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Responses of Rice and Cowpea Intercropping to Nitrogen Fertilizer and Plant Population (1): Nodulation, Nitrogen Fixation and Agronomic Efficiency

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Abstract: The study aimed to determining the response of cowpea to nodulation and its effect on nitrogen fixation (using the nitrogen difference method) and agronomic efficiency (A_E) of fertilizer N in a rice/cowpea intercrop at varying N-fertilizer rates (15, 30, 45 kgN/ha) and planting densities (50000, 100000, 200000 plants/ha). Increasing nitrogen fertilizer rates decreased number of nodules, while plants with high density had higher nodule number. Nodule number under fertilizer nitrogen ranged from 19.63 (45 kgN/ha) to 24.50 (15 kgN/a) in sole cowpea; and 15.80 (0 kgN/ha) to 24.20 (15 kgN/ha) in intercropped cowpea. Mean nodule number (22.10 and 22.70 in first and second growing seasons, respectively) in residual N was higher for both sole and intercrops. Mean values of N-fixed using fertilizer nitrogen ranged from 2.66 mg/plant under 0 kgN/ha to 10.50 mg/plant. However, under residual N, N-fixed ranged from 3.62 mg/plant under 0 kgN/ha to 8.90 mg/plant at 30 kgN/ha.The quantity of N-fixed decreased with density of the rice/cowpea intercrop. Under fertilizer N, the lowest and highest values of A_E were-0.89 (15 kgN/ha at 100000 plants/ha) and 14.89 (30 kgN/ha at 200000 plants/ha), respectively. A_E was increased with quantity of fertilizer N applied and plant population in sole rice stands. The present study shows that higher nitrogen rates cannot compensate for interspecific competition. Increase nodulation in intercrops was observed, while higher nitrogen rates reduced nodulation.

Key words: Plant density · Nitrogen fixation, Agronomic efficiency, Residual nitrogen, Fertilizer nitrogen, Nodule number

INTRODUCTION

Nitrogen transfer and increase in the utilization of available nutrients and water have been reported to the potential benefits using nodulating grain legumes in intercrops with non-nitrogen fixing crops [1]. In a situation in which the farmer uses little or no fertilizer and the soil is very low in organic matter, the issue of transfer of nitrogen from legume to cereal assumes great importance. The nitrogen fixation by the legume component may be available to the companion crop during the growing season [2]. Two types of beneficial effects have generally been reported: higher nitrogen content and/or higher grain yield of the intercropped cereal in comparison with cereal alone without any added nitrogen.

Okereke and Ayama [3], using variety Ife Brown and OS 6 (in cowpea/rice) mixed cropping at Ikwo, Southeastern Nigeria observed negative nitrogen transfer (-26.7%) to rice at 55 days after planting while -1.2% negative transfer was obtained at 65 days after planting using 15_N Isotope dilution method. They concluded that there might not have been any nitrogen transfer from cowpea to rice. Jifeng [4] conducted a field experiment in Thailand to measure the amount of nitrogen fixed in soybean grown after rice. Who observed that nitrogen fixation was increased by using nitrogen fertilizer with previous crop (either rice or soybean). Without nitrogen to either crop, soybean fixed 122kgN/ha. Starter N at 25kgN/ha and 50kgN/ha, or the residual effect of 100-300kgN/ha for rice increased the amount of nitrogen fixed to between 132 and 140kgN/ha. Starter nitrogen at 50kgN/ha significantly decreased nitrogen fixation of soybean following the application of 300kgN/ha to previous rice crop. Jifeng [4] also observed that nodulation of soybean was inhibited by nitrogen fertilizer applications to soybean during early growth period.

Since nodulation, nitrogen-fixation and agronomic efficiency of fertilizer, all contribute to the overall performance of the crop, this study aimed to evaluating the effects of nitrogen fertilizer and planting density on the above mentioned parameters in a rice/cowpea intercrop.

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MATERIALS AND METHODS

The experimental trial was located at the Delta State ADP Research, Agbarho in Ughelli Local Government Area of Delta State. Agbarho is located on latitude 5^0 34'N and longitude 5^0 53^0 E in the wet high humid rainforest zone of southern Nigeria with annual rainfall of about 2116mm and 2660mm in 2003 and 2004 planting seasons.

The trail was made up of three treatments, namely nitrogen fertilizer levels (0,15,30 and 45kgN/ha), plant density (50000, 100000 and 200000 plants/ha corresponding to low, medium and high densities respectively) and three cropping patterns (sole rice, sole cowpea and rice/cowpea mixture). Mixture of rice and cowpea were planted in alternate rows to achieve a 1:1 proportion. The three factors were combined in a 4x3x3 factorial with three replicates and laid out in a randomized complete block. In other to assess residual effect of fertilizer N, the second cropping had no applied nitrogen fertilizer.

Nodule number was determined at 55 days after planting using the recommendation of Okereke and Ayama [3], by carefully digging out five randomly selected cowpea plants without destroying nodules. The roots were washed gently to remove the adhering soil, enabling the detachment of nodules, before counting.

At harvest samples of rice and cowpea were taken for total nitrogen analysis using methods described by AOAC [5]. The nutrient uptake for both rice and cowpea were determined as the product of shoot dry weight and the concentration of the nutrient found in the plant material [6].

Data collected for number of nodules in cowpea were subjected to analysis of variance (ANOVA) appropriate for factorial and randomized complete block design Gomez and Gomez [7] using bivariate techniques for analyzing intercropping trials. Means separation was by the Duncan's multiple range tests.

To evaluate nitrogen use by different crops stands the amount of nitrogen fixed (nitrogen-fixation) and agronomic efficiency of fertilizer nitrogen were calculated.

Nitrogen-Fixation: This was calculated based on the nitrogen (N) difference method equation as stated by Hauser [8] and Giller [9].

$$N_{fixed} = N_{shoot\ leg} - N_{shoot\ ref}$$

Where

N_{fixed} = Fixed nitrogen in the soil

$N_{shoot\ leg}$ = Amount of nitrogen (N uptake in mg/plant) in shoot of legume (cowpea)

$N_{shoot\ ref}$ = Amount of nitrogen (N uptake in mg/plant) in shoot of reference crop (rice)

Agronomic Efficiency(a_e) of Fertilizer Nitrogen: Agronomic efficiency (A_E) of fertilizer nitrogen application was determined as the incremental change in grain weight (kg) produced divided by the increment (kg) of fertilizer nitrogen (Dunn and Beecher [10], Dobermann *et al.* [11]). This was mathematically represented by Baumann *et al.* [12] Thus;

$$A_E = \frac{Y_F - Y_O}{N_F - N_O}$$

Where

A_E = agronomic efficiency of fertilizer nitrogen

Y_F= yield in kg/ha at F fertilizer rate

Y_O = yield in kg/ha at 0 fertilizer rate

N_F and N_O = Amount of nitrogen fertilizer at F and 0 rates in kg/ha

RESULTS

Number of Nodules: N umber of nodules of cowpea was not significantly affected by nitrogen, cropping density and cropping pattern during the first season (Table 1). Although 15kgN/ha increased number of nodules by 10.1% over the unfertilized plants, additional application of nitrogen fertilizer resulted in reduction in number of nodules. Increasing N fertilizer rate from 15kgN/ha to 30kgN/ha or 45kgN/ha decreased nodule number by 8.0% and 17.5%, respectively. Cowpea at high densities had more nodules than those planted at low densities. Increasing density from 50000 plants/ha to 100000 plants/ha resulted in 3.7% increase in number of nodules, however higher population density of 200000 plants/ha reduced nodule number by 0.16% over the 100000 plants/ha. Intercropping cowpea with rice slightly increased number of nodules by 2.2%.

Residual nitrogen significantly (P<0.05) affected number of nodules in the second growing season for cowpea plants. Neither planting density nor intercropping

Table 1: Response of nodulation of cowpea to intercropping with rice under varying nitrogen fertilizer and plant population

		Nitrogen treatment			Density treatment	
		FN	RN		FN	RN
Sole	0	21.60ns	18.00bc	500000	20.90ns	21.83ns
	15	24.50ns	21.80a	100000	22.14	21.92
	30	22.41ns	24.40a	200000	23.10	22.61
	45	19.63ns	24.30a			
	Mean	22.00	22.10	Mean	22.04	22.61
Intercrop	0	15.80ns	18.70bc	50000	22.80	20.70
	15	24.20ns	22.10a	100000	23.80	23.59
	30	22.60ns	25.20a	200000	23.04	23.59
	45	20.70ns	24.90a			
	Mean	20.80	22.70	Mean	22.60	22.60
	SE	56.30	10.60			
Nitrogen x density	0.64ns	1.15ns				
Nitrogen x cropping pattern	1.30ns	3.72*				
Density x cropping pattern	6.69**	23.27**				

FR- fertilizer nitrogen; RN-residual nitrogen; * significant at 0.05%; **significant at 0.01%;ns-not significant

In each column, means followed by the same letter (s) do not differ significantly at 5% DMRT

Table 2: Response of nitrogen fixation of cowpea in rice-cowpea intercropping under varying nitrogen fertilizer and plant population

	Fertilizer nitrogen			Residual nitrogen		
	N-uptake (mg/plant) by cowpea	N-uptake (mg/plant) by rice	N-fixed (mg/plant)	N-uptake (mg/plant) by cowpea	N-uptake (mg/plant) by rice	N-fixed (mg/plant)
0 kgN/ha						
50000	2.26	0.20	2.06	3.97	0.17	3.80
100000	3.17	0.20	2.97	4.13	0.13	4.00
200000	3.11	0.17	2.94	3.17	0.15	3.05
Mean	2.85	0.19	2.66	3.76	0.14	3.62
15 kgN/ha						
50000	9.39	0.18	9.21	12.32	0.33	11.99
100000	7.51	0.22	7.29	6.62	0.16	6.46
200000	8.88	0.14	8.74	4.08	0.13	3.95
Mean	8.59	0.18	8.41	7.67	0.21	7.47
30 kgN/ha						
50000	10.69	0.49	10.19	10.56	0.21	10.37
100000	9.72	0.49	9.23	9.16	0.26	8.90
200000	7.81	0.32	7.49	7.63	0.19	7.47
Mean	9.40	0.43	8.91	9.12	0.22	8.90
45 kgN/ha						
50000	12.51	0.12	12.39	12.14	0.19	11.95
100000	14.43	0.16	14.29	7.04	0.18	6.86
200000	5.09	0.27	4.82	4.19	0.14	4.05
Mean	10.68	0.18	10.50	7.79	0.17	7.62

Table 3: Agronomic efficiency (AE) of fertilizer nitrogen in a rice - cowpea intercrop as influenced by nitrogen fertilizer and plant population

	Fertilizer nitrogen				Residual nitrogen			
	rice		cowpea		rice		cowpea	
	sole	mixed	sole	mixed	sole	mixed	solem	ixed
15 kgN/ha								
50000	6.69	16.69	1.00	2.73	28.53	23.53	1.19	2.73
100000	3.17	23.53	- 0.89	5.97	4.12	- 2.60	- 0.89	5.92
200000	4.12	- 2.60	13.20	4.43	1.39	6.99	0.67	4.43
30kgN/ha								
50000	4.04	11.84	0.78	1.78	17.33	9.47	0.77	1.78
100000	4.65	9.47	- 0.66	0.01	14.90	- 0.07	- 0.66	0.01
200000	14.89	- 0.70	0.10	2.39	5.57	4.16	0.10	2.39
45kgN/ha								
50000	5.94	8.33	0.89	1.36	26.69	4.26	0.89	1.36
100000	4.02	6.09	- 0.39	0.95	10.04	1.96	- 0.39	0.95
200000	14.19	- 0.71	0.98	2.48	0.80	0.37	0.96	2.47

Nitrogen fertilization kg /ha	Plant density
15	
	50000
	100000
	200000
30	
	50000
	100000
	200000
45	
	50000
	100000
	200000

You can change the design of Table 2 and 3 as red color example

cowpea with rice had any significant effect on number of nodules of cowpea. However, significant (P<0.05) increase of nodule number was observed for plant density and planting pattern interaction. Increasing cowpea population from low (50000 plants/ha) to medium (100000 plants/ha) resulted in a 7.0% increase in number of nodules,while a further increase to high density (200000 plants/ha) raised number of nodules by 2.3%. Generally, cowpea in mixture with rice had higher number of nodules than the monoculture. With respect to the unfertilized cowpea plants of the first growing season, residual nitrogen increased number of nodules by 20.9, 35.6 and 35.1% (sole cowpea) and 18.2%, 34.4% and 33.3% (mixtures cowpea) at previously applied nitrogen of 15,30 and 45kgN/ha.

Nitrogen Fixation: Nitrogen-fixed in the rice/cowpea intercropped system is as shown in Table 2. During the first cropping, the quantity of nitrogen fixed in the soil generally increased by 216-7% over the unfertilized plants (O kg/ha) when 15kgN/ha was applied. However, a 6.7% marginal increased was observed with fertilizer nitrogen from 15kgN/ha to 30kgN/ha resulted in corresponding increasing of 16.8% of nitrogen fixed in the soil. Similar trend in nitrogen fixation was observed for the second growing season with respect to residual N from the soil. The quantity of fixed nitrogen tends to decreased with density of the rice/cowpea intercrop in both cropping seasons.

Agronomic Efficiency (*A_e*) *of Fertilizer n:* The values of agronomic efficiency (A_E) of fertilizer nitrogen are presented in Table 3. Although high density mixture rice stands had values below unity, other values were generally high. Agronomic efficiency increased with quantity of fertilizer nitrogen applied and increasing plant population density in sole rice stands. However, in intercrop rice populations, A_E decreased with higher amount of nitrogen fertilizer applied. Lower values of A_E were also obtained with increasing plant population of rice mixtures. In the second planting season A_E decreased with increasing density in sole rice stands. However, no trend was observed for rice intercropped.

In cowpea, values of A_E were generally higher in mixed stands, compared to the sole crop. The range of A_E values obtained was between-0.39 and 13.20 for sole cowpea and 0.01 to 5.97 for mixture stands. In both sole and mixture cowpea populations no consistent trend was observed with population density in both cropping seasons.

DISCUSSIONS

Nodulation in this study was low relative to other studies, which got the range of 24 to 48 and 27 to 38 nodules/plant for Ife Brown [3]. Omokaro [13] also got about 92.8 nodules per plant. During the first growing season, marginal depression of nodulation may be attributed to the use of mineral fertilizers. This is supported by Midmore [14], who noted that addition of nitrogen to a cereal/cowpea system is generally thought to favour the cereal at the expense of cowpea. Fukai *et al.* [15] also reported that when soil nitrogen levels are low, the legume is less affected than the cereal, but the addition of nitrogen has the effect of decreasing the legumes nitrogen fixation. In a related study, Chiezey *et al*. [16] pointed out that the application of nitrogen fertilizer depressed nodulation in legumes.

Higher nodule number as in other studies (Omokaro [13]; Okereke and Ayama, [3]) may not have been achieved in the second growing season probably because of high rainfall which may have created anaerobic condition in the soil. Aerobic conditions have been shown to be detrimental to the number of rhizoids that will form root nodules [17]. The lowest number of nodules may also be due to the acidic nature of the soil. Russell [18] noted that there are very few *Rhizobia* in the soils greater than pH 4.2, the numbers tend to increase up to a pH of about 7.

The lowest nodulation of cowpea without nitrogen fertilizer indicates the importance of starter nitrogen in soils of low nitrogen. This is further supported by Omoregie and Okpefa [19], who noted that when initial levels of available soil nitrogen were low, a period of nitrogen hunger can reduce nodulation.

Cowpea at high densities had averagely more nodules than those planted at low densities. Intercropped cowpea also had more nodules than the sole crops. Similar results have been reported in related studies (Nair *et al.* [20]; Graham and Chattel [21]).

In the present study, using the nitrogen difference method, nitrogen fixation increased with nitrogen rates. Data in the present study indicated lower nitrogen fixation with increasing density, which is associated with more cereal-legume competition. A similar trend was reported by Danso *et al.* [22] which showed that the total amount of nitrogen fixed by faba bean was generally lower in the mixed crops than in the sole crops. This contradicts a report by Alaides *et al.* [23] who noted that plants in competition use up nitrogen fertilizer and soil nitrogen more rapidly and thus stimulate nitrogen fixation.

High densities affected agronomic efficiency (A_E) of rice in mixed stands resulting in low values. Agronomic efficiency tends to decrease with lower planting density in sole crops. However, the reverse was the case in mixed stands. Agronomic efficiency also decreased as nitrogen input levels increased. Similar result was reported by Durbury *et al.* [24]. Since agronomic efficiency appears to increase with planting density, it is possible that insufficient plant density as noted by Dobermann *et al.*[25] may have decreased the agronomic efficiency of the plants. The lowest values of agronomic efficiency in sole cowpea relative to the sole rice crops agree with the studies of Midmore [14] and Blade *et al.* [26]. They noted that the addition of nitrogen to a cereal/cowpea system is generally thought to favour the cereal at the expense of the cowpea.

CONCLUSION

It is obvious from this study that the space allocated to the component crops in an intercropping system is directly related to the resources available. For rice and cowpea in the present study, shows that higher nitrogen rates cannot compensate for interspecific competition, hence lower nitrogen fixation and agronomic efficiency of fertilizer N with higher densities. The study also showed increased nodulation in intercrops, while higher nitrogen rates reduced nodulation.

REFERENCES

1. Kessel, C. and C. Hartley, 2000. Agricultural management of grain legumes, has it led to an increase in nitrogen fixation. Field Crops Research, 93: 1354-1361.
2. Singh, B.B., 1993. Cowpea breeding: archival report (1988-1992) of grain legume improvement programme. International Institute of tropical agriculture (IITA), Ibadan, pp: 10-53.

3. Okereke, U.U. and N. Ayama, 1992. Nodulation and nitrogen fixation and transfer in cowpea/rice cropping system in: Biological Nitrogen Fixation and Sustainable Agriculture Mulongoy, K; Gueye, M, Spencer D. S.C (eds) International Institute of Tropical Agriculture Ibadan / John Wiley Sons New York. pp: 353-360.
4. Jifeng, Y., 1990. Nitrogen Fixation of Soybean in Rice Based Cropping Systems Theses Abstract of AGS Students 1990.
5. AOAC, 1990. Official Methods of Analysis. Association of Official Analytical Chemists 15th (Eds). AOAC, Washington, D.C USA.
6. Pal, U.R., 1991. Effect of source and rate of nitrogen and phosphorus on yield, nutrient uptake and apparent fertilizer nutrient recovery by maize in the southern guinea savanna. J. Agricultural Science and Technol., (1): 21-24.
7. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. John Wiley Sons Inc New York .
8. Hauser, S., 1992. Estimation of Symbiotically Fixed Nitrogen Using Extended N Difference Method In Biological Nitrogen Fixation and Sustainability of Tropical Agriculture Mulongoy, K; Gueye, M, Spencer D. S.C (Eds) International Institute of Tropical Agriculture Ibadan / John Wiley Sons New York. pp: 309-321.
9. Giller, K.E., 1992. Measuring Inputs from Nitrogen Fixation in Multiple Cropping Systems In Biological Nitrogen Fixation and Sustainability of Tropical Agriculture Mulongoy.K; Gueye, M, Spencer D. S.C (Eds) International Institute Of Tropical Agriculture Ibadan / John Wiley Sons New York .pp: 297-308.
10. Dunn, B.W. and H.G. Beecher, 1994. Green manuring legume pasture for aerial sown rice. Australian J. Experimental Agri., 34: 967-975.
11. Dobermann, A., D. Dawe, R.P. Roetter and K.G. Cassman, 2000. Reversal of rice yield decline in a long term continuous cropping. Agronomy J., 92: 633-643.
12. Baumann, D.T., L. Bastiaans, and M.J.K. Kropff, 2001. Competition and crop performance in a leek-celery intercropping system. Crop Sci., 41: 764-774.
13. Omokaro, D.N., 1990. Comparative studies on nodulation, chlorophyll content growth, dry matter production and forage quality in two cowpea cultivars. Nigerian J. Sci., 24: 20-24.
14. Midmore, D., 1973. Agronomic modification of resource use and intercrop productivity. Field Crops Res., 34: 357-380.
15. Fukai, S., J.S. Tsay, G.I. Wilson, U. Cenpukdee and D.P.S. Grady, 1980. Cassava legume intercropping in the subtropics. In the Proceeding 8th Symposium for Tropical Root Crops ISTRC, Bangkok Thailand. pp: 203-209.
16. Chiezey, U.F., T.V. Yayock and Y.A.Y. Shebayan, 1992. Response of Soybean (*Glycine max* L. Merill) to nitrogen and phosphorus fertilizer level. Tropical Sci., 32: 360-368.
17. Minchin, F.R and R.J. Summerfield, 1976. Symbiotic nitrogen fixation and vegetative growth of cowpea in waterlogged conditions. Plant and Soil, 45: 113-127.
18. Russell, W.E., 1973. Soil Conditions and plant growth.Longman, New York
19. Omoregie, A.U. and G.O. Okpefa, 1999. Effects of time of application of nitrogen on nodulation, dry matter and mineral nutrition of cowpea Vigna *unguiculata* L (Walp) in the Delta area of Nigeria. Nigerian Agri. J., 30: 32-40.
20. Nair, K.P.P., U.K. Patel, R.P. Singh and J.K. Kanshik, 1979. Evaluation of legume intercropping in conservation of fertilizer nitrogen in maize culture. J. Agri. Sci. Camb., 93: 189-194.
21. Graham, P.H. and D.I. Chattel, 1983. Agronomy In: Nitrogen fixation B: legumes Broughton W.J (Eds) Charendon press Oxford, pp: 56-58.
22. Danso, S.K.A., C. Her and C. Douka, 1987. Nitrogen fixation in Soybean as influenced by cultivar and Rhizobium strain. Plant and Soil, 99: 16 3-174.
23. Alaides, P.R., P.B. Vose, R.L. Victoria and E. Salan, 1979. Comparison of isotope technique and non-nodulating isolines to study the effect of ammonium fertilization on dinitrogen fixation soybean Glycine max. Plant and Soil, 53: 513-521.
24. Durbury, J.M., I.P. Abrol, R.K. Gupta and F.K. Bronson, 2000. Analysis of long term soil fertility experiments with rice wheat rotations in south Asia in: Long Term Soil Fertility Experiments With Rice-Wheat Rotations In South Asia I. P Abrol *et al* (Eds). Rice Wheat Consortium Paper series No. 6, rice wheat Consortium for the Indo-Gangetic Plains, New Delhi., pp: 7-22 .
25. Dobermann, A., C. Witt, S. Abdulrachman, H.C. Gines *et al.* 2003. Soil fertility and indigenous nutrient supply in irrigated domains of Asia. Agronomy J., 95: 913-923.
26. Blade, S.F., S.V.R. Shetty, T. Terao and B.B. Singh, 1997. Recent development in cowpea cropping systems research In: Advances in Cowpea Research Singh B.B., Mohan D.R Raj, K.E. Dashiell, and L.E.W. Jackai, Co-Puiblication of 11TA Ibadan and Japan International Research Centre for Agricultural Sci., (JARCAS) pp: 114-128.