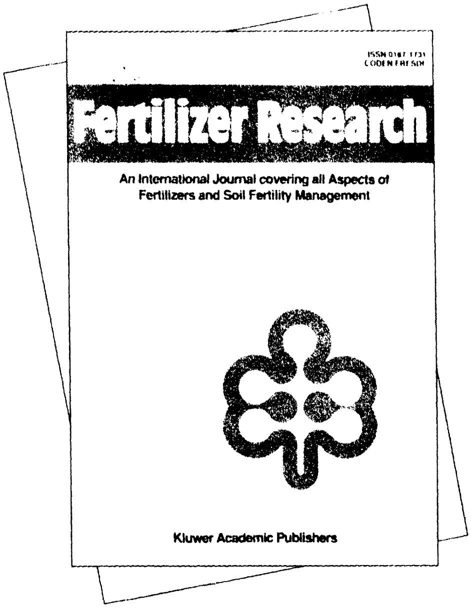
ISSN 0167-1731
OFFPRINT FROM



1052

Fertilizer Research

An International Journal covering all Aspects of Fertilizer and Soil Fertility Management

Fertilizer Research publishes original papers and short communications based on research results, as well as literature- and book reviews dealing with fertilizers and soil fertility management. Occasionally, special issues will be dedicated to the proceedings of symposia and workshops. Contributions are accepted in the fields of inorganic, organic and biofertilizers in relation to crop and forest production and quality, soil productivity as related to soil fertility, chemistry and microbiology, and the environmental and economic aspects of fertilizer adoption and use. Papers in the area of fertilizer technology covering chemical processing, engineering, identification and characterization of fertilizer raw materials, fertilizer application equipment, pollution, economics and marketing are also invited. All contributions should be submitted in English and are subject to peer reviewing.

Fertilizer Research is abstracted/indexed in *Biological Abstracts, Chemical Abstracts, Current Advances in Plant Science, Soils, Fertilizer and Agricola, SciSearch, Research Alert, Current Contents/Agriculture, Biology, & Environmental Sciences, Current Awareness in Biological Sciences, CAB Abstracts, Research Trends in Agrochemicals, Geographical Abstracts: Physical Geography, GEOBASE, PASCAL Database*

Kluwer Academic Publishers, P.O. Box 17, 3300 AA Dordrecht, The Netherlands

Fertilizer Research **42:** 315–319, 1995.

JA 1653

Nitrogen balance and root behavior in four pigeonpea-based intercropping systems *

K. Katayama[1], O. Ito[2], R. Matsunaga[2], J.J. Adu-Gyamfi[3], T.P. Rao[3], M.M. Anders[3] & K.K. Lee[3]
[1]*National Agriculture Research Center, 3-1-1, Kannondai, Tsukuba, Ibaraki, 305 Japan;* [2]*Japan International Research Center for Agriculture Sciences 1-2 Ohwashi, Tsukuba, Ibaraki, 305 Japan;* [3]*International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 502 324 India*

Key words: biological N_2 fixation, *Cajanus cajan* L. Millsp. intercropping, minirhizotron, natural ^{15}N abundance, pigeonpea

Introduction

A medium-duration pigeonpea (*Cajanus cajan* L. Millsp.) is usually grown as intercrop. A wide range of crop combination in pigeonpea-based intercropping systems is found in India and eastern Africa (Ofroi and Stern, 1987; Rao and Willey, 1980; Venkateswarlu and Subramanian, 1990). Although much information is available on the production efficiency and monetary advantage of intercropping, very little is known about the nitrogen (N) economy and root behavior. The study was carried out to examine how the nitrogen balance sheet and root development of pigeonpea could be altered by companion crops.

Materials and method

The experiment was conducted during the 1992 rainy season on a shallow Alfisols at ICRISAT Center, near Hyderabad, India. Medium duration pigeonpea (cv. ICP 1–6), hybrid grain sorghum (*Sorghum bicolor* L. Moench cv. CSH 5), pearl millet (*Pennisetum glaucum* L. R.Br. cv. ICMH 89988), groundnut (*Arachis hypogaea* L. cv. ICGS 11) and cowpea (*Vigna unguiculata* Walp. cv. Russian Giant) were sown on the broad bed furrow on 25 June 1992. Spacings for the sole crops were pigeonpea (75 × 20 cm), sorghum (50 × 15 cm), pearl millet (50 × 15 cm), groundnut (37.5 × 10 cm), and cowpea (50 × 10 cm). The ratio of the row arrangements in the intercrops was 2:1 for all combinations except the groundnut/pigeonpea which was 4:1. The spacing arrangements gave an identical number of plants on area basis for each component crop in sole and intercropping system with the exception of pigeonpea. All plots received uniform basal application of 14.4 kg N ha^{-1} as urea and 36.9 kg P ha^{-1} as single superphosphate prior to sowing. The experimental layout was a randomized complete block design with three replications. The size of each plot was 6 m × 12 m, consisting of 8 broad beds with 75 cm width.

The crops were harvested at maturity, 83, 105, 110, 130 and 209 days after sowing (DAS) for pearl millet, groundnut, sorghum, cowpea and pigeonpea, respectively. Land equivalent ratio (LER) for yield was used to evaluate the biological efficiency of the intercropping system relative to sole cropping (Mead and Willey, 1980). The dry weight of samples was determined after oven-dried at 70 °C, and a portion of the ground material used for N analysis. Total N was determined by indophenol color formation (Chykin, 1969). For analysis of ^{15}N natural abundance, N_2 gas from digested samples was introduced into a mass spectrometer (Finnigan Mat 251). Detailed procedure for ^{15}N natural abundance analysis and the estimation of N derived from air (N_{dfa}) have been described elsewhere (Tobita *et al.*, 1994).

Root length was measured with the minirhizotron method (CIRCON MV9011 agriculture system with MV9390 color CCD microvideo camera). The transparent plastic minirhizotron tubes (58 mm in diameter

* ICRISAT Journal Article No. 1653

Table 1. Shoot dry matter (SDM) at harvest, harvest index (HI) and grain yield of sole crop and intercrop

Crop	Companion crop	SDM ($kg\ ha^{-1}$)	HI	Yield ($kg\ ha^{-1}$)
Pigeonpea	None	8755	0.203	1777
	Sorghum	5771	0.289	1668
	Pearl millet	6150	0.279	1716
	Groundnut	5893	0.303	1786
	Cowpea	2220	0.242	537
	SE (±)	1470**[a]	0.012**	332**
	CV (%)	25.5	4.6	22.2
Sorghum	None	10292	0.274	2820
	Pigeonpea	9191	0.288	2647
	SE (±)	183*	0.013NS	86.4NS
	CV (%)	1.9	4.7	3.2
Pearl millet	None	3950	0.389	1536
	Pigeonpea	4052	0.376	1524
	SE (±)	207NS	0.055NS	202NS
	CV (%)	5.2	14.2	13.2
Groundnut	None	4219	0.330	1392
	Pigeonpea	3150	0.244	769
	SE (±)	71.5**	0.046NS	149*
	CV (%)	1.9	16.1	13.7
Cowpea	None	3862	0.242	935
	Pigeonpea	3824	0.227	868
	SE (±)	718NS	0.018NS	233NS
	CV (%)	18.7	7.5	25.8

[a] *: $p < 0.05$,** $p < 0.01$, NS: not significant.

Table 2. Yield and land equivalent ratio (LER) for yield of four intercrops

Crop combination	Yield ($kg\ ha^{-1}$)	LER[a]
Pigeonpea/Sorghum	4315	1.88
Pigeonpea/Pearl millet	3240	1.96
Pigeonpea/Groundnut	2555	1.56
Pigeonpea/Cowpea	1405	1.23
SE (±)	347**[b]	0.26*
CV (%)	12.0	15.1

[a] LER= (Int Y_p/Sole Y_p) + (Int Y_0/Sole Y_0) where Y_p and Y_0: Yield of pigeonpea and other crops
[b] *: $p < 0.05$, **: $p < 0.01$.

and 100 cm in length) were installed at a 45 degree angle between rows of component crops before sowing. Root length at 10 cm intervals up to 70 cm depth was calculated from the number of roots observed on a video display (Upchurch and Ritchie, 1983).

Results

Growth and yield parameters

Shoot dry matter (SDM) and yield of pigeonpea intercropped with cowpea was significantly lower than sole pigeonpea and other intercropped pigeonpea (Table 1). Harvest index (HI) of sole pigeonpea was significantly lower than intercropped pigeonpea. The SDM and yield of groundnut intercropped with pigeonpea was significantly lower than sole groundnut. These yield reductions could be closely associated with the reduction in SDM. There was no significant difference in yield of sorghum, pearl millet and cowpea of sole and intercrops.

The combined yield of pigeonpea/sorghum was the highest, followed by pigeonpea/pearl millet, pigeonpea/groundnut and pigeonpea/cowpea (Table 2). The LER values for grain yield were greater than the unity in all intercrops. Pigeonpea intercropped with cereals and groundnut recorded a significantly higher LER than pigeonpea with cowpea.

Nitrogen balance sheet

Nitrogen yield of pigeonpea intercropped with cowpea was significantly lower than sole pigeonpea and pigeonpea intercropped with other component crops (Table 3). N yield of groundnut intercropped with pigeonpea was significantly lower than sole groundnut. There was no significant difference in N yield of sorghum, pearl millet and cowpea in sole and intercrops. The proportion of nitrogen derived from air (% N_{dfa}) was significantly higher in pigeonpea intercropped with cereals than pigeonpea intercropped with legumes. There was no significant difference in %N_{dfa} between sole and intercrop of groundnut and cowpea. Although the %N_{dfa} of pigeonpea intercropped with cereals was significantly higher than with legumes and sole pigeonpea, the amount of N derived from air (N_{dfa}) was not significant among pigeonpea treatments except pigeonpea intercropped with cowpea. The N_{dfa}

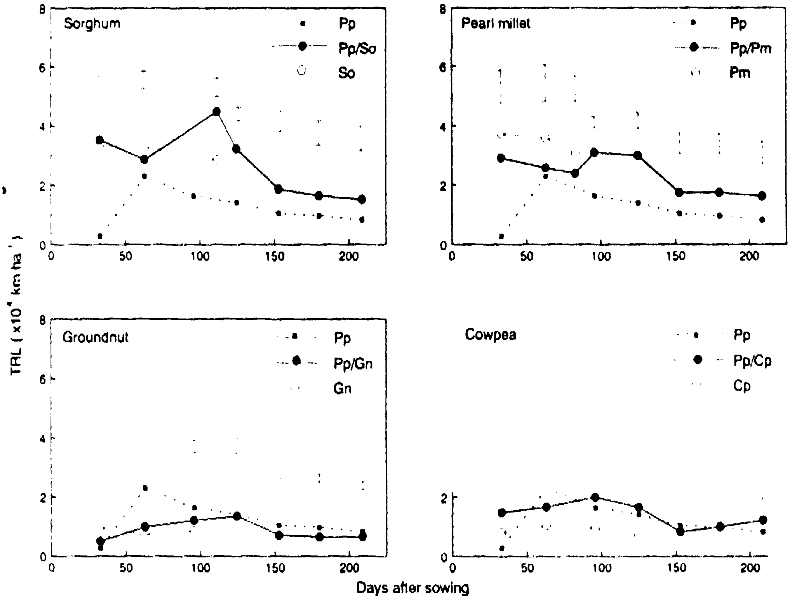


Fig. 1. Seasonal changes in total root length (TRL) of pigeonpea and companion crops in sole and intercropping system. Vertical bars indicate SE's at each sampling time.

for groundnut intercropped with pigeonpea was significantly lower than that of sole groundnut.

Root system development and nitrogen uptake

Total root length (TRL) of sole pigeonpea was significantly lower than sole cereals and pigeonpea/cereals combinations at 33 DAS, and this trend was steady until the end of growth season (Fig. 1). However, there was no significant differences in TRL between legumes in sole crop and legumes intercropped with pigeonpea. The TRL of cereals was significantly higher than that of legumes. The amount of nitrogen derived from soil and fertilizer (N_{dffs}) was calculated using total-N in the plants and $\%N_{dfa}$ in case of legumes in intercropping. Then ratio of N_{dffs} for component crop over pigeonpea was positively correlated with $\%N_{dfa}$ of pigeonpea grain shown in Table 3 (Fig. 2). This suggests that a higher N consumption of companion crop relative to pigeonpea may have increased the dependency on biological nitrogen fixation.

Discussion

Shoot dry matter of pigeonpea intercropped with cowpea was significantly lower than other combinations, though, HI was not affected (Table 1). This reduction in SDM is explained by competition for light between pigeonpea and cowpea. Maximum leaf area index of pigeonpea intercropped with cowpea was 0.41 which was only a third or a fourth compared to those of pigeonpea with other crops (data not shown). Since crop growth is correlated with solar radiation intercepted by leaf, irrespective of crop (Monteith, 1977), pigeonpea with large leaf area would have an advantage in intercepting light over pigeonpea with smaller leaf area. The indeterminate, spreading and climbing nature of the cowpea used in this experiment may be a key factor in suppressing pigeonpea growth. Indeterminate cowpea is reported to reduce the yield of pigeonpea compared to the determinate ones (Rao and Willey, 1980).

Pigeonpea/cereal combinations were more beneficial than pigeonpea/legume combinations as indicated by their respective LERs and grain yield (Table 2). In this regard, the overall yield of pigeonpea/cereal combinations has been reported to be higher than pigeonpea/legume combinations (Rao and Willey, 1980).

A significantly higher $\%N_{dfa}$ of pigeonpea was observed with cereal companion crops than with legumes (Table 3), suggesting that pigeonpea increases its dependency on biological nitrogen fixation (BNF) only when intercropped with cereals. Such an increase in $\%N_{dfa}$ has been reported for fababeans intercropped with barley (Danso *et al.*, 1987) and ricebean with

Table 3. Nitrogen yield in grain (NY), proportion of nitrogen derived from air (% N_{dfa}) and amount of nitrogen derived from air (N_{dfa}) of sole crop and intercrop

Crop	Companion Crop	NY (Kg ha^{-1})	%N_{dfa}	N_{dfa} (kg ha^{-1})
Pigeonpea	None	58.3	63.7	37.1
	Sorghum	50.7	82.6	41.9
	Pearl millet	55.7	84.9	47.3
	Groundnut	55.7	64.8	36.1
	Cowpea	16.0	70.1	11.2
	SE (±)	12.4**	5.8**	8.7**
	CV (%)	26.2	8.0	25.3
Sorghum	None	28.4	–	–
	Pigeonpea	33.0	–	–
	SE (±)	7.0^{NS}		
	CV (%)	23.0		
Pearl millet	None	17.7	–	–
	Pigeonpea	18.4	–	–
	SE (±)	3.5^{NS}		
	CV (%)	19.4		
Groundnut	None	44.5	55.1	24.5
	Pigeonpea	24.2	51.6	12.5
	SE (±)	1.6**	6.6^{NS}	2.4*
	CV (%)	4.6	12.4	13.0
Cowpea	None	34.6	61.7	21.3
	Pigeonpea	32.2	64.7	20.8
	SE (±)	9.1^{NS}	2.1^{NS}	5.4^{NS}
	CV (%)	27.3	3.3	25.5

[a] *: p <0.05, **: p <0.01, NS: not significant.

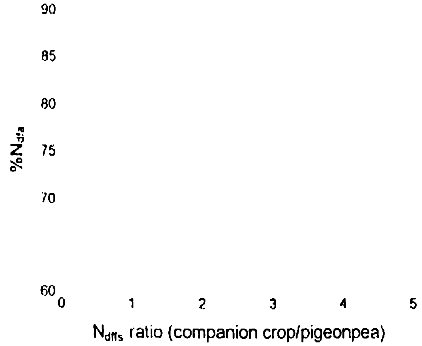


Fig. 2. Relationship between N_{dffs} (nitrogen derived from fertilizer and soil) ratio of companion crop over pigeonpea and %N_{dfa} (nitrogen derived from air) of pigeonpea in intercropping.

maize (Rerkasem *et al.*, 1988). The reduction in soil N level due to the high uptake by cereals, especially at the early stage, may cause the legumes to depend more on BNF (Herridge and Brockwell, 1988)

The TRL of cereals was three to six times higher than that of legumes, suggesting that cereals may have an advantage in exploiting N from soils over legumes. The TRL of the intercrops in pigeonpea/cereal combinations was higher than that of sole pigeonpea even after the harvest of the cereals (Fig. 1). Since cereals developed the ratoon after harvest of above-ground parts, their roots would be kept alive in soils, resulting in an overestimation of the TRL in intercropping. The ratoon roots was unable to be separated out due to difficulties in recognizing roots of two component crops by the minirhizotron observation. In contrast, the TRL of the intercrops in pigeonpea/legume combinations was not higher than that of sole pigeonpea. Considering that dry matter production of above-ground parts was enhanced by intercropping with legumes as indicated with LER (Table 2), there would be an allelopatic inhibition of root growth between two legume crops.

Assuming that below-ground competition for N from soil and fertilizer is a limiting factor for the growth of each component crop (Fig. 2), cereals may have an advantage over legumes to meet their N requirement, particularly during the active growing stage, due to their more extensive root proliferation in the surface soil. Consequently, cereals would deplete soil N more rapidly than legumes. It is reported that nitrate, which is a main form of N under upland conditions, disappears completely from soils in sole and intercropped sorghum fields at 45 DAS, whilst an appreciable amount still remained unutilized in sole pigeonpea (Ito *et al.*, 1994)

Pigeonpea is reported to develop a deeper root system than soybean and maize on Alfisols (Arihara *et al.* 1991). Therefore intercropped pigeonpea could utilize N in the deeper soil, even though soil N in the surface becomes depleted. When pigeonpea is grown on a shallow Alfisol with a hard stony layer below 30 cm depth, like in the present study, it is unable to exhibit its deep rooting characteristics (Ito *et al.*, 1992). Pigeonpea intercropped with cereals must have been forced to grow under limited soil N from the early growth stage. It is concluded from this experiment that the increase in %N_{dfa} of pigeonpea could be attributed to the higher utilization of soil and fertilizer N by the cereal companion crops.

References

Arihara J, Ae N and Okada K (1991) Root development of pigeonpea and chickpea and its significance in different cropping systems. *In*: Johansen C, Lee KK and Sahrawat KL (eds) Phosphorus Nutrition of Grain Legumes in the Semi-arid Tropics, pp 183–194. Patancheru, A.P. 502 324, ICRISAT, India

Chykin S (1969) Assay of nicotinamide deaminase. Determination of ammonia by the indophenol reaction. Anal Biochem 32: 375–382

Danso SKA, Zapata F and Hardarson G (1987) Nitrogen fixation in fababeans as affected by plant population density in sole or intercropped systems with barley. Soil Biol Biochem 19: 411–415

Herridge DF and Brockwell J (1988) Contributions of fixed nitrogen and soil nitrate to the nitrogen economy of irrigated soybean. Soil Biol Biochem 20: 711–717

Ito O, Matsunaga R, Tobita S and Rao TP (1992) Rooting behavior of intercropped pigeonpea (*Cajanus cajan* (L.) Millspaugh) and sorghum (*Sorghum bicolor* (L.) Moench). *In*: Kutschera L, Hübl E, Lichtenegger E, Persson H, Sobotik M (eds) Root Ecology and its Pactical Application: 3.ISRR Symposium, Wien, University Bodenkultur, 1991, pp 419–422. Verein für Wurzeelforschung, A-9020 Klagenfurt, Austria

Ito O, Matsunaga R, Katayama K, Tobita S, Adu-Gyamfi JJ, Rao TP and Gayatri Devi (1994) Nitrate in soil solution under sorghum and pigeonpea plants in mono and intercrops. In: Proceedings of 15th World Congress of Soil Science Vol 5b: 48–49. Acapulco, Mexico

Ofroi F and Stern WR (1987) Cereal-legume intercropping systems. Adv Agron 41: 41–90

Mead R and Willey RW (1980) The concept of a 'Land Equivalent Ratio' and advantages in yields from intercropping. Exp Agric 16: 217–228

Monteith JL (1977) Climate and the efficiency of crop production in Britain. Phil Trans R Soc Lond B 81: 277–294

Rerkasem B, Rerkasem K, Peoples M B, Herridge DF and Bergersen FJ (1988) Measurement of N_2 fixation in maize (*Zea mays* L.)-ricebean (*Vigna umbellata* [Thunb.] Ohwi and Ohashi) intercrops. Plant and Soil 108: 125–135

Rao MR and Willey RW (1980) Preliminary studies of intercropping combinations based on pigeonpea or sorghum. Exp Agric 16: 29–39

Tobita S, Ito O, Matsunaga R, Rao TP, Rego TJ, Johansen C and Yoneyama T (1994) Field devaluation of nitrogen fixation and use of nitrogen fertilizer by sorghum/pigeonpea intercropping on an Alfisol in the Indian semi-arid tropics. Biol Fertil Soils 17: 241–248

Upchurch DR and Ritchie JT (1983) Root observations using a video recording system in minirhizotrons. Agron J 75: 1009–1015

Venkateswarlu S and Subramanian VB (1990) Productivity of some rainfed crops in sole and intercrop systems. Indian J Agric Sci 60: 106–109

For information about current subscription rates and prices for back volumes for
Fertilizer Research, ISSN 0167-1731
please contact one of the customer service departments of Kluwer Academic Publishers or return the form overleaf to:

Kluwer Academic Publishers, Customer Service, P.O. Box 322, 3300 AH Dordrecht, the Netherlands, Telephone (+31) 78 524 400, Fax (+31) 78 183 273, Email: services@wkap.nl

or

Kluwer Academic Publishers, Customer Service, P.O. Box 358, Accord Station, Hingham MA 02018-0358, USA, Telephone (1) 617 871 6600, Fax (1) 617 871 6528, Email: kluwer@world.std.com

Call for papers

Authors wishing to submit papers related to any of the themes or topics covered by *Fertilizer Research* are cordially invited to prepare their manuscript following the 'Instructions for Authors'. Please request these instructions using the card below.

Author response card

Fertilizer Research

I intend to submit an article on the following topic:

Please send me detailed 'Instructions for Authors'.

NAME :

INSTITUTE :

DEPARTMENT :

ADDRESS :

Telephone

Telefax

Email

Library Recommendation Form

Route via Interdepartmental Mail

To the Serials Librarian at:

From: Dept./Faculty of:

Dear Librarian,

I would like to recommend our library to carry a subscription to
Fertilizer Research, ISSN 0167-1731
published by Kluwer Academic Publishers.

Signed: Date:

Request for information about current subscription rates and prices for back volumes of

Fertilizer Research, ISSN 0167-1731

Please fill in and return to:

Kluwer Academic Publishers, Customer Service, P.O. Box 322, 3300 AH Dordrecht, the Netherlands

Kluwer Academic Publishers, Customer Service, P.O. Box 358, Accord Station, Hingham MA 02018-0358, USA

- [ ] Please send information about current program and prices
- [ ] Please send a free sample copy

NAME

INSTITUTE

DEPARTMENT

ADDRESS

Telephone

Telefax

Email

STAMP

Fertilizer Research
Kluwer Academic Publishers,
P.O. Box 17
3300 AA Dordrecht
The Netherlands

REF. OPC

TO : The Library
FROM:

VIA INTERDEPARTMENTAL MAIL