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RESIDUAL EFFECT OF PIGEONPEA (*CAJANUS CAJAN*) ON YIELD AND NITROGEN RESPONSE OF MAIZE†

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SUMMARY

Field experiments during 1979 and 1980 on a Vertisol soil at ICRISAT Centre, Hyderabad, India, examined the residual effect of pigeonpea (*Cajanus cajan*) on growth and yield of a following maize crop. Pigeonpea was grown alone or as an intercrop with sorghum fertilized or not with 80 kg N ha^{-1}. Sorghum alone and fallow treatments were included for comparison. In the first year, the sorghum/pigeonpea intercrop produced the largest grain and dry matter yields, but the yield of intercropped pigeonpea was about 50% less than that produced by the sole crop. Pigeonpea alone had a large residual effect on maize, increasing grain yield by 57% and total plant dry matter by 32% compared with corresponding values after fallow. In comparison, intercrop pigeonpea had little residual effect. Maize following either fallow, sorghum grown alone, with or without N, or the sorghum/pigeonpea intercrop, again with or without N, required fertilizer equivalent to 38–49 kg N ha^{-1} in order to attain yields similar to that of unfertilized maize following sole crop pigeonpea.

Legumes in a rotation can improve soil fertility, particularly soil nitrogen (N) content, and thereby increase the productivity of subsequent non-legume crops. For example, Sen *et al.* (1962) have reported a beneficial effect on maize from a preceding crop of berseem in North India and Jones (1974) has shown that a previous crop of groundnut, but not cowpea, increased the yield of maize at Samaru, Nigeria. Giri and De (1979) and Ahlawat *et al.* (1981) have made similar observations in India, the magnitude of the benefit to the cereal varying between 18 and 68 kg N ha^{-1} depending on the preceding legume. Nair *et al.* (1979) and Searle *et al.* (1981) have also described how cereal–legume intercrops can benefit a subsequent cereal crop.

Pigeonpea (*Cajanus cajan* L. Millsp) is an important grain legume crop in the semi-arid tropics. In India, it is grown most often as an intercrop with sorghum, millet or maize, although mixtures with sorghum are the most common combination. Pigeonpea is also gaining popularity as a sole crop. However, very little information is available on the residual effects of either sole or intercropped pigeonpea on the growth and yield of a subsequent cereal crop. This paper describes the methods employed and the results obtained in estimating quantitatively the residual effects on maize of the preceding crop and cropping system.

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MATERIALS AND METHODS

Experiments were conducted during the rainy seasons of 1979 and 1980 at ICRISAT Centre, Hyderabad, India (17.5° N, 78.5° E, 545 m altitude). The plots were located on a black Vertisol soil having pH 8.3, 0.03% total N, 40 ppm available N (estimated by an alkaline-permanganate method; Subbiah and Asija, 1956) and 4 ppm available P (Olsen) in the top 30 cm. A split-plot design was used, with cropping systems in the first year as main plots and N applications to maize in the second year as sub-plots. The six main treatments sown during the rainy season of 1979 are given below (with respective designations):

1.	Pigeonpea (cv. ICP-1) without N	PP
2.	Sorghum (cv. CSH-6) without N	S-0 N
3.	Sorghum given 80 kg N ha^{-1}	S-80 N
4.	Sorghum/pigeonpea intercrop without N	SP-0 N
5.	Sorghum/pigeonpea intercrop with 80 kg N ha^{-1} supplied in a band to the sorghum only	SP-80 N
6.	Fallow	F

Treatments were grown in four complete randomized blocks on individual plots measuring 50 m x 6 m. Before planting, single superphosphate was applied uniformly to the whole field at a rate which supplied 17 kg P ha^{-1}. The crops were sown on 3 August 1979 on broad beds 1.5 m wide. Sorghum and pigeonpea were seeded in rows 45 and 150 cm apart, respectively. In the intercropping treatments, pigeonpea and sorghum were grown in a constant arrangement of two rows of sorghum bordering one row of pigeonpea on each bed, with 45 cm between all rows. A population density of 160,000 plants ha^{-1} for sorghum and 50,000 plants ha^{-1} for pigeonpea was maintained in both the sole and intercrop treatments.

Pigeonpea seeds were inoculated with peat inoculant containing a mixture of four effective strains of *Rhizobium*. The crops were grown under rainfed conditions and the Vertisol retained sufficient water to support good plant growth during the rainy and post-rainy seasons. All plots were hand-weeded as required. The sorghum was harvested on 28 October 1979, 86 days after planting, and the pigeonpea on 31 January 1980 (after 181 days). At harvest, records of grain and total dry matter yields were taken. All the above-ground plant parts which were intact at the end of the season were then removed from the plots.

During the 1980 rainy season, the whole field was disked and prepared with ridges and furrows spaced 75 cm apart. A uniform basal dressing of 17 kg P ha^{-1} was then applied. On 27 June, the whole site was planted with maize cv. Deccan Hybrid 101 at a population density of approximately 67,000 plants ha^{-1}. Each of the former (1979) main plots was divided into five sub-plots measuring 9 m x 6 m. The sub-plots, selected at random, were then given either 0, 20, 40, 60 or 80 kg N ha^{-1}, as urea. The two smaller rates of N were applied before sowing, while the two larger ones were split, 40 kg applied as a basal dressing and the remainder as a top dressing on 27 August. Details of plant height and dry weight, leaf area and cob number were recorded on 72-day-old plants. At maturity, grain and total dry matter yields were recorded from a harvested area of 7 m x 3 m from each sub-plot. Total N contents of the plant material were estimated by a micro-Kjeldahl block digestion method and a Technicon Auto-analyser.

RESULTS AND DISCUSSION

Yields of pigeonpea and sorghum in sole and intercrop systems

The grain and total dry matter yields of pigeonpea and sorghum as sole or intercrops in the main plots sown in 1979 are given in Table 1. All cultivars and cropping systems, as expected, produced large yields. Sorghum yields from unfertilized plots were also large, although the reasons why are not known. It is possible that absence of moisture stress and availability of nutrients in the subsoil below 30 cm might have enabled the sorghum to grow and yield well. Sole and intercropped sorghum produced similar respective yields of grain and total dry matter, which suggests that it suffered relatively little from competition with the pigeonpea. However, intercropping severely depressed both grain and total dry matter yields of pigeonpea relative to the sole crop. Beets (1977), Natarajan and Willey (1980b) and Searle *et al.* (1981) have also shown that when cereals and legumes are grown together, cereal productivity is usually less affected than that of the legume by any competitive interactions. Yields of sorghum, intercropped or not, were also increased by N fertilizer. One of the main advantages of intercropping compared with sole crops is that overall productivity can be improved (Natarajan and Willey, 1980a). This benefit was reflected here by combined yield advantages relative to sole crops of 47 and 37% for grain and plant top dry matter yields, respectively. The overall yield

Table 1. *Grain and total dry matter yields (kg ha^{-1}) of crops grown in the first year (rainy season, 1979)*

Treatment and designation		Seed yield: Actual	Seed yield: Relative to the pure stand	Total dry matter: Actual	Total dry matter: Relative to the pure stand
Pigeonpea (PP)		1630	–	6040	–
Sorghum (S-0 N)		3950	–	9870	–
Sorghum (S-80 N)		5000	–	12610	–
Sorghum/pigeonpea (SP-0 N)	S	3800	0.96	9035	0.92
	PP	840	0.51	2690	0.45
	S + PP		1.47		1.37
Sorghum/pigeonpea (SP-80 N)	S	4730	0.95	11550	0.92
	PP	680	0.42	2460	0.41
	S + PP		1.37		1.33
CV (%)	S	8.1		6.6	
	PP	21.7		21.2	
SE of Means	S	± 177		± 356	
	PP	± 114		± 395	

Table 2. *N concentration (%) in dry matter and N uptake (kg ha^{-1}) in pigeonpea and sorghum grown in the first year (rainy season, 1979)*

Treatment and designation		N(%) Plant top	Grain	Husk	N uptake (kg ha^{-1}) Plant top	Grain	Husk	Total for each species	Total for each treatment
Pigeonpea (PP)		0.71	3.11	0.72	26.3	51.0	5.9	83.2	83.2
Sorghum (S-0 N)		0.35	1.42	0.53	16.5	56.8	6.7	80.0	80.0
Sorghum (S-80 N)		0.48	1.65	0.63	28.7	82.5	10.6	121.8	121.8
Sorghum/pigeonpea (SP-0 N)	S	0.44	1.46	0.54	17.9	55.7	6.5	80.1	
	PP	0.67	3.03	0.67	9.8	25.4	2.9	38.0	118.1
Sorghum/pigeonpea (SP-80 N)	S	0.52	1.58	0.60	27.6	74.4	9.3	111.3	
	PP	0.81	3.09	0.70	12.3	21.4	2.9	36.5	147.8
CV (%):									28
SE of Means:									± 6.8

advantages from intercropping were slightly larger when N fertilizer was not applied (Table 1).

The concentration (%) of N in the pigeonpea at harvest was greater than in sorghum, and was not affected by intercropping (Table 2). Differences in total N uptake by maturity between pigeonpea grown alone and in intercropping were due mainly to differences in plant yield rather than changes in N concentration. Unfertilized sole crops of pigeonpea and sorghum had accumulated similar amounts of N by maturity. Without applied N, the sole crop sorghum removed a similar amount of N as in the intercrop (about 80 kg ha^{-1}), but the N taken up by intercropped pigeonpea (38 kg ha^{-1}) was less than half of that assimilated in pure stands. Natarajan and Willey (1980b) also found that pigeonpea was the poorer competitor for nutrients when intercropped with sorghum, and we have no evidence of transfer of N fixed symbiotically from the legume to the sorghum. Henzell and Vallis (1976) have argued that such a transfer would only be possible if the legume had senesced well before the sorghum plants matured.

Effect of previous crop and cropping system on maize

The effects of cropping history on growth of a subsequent crop of maize were visible within 45 days of planting when no N fertilizer was applied. Plants harvested at 72 days clearly indicated the beneficial residual effect of pigeonpea and poor growth after sorghum given 80 kg N ha^{-1}; they were taller, heavier and more leafy after pigeonpea (Table 3). These effects were evident irrespective of the amount of N given to the maize.

Grain yields of maize were similarly affected by the previous cropping pattern. Again, the most beneficial effect was evident after pigeonpea (Tables 3 and 4) when the maize crop significantly outyielded those following all other treatments, including fallow. This superiority was maintained irrespective of the amount of N applied to the maize, although the magnitude of the yield differences varied (Table 4).

Table 3. *Effect of previous cropping pattern on maize grown without N fertilizer (at 72 days after planting)*

Cropping pattern	Plant height (cm)	Plant dry weight (g)	Leaf area plant^{-1} (cm^2)	Cobs 100 plants^{-1}
Pigeonpea (PP)	179	98	24827	102
Sorghum (S-0 N)	110	50	20603	68
Sorghum (S-80 N)	105	46	13565	60
Sorghum/pigeonpea (SP-0 N)	125	56	19874	60
Sorghum/pigeonpea (SP-80 N)	128	52	18956	73
Fallow (F)	128	57	17030	83
SE of Means	9	10	3484	8
CV (%)	14.0	17.6	36.4	22.3

Pigeonpea was also most beneficial in terms of total dry matter yield of maize (Table 5), although there were significant differences in response depending on the amount of N applied to the maize. There were no significant interactions between the effects of previous crops and the rates of N applied to maize. The relative beneficial effect of pigeonpea, when grown alone, was not significantly affected by the rate of fertilizer application to maize.

Nitrogen taken up by the maize crop is an index of the N mineralized from residues of preceding crops. The N uptake of maize after fallow can be considered to be an index of the N mineralized from organic reserves present in the soil before the cropping sequences were imposed, so that differences in N uptake by maize after fallow and after a given crop indicate the available (or residual) N from that previous crop. Table 6 shows that a preceding crop of pigeonpea promoted a greater N uptake by maize than after either sorghum (grown alone or intercropped) or fallow, irrespective of the amount of N given to the maize. The relations between rate of applied N and total dry matter production and total N uptake by maize, following each of the previous crops,

Table 4. *Effect of previous cropping and N fertilizer (kg ha^{-1}) applied to maize on grain yields of maize (kg ha^{-1})*

	Nitrogen rates (kg ha^{-1})					
Previous crop	0	20	40	60	80	Mean
Pigeonpea (PP)	1364	2095	2595	3153	4385	2720
Sorghum (S-0 N)	300	620	1450	1924	2963	1450
Sorghum (S-80 N)	508	954	1373	2105	3463	1680
Sorghum/pigeonpea (SP-0 N)	768	861	1406	2236	2956	1650
Sorghum/pigeonpea (SP-80 N)	629	1064	1893	2148	3411	1830
Fallow (F)	530	898	1387	2765	3086	1730
Mean	680	1080	1680	2390	3380	

Comparison of means	*SE of means*
Previous crops	± 119
Nitrogen rates	± 85
Nitrogen rates at a given level of previous crop	± 208
Previous crop at the same or different nitrogen rates	± 220

Table 5. *Effect of previous cropping and N fertilizer (kg ha^{-1}) applied to maize on total dry matter yield of maize (kg ha^{-1})*

	Nitrogen rates (kg ha^{-1})					
Previous crop	0	20	40	60	80	Mean
Pigeonpea (PP)	5925	7842	8856	8863	11016	8500
Sorghum (S-0 N)	2177	3945	6148	6651	8901	5560
Sorghum (S-80 N)	2249	4547	6292	6922	9175	5840
Sorghum/pigeonpea (SP-0 N)	3267	4618	5979	7175	8574	5920
Sorghum/pigeonpea (SP-80 N)	3049	5176	7177	6941	9150	6300
Fallow (F)	3129	4931	6466	8550	9089	6430
Mean	3300	5180	6820	7520	9320	

Comparisons of means	*SE of means*
Previous crop	± 295
Nitrogen rates	± 178
Nitrogen rates at a given level of previous crop	± 435
Previous crop at the same or different nitrogen rates	± 488

are shown in Tables 7 and 8 and (since the slopes were not significantly different) for three selected treatments only in Figs 1 and 2. The relations were linear and provide a useful means of estimating the effect of the previous crop on the N requirements of maize. Data show that fertilizing at 80 kg N ha^{-1} is below the optimum for maize production. The regression lines were tested for homogeneity and their slopes were found not to be significantly different. Hence, the rates of change in total dry matter yield and total N uptake by maize in response to fertilizer-N are not dependent on the previous crop. Intercept differences were examined by the Student–Newman–Keuls test (Zar,

Table 6. *Total N uptake (kg ha^{-1}) by maize as affected by previous crop and N application (kg ha^{-1}) to the maize*

	Nitrogen rates (kg ha^{-1})					
Previous crop	0	20	40	60	80	Mean
Pigeonpea (PP)	34	45	55	65	84	57
Sorghum (S-0 N)	13	21	36	44	63	35
Sorghum (S-80 N)	16	28	36	46	71	39
Sorghum/pigeonpea (SP-0 N)	23	25	35	53	63	40
Sorghum/pigeonpea (SP-80 N)	19	30	44	48	69	42
Fallow (F)	17	25	34	57	62	39
Mean	20	29	40	52	68	

Comparisons of means	*SE of means*
Previous crops	± 2.2
Nitrogen rates	± 1.3
Nitrogen rates at a given level of previous crop	± 3.2
Previous crop at the same or different nitrogen rates	± 3.6

Table 7. *Relations between total top dry matter yield (Y) and nitrogen application to maize (X) as affected by previous crop ($Y = a + bx$; both Y and X are in kg ha^{-1}; slopes are not significantly different at $P < 0.01$)*

Previous crop	a†	b	r^2
Pigeonpea (PP)	6260a	56	0.77
Sorghum (S-0 N)	2333b	81	0.80
Sorghum (S-80 N)	2591bc	81	0.88
Sorghum/pigeonpea (SP-0 N)	3288bc	66	0.88
Sorghum/pigeonpea (SP-80 N)	3505c	70	0.67
Fallow (F)	3325c	78	0.85

† Values followed by a common letter are not statistically different from each other.

1974) and, as shown in Tables 7 and 8, the intercept of pigeonpea was significantly different from the rest for total dry matter yield and total N uptake. The intercept of the N response line for pigeonpea corresponded to 6260 kg total dry matter ha^{-1}. To achieve the same dry matter production after fallow, sorghum at 0 N and 80 N, and sorghum intercropped with pigeonpea at 0 N and 80 N, required applications of 38, 49, 45, 45 and 39 kg N ha^{-1}, respectively (Fig. 3). We assume that sorghum would have derived most of its N from the soil, thereby depleting the soil pool, while pigeonpea would have assimilated most N from symbiosis with *Rhizobium*, though we do not have experimental evidence relevant to this hypothesis. However, total and available N values in the soil profile (0–30 cm) after the maize harvest revealed few, if any, differences due to previous cropping treatments (Table 9). The beneficial effect of sole crop pigeonpea could be due to enhanced mineralization of legume residues and/or dinitrogen fixation increasing the N available for carry-over to subsequent crops. Although the mechanisms underlying this beneficial effect have not been clarified, the considerable amount of leaf fall from pigeonpea, reported to be able to provide 30–40 kg N ha^{-1} (Sheldrake and Narayanan, 1979; Kumar Rao *et al.*, 1981), could be a contributing factor. Although we

Table 8. *Relations between N uptake (Y) and nitrogen application to maize (X) as affected by previous crop ($Y = a + bx$; both Y and X are in kg ha^{-1}; slopes are not significantly different at $P < 0.01$)*

Previous crop	a†	b	r^2
Pigeonpea (PP)	32.5a	0.60	0.88
Sorghum (S-0 N)	10.9b	0.61	0.84
Sorghum (S-80 N)	13.4bc	0.64	0.84
Sorghum/pigeonpea (SP-0 N)	18.6bc	0.53	0.86
Sorghum/pigeonpea (SP-80 N)	18.8c	0.58	0.74
Fallow (F)	14.3bc	0.61	0.85

† Values followed by a common letter are not statistically different from each other.

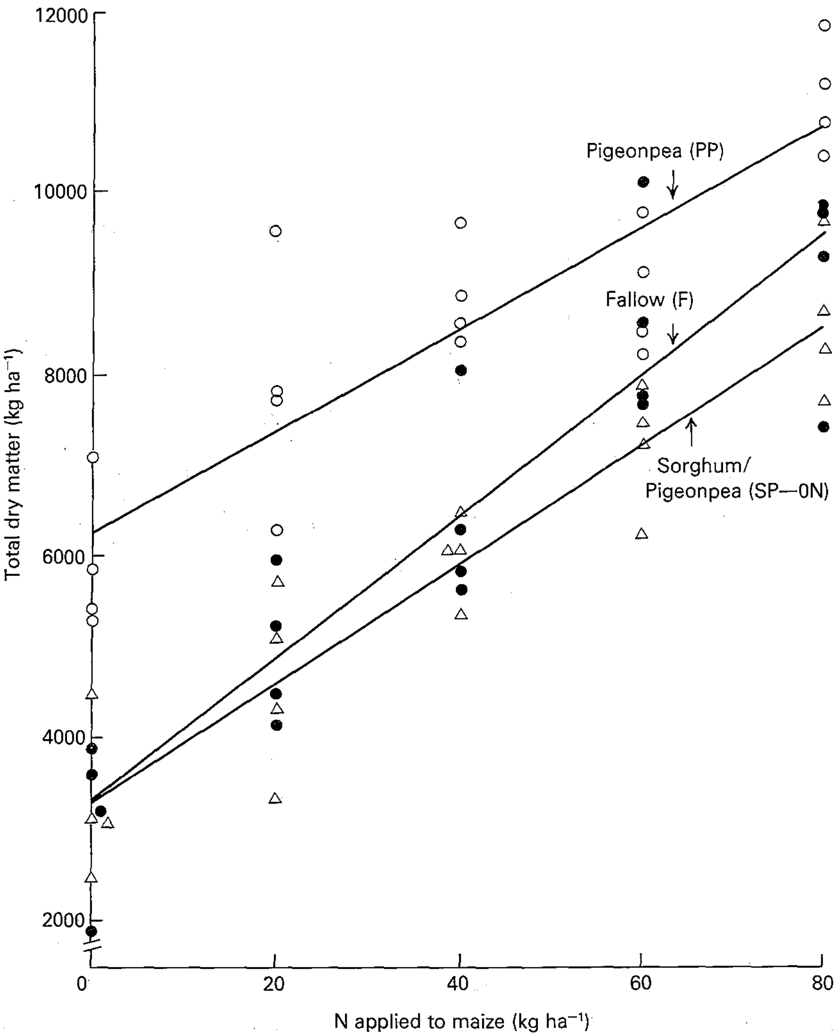

Fig. 1. Relations between total dry matter yield and nitrogen application to maize as affected by previous crop of pigeonpea (○), sorghum/pigeonpea at 0 N (△) and fallow (●).

Table 9. *Total N (%) and available N (ppm) in top-soil (0–30 cm) after maize harvest from plots not given fertilizer-N*

Cropping pattern	Total N (%)	Available N (ppm)
Pigeonpea (PP)	0.032 ± 0.002	37.3 ± 3.4
Sorghum (S-0 N)	0.032 ± 0.003	35.5 ± 3.2
Sorghum (S-80 N)	0.031 ± 0.001	36.2 ± 4.6
Sorghum/pigeonpea (SP-0 N)	0.033 ± 0.003	30.6 ± 3.9
Sorghum/pigeonpea (SP-80 N)	0.034 ± 0.003	39.0 ± 3.1
Fallow (F)	0.031 ± 0.002	36.5 ± 5.5

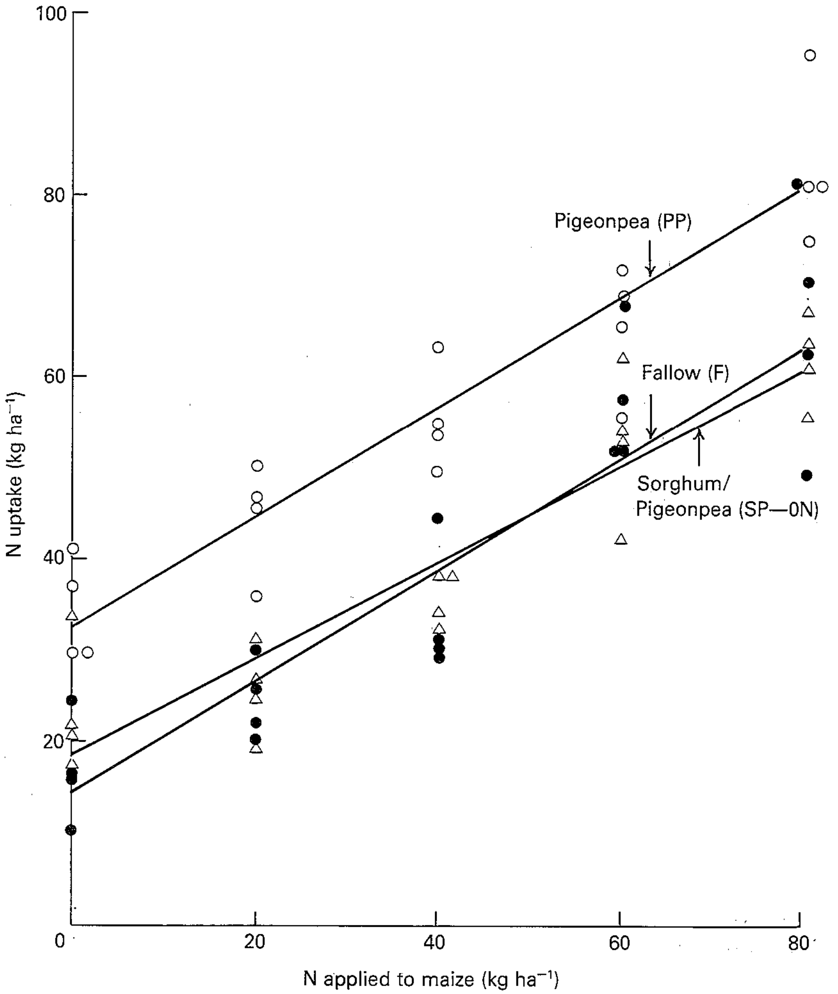

Fig. 2. Relations between N uptake and N application to maize as affected by previous crop of pigeonpea (○), sorghum/pigeonpea at 0 N (△) and fallow (●).

did not measure the amount of leaf fall, it was less in intercropping than in pure stands. Even larger inputs of residual-N from the legume would have been obtained if shoots had been returned to the soil after harvest.

The smaller residual N values after the sorghum/pigeonpea intercrop compared with monocropped pigeonpea may have been caused by suppression of legume growth in the intercrop. This would result in poor nodulation and dinitrogen fixation and, consequently, a greater depletion of soil-N. Nambiar and Dart (1980) have found that groundnut nodulated poorly, and fixed less dinitrogen, when intercropped with pearl millet than when grown alone.

A cursory examination of the economic benefits over a two year period from the pigeonpea treatments at zero N revealed a gross return of Rs† 6783 ha^{-1}

† Rs denotes Indian rupees.

Table 10. *Gross economic returns from different cropping patterns (1st year, (1979) for different cropping systems; 2nd year, (1980) for maize at 0 N)*

Cropping pattern	Gross returns (Rs ha^{-1}) 1979	1980	Total†
Pigeonpea (PP)	4758	2025	6783
Sorghum (S-0 N)	4377	533	4910
Sorghum (S-80 N)	5563	758	6321
Sorghum/pigeonpea (SP-0 N)	6554	1133	7687
Sorghum/pigeonpea (SP-80 N)	7181	965	8146
Fallow (F)	0	869	869

† Includes the value of grain, stalks and husk.

from pigeonpea alone compared with Rs 7687 ha^{-1} from intercropping (Table 10). Our data (Fig. 3) clearly indicate that maize grown after a sorghum/pigeonpea intercrop required 45 kg N ha^{-1} to achieve total dry matter yields similar to those obtained after sole pigeonpea. Even after deducting the cost of 45 kg N (about Rs 202) from the gross returns, the total monetary benefit from pigeonpea intercropped with sorghum was still greater than from sole pigeonpea.

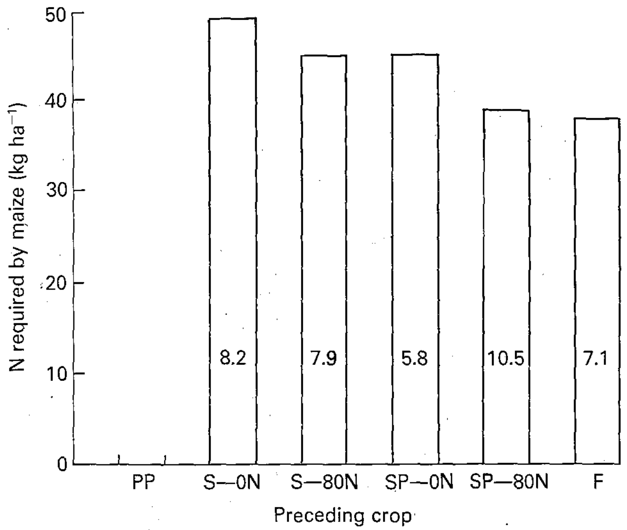

Fig. 3. Effect of preceding crop on N required by maize to produce a total dry matter yield equivalent to that of unfertilized maize after pigeonpea (6260 kg ha^{-1}). (Standard errors of estimates are given within each column.)

CONCLUSIONS

The present experiment, conducted for one cropping cycle only, has shown the beneficial effect of a preceding pigeonpea crop on a following crop of maize; it increased grain yield by 57% and total dry matter by 32% compared with a rotation with fallow. Although the intercropping of sorghum and pigeonpea was more productive in terms of overall grain yield, and more remunerative, than sorghum grown alone, the intercrop pigeonpea did not benefit the succeeding maize crop. There is a need to examine further the various sources of the N which is made available from these cropping combinations to the subsequent cereal crop.

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