ha^{-1}) 0	30	60	90	Mean
Fallow	4.21 (4.97)	5.08 (5.60)	4.75 (5.35)	4.96 (5.18)	4.75 (5.27)
Maize	3.26 (4.44)	4.28 (5.14)	4.29 (5.11)	4.84 (5.47)	4.17 (5.04)
Short-duration pigeon pea	3.15 (4.14)	3.81 (4.25)	4.33 (5.06)	4.91 (4.90)	4.05 (4.59)
Medium-duration pigeon pea	2.87 (4.15)	3.96 (4.34)	5.04 (4.99)	4.99 (4.97)	4.21 (4.61)
Mean	3.37 (4.42)	4.28 (4.83)	4.60 (5.12)	4.92 (5.13)	
SEM					
Preceding crop		±0.121 (±0.135)			
N levels		±0.101 (±0.144)			
Preceding crop × N		±0.214 (ns)			
For comparing means within a preceding crop		±0.203			

SEM, standard error of the mean
ns, not significant

Table 5 Effects of fallowing and preceding crops on total N uptake by sorghum in response to N fertilizer

Preceding crop	Sorghum N uptake ($kg\ ha^{-1}$) at fertilizer N rate ($kg\ ha^{-1}$) 0	30	60	90	Mean
Fallow	66.5	87.8	88.4	90.0	83.2
Maize	48.1	68.7	78.3	97.4	73.1
Short-duration pigeon pea	48.2	60.8	80.3	96.5	71.4
Medium-duration pigeon pea	46.4	64.3	85.8	99.8	74.1
Mean	52.3	70.4	83.2	95.9	
SEM					
Preceding crop			±4.05		
N levels			±2.28		
Preceding crop × N			±5.66		
For comparing means within a preceding crop			±4.56		

SEM, standard error of the mean

ha^{-1} was added through the fallen material from medium-duration pigeon pea cultivars.

These results also differ from those reported by Kumar Rao *et al.* (1983) who found that a preceding crop of medium-duration pigeon pea significantly increased the yield of a succeeding maize crop. However, a comparison of the soil fertility of the Vertisol in the present study as well as in that by Kumar Rao *et al.* (1983) shows that the Vertisols differed considerably in their native soil fertility. For example, the Vertisol site in the study by Kumar Rao *et al.* (1983) had a total N content of 300 mg kg^{-1} soil but the Vertisol site in the present study contained 652 mg N kg^{-1} soil in the 0–15 cm layer which is more than double the total N content of the Vertisol used by Kumar Rao *et al.* (1983).

Additional data on the site in the present study indicate that the soil had a better supply of organic matter and this resulted in an accumulation of large amounts of mineral N through the mineralization of soil organic N in different treatments. The weed-free fallow accumulated the largest amounts of mineral N and thus gave least response to applied N. The present results emphasize that the residual effects of pigeon pea would greatly depend on the native fertility of the soil in addition to other crop and environment-related factors. The Vertisol used in the present study was at least moderately fertile and thus the small residual effects of pigeon pea in terms of N economy of the system were not observed against a relatively larger pool of mineral N released by the soil.

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