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EFFECT OF INTERCROPPING ON NODULATION AND N_2-FIXATION BY GROUNDNUT†

By P. T. C. NAMBIAR, M. R. RAO, M. S. REDDY, C. N. FLOYD, P. J. DART *and* R. W. WILLEY

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru PO 502 324, AP, India

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SUMMARY

Nodulation and N_2-fixation of groundnut were investigated in sole and intercropping systems. Intercropping with pearl millet, maize, or sorghum reduced nodulation and N_2-fixation. This effect is ascribed to the shading of groundnut by the cereal component and the consequent decrease in photosynthesis of the legume canopy.

Growing two or more crops together on the same land is a traditional cropping system in the rainfed areas of many tropical countries. This practice is known as intercropping or mixed cropping, depending on whether the crops are sown in separate rows or mixed within the row, respectively, and it can produce larger and more dependable yields than those from sole crops (Willey, 1979; Rao and Willey, 1980). Although many species are intercropped, cereal/grain legume combinations are common. Similarly, mixtures of grasses and forage legumes are common in many temperate countries. One of the reasons for including legumes is that they have the potential to fix at least some of their own requirement for nitrogen and so may conserve soil nitrogen to the benefit of subsequent crops.

Groundnuts (*Arachis hypogaea*) are commonly intercropped with cereals (millet, maize or sorghum) or with long-season, widely-spaced crops such as cotton, pigeonpea, castor or cassava (Reddy *et al.*, 1980). Although soyabeans and *Phaseolus* beans have been examined for nodulation and N_2-fixation in intercropping with sorghum and maize, respectively (Wahua and Miller, 1978; Graham and Rosas, 1980), no information is available on the intercropping effects on fixation by groundnuts. This paper summarizes the results of several studies on N_2-fixation in this species when grown as a sole crop or when intercropped with pearl millet (*Pennisetum typhoides*), maize (*Zea mays*) or sorghum (*Sorghum bicolor*).

MATERIALS AND METHODS

Nodulation and N_2-fixation were examined in three sets of experiments conducted on Alfisols at ICRISAT Center, Patancheru, Andhra Pradesh, India during 1977–80.

† ICRISAT Journal Article 214.

Crop conditions

(i) *Pearl millet/groundnut.* The first experiment was conducted during the 1978 rainy season. Sole treatments of each crop, and a *replacement* intercrop treatment of one row millet:three rows of groundnut, were grown in rows 30 cm apart, with four replicates in a randomized block design (RBD). Plant spacing within rows was the same for sole crops and intercrops, namely 15 cm for millet and 14.3 cm for groundnuts, giving near-optimum populations for the respective sole crops (22.2 and 23.3 plants m^{-2} for millet and groundnuts, respectively). A basal application of 50 kg ha^{-1} P_2O_5 was applied to all plots; millet was top dressed with N at the same rate per row in both sole and intercrop (80 kg N ha^{-1}). Both crops were sown on 25 June; millet (cv. BK-560) was harvested 82 days after sowing and the groundnut (cv. Robut 33-1) 23 days later (105 days).

During 1980 a second experiment was conducted, using the same cultivars and populations as in 1978. The treatments in RBD and four replications were: (a) sole crop groundnuts, (b) 1:3 intercrop without N and (c) 1:3 intercrop with 80 kg N ha^{-1} applied to the millet alone. All treatments received 50 kg P_2O_5 ha^{-1} at planting. Observations on nodulation and N_2-fixation were recorded at about 10-day intervals during the growing season.

(ii) *Maize/groundnut.* These experiments were conducted in RBD with four replicates, during the rainy seasons of 1979 and 1980. The treatments included sole crop groundnuts and maize/groundnut intercrops at four levels of N (0, 50, 100 and 150 kg N ha^{-1}). All treatments received a uniform dose of 50 kg P_2O_5 ha^{-1}, but nitrogen was applied only to maize (as urea) in two equal top dressings at 15 and 30 days after planting. Crops were sown on raised beds 1.5 m wide, sole maize (cv. SB 23) at two rows per bed with 90 cm between rows (6 plants m^{-2}) and sole groundnuts (cv. TMV-2) at four rows per bed with 30 cm between rows (26.7 plants m^{-2}). The intercrop was created by sowing two groundnut rows between two rows of maize, to give rows 30 cm apart and populations of 6 plants m^{-2} of maize (100% of sole crop) plus 13.3 plants m^{-2} of groundnut (50% of sole crop). Observations on nodulation and N_2-fixation were recorded once at 70 days after sowing during 1979, and on five occasions (39, 56, 67, 84, and 90 days after sowing) during 1980. Both crops were harvested at 100 days after sowing.

(iii) *Sorghum/groundnut.* This experiment was conducted during the 1980 summer season. Six groundnut cultivars, representing the Spanish (Chico 17200, TMV-2), Valencia (MH 2, Gangapuri) and Virginia (Robut 33-1, MK 374) types, were grown as sole crops and as intercrops with sorghum (cv. CSH 8).

The intercrop was a two groundnut:one sorghum replacement series using 34 cm rows and optimum sole crop populations for both species, with four replicates in a split-plot design. Plant spacing within rows was the same for sole crops and intercrops, namely 16 cm for sorghum and 9 cm for groundnuts. Two levels of shading (*partial* and *full*) were created in the intercrops by manipulating the sorghum canopy; alternate pairs of leaves were removed to provide partial shade, and full shade was created by the normal sorghum canopy. A basal dressing of 50 kg ha^{-1} P_2O_5 was applied to all plots before planting on 27 December 1979. The sorghum was top dressed with N 40 days after sowing at a rate per row equivalent to 80 kg ha^{-1} in the sole crop.

Light measurements

To quantify the light available to groundnuts under the cereal canopy in the intercropped situation, tube solarimeters (Szeicz *et al.*, 1964) were placed just above the groundnut canopy and data from them compared with those from a control solarimeter kept in the open.

Acetylene reduction assay

N_2-fixation activity in sole and intercropped groundnuts was estimated using the acetylene reduction assay (Dart *et al.*, 1972). Twenty-five plants were sampled, and their root systems, from which shoots had been separated, were incubated with 10% acetylene in 6-litre gas-tight containers. Gas samples were taken after 30 minutes, and their ethylene content was determined using a gas chromatograph with a flame ionization detector.

RESULTS

Millet/groundnut. In the 1978 rainy season, nodulation and N_2-fixation by groundnuts intercropped with pearl millet were poor compared to the sole crop situation (Table 1; Fig. 1). There were no marked differences between the sole and intercropped groundnuts during the initial stages of crop growth or after the millet had been harvested, but N_2-fixation was significantly affected during the period of 60–70 days after planting, when seasonal nitrogenase activities reached peak values. All three groundnut rows between the millet were affected similarly (Table 2). In the second experiment, conducted during 1980, intercropping reduced both nodule weight and nitrogenase activity per plant irrespective of the amount of inorganic nitrogen applied to the millet (Fig. 2). Differences between the two nitrogen levels (0 and 80 kg N ha^{-1}) were not significant.

Maize/groundnut. During 1979 the unfertilized maize intercrop did not affect nodulation and N_2-fixation of groundnuts, but fertilized maize affected fixation markedly (Table 3). As the amount of nitrogen added to the maize

Table 1. *Nodulation of groundnut plants in sole crops and intercropped with pearl millet (rainy season 1978)*

Days after planting	Nodule weight (mg $plant^{-1}$) Sole crop	Intercrop	SE
39	85	82	8
52	172	117	14
81	440	255	41

Table 2. *N_2-fixation of groundnuts from different rows in a millet/groundnut intercrop at 42 days after planting (rainy season 1978)*

Treatment	Nodule weight (mg $plant^{-1}$)	Nitrogenase activity (μmoles ethylene $plant^{-1}$ $hour^{-1}$)
Sole crop	107	21.9
Intercrop:		
(a) Middle row	69	10.4
(b) Side row (adjacent to millet)	74	11.3
SE	14.0	2.4

increased, nodule number, nodule weight, and N_2-fixation of groundnuts were reduced. Pod yields per plant were correspondingly affected in intercropping, the yield reduction being most acute at the largest rates of nitrogen application to maize. Similar results were observed during the 1980 experiment, and at all stages of groundnut development (Figs 3 and 4).

Sorghum/groundnut. As with millet and maize, intercropping with sorghum significantly reduced nodule number, nodule weight and N_2-fixation in all the six cultivars of groundnut tested (Table 4). The effect of a *full* canopy of sorghum was more severe than that of the *partial* canopy where alternate leaves of sorghum had been removed. Although groundnut cultivars differed slightly in their ability to fix dinitrogen in the intercrop situation, the genotype x system interaction was not significant, which suggests that any genotypic differences in intercropping reflected genotype differences in sole crops. Yields

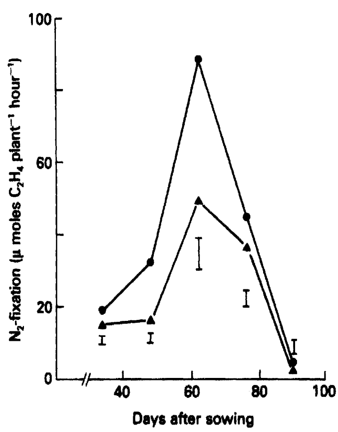

Fig. 1. N_2-fixation of sole (●) and intercropped (▲) groundnuts (3 rows of groundnut:1 row of millet). The millet was fertilized at a rate equivalent to 80 kg N ha^{-1} (Rainy season 1978. Bars represent SE).

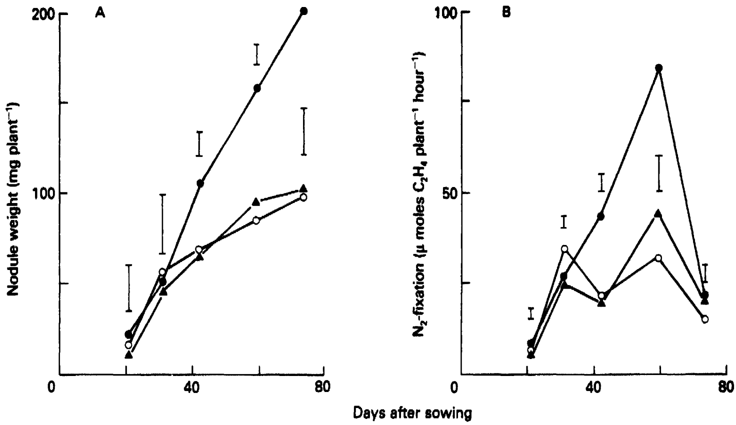

Fig. 2. Nodulation (A) and N_2-fixation (B) of sole crop groundnuts (●) and three rows of groundnut intercropped with one row of N-fertilized millet (▲), or millet without N fertilization (○). (Rainy season 1980. Bars represent SE).

per plant were also reduced considerably in intercropping except in the case of cvs TMV-2, Robut 33-1 and MK 374 beneath the partial sorghum canopy, where yields were not affected. In general, the partial canopy allowed better performance of groundnuts than the normal sorghum canopy.

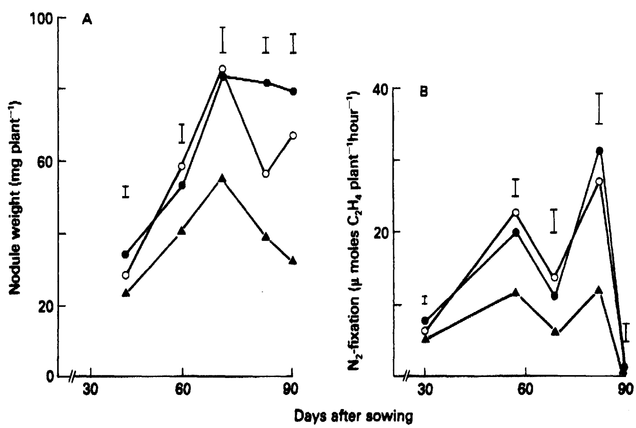

Fig. 3. Effect of intercropping with maize on nodulation (A) and N_2-fixation (B) of groundnuts. Sole crop groundnuts (●), 2 rows of groundnut intercropped with 2 rows of maize without nitrogen (○) and with 100 kg N ha^{-1} (▲). Bars represent SE.

Table 3. *Nodulation, N_2-fixation and pod yield of groundnuts in sole crops and intercropped with maize at 70 days after sowing (1979 rainy season)*

Treatment	Nodule number plant^{-1}	Nodule weight (mg plant^{-1})	N_2-fixation (μmoles C_2H_4 plant^{-1} h^{-1})	Light transmitted through maize canopy (%)	Pod yield (g plant^{-1})
Sole crop	171	124	21.1	100	3.94
Intercrop:					
N 0	160	117	20.2	67	3.07
N 50	165	93	9.4	54	2.43
N 100	150	78	7.0	43	2.35
N 150	134	65	3.5	46	2.09
SE	15.4	11	1.9	–	0.38

DISCUSSION

N_2-fixation of groundnut was affected adversely in all the three intercropping situations examined here. Two possible explanations for such effects are (a) inhibition of nodulation by the nitrogen fertilizer applied to the cereal, or (b) adverse shading effects due to the tall cereal canopy. Although nitrogen was applied only to the cereal in all the experiments, groundnut plants may still have been able to exploit the inorganic nitrogen because of close row spacing (30 cm) and the proximity of root systems. However, in the millet/groundnut intercrop plants from the middle row, well away from the fertilizer placement, were affected similarly to those from rows adjacent to millet. Moreover, in the 1980 experiment, N_2-fixation was less even when millet had not been fertilized with nitrogen. Hence, applied nitrogen was possibly not the main cause of the relatively poor dinitrogen fixation rates.

Table 4. *Nodulation and N_2-fixation of six groundnut cultivars in sole crops and intercropped with sorghum at 70 days after planting*

Cultivars	Nodule number plant^{-1}			Nodule weight (mg plant^{-1})			N_2-fixation (μmoles C_2H_4 plant^{-1} h^{-1})			Yield plant^{-1} (% of sole crop)	
	Sole	Intercrop		Sole	Intercrop		Sole	Intercrop			
		Partial† canopy	Normal canopy		Partial† canopy	Normal canopy		Partial† canopy	Normal canopy	Partial† canopy	Normal canopy
Chico 17200	104	75	64	74	46	36	15.2	11.8	6.8	72	58
TMV-2	108	81	64	99	78	61	18.1	12.6	8.3	120	84
MK 374	190	137	100	139	78	44	25.8	23.6	12.3	113	93
Robut 33-1	118	86	75	–	–	–	21.5	15.9	12.2	100	76
MH 2	151	66	68	77	43	38	15.4	7.9	9.1	78	66
Gangapuri	137	84	62	108	64	44	15.7	10.6	6.5	78	70
SE (for treatment mean)		11			6			1.4			

† Alternate leaves were removed from sorghum plants to increase the light transmitted through the cereal canopy. At the time of assay, sorghum in the partial canopy transmitted 57% of the light received compared with 42% through the normal canopy.

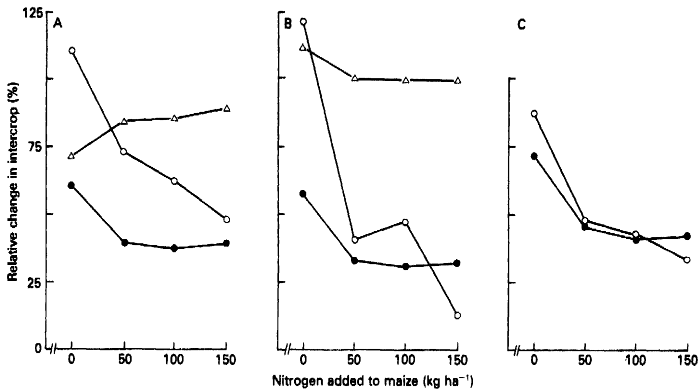

Fig. 4. Effect of nitrogen fertilization of maize on N_2-fixation (○) and top growth (△) of the companion groundnut in a maize/groundnut intercrop; rainy season 1980. (●) indicates light available to the groundnut crop. All values expressed as percentages of those for sole crop groundnuts; (A) 57 days, (B) 69 days, and (C) 80 days after sowing.

Measurements confirmed that light reaching the groundnut canopy in the intercropped situation was at least 33% less than that available to the sole crop. As the rate of fertilizer nitrogen increased so did the growth of the cereal, and even less light reached the groundnut plants. When alternate leaves were removed from the sorghum plants the intercropped groundnut plants nodulated better and fixed more nitrogen (Table 4). Hence it seems more likely that competition for light was the major cause of the poor dinitrogen fixation of intercropped groundnuts. However, the maize/groundnut combination given 150 kg N ha^{-1} was an exception. Here, although the light available to groundnuts was the same as at 100 kg N ha^{-1}, nitrogenase activity was significantly smaller (Table 3 and Fig. 4). This may reflect a confounding effect of light and inorganic nitrogen at this largest rate of fertilizer application.

Reduced light in intercropping situations could affect N_2-fixation by restricting photosynthesis of host shoots and so the energy supply to the nodules (Bethlenfalvay and Philips, 1977). This view is supported by earlier work at ICRISAT, where artificial shading to cut off 60% radiation throughout a day decreased N_2-fixation of groundnuts by 30% during the following day (Nambiar and Dart, 1980). Wahua and Miller (1978) have reported that dinitrogen fixation by soyabeans intercropped with tall sorghum was reduced by 99% compared to that of the sole crop; nodule number as well as specific fixation activity were affected similarly and these decreases were attributed to the shading effect of sorghum. However, in a maize/climbing bean intercropping system, Graham and Rosas (1980) did not detect any decrease in the N_2-fixation of beans because seasonal fixation rates had peaked before the competition for light and nutrients from maize affected the beans. Although nodule number and weight were affected adversely in the present intercropping experiments (Tables 3 and 4), it was not clear if the decrease in irradiance had restricted nodule formation *per se* and/or the growth and activity of nodules.

Any effects of intercropping on N_2-fixation of legumes has an important practical implication with respect to the nitrogen economy of the cropping system. Sole cropping of groundnuts has shown considerable residual effects on subsequent cereal crops (Jones, 1974; Giri and De, 1979; Nambiar and Dart, 1980). A reduction in the N_2-fixation of intercropped groundnuts suggests that the residual effect in these situations may be less than that expected from the general growth and yield of the legume crop. For example, an intercrop situation which produces a groundnut yield equivalent to 50% of that from the sole crop may not give half the residual benefit of the sole crop. Hence, further investigations are needed to develop intercropping systems in which N_2-fixation by groundnuts is less restricted, either by using cereal cultivars which are less competitive, or by manipulating the nitrogen fertilization practices for the cereal.

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