

Agro-Economic Returns from Rice + Cowpea Intercropping Under Varying Nitrogen Rates

*Oroka, Frank O. and Emuh, F.N
Department of Agronomy, Delta State University, Asaba Campus, Delta State, Nigeria

ABSTRACT
Field experiments were conducted in the cropping seasons of 2009 and 2010 at the Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46' and longitude 6^0 5') in the wet humid rainforest of Southern Nigeria. The main aim of the experiment was to evaluate the agro-economic returns obtainable from the intercrop involving rice (*Oryza sativa* L.) and cowpea (*Vigna unguiculata* L. Walp) at varying levels of nitrogen fertilizer (0, 15, 30 and 45 kgNha^{-1}). The mean yield of rice grown under sole cropping was higher than that intercropped with cowpea. Maximum rice grain yield of 2340.82 kg ha^{-1} and 1960.59 kg ha^{-1} in sole and intercrop respectively, were achieved with 45 kgNha^{-1}. Rice-cowpea intercrops with 30 kgNha^{-1} gave the highest net returns of $628.72, high benefit/cost ratio, land equivalent ratio and monetary advantage index. From this study, it is inferred that intercropping of rice with cowpea at 30 kgNha^{-1} is most likely to give higher income, increased use efficiency and thus enhancing sustainability of crop production than sole cropping of each crop species. Hence it is recommended for farmers to intercrop rice and cowpea and apply nitrogen at 30 kgNha^{-1} in other to achieve optimum economic crop yield in upland rice based ecosystems.
Keywords Monetary advantage index, benefit/cost ratio, rice, cowpea, nitrogen fertilizer

INTRODUCTION

Rice is one of the most important food crops in the world. Demand for rice has in fact been increasing rapidly much in Africa. Within a 16-year period (1985 to 2001), rice imports to Africa increased from the initial 3 million tons to over 7 million tons per annum [9]; thus becoming an important food crop in the context of food security. However, the major concern of rice farmers and researchers in sub-Saharan Africa has been consistent grain yield decline. Grain yield decreases have been associated with soil degradation. As earlier observed, environmental degradation of cropland under continuous cultivation without appropriate soil management practices has contributed to reduced crop yield in tropical Africa during the last 30 years (Bationo et al., 2006)). Most farmlands are degraded by erosion that washes away soil nutrients; harvested products (including crop residues) are often taken out of the field and fertilizer applications are insufficient or not properly carried out (Ahmed et al., 2009)).

Nitrogen is considered one of the most limiting nutrients for rice production; therefore, increased nitrogen availability should translate into yield increase. Rice farmers are aware that the only way to overcome nitrogen nutrient depletion is the use of fertilizers (organic and/or inorganic). High cost of inorganic nitrogen fertilizer at recommended rates is one of the major limitations to its full adoption by poor farmers. As earlier reported, while the fertilizer costs of the average Asian farmer are equivalent to 2 - 3 kg of grain, those of his/her African counterpart are about three to four times more (Isherwood, 1996). The use of organic manures such as farmyard, poultry manure and cow dung, is limited because of their bulkiness and high transport and labor costs.

Intercropping upland rice with a leguminous crop, mostly with cowpea mostly practiced by upland rice farmers is aimed at soil fertility and productivity improvement, weed suppression are some of the gains derived from intercropping systems (Kombiok, et al., 2012). Increased grain yield and profitability of rice cropping with application of nitrogen has been reported (Kumari,. and Reddy, 2010; Singh et al., 1996). Several researchers have also identified the use of nitrogen fertilizers (inorganic) along with cropping systems that integrate legumes (organic) as a means of increasing soil nitrogen. Intercropping cereals with legumes is a promising system that results in an effective use of land and other resources (Saleem, et al. 2000), and reduces the cost of production (Bijay et al. 1998). Dual cropping of cowpea with seeded rice could add about 12 tha^{-1} of organic manure, guarantee 25% nitrogen saving (22.5 kgha^{-1}) with 11% yield enhancement and increase in profitability Anitha (2010). High land equivalent ratio, relative value total, high gross and net return ratio was reported when maize was intercropped with red gram, green gram, black gram, soybean and groundnut Kheroar and Patra (2014). In a related study, Rehman et al (2010), also showed that maize (Zea mays L.) intercropped with cowpea and an application of nitrogen at 225kg ha^{-1} gave higher maize grain yield, maximum farm income and cost benefit ratio of 2.02. Higher net income and cost- benefit ratio was also observed in a rice- based intercrop compared with rice alone Saleem et al (2000) . Higher net benefits in rice- cowpea intercrop were reported and the researchers also noted that the intercrops of rice and cowpea were 14.03% higher than sole rice (Abdul Jabba et al 2010)..

Previous reports also noted that despite the high cost of some farm inputs, farmers who diversified their crops tend to have higher economic returns in the medium term compared to sole crop farmers (Zentner, 2002)

Optimum nitrogen dose in rice-cowpea intercropping system that is economically and biological beneficial is an important approach to improving rice productivity; but has not been extensively studied in Nigeria. The current study was therefore aimed at experimenting nitrogen fertilizer application in a rice-cowpea production system. The specific objectives of the study were: to identify the effects of intercropping on individual yields of rice and cowpea at various nitrogen fertilizer rates; to determine the costs and returns at each level of nitrogen rate and to identify the most economical rate of nitrogen fertilizer in a rice-cowpea production system based on findings and recommend same to farmers.

MATERIALS AND METHODS

Field experiments were established in the 2009 and 2010 cropping seasons at the Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46' and longitude 6^0 5') in the wet humid rainforest of Southern Nigeria. Soil properties of experimental site before cropping include: particle size analysis (Bouycous method) 760 g kg^{-1} sand; 100 g kg^{-1} silt; 140 g kg^{-1} clay; pH in water = 5.4; 0.7 g kg^{-1} ; total N (Kjedahl method); and 47.1 g kg^{-1} organic matter (wet dichromate oxidation method).

The study consisted of two treatments, which were made up of four nitrogen fertilizer rates and three cropping patterns. The nitrogen fertilizer (urea) was applied at the following rates: 0, 15, 30 and 45 $kgNha_{-1}$. The zero plots served as the control. The nitrogen fertilizer rates used in the experiment were based on recommended rates of 30kg/N and 15kg/N for rice and cowpea respecively in the study area. Cropping patterns used were sole rice, sole cowpea and rice-cowpea intercrop. The two treatments (nitrogen fertilizer rate and cropping pattern) were arranged in a 4 x 3 factorial in a randomized block design using three replicates. All the plots were planted at density of 100000 plants ha_{-1} (averagely 133 plants per plot) for each crop at a spacing of 30cm by 30cm for rice and cowpea in both sole and intercrops with each system having a corresponding total population of 100000 and 200000 plants ha^{-1} respectively. Intercrops of rice and cowpea were planted in a 1:1 ratio. Varieties of crops used were FARO 46 (100-105 days) for rice (Oryza sativa L.) and cowpea Ife Brwon (*Vigna unguiculata* L. Walp.). Crop yield data were obtained from a net plot area of 12m2 (4.8m x 2.5m) .Data on yield were subjected to an analysis of variance (ANOVA) appropriate for a factorial randomized block design. Comparison of means was done by the least significant difference (LSD) at 5% level of probability.

Economic analysis of urea fertilizer in the trial was calculated as described by Rohrmoser, (1985) using the following formula:

Incremental yield, IY (%) = Y_F-Y_0/Y_F x 100 where Y_F is the yield of fertilizer variant and Y_0 is the yield of the zero variant

Fertilizer costs, FC (USD/kg) = Fertilizer rate (kg) x unit price; while the difference between the cost of the fertilizer variant and that of the zero variant gave the incremental fertilizer costs (IFC).

Gross returns, GR (USD/ha) = (Y_F-Y_0) x selling price

Net returns, NR (USD/ha) = GR- FC

Cost-Benefit Ratio (CBR) = NR/FC

Land Equivalent Ratio (LER) = (Yab/Yaa) + (Yba/Ybb), whereas Yaa and Ybb are corresponding yields of sole crops of a and b while Yab and Yba are the corresponding yields of intercrops of a and b. Values of LER greater than 1 are considered advantageous.

Monetary advantage index (MAI) = Value of combined intercrops yield x (LER-1/LER) where LER is land equivalent ratio. The higher the index value the more profitable the system.

The unit price of rice and cowpea were taken as \$0.56 kg-1 and \$0.89 kg-1 respectively in 2009 and \$0.59 kg-1 and \$0.91 kg-1 respectively in 2010.The unit price of 1 kg of nitrogen in urea was taken as \$0.38 kg-1 on the basis of the market prices of 2009 and 2010 (1 US Dollars equals about 150 Nigeria Naira as average of 2009 and 2010).

RESULTS AND DISCUSSION

Crop Yield

Grain yield of rice was significantly increased ($P<0.05$) with nitrogen application both in sole and intercrops during the first and second cropping seasons (Table 1). Increasing nitrogen fertilizer rate resulted in a significant increase in grain yield of rice in both sole and intercrops. The results indicated that application of nitrogenous fertilizer increased grain yield of rice in both sole and intercrops. This increase may be due to increasing supply of nitrogen to both crops. Increased supply of nitrogen to plants promote nutrient absorption and assimilation resulting in increase in size and number of filled grains, which consequently contribute to improved yield of the cereal crop (Anon, 2003; Valadabadi and Farahani, 2010). Increasing fertilizer nitrogen application resulted in a non-significant increase in yield of cowpea in both sole and intercrops in the first and second cropping seasons (Table 2). The findings from this study show that rice was the major contributor to the mixture yield. Rice being a nitrogen demanding crop may have increased in vigor and growth better than cowpea as a result of nitrogen supply from both the mineral fertilizer and legume association. As earlier observed, the addition of nitrogen to a cereal/cowpea system is thought to favor the cereal at the expense of the cowpea (Midmore , 1973; Blade, et al., 1997).

Table 1. Yield (kg ha^{-1}) of rice as influenced by nitrogen fertilizer and cropping pattern

	2009 cropping			2010 cropping		
N rate ($kgNha^{-1}$)	Sole	Intercrop	% decrease	Sole	Intercrop	% decrease
0	1248.21d	1008.11c	19.24	1296.31d	1201.11c	7.34
15	1663.40c	1350.60b	18.80	1688.40c	1512.59b	10.41
30	2105.30b	1888.60a	10.29	2082.00b	1890.30a	9.21
45	2340.82a	1960.59a	16.24	2390.91a	1909.50a	20.14
Mean (Cs)	1839.43a*	1552.00b*	15.63	1864.41a*	1628.38b*	12.66
N x Cs	2.76ns					

* Significant at 5% level of probability; ns –not significant
In each column means followed by the same letter (s) do not differ significantly at 5% LSD.
*In each row means followed by the same letter (s) do not differ significantly at 5% LSD

Table 2. Yield (kg ha^{-1}) of cowpea as influenced by nitrogen fertilizer and cropping pattern

	2009 cropping			2010 cropping		
N rate ($kgNha^{-1}$)	Sole	Intercrop	% decrease	Sole	Intercrop	% decrease
0	893.60b	820.40b	8.19	903.90b	835.60c	7.55
15	974.79a	965.61a	0.94	1066.19a	976.71b	8.39
30	980.11a	969.30a	1.10	1108.50a	1075.24a	3.00
45	970.20a	953.81a	1.69	1119.59a	1086.01a	3.00
Mean (Cs)	954.68a#	927.28a#	2.87	1049.55a#	993.39a#	5.35
N x Cs	3.30*					

* Significant at 5% level of probability; ns –not significant
In each column means followed by the same letter (s) do not differ significantly at 5% LSD.
*In each row means followed by the same letter (s) do not differ significantly at 5% LSD

Intercropping had a significant affect on grain yield of rice crop (Table 1). A significant reduction in grain yield of the intercropped rice was observed as compared to rice alone. The minimum grain yield was recorded from plots where rice was intercropped with cowpea without nitrogen application. Intercropping of cowpea with rice showed a non-significant reduction in grain yield of cowpea (Table 2) in this study. It is evident from the results that significant reduction in rice grain yield was due to cowpea intercropping and it may be attributed to the luxuriant growth of cowpea and its thick shading effect on the associated rice crop which ultimately resulted in minimal reduction in growth and reduced yield of the rice crop. As earlier observed by Onyibe et al. (2006), too much nitrogen fertilizer for cowpea makes the plant to grow luxuriantly with poor grain yield.

Economic Analysis

The data in Tables 3 and 4 have revealed that the highest incremental net return on nitrogen fertilizer application on rice increased with rate of fertilizer nitrogen in both sole and intercrops. The highest incremental net return was obtained with application of $45kgNha^{-1}$ during the first and second cropping seasons. However the fertilizer costs involved amount to $17.10. The fertilizer variant of $30kgNha^{-1}$ gave the highest benefit/cost ratios (BCR) in the first cropping.

As shown in Tables 5 and 6, the lowest fertilizer variant ($15kgNha^{-1}$) with fertilizer costs of $5.70 gave the highest incremental net returns for cowpea during the first cropping season. Incremental net returns were however higher in the highest fertilizer variant of $45kgNha^{-1}$ in the second cropping season. Values of BCR for cowpea consistently decreased with increasing nitrogen fertilizer rate, though the intercrops at $30kgNha^{-1}$ and $45kgNha^{-1}$ were higher than sole cowpea. The reduction in BCR with increasing nitrogen fertilizer in both cropping seasons is an indication that high nitrogen rates are not economically sustainable for sole cowpea production.

Table 3. Economic analysis of nitrogen fertilizer for rice during the 2009 cropping

N rate (kgNha^{-1})	IFC (USD/kg)	IY (%)	GR (USD/ha)	NR (USD/ha)	BCR
Sole crop					
0	-	-	-	-	-
15	5.70	33.26	232.40	325.70	39.77
30	11.40	68.67	479.87	468.47	41.09
45	17.10	87.69	611.76	594.66	34.76
Intercrop					
0	-	-	-	-	-
15	5.70	33.97	191.80	186.10	32.65
30	11.40	87.04	493.08	481.68	42.25
45	17.10	94.48	533.39	516.29	30.19

Table 4. Economic analysis of nitrogen fertilizer for rice during the 2010 cropping

N rate (kgNha^{-1})	IFC (USD/kg)	IY (%)	GR (USD/ha)	NR (USD/ha)	BCR
Sole crop					
0	-	-	-	-	-
15	5.70	30.25	231.34	225.64	39.59
30	11.40	60.61	463.56	452.16	39.66
45	17.10	84.44	645.82	628.72	36.77
Intercrop					
0	-	-	-	-	-
15	5.70	25.93	83.79	178.09	31.24
30	11.40	57.38	406.75	395.35	34.68
45	17.10	58.98	417.96	400.86	23.44

Table 5. Economic analysis of nitrogen fertilizer for cowpea during the 2009 cropping

N rate (kgNha^{-1})	IFC (USD/kg)	IY (%)	GR (USD/ha)	NR (USD/ha)	BCR
Sole crop					
0	-	-	-	-	-
15	5.70	9.09	72.26	66.56	11.68
30	11.40	9.68	77.00	65.60	5.75
45	17.10	8.57	68.18	51.08	2.99
Intercrop					
0	-	-	-	-	-
15	5.70	17.64	129.23	123.53	21.67
30	11.40	18.15	132.52	121.12	10.62
45	17.10	16.26	118.73	101.63	5.94

Table 6. Economic analysis of nitrogen fertilizer for cowpea during the 2010 cropping

N rate (kgNha^{-1})	IFC (USD/kg)	IY (%)	GR (USD/ha)	NR (USD/ha)	BCR
Sole crop					
0	-	-	-	-	-
15	5.70	17.95	147.68	141.98	24.91
30	11.40	22.64	186.19	174.74	15.33
45	17.10	23.86	196.28	179.18	10.48
Intercrop					
0	-	-	-	-	-
15	5.70	16.89	128.41	122.71	21.53
30	11.40	23.96	218.07	206.67	18.13
45	17.10	25.04	227.87	210.77	12.33

The BCR values obtained in this study are far higher than the BCR of 2 required to ensure farmers' willingness to invest in nitrogen fertilizer use. These results and other numerous responses from site-specific studies from other researchers (Bationo et al, 2006; MOFA, 2003) are clear evidence that the use of inorganic nitrogen fertilizer in rice-cowpea intercropping could indeed be a profitable investment. The higher BCR with lower nitrogen application; i.e. 30kgNha^{-1} for rice and 15kgNha^{-1} for cowpea in both sole and intercrops, indicates the economically optimum rate (though not the biological maximum) response. This implies that if the fertilizer is placed at the root zone of the crops and properly distributed, it can result in more efficient nutrient uptake. The higher BCR in the intercrops agrees with earlier research reports {Baba et al., 2013; González et al, 2013). They observed high economic returns in diversified legume-cereal based cropping systems.

LER and Monetary Advantage

Results from this study indicate yield advantage of intercropping at all levels of nitrogen application (Table 7). In both cropping seasons, LER were highest at 30kgNha^{-1} where rice and cowpea achieved intercrop productivity of 86% and 88% of their sole yields respectively indicating higher biological and economic efficiency. The monetary advantage index (MAI) values were positive for all levels of nitrogen application in both cropping seasons. The highest MAI of $887.88 and $969.98 were obtained in the 30kgNha^{-1} plot in the first and second cropping respectively. The higher LER values resulted in economic benefit, which is expressed with corresponding higher MAI values. The higher monetary returns from systems involving intercropping of legumes and non-legumes compared to sole non-legume cropping may be attributed to better utilization of resources.

Table 7. Land equivalent ratio and monetary advantage of rice-cowpea intercropping as influenced by nitrogen fertilizer

Nitrogen rate (kgNha^{-1})	LER	Value of combined intercrop (USD/ha)	MAI (USD)
2009 cropping			
0	1.73	1294.70	546.72
15	1.80	1615.72	718.10
30	1.86	1920.30	887.88
45	1.83	1946.48	882.83
Mean	1.81	1694.30	758.88
2010 cropping			
0	1.77	1467.05	647.78
15	1.82	1781.24	802.54
30	1.88	2072.24	969.98
45	1.83	1946.48	882.83
Mean	1.83	1816.75	825.78

CONCLUSION

Findings from this study indicate that integration of legumes and nitrogen fertilizer in rice based systems can be a way of improving rice grain yield as well as reducing quantity of inorganic nitrogen application. Crop productivity indices such as LER, MAI and BCR were highest at 30kgNha^{-1}. This implies that if the farmers use at the economically optimum level nitrogen dose of 30kgNha- 1, they can decrease their input costs (nitrogen fertilizer) and achieve better total land use efficiency and profitability. Therefore, intercropping of rice and cowpea with application of nitrogen at 30kgNha^{-1} may be recommended to farmers as an option for diversifying income and increasing productivity in upland rice based systems.

ACKNOWLEDGMENTS

The author wish to acknowledge the staff of the Teaching and Research Farm of Delta State University, Abraka, Nigeria for assisting in field data collection

REFERENCES

Abdul Jabbar, R.A., H.B. Iftikhar, Z.A Atiqueur-Rehman1 and N.V. Shah, 2010. Effect of different rice-based intercropping Systems on rice grain yield and residual soil fertility Pakistan Journal of Botany, 42(4): 2339-2348

Ahmed, B, Dayo P.O.A., Dangbegnon C, Kudi T.M., Ajala M.K. and G.Y.Kajang 2009. Socioeconomic baseline report. KKM-NGS [Kano–Katsina–Maradi Northern Guinea Savannah] Task Force. 79 p.

Anitha S., Mathew, J and C.M. Abraham, 2010. Dual cropping of rice (Oryza sativa) and green manure crops – A cost effective management alternative for direct seeded semi-dry system of rice cultivation Indian Journal of Agronomy 55 (3): 165-170

Anon (2003) Rice production handbook. University of Arkansas Cooperative & Extension Stuttgart

Baba I. I. Y., Mumuni Abudulai, Mohammmed Askia Musah, Wilson Dogbe and Mohammed Haruna (2013) Effects of NERICA - Cowpea intercropping systems on yield components and productivity of NERICA and Cowpea Afr. J. Agric. Res.8 (48):6323-6331

Bationo A., Hartemink A., Lungu, O., Okoth E., Samling, E. and E.Thiombiano, 2006. African soils: their productivity and profitability of fertilizer use. Background paper presented at the African Fertilizer Summit, Abuja, Nigeria.

Bijay S., Rana D.S, and G.S. Sekhon 1978. Some measures of reducing leaching loss of nitrate beyond rooting zone in intercropping Plant Soil, 49(3): 633-639.

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)

FAO, 2005. Fertilizer Use by Crops in Ghana. Food Agriculture Organization, Rome Isherwood, K. F. 1996. Fertilizer subsidy policies in regions other than Asia and the Pacific.Agro-chemicals: News in brief. Special issues. September.

González, Jorge, U., Pablo Undurraga, Juan Hirzel, and Ingrid Martínez G.(2013) Economic evaluation of a crop rotation portfolio for irrigated farms in central Chile Chilean Journal of Agricultural Research

Isherwood, K. F. 1996. Fertilizer subsidy policies in regions other than Asia and the Pacific.Agro-chemicals: News in brief. Special issues. September

Kheroar, S. and Patra, B.C. (2014) Productivity of maize-legume intercropping system under rainfed situation African Journal of Agricultural Research 9(20): 1610-1617

Kombiok JM, Buah SJ, Dzormeku IK (2012). Rice Influence on Grain Yield of Maize in Maize/Rice Mixture in the Northern Guinea Savanna Zone of Ghana. Journal of Crop Improvement. 1:87-100

Kumari, C.R. and D.S. Reddy 2010. Adding nitrogen through crop residues, organics and norganics in rice based cropping system Advance Research Journal of Crop Improvement 1(2):51-61

Qamar-uz-Zaman and M. A. Malik 2000. Ricebean (Vigna umbellata) productivity under various maize-ricebean intercropping systems. International Journal of Agriculture & Biology 3: 255-257

Midmore, D., 1973. Agronomic modification of resource use and intercrop productivity. Field Crops Res., 34: 357-380

Ministry of Food and Agriculture, MOFA, 2003. Agriculture in Ghana; Facts and Figures. Statistics and Information Directorate, Accra.

Onyibe, J.E., Kamara, A.Y and Omoigui, L.O. (2006) Guide to cowpea production in Borno State, Nigeria. International Institute for Tropical Agriculture, Ibadan.

Rehman, H., Ali, A., Waseem, M., Aseef, T. Tahir, M., Nadeem, M.A., Zamir,M.S. (2010) Impact of nitrogen application on the growth and yield of maize (Zea mays L.) grown alone and in combination with cowpea Vigna unguiculata L. American-EURASIAN J. Agric & Environmental Studies 7(1):43-47

Rohrmoser, K., 1985. Handbook for Field Trials in Technical Cooperation. CTA/GTZ Institut fur Grundland, Braunschweig.

Saleem, F.M., Shamshad H.S., Malik, M.A and M. K. Munir 2000 Bio-Economics of different Upland Rice-Based Intercropping Systems under Strip Plantation International Journal of Agriculture & Biology 2(4): 294-296

Singh, G., O.P. Singh, M. Kumar, A.L. Rajput and S. Murya, 1996. Effect of intercrops on yield and economics, weeds and pest infestation of deep water rice. Ann. Agric. Res., 17(1): 14-17.

Valadabadi, S.A. and H.A. Farahani , 2010 Effects of planting density and pattern on physiological growth indices in maize (Zea mays L.) under nitrogenous fertilizer application Journal of Agricultural Extension and Rural Development 2(3):40–47

Zentner, R.P., G.P. Lafond, D.A. Derksen, and C.A. Campbell. 2002 Tillage method and crop diversification: effect on economic returns and riskiness of cropping systems in a Thin Black Chernozem of the Canadian Prairies. Soil and Tillage Research 67:9-21.