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YIELD AND YIELD COMPONENTS OF LOW LAND RICE (*Oryza sativa* L.) AS AFFECTED BY DIFFERENT CULTIVATION METHODS IN THE SUDAN SAVANNAH

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Abstract

A field experiment was conducted during 2012 and 2013 wet seasons, at the Institute for Agricultural Research (IAR) Ahmadu Bello University farm, situated at the Irrigation Station Kadawa, Sudan Savannah, to investigate the effect of nitrogen fertilizer (0, 50 and 100 kgha^{-1}),poultry manure (pm) (0, 3 and 6 tha^{-1}), green manure (gm) rates (with and without green soyabean biomass) and method of cultivation (system of rice intensification (SRI) and conventional farmers' practice). The experiment was laid out in a split plot design, with the factorial combination of pm and nitrogen fertilizers assigned to main plots while the combination of gm and cultivation methods were assigned subplots. SRI recorded average respective grain yields of 5.59 and 6.05 t ha^{-1} as compared 4.75 and 4.86 t ha^{-1}respectively under conventional practice. The yield and yield components of rice were improved as a result of applied green soyabean manure but not significant in both years. Yield and the panicle number m^{-2}were greatly increased up to the levels of 100kg N ha^{-1}. Whilst the absolute use of pm significantly increased filled grain number panicle^{-1} up to 6 t ha^{-1} in both years, increased grain yield up to the 3t ha^{-1} in 2012 and up to 6 t ha^{-1}in the following year of 2013. Application of absolute pm and nitrogen fertilizer gave significantly higher values than in the control in both years. The interaction between nitrogen fertilizer and pm and cultivation method on grain yield was significant in both 2012 and 2013. The 6t ha^{-1} poultry manure +100kgNha^{-1}and 100kgNha^{-1}+ 3t ha^{-1} pm produced the highest grain yield of 7.842 and 7.532 t ha^{-1} respectively in 2012 under the SRI method compared to the others. While 8.054 and 7.967 were obtained from 6 t ha^{-1} pm +50kgN ha^{-1} and 100kgN ha^{-1} + 3t ha^{-1} pm respectively in the SRI method compared to others. The use of soyabean green manure, application of 3 t/ha poultry manure and 100 kg N/ha and 6t ha^{-1} pm + 50kgN ha^{-1} under SRI had produced better rice crop when compared to use of same fertility improvement technique under conventional method of rice production.

Keywords: Lowland rice; cultivation methods; poultry manure; green manure; inorganic nitrogen fertilizer

INTRODUCTION

Rice (*O. sativa*) is the most important cereal crop consumed after wheat in terms of total production (FAO, 2002). About 80% of the Nations rice production comes from rain-fed and irrigated lowland. Methods of establishing rice along with other factors such as low soil fertility, pests and diseases, moisture stress, accessibility to improve crop varieties and technology were among the major constraints to rice production in the region (Odion and Abubakar, 2005). The inappropriate technology, include lack of farmers' attention to the age of seedlings, the number of seedlings, plant spacing and improper use of organic fertilizer, which can cause nitrate accumulation in ground water and also in crops if they are taken up by the plant roots. The conventional methods of transplanting rice at old age (5-6 weeks) and overcrowding of seedlings are practices that have been investigated and found to greatly reduce rice paddy yield. Damage of the phyllochron from transplanting of older seedlings and competition for scarce growth resources from higher plant density could be the likely reason for the reduction in paddy yield (Counce and Wells, 1990). Production of rice on poor soils have proved impossible, and where there are inputs from both organic and inorganic sources the performance of the crop generally improved (Janssen, 1993).

The system of rice intensification is essentially an irrigated rice technology wherein farmers need absolute control over the water. Agronomic practices and water management aspects take over other issues. The system adopt technique of raising seedlings in nursery and transplanting them early (2 weeks) with minimized plant population and therefore competition for growth scarce resources. It increases rice yield through better management of plants, soil, nutrients, and water (De Laulanie, 2011). It is a system that have been developed in 1960's in Madagascar and proved to greatly enhance rice productivity. This system is new in Nigeria and thus form the basis for this study with a view to determining the growth and yield performance of rice and use of organic and inorganic fertilizers and different methods of cultivation.

MATERIALS AND METHODS

The Study Area

The study site of Kadawa is a predominant rice growing area situated between the south of Kura town and north of Daka-tsale town in Kura LGA of Kano state. The area is located on Latitude 11^{o} 39′N and 0.8^{o} 26′E longitude at the elevation of 496 m from the sea level. It has mean annual rainfall of about 830 mm almost all of which falls between June and October. The daily average temperature ranges from 29 to 38^{o}C. The vegetation of the area consists of varying proportions of herbaceous grasses and sedges with a low distribution of trees and shrubs. The soil of the experimental field is alfisols according to the USDA classification. The soil texture was silt loam having pH 6.2 and contains organic matter 1.19 g kg^{-1}, total N 0.46 g kg^{-1}, available P 23.66 mg kg^{-1} and available K 0.27 mg kg^{-1}.

The experiment was to investigate the effect of nitrogen fertilizer rates (0, 50 and 100kg ha^{-1}) and poultry manure rates (0, 3 and 6 t ha^{-1}) and two levels each of green manure (with and without green soyabean biomass), and rice cultivation method (system of rice intensification (SRI) and conventional farmer's practice). The study was conducted in 2012 and 2013 at the Kadawa farm of the Institute for Agricultural Research A.B.U, Zaria, in the Sudan Savanna zone of Nigeria.

Treatments and Experimental Design

Composite soil samples were taken from a depth of 0-30 cm in each field before the establishment of the trial in both years. Treatments were arranged in a split-plot design with a factorial combination of three each of poultry manure (0, 3 and 6 t ha^{-1}) and nitrogen (0, 50 and 100 kg ha^{-1}) assigned main plot and two levels each of green manure (with or without) and cultivation methods (conventional vs SRI) assigned sub plots. All the treatments combinations were replicated three times.

Field Trials and Data Collection

Rice seedlings were raised at the nursery on 5th and 27th June, 2012 for conventional and SRI system respectively and transplanted on 11th July, 2012. While the nursery was established in 2013 season on 15th May and 6th June for conventional and SRI respectively and transplanted on 20th June, 2013. Regular irrigation was carried out until seedlings were ready to be transplanted into both the SRI and conventional fields. The seedlings were aged 35 and 15 days for the respective cultivation methods. The main field was harrowed and leveled. Basins were constructed with earth bunds of 40cm height for all resulting 108 plots. Immediately following construction, the bunds were decreased from 40cm height for SRI only to 20cm height. Poultry manure was applied 3 weeks to transplanting date to allow mineralization of nutrients. All plots were puddled followed by leveling under the SRI.

One and three seedlings for the 14 days (SRI) and 35 days (conventional method of rice production) respectively were washed and transplanted. Rice in the SRI method was spaced at 30 cm while for the conventional method they were spaced 20cm x 20cm. Moisture supply to the crop was mostly from rainfall but irrigation was employed in few instances when dry spelt was experienced. Water in the SRI plots were maintained at 10cm level while those for conventional method was flooded to the brink.

Five days after transplanting of rice, water was drained out from all the 108 plots and Soyabean variety Samsoy 2 were sown in between rows of rice at 5cm intra row spacing for plots with green manure. The soyabean were uprooted and incorporated into green manure affected plots at 40 days after sowing. In case of plots with N fertilizer treatment, the fertilizer was split applied in two equal doses at 2 and 4 WAT while 60 $kgha^{-1}$ each of K_20 and P_20_5 was applied to each of the plots at 2 and 4 WAT.

Butachlor was applied at the rate of 4L/ha as pre-emergence in the conventional plots and at maximum tillering before booting as post-emergence Butachlor + Propanil (Orizo plus) was used at 4L / ha. The SRI plots were hand pulled at early and mid-tillering stage.

Harvesting was done when rice reached physiological maturity by cutting from the base of the plants from the centre of each plot using 1m by 1m quadrat. The cleaned grains from rice plants were weighed in grammes using L 200 metler balance and values later converted to t/ha and recorded. At harvest time, yield component was measured as number of panicles hill, number of filled and unfilled grains $panicle^{-1}$. The number of panicles $hill^{-1}$ were counted from randomly selected five hills of harvested area. From randomly selected ten panicles of harvested area, the grains were threshed and bulked, the number of filled grain and unfilled grains were counted and thousand grain weight was measured.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1967), using the statistical analysis system (SAS Institute, 1997) and the differences in means were separated using Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$ (Duncan, 1955).

RESULTS AND DISCUSSION

Alternate Wetting and Drying (AWD): Table 1 indicated that the SRI methods of cultivation increased significantly the number of panicles m-^{2} and filled grain number panicle^{-1} over conventionally grown plants in both years and thousand grain weight in 2013. The use of poultry and green manure as well as N fertilizer in this study resulted in the growth of algae over the water surface layer which was more in the conventional method. This persisted beyond the maximum tillering stage in conventional as compared to the SRI. Under field condition, the nitrification process converts NH_4^+ to NO_3^- and could have resulted in losses of N from leaching under the conventional method with plants grown in submerged condition continuously. Kronzucker *et al.* (1999) reported the practice of AWD irrigation led to a fluctuation of NH_4^+ and NO_3^- in the soil continuously flooded. Thus, losses of N from leaching could have been offset by higher levels of N resulting from a mixing and jixtaponix of aerobic and anaerobic soil condition (Paddy water environment, 2011) under shallow standing water maintained in the SRI method with healthier and vigorous plants. The number of panicles per unit area is determined by tiller development during the vegetative phase (Fageria *et al.*, 2003). The effect of mimicking the AWD practice in the SRI method from transplanting to maximum tillering when water levels in the SRI was maintained at lowest level, might have increased oxygen ions nourishment in soil and facilitated sufficient nutrient to plants during the vegetative growth which consequently led to more tillers development to produce panicles. The plants in the SRI plots were stouter and had better morphological features. This important component of the SRI could also have increased roots elongation and accessibility to indigenous nutrients of the soil in response moisture stress. The increased accessibility to lower soil water horizon compensates for loss of water at the upper layer of soil in the SRI to increase translocation of assimilates from source to sink for panicle development.

Seedling Age: The final yield is mainly a function of the number of panicles bearing tillers per unit area. Stoop *et al.* (2002) reported that increased tillering potential of young seedlings during vegetative phase was systematically favourable whatever their genotype. This might be because young seedlings enhanced tiller production and thus hastened rice maturity, enabling the synchrony of the various growth phases to be completed within the crops' stipulated maturity period for higher production. This study is in accord with Pasuquin *et al.* (2008) who did not observe any significant difference in duration from transplanting to the emergence of the first tiller while working with seedling ages between 7 and 21 days old. It has been reported that seedlings which has not exceeded their fourth phyllochron stage of growth did not suffer the shock of relocation (Singh *et al*., 2007). On the other hand, the use of 35 days old seedlings transplanted in the conventional method resulted in decreased panicle number m-^{2} which might have been as a result of delayed physiological growth of vegetative stages at the expense of the reproductive phase due to shock of relocation being greater using older seedlings. Tillers that started late produced small tillers in later part of their growth cycle and flowered late. These small and lately produced panicles ripened late and could not mature along with the earlier formed panicles and resulted in unproductivity. The potential number of grains is determined at the panicle initiation stage and is influenced by the plant's nutritional status during vegetative growth (Fageria *et al.*, 2003). The higher unfilled number of grains (Table 1) in the conventional method might be the reason for the fewer filled grain number recorded. Spikelets sterility is an indication of hardship experienced by the rice crop during the period from pollination and fertilization of ovules to physiological maturity. Because tillers that started late flowered late and could not mature along with the earlier formed panicles, this could have resulted from insufficient assimilate supply at the later growth stage because root activity declined.

Table 1: Effect of cultivation methods, Panicle m^{-2}, Unfilled grain $panicle^{-1}$, Filled grain $panicle^{-1}$, 1000-grain weight and Grain yield (t/ha) at Kadawa in 2012 and 2013

Treatments	Panicle m^{-2} (no m^{-2})		Filled grain $panicle^{-1}$ (no $panicle^{-1}$)		Unfilled grain $panicle^{-1}$ (no $panicle^{-1}$)		1000-grain weight (g)		Grainyield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cultivation method										
SRI	267.2[a]	290.7[a]	86.39	97.40[a]	12.68[b]	13.41	28.60	29.44	5.59[a]	6.05[a]
Conventional	250.2[b]	266.9[b]	83.29	89.85[b]	15.75[a]	13.43	29.05	28.74	4.75[b]	4.86[b]
SE±	3.69	4.10	0.880	1.183	0.312	0.355	0.185	0.215	0.272	0.187
Green manuring										
+ GM	259.5	283.2	86.85	92.78[a]	15.09	13.13	28.84	29.34	5.35	6.56[a]
-GM	258.3	279.5	85.10	89.21[b]	16.33	13.69	28.58	29.07	5.00	5.91[b]
SE±	3.69	4.10	0.880	1.183	0.312	0.355	0.185	0.215	0.272	0.187
Poultry manure(t/ha)										
0	170.7[b]	152.4[b]	55.53[c]	49.70[c]	12.80	8.04[b]	27.83[b]	27.44[b]	3.60[b]	3.74[c]
3	257.6[a]	280.2[a]	88.74[b]	92.44[b]	13.26	12.85[a]	28.23[a]	29.79[a]	5.72[a]	5.93[b]
6	275.2[a]	298.4[a]	99.06[a]	100.96[a]	14.02	11.85[a]	29.27[a]	31.04[a]	6.20[a]	6.69[a]
SE±	5.53	5.34	1.496	1.687	0.489	0.380	0.350	0.401	0.196	0.191
Nitrogen level (kg/ha)										
0	174.4[c]	149.2[c]	55.85[b]	49.40[b]	12.85[b]	7.71[c]	27.63[c]	27.25[b]	3.58[c]	3.78[c]
50	240.9[b]	232.9[b]	87.07[a]	94.90[a]	15.97[a]	13.06[b]	28.10[b]	28.54[a]	5.40[b]	5.96[b]
100	300.4[a]	299.2[a]	94.02[a]	98.20[a]	16.46[a]	14.93[a]	29.75[a]	29.96[a]	6.54[a]	6.62[a]
SE±	5.53	5.34	1.496	1.687	0.489	0.380	0.350	0.401	0.196	0.191
Interactions										
N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x N	NS	NS	NS	NS	NS	NS	NS	NS	X	NS
C x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x N x P	NS	NS	NS	NS	NS	NS	NS	NS	X	X
C x G x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x G x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x G x N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same column and treatments group are not significantly different ($p>0.05$) using DMRT. * = Significant at 0.05 probability level ** = significant at 0.01 probability level, NS = Not significant, SE = Standard error, + GM = with Green manure, -GM = without green manure

Plant Spacing: Plants with ample space will compete less for environmental factors. Thus, increased plant spacing (30 x 30 cm) might have increased individual plant performance that led to greater vegetative growth and its translocation to the sink, as opposed to the closely spaced (20 x 20 cm) in conventional plots which could be attributed to minimal competition for nutrients. Morrison *et al.* (1990) explained further that well-spaced plants received more solar radiation and are therefore more photosynthetically efficient than closely spaced ones. Dense spacing also increases competition for water and nutrients which results in inadequate vegetative growth (Knavel, 1988).

Single Seedling: The fact that single seedling might consume more nutrients than 2 and 3 seedlings and took advantage of low vegetative biomass at the initial growth stages, it might develop better morphological growth and structures which resulted in larger stem girth/plants produced at later growth. A larger stem girth is known to be involved in larger nutrients uptake and greater assimilates translocation for a larger source and sink and vice versa. This could have led to remarkable higher absolute partitioning rate of stored matter from the vegetative organs of the leaves, stems and sheaths to the grains. Wen and Yang (1991) obtained higher rice yield, effective panicles, number of grains per panicle and 1000-grain weight by planting 1 seedling hill^{-1}. These activities might have promoted higher photosynthetic efficiency leading to production of enough assimilates for subsequent translocation to various sinks and hence the production of higher yields and yield components of rice.

Soyabean Green Manure*:* Yield is the optimum reflection of the yield components. The results depicted in Table 1 showed consistent increase in yield attributes in plots with incorporated fresh green manure compared to the plots without, but the increases were seldom not significant. Among which mineralization of soyabean green biomass and its availability for uptake has been reported to be dependent on several factors; Hardarson *et al.* (1984) reported soyabean lines such as IAC 100 which have a high harvest index can make only marginal contribution to the status of the soil compared with those with high N_2 fixation and low, N harvest index and this might be likelihood reason for the lack of response. The masking effect as a result of application of inorganic N and poultry manure could be another likely reason for poor response. Probably, these two sources of fertilizer might have added adequate nutrients that satisfied the crop's requirement for these parameters at the early periods of critical needs for nutrients which strongly influenced the grain yield of rice (Amina Khatun *et al.*, 2016).

Nitrogen Fertilizer: The results depicted in Table 1 shows significant increase in number of panicles m^{-2} with varying application rates of nitrogen from 0 kg ha^{-1} through 50 kg ha^{-1} in both years. Chemical fertilizers offer nutrients which are instantly available in soil solution. This might be attributed to the consequence of the participation of N in structural functions of the plant, such as cell multiplication and differentiation, genetic inheritance and formation of tissues (Mauad *et al.*, 2003), which likely occurred at early and mid-tillering stages to maximize panicle number m^{-2}, because of its requirement as much as possible at these stages (Sathiya and Ramesh, 2009). This might also be attributed to the high response characterized by the variety to nitrogen fertilizer.

Nitrogen fertilization resulted in significant increase in number of filled grains panicle^{-1} only up to 50kg ha^{-1} beyond which it was insignificant (Table 1). The number of filled grain is dependent upon pollen grain meiosis, anthesis, pollination, fertilization and carbohydrate translocation, and is influenced by prevalent environmental conditions especially 10 days before and after flowering as well as by excessive rates of nitrogen fertilizer (Mauad *et al*., 2003). The non-significant difference in filled grain number panicle^{-1} between plots receiving the maximum and medium rates of 100 and 50 kg N ha^{-1} respectively might be attributed to excessive nitrogen supply by the 100 kg ha^{-1}rate at the vegetative stage producing greater number of panicles m^{-2} that bore more spikelets. This could have led to the decline in the amount of carbohydrate produced from nitrogen during the critical flowering stage to fill the greater number of spikelets as a result of competition by individual rice crop that grew vigorously, thereby affecting the production of filled grains with corresponding increase in unfilled grains on spikelets. This might be the same reason for the non-significant weight of the 1000-grains recorded (Table 1) by nitrogen rate up to 100 kg ha^{-1}. This might also be attributed to the instability of nitrogen in soil solution for longer periods.

Poultry Manure: The results depicted in Table 1 shows significant increase in number of panicle m^{-2} only up to 3 t ha^{-1} of poultry manure application. This indicated that the crop requirement was achieved at this lower rate rather than higher rate. The confounding effect of green manure along with the different rates of N fertilizer applied might have provided adequate amount of N for absorption and use for growth and development of panicles thereby resulting in response to low PM rate. Similar observation was reported by Abumere *et al.* (2016).

The number of grains contributes materially towards the final grain yield. The results depicted in Table 1 shows number of filled grains per panicle was significantly increased up to 6 t ha^{-1} poultry manure rate. The increased filled grain number per panicle produced by higher poultry manure rates was probably due to higher nutrients released status of plant maintained during the reproductive, panicle initiation and grain filling periods. This could be attributed to slow-release nutrient character of organic manures long after reproductive growth stage at maturity. Poultry manure contains high nitrogen, phosphorus, potassium and other essential nutrients (Mirza *et al*., 2010) and the highest phosphorus uptake is the young panicle development stage, although much phosphorus is also absorbed at the maturity stage. The need for enhanced nutrient and carbohydrate translocation from source to sink (Sathiya and Ramesh, 2009) might have been particularly critical during grain filling to fill the spikelets and to produce higher percentage filled grains panicle^{-1} and has been part of DNA, phosphorus plays an imperative role in building genetic parts of plants (Am-Eura, 2009), to produce the thousand grain weight at the kernel development stage.

The heavier weight of 1000-grain in plots that received poultry manure could be due to comparatively higher nutrients and water exploration which are necessary in the later stage of rice development after flowering as nutrients like phosphorus released by PM promotes the growth and development of roots. This might have subsequently led to higher photosynthesis for the production of higher photo assimilates translocated to grain filling to produce heavier grains than in control plots.

Table 2 shows the interaction of nitrogen fertilizer, poultry manure rates and cultivation method on rice paddy grain in 2012. Cultivation of rice using SRI method in combination with the use of 100 kg N ha^{-1} plus either 3 or 6 t had^{-1} poultry manure produced the overall highest grain yield while the least grain yield was when neither type of fertilizer was used in either method of rice cultivation.

Table 3 shows the interactions of rates of nitrogen fertilizer, poultry manure, and cultivation methods at Kadawa in 2013 on rice paddy grain yields. The combination of SRI method + 6 t ha^{-1} poultry manure + 50 or 100 kg N ha^{-1} + 3 t ha^{-1} poultry manure gave the highest rice grain yield while the least grain yield was from conventional method + 0 kg N +

0 t ha^{-1} poultry manure. Yang et al (2004) also made similar of observation when they reported that moisture levels affect the organic matter accumulation and mineralization when chemical fertilizers were used in combination with farmyard manure or wheat straw in alternate wetting and drying conditions, which increased N, P, & K uptake by rice plants, as well as increased 100 grain weight yield of rice.

Table 2: Interaction effects of nitrogen fertilizer X poultry manure (t/ha) and X cultivation method on grain yield tonne hectare^{-1}of rice at Kadawa during 2012.

Treatment	SRI			Conventional		
	Nitrogen levels (kg/ha)			Nitrogen levels (kg/ha)		
	0	50	100	0	50	100
Poultry manure (t ha)						
0	3.405^{fg}	3.912^{f}	5.372^{d}	2.423^{h}	2.963^{g}	3.523^{fg}
3	4.992^{e}	6.592^{c}	7.532^{a}	4.000^{f}	5.049^{e}	6.140^{cd}
6	6.422^{c}	7.283^{b}	7.842^{a}	4.720^{e}	5.490^{d}	5.770^{d}
SE±			0.1682			

SE = Standard error, Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using DMRT.

Table 3: Interaction effects of nitrogen fertilizer X poultry manure (t/ha) and X cultivation method on grain yield tonne hectare^{-1}of rice at Kadawa during 2013.

Treatment	SRI			Conventional		
	Nitrogen levels (kg/ha)			Nitrogen levels (kg/ha)		
	0	50	100	0	50	100
Poultry manure (t ha)						
0	3.029^{g}	4.040^{f}	5.797^{c}	2.040^{h}	3.030^{g}	4.483^{e}
3	4.702^{e}	6.657^{b}	7.967^{a}	4.224^{ef}	5.568^{d}	6.472^{b}
6	6.679^{b}	8.054^{a}	7.530^{b}	5.491^{d}	6.259^{bc}	6.100^{c}
SE±			0.1566			

SE = Standard error, Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability using DMRT.

CONCLUSION

The use of soyabean green manure, application of 3 t/ha poultry manure and 100 kg N/ha under SRI had produced better rice crop in both years when compared to use of same fertility improvement technique under conventional method of rice production.

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