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INFLUENCE OF SEED QUALITY AND SOIL FERTILITY MANAGEMENT ON THE PRODUCTIVITY OF RICE (*ORYZA SATIVA* L.) IN THE GUINEA SAVANNA OF GHANA

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Abstract

*Seed quality and soil fertility improvement are two key determinants of enhanced crop production to ensure food security in the savannah ecology. Field studies were conducted at the experimental field of the Savanna Agricultural Research Institute (SARI) during the 2011 and 2012 cropping seasons, from July to November, to determine the interaction effects of seed quality and soil amendments on yield components and grain yield of Gbewaa rice (Jasmine 85). Seed quality, using farmer-saved seed and certified seed, was combined with five levels of soil amendments and laid out in a randomized complete block design with four replications. The soil amendments were: No-amendment control, 28.75-12.5-6.25 kg NPK/ha and 60 kg urea /ha (55.2 kg N/ha) as basal and top-dressing applications, respectively (Half Recommended Rate of inorganic fertilizer = HRR), Half Recommended Rate of inorganic fertilizer + 1.5 tonnes of compost per hectare, 57.5-25-12.5 kg NPK/ha and 120 kg urea/ha (110.4 kg N/ha) as basal and top-dressing applications, respectively (Recommended Rate of inorganic fertilizer = RR) and Recommended Rate of inorganic fertilizer + 3 tonnes of compost/hectare. In 2011, improved seed quality in combination with soil amendments made significant improvements in panicle length ($P<0.03$), number of seeds per panicle ($P<0.01$) and thousand-grain weight ($P<0.04$). Parameters that improved in both years with improved seed quality and also soil amendments were tiller count ($P<0.01$), number of seeds per panicle ($P<0.01$), and grain yield ($P<0.001$), with certified seed gave better results than farmer-saved seed, whilst RR + 3 t/ha compost optimized each parameter. However, RR alone promoted grain yield similar to RR + 3 t/ha compost. Tiller count ($r=0.889$**), number of panicles per hill ($r=0.834$**), number of seeds per panicle ($r=0.922$**) and thousand grain weight ($r=0.893$**) were all positively correlated with grain yield in 2012. Tiller count consistently accounted for more than 75% of the grain yield. The food security implications of the results are discussed in the full paper.*

Keywords: Soil Management, Rice production, Seed Quality, Guinea Savanna

Introduction

Rice (*Oryzasativa* L) has increasingly become an important strategic crop for the world's population in terms of its food security; socioeconomic, cultural and commercial outlook in both developed and developing countries (FAO, 2011). Brar and Khush (2002) noted that the crop contributes about 23% of the world's supply of calories. Rice production must therefore be accelerated to keep pace with demand as about 3 billion people, nearly half the world's population, depend on the crop for

survival (Kwarteng and Towler, 1994). Sub-Saharan Africa cultivated about 7.86 million hectares of rice per year during 2001–2005, with 3.29% per annum growth rate (WARDA, 2004). Despite the high hectarage outlay in rice production in Africa, a large proportion of consumer demand is met through imports with Ghana, for example importing as much as 58% of rice grains in a year, due to low grain yields (MoFA, 2009).
Despite recent efforts at encouraging increases in rice production, such as development of the varieties of New Rice for Africa (NERICA) (WARDA, 2004), which could withstand varied biotic stresses, grain yields are still very low in the Guinea and Sudan savannah zones of Ghana (JICA/CSIR report, 2001). Pertinent factors militating against enhanced rice production could be due to weed interference, poor water management, the inability of farmers to use the required seed quality and declining soil fertility.

Seed quality is a relative term and can be defined as the degree of excellence when compared to an acceptable standard seed. Seeds that satisfy the required standard of genetic purity, good health and physiological purity (viability and vigour) and other attributes are referred to as quality seed. Good quality seed is one that is pure (of the chosen variety), full and uniform in size, viable (more than 80% germination with good seedling vigor), and free of weed seeds, seed-borne diseases, pathogens, insects or other matter (IRRI, 2003). Such seeds have high return per unit area as the genetic potential of the crop can be fully exploited, supporting use of lower seed rate with high seedling emergence (>70%), reduced replanting, more uniform plant stands, and more vigorous early crop growth. Vigorous growth in early stages reduces weed problems and increases crop resistance to insect pests and diseases. A combination of higher crop emergence, vigorous early crop growth, and increased crop resistance to insect pests and diseases will result to a 20% increase in yield (IRRI, 2003). Poor quality seed gives poor seedling vigor, non uniform growth and maturity and further prone rice seedlings to insects and disease and weed-pests, and adverse environmental conditions (Ellis *et al.*, 1995). Good quality seeds have high return per unit area as the genetic potential of the crop can be fully exploited. Planting good quality seed is often one of the areas taken for granted, as farmers realize crop growth even from farmer saved poor quality seed. One of the farmer's most critical management decisions is the selection of the variety and the source of seed that could sustain grain yield.

Grain yield under rainfed conditions is declining with cropping intensification as soil fertility declines (WARDA, 2002; Fairhurst and Witt, 2002). Abunyewa *et al.*(2005) reported that poor soil fertility is one of the major limitations to increased crop production among small-holder farmers in the savannah region of West Africa. In current intensive rice mono-cropping systems, soil organic matter declines and the buffer equilibrium has been disturbed with inputs of mineral fertilizers now playing a significant role in soil fertility maintenance (Ladha*etal*., 2000; Van Kauwenbergh, 2006). It was noted that the sustainability in rice crop production could be achieved through the integration of chemical fertilizers and organic manures (Khan *et al*., 2001). However, fertilizer use in sub-Saharan Africa is quite low, averaging about 10 kg/ha of NPK, whereas Asia and Latin America have experienced significant increase in use (Laegreid*et al.*, 1999). Rice responds well to fertilizer with nitrogen and phosphorus being the most important requirement in the Guinea Savanna (Kwarteng and Towler, 1994). Hussain *et al*. (1998, 2001) reported significant improvement in soil physical properties such as bulk density, porosity, void ratio, water permeability and hydraulic conductivity when 10t/ha of farm yard manure was applied in combination with chemical amendments, with consequential increase in grain yield of rice. Grain and straw yields of rice were significantly higher in treatments that received FYM or green manure or urban compost besides N, P and K than in no manure NPK treatments, thereby highlighting the beneficial effects of integration of organic manure with chemical fertilizer in increasing the crop yield. Overall, grain and straw yields of rice and uptake of N, P and K showed that manure plus fertilizer schedule with either FYM or green manure or urban compost with the recommended doses of N, P and K could maximize the rice yield and uptake of nutrients than the application of recommended levels of fertilizers alone without any manure (Jagadeeswari and Kumaraswamy, 2000; Singh and Gangwar, 2000).

Rice is a heavy feeder and extremely sensitive to the amount and balance of nutrients in the soil; a suitable combination of organic and inorganic source of nutrients could therefore be necessary for sustainable production (Reganold *et al.*, 1990; WARDA, 2002). Nambiar (1991) viewed that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in soil fertility and production. The present study was to determine how seed quality and/or optimum organic/inorganic soil amendment could influence the yield components and grain yield of Gbewaa rice in the savannah ecology.

Materials and methods

Site description

The experiment was conducted during the 2011 and 2012 cropping seasons from July to November in each year on the same experimental field of Savanna Agricultural Research Institute (SARI) at Nyankpala, near Tamale in the Tolon Kumbungu District in the Northern Region of Ghana. The location lies on an altitude of 183m, and latitude 09^o 25' N and longitude 0^o 58'W. It has a unimodal rainfall of about 1000mm which is evenly distributed from May to October with the peak in August and September. Temperature distribution is uniform with mean monthly minimum of 23.4^{o}C and maximum of 34.5^{o}C with a minimum relative humidity of 46% and maximum of 76.8% (SARI, 2008).

Experimental design and treatments

The study was a 2 x 5 factorial experiment laid out in a randomized complete block design (RCBD) in four replications. Each replication consisted of ten plots each measuring 3m x 5m with 1m and 2m alleys between plots and replications respectively. Treatments consisted of the combination of (1) Seed quality using farmer-saved seed and certified seed, and (2) five levels of soil amendments. The soil amendments were:

1. No-amendment control.
2. 28.75-12.5-6.25 kg NPK/ha and 60 kg urea /ha (55.2 kg N/ha) as basal and top-dressing applications, respectively (Half Recommended Rate of inorganic fertilizer = HRR).
3. Half Recommended Rate of inorganic fertilizer + 1.5 tonnes of compost per hectare
4. 57.5-25-12.5 kg NPK/ha and 120 kg urea/ha (110.4 kg N/ha) as basal and top-dressing applications, respectively (Recommended Rate of inorganic fertilizer = RR)
5. Recommended Rate of inorganic fertilizer + 3 tonnes of compost/hectare

Both NPK and urea were applied by dibbling. Basal applications were done two weeks after planting (WAP) and top dressing 6 WAP.

Land preparation and planting

The field was ploughed to a depth of about 20 cm and harrowed two weeks after, and then levelled using hand hoe to create a favourable condition for planting and emergence of seedlings. Blocking was done across the slope to check erosion and to minimize any incidence of soil fertility gradient that may exist on the field. The application of compost was done to targeted plots and incorporated by hoe. Planting was done in early July by dibbling at a crop spacing of 20 cm x 20 cm with 4 seeds/hill. Bunds were created around each plot to prevent spillage of fertilizers from plots.

Data collection

Percent seedling emergence counted at 2 WAP and seedling population was made up by transplanting from a nursery or by thinning within same plots to refill, to ensure uniform number of hills per plot. Tiller count per hill was taken per plot at the maximum tiller stage (8 WAP), using the 2 x 2 hill method where four hills were randomly selected five times in each plot and tagged for panicle number per hill data at harvest. Plant height was measured at harvest stages from five hills randomly selected and tagged. Fifty percent flowering was noted by visual observation. Pests and disease incidence specifically stem borers; brown spots and blast were monitored and controlled by standard chemicals at recommended rates. Panicle weight of ten panicles selected from each plot was weighed. Panicle length of ten panicles were randomly selected from each plot and lengths measured. The number of seeds per each of the ten sampled panicles was counted and their means were calculated. Thousand grain weights from each plot were counted after harvesting and threshed and weighed. Grain yield was taken at 14% moisture content taken after harvesting and threshing.

Data analysis

Data collected was subjected to the two-way Analysis of Variance (ANOVA) model using Genstat statistical package. Means were separated using Least Significant Difference (LSD) at 5%. Correlation and simple regression relationships were calculated.

Results and discussions

Interaction effect of seed quality and soil amendment on rice parameters

Three yield components of rice were improved by the combination of seed quality and soil amendment in the 2011 cropping season. Panicle length and thousand-seed weight were maximised with the use of certified seed lot in combination with the application of 250 kg 23-10-5 NPK/ha and 120 kg Urea/ha as basal application and top dressing respectively (RR) or RR supplemented with 3 tonnes/ha of compost and were superior to other treatments (Table 1). For number of seeds per panicle, certified seed combined with RR without compost gave superior results (Table 1).

Table1: Effect of seed quality (SQ) x soil amendment (SA) interaction on panicle length (PL) and number of seed per panicle (NSPP) and thousand seed weight (TSW).

Factors		**2011**		
SQ	SA	PL(cm)	NSPP	**TSW (g)**
FS	Control	18.50	53.75	21.65
FS	HRR	19.75	77.00	23.30
FS	HRR+1.5 ton/ha C	21.00	84.25	23.65
FS	RR	24.00	109.50	24.58
FS	RR+3 ton/ha C	24.00	118.00	24.90
CS	Control	17.00	64.50	20.950
CS	HRR	21.00	70.75	23.58
CS	HRR+1.5 ton/ha C	22.00	84.75	24.18
CS	RR	24.00	115.25	25.33
CS	RR+3 ton/ha C	25.00	127.50	25.85
LSD(5%)		1.98	7.48	0.79
CV%		8.90	5.70	2.30

HRR= 125 kg 23-10-5 NPK/ha and 60 kg Urea/ha as basal application and top dressing respectively, **RR**= 250 kg 23-10-5 NPK/ha and 120 kg Urea/ha as basal application and top dressing respectively, CS=Certified seeds, FS= farmers seed, C= compost, **LSD**= least significant difference and **CV**= coefficient of variation.

Effects of seed quality

Certified seed did not determine percentage seedling emergence, but was superior in performance in days to 50% flowering, plant height, tiller count, number of panicles per hill, panicle weight (Table 2) and grain yield (Figure 3) in comparison with Farmer’s saved seed.

Table 2: Effect of seed quality on percentage seedling emergence (PSE), days to 50% flowering (DFF), plant height at maturity (PHM), tiller count (TC), number of panicles per hill (NP) and panicle weight (PW).

Parameters	2011			2012		
	Farmers seed	Certified seed	LSD (5%)	Farmers seed	Certified seed	LSD (5%)
PSE	95.1	95.55	2.95	86.55	87.85	2.43
DFF	97	93	2	110	98	2
PHM	63.1	58.7	3.88	77.8	76.8	4.78
TC	14.85	15.95	0.89	16.85	17.85	0.94
NP	10	12	0.65	11.8	15.6	1.41
PW	23.48	24.56	1.19	23.23	24.31	1.19

LSD= least significant difference

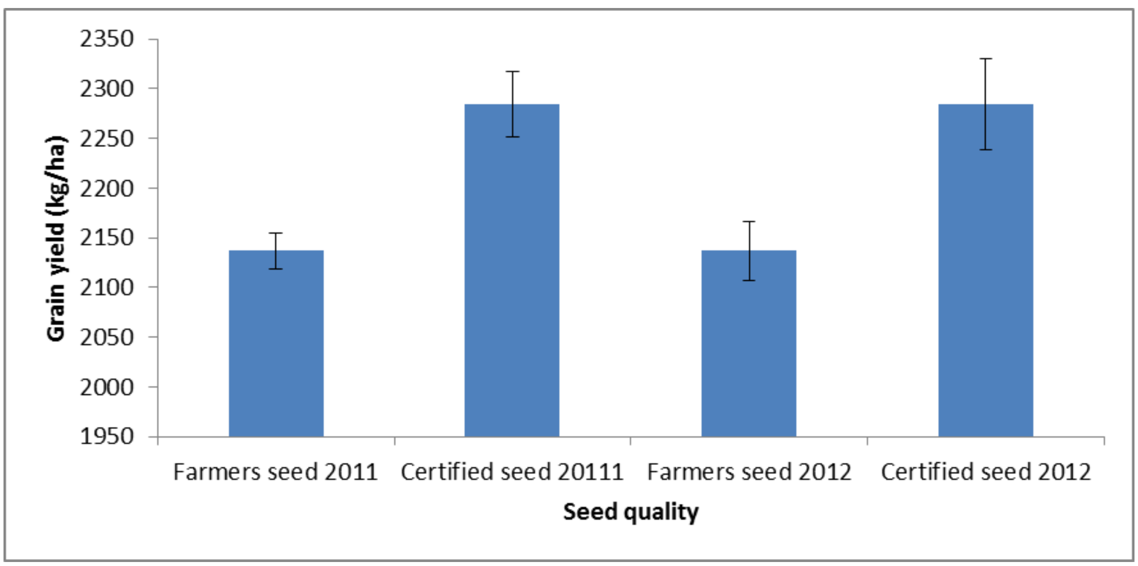

Figure 1: Effect of seed quality on grain yield. Bars represent SEM.

Effects of soil amendment

Generally, the recommended rate of fertilizer (RR = 250 kg 23-10-5 NPK/ha and 120 kg Urea/ha as basal application and top dressing respectively) alone or supplemented with 3 tonnes/ha of compost maximised all the parameters in this experiment with few exceptions (Tables 3 and 4 and Figures2 and 3).

Table 3: Effect of seed quality on percentage seedling emergence (DFF), days to 50% flowering (DFF), plant height at maturity (PHM), tiller count (TC) and number of panicles per hill (NP).

Soil Amendment	2011					2012				
	PSE	DFF	PHM (cm)	TC	NP	PSE	DFF	PHM (cm)	TC	NP
Control	96.2	105	56.62	10	7	79.12	108	80.4 78.5	12	10
HRR	92.5	98	55.75	12	10	83.5	105		14	13
HRR+1.5 ton/ha C	96.5	94	62.38	14	11	91.25	102	74.8	16	14
RR	95.5	90	63.62	19	12	87.75	105	75.5	21	15
RR+ 3 ton/ha C	95.88	89	66	23	14	94.38	101	77.6	25	17
LSD(5%)	4.67	3	6.13	1	1	3.835	4	7.56	1	2
CV%	4.8	3.4	9.8	8.9	9.2	4.3	3.5	9.5	8.4	15.8

HRR= 125 kg 23-10-5 NPK/ha and 60 kg Urea/ha as basal application and top dressing respectively, **RR**= 250 kg 23-10-5 NPK/ha and 120 kg Urea/ha as basal application and top dressing respectively, CS=Certified seeds, FS= farmers seed, C= compost, **LSD**= least significant difference, **CV**= coefficient of variation.

Table 4: Effect of seed quality on panicle length (PL), panicle weight (PW), number of seed per panicle (NSPP) and thousand seed weight (TSW).

Soil amendment	2011				2012			
	PL(cm)	PW (g)	NSPP	TSW (g)	PL(cm)	PW (g)	NSPP	TSW (g)
Control	17.75	14.19	59	21.30	16.62	13.94	52.13	21.30
HRR	20.38	19.26	74	23.437	18.12	19.01	76.00	23.44
HRR+1.5 ton/ha C	21.5	23.75	85	23.912	19	23.5	83.25	23.91
RR	24	28.85	112	24.950	20.88	28.6	108.50	24.95
RR+3 ton/ha C	24.5	34.03	123	25.375	21.88	33.78	117.00	25.20
LSD(5%)	0.95	1.88	5.287	0.5594	1.16	1.88	4.588	0.741
CV%	4.3	7.6	5.7	2.3	5.9	7.7	5.1	3.0

HRR= 125 kg 23-10-5 NPK/ha and 60 kg Urea/ha as basal application and top dressing respectively, **RR**= 250 kg 23-10-5 NPK/ha and 120 kg Urea/ha as basal application and top dressing respectively, CS=Certified seeds, FS= farmers seed, C= compost, **LSD**= least significant difference, **CV**= coefficient of variation

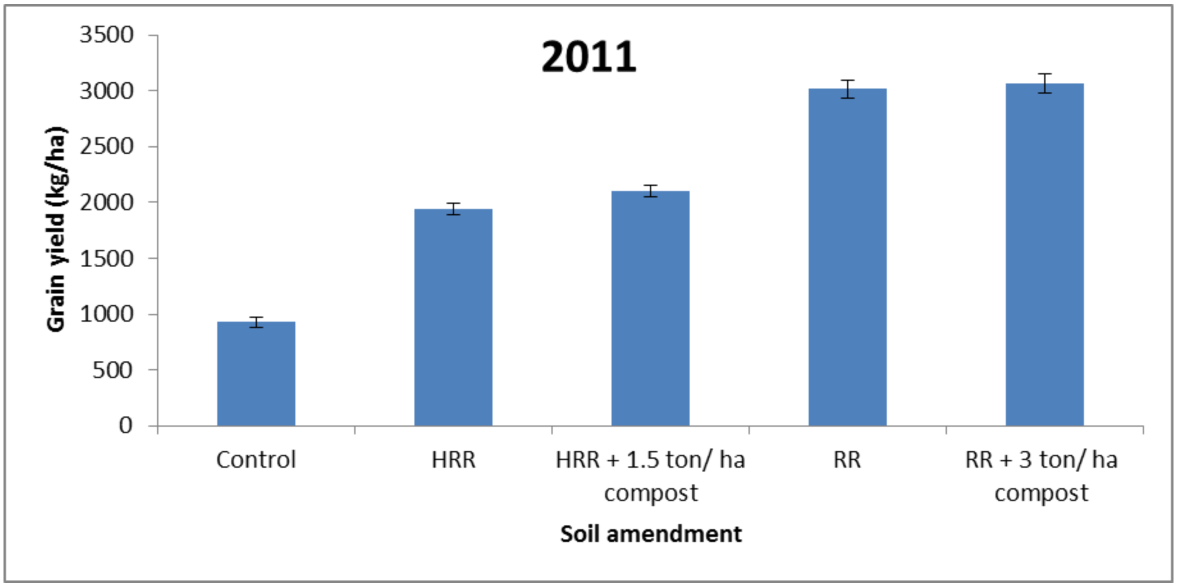

Figure 2: Effect of soil amendment on grain yield. Bars represent SEM.

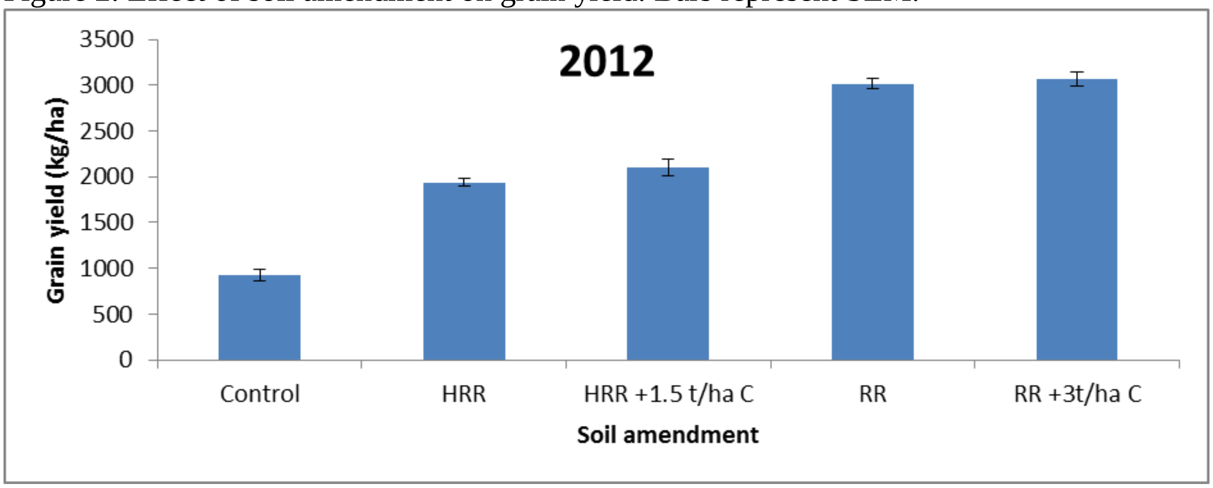

Figure 3**:** Effect of soil amendment on grain yield. Bars represent SEM

Overall deductions

The better-quality performance of certified seed to farmer's saved seed, for example in earlier flowering, higher tillering and grain yield, probably was due to greater purity and quality of the genetic material which promoted the expression of the standard traits as observed in cowpea by Singh *et al.*. (2003). Tillering, for example, is a major yield determinant trait of rice, which was consistently enhanced in both years of experimentation by certified seed relative to Farmer saved seed, probably due to their effects on enhanced seedling emergence and vigorous growth in early stages.

The earliness in flowering with the highest rate of soil amendment in both organic and inorganic fertilizers in this trial probably showed that the rates did not present superfluous quantity of nutrients, especially nitrogen. Earlier findings by WARDA (2004) reported that superfluous levels of nitrogen promotes late flowering as a result of prolonged vegetative growth. Integration of compost and inorganic fertilizer influenced significantly tiller count, number of panicle per hill and panicle weight. This might probably be due to the increased availability of the appropriate nutrients from the soil amendments in the right quantities which played a vital role in promotion of plant growth as reported by Mizra et *al*. (2010). Miller (2007) emphasised the importance of organic sources of fertilizer as a more balanced source of nutrition to plants, especially micro-nutrients which could positively affect tillering and other growth and yield components of rice. Benefits of improvement in the soil physical properties for optimum crop productivity due to organic matter application is numerously reported (Ramamoorthy*et al.*,2001, Balamurali, 2006, Nakamura *et al*., 2012, Nakamura *et al*., 2013).

Overall certified seeds enhanced grain yield over farmers seed (Figure. 5), likewise the recommended inorganic fertilizer with or without organic manure (Figure. 6) might have provided the required and adequate amount of nutrients to sustain crop growth and development, as similarly reported by IRRI (2003). The supply of required nutrients might have facilitated a balanced nutrition of the crop, which resulted in enhanced grain yield (Jeyabal*et al*. 1999). The nutrient sources, most likely, made available both the major nutrients such as nitrogen, phosphorus and potassium and micro-nutrients to enhance vegetative growth and reproductive development as exhibited in the parameters examined. The application of compost with inorganic N combinations might have prolonged the availability of N and thereby delayed senescence and contributing more to photosynthesis during the seed filling stage (Kadyal*et al*., 2002, Fageria and Baligar, 2001). The findings confirmed many reports that credible agronomic rice responses could be obtained from the combination of inorganic and organic matter schedules (Maqsood, 1998, Jagadeeswari and Kumaraswamy, 2000; Singh and Gangwar, 2000, Woporeis-Pura*et al*., 2002, Meena*et al*., 2003, and Nakamura *et al*., 2012).

Correlation and regression analysis

Grain yield of rice highly and positively correlated with tiller count (r=0.8891**), panicle number (r=0.8344**), panicle length (r=0.8840**), number of seeds per panicle (r=0.9151**) and thousand grain weight (r=0.8926**) (Table 5). About 70% and 80% of grain yield could be accounted for by number of panicles and 1000 seed weight respectively (Figure. 4 and 5) respectively.

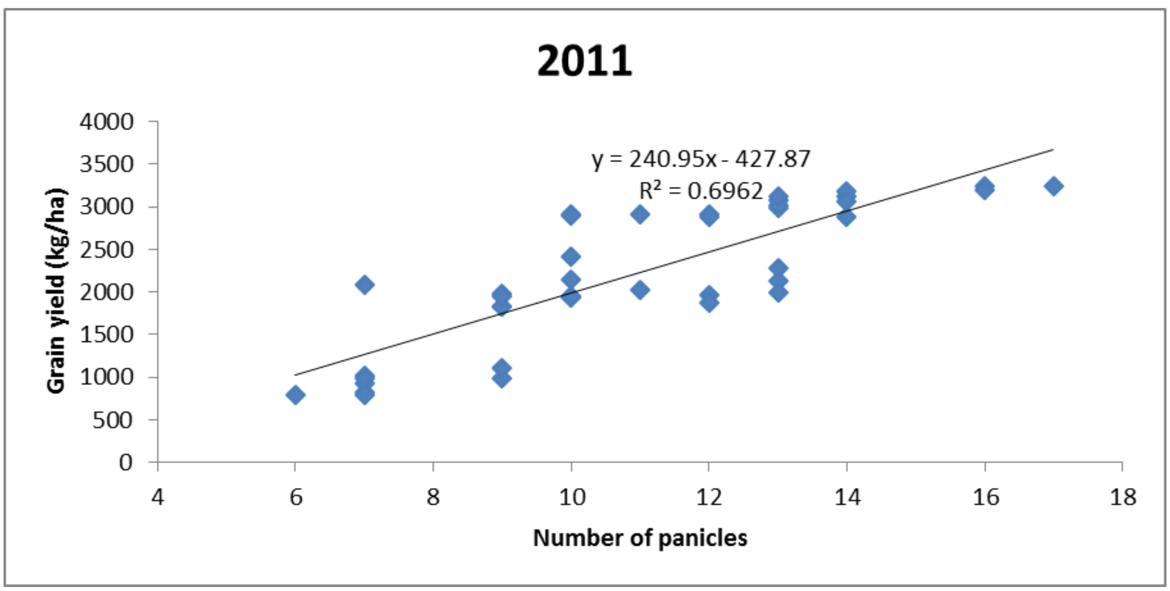

Figure 4: Linear relationship between number of panicles and grain yield.

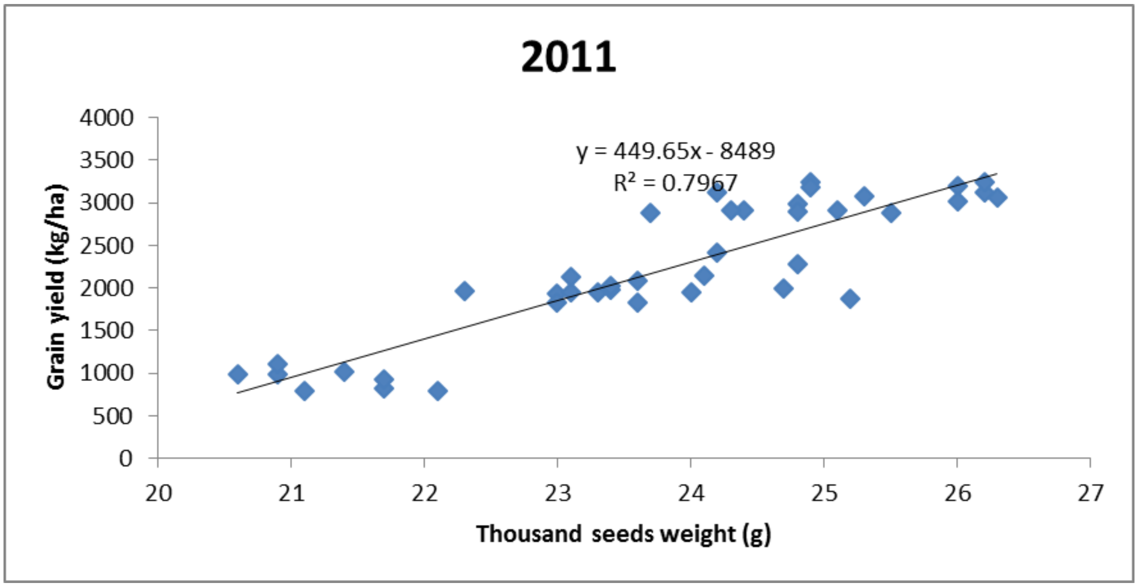

Figure 5: Linear relationship between thousand seeds weight and grain yield.

Table 5: Correlation coefficient (r) among yield components and grain yield.

Parameters	TCPH	GY	TSW	PW	PL	NPPH
TCPH	1					
NPPH	0.8449	1				
PL	0.7885**	0.6329	1			
PW	0.8985**	0.7884**	0.9055	1		
TSW	0.7825**	0.7670**	0.7685**	0.8398**	1	
GY	0.8891**	0.8344**	0.8840**	0.9151**	0.8926**	1

Conclusion and recommendation

The purpose of the experiment was to determine the influence of seed quality and soil fertility management on the yield components and grain yield of Jasmine 85 rice in the Guinea savannah zone. It was deduced that certified seed was superior to farmer saved seed and overwhelmingly promoted most of the parameters investigated.

Whilst the recommended rate of inorganic fertilizer at 250 kg NPK/ha plus 120 kg urea/ha as basal and top-dressing applications respectively, was sometimes adequate to support the performance of production, the effect of the recommended fertilizer rate supplemented with 3tons/ha of compost was overwhelming.

The results of this study re-emphasised the need to build the capacity of farmers in the integration of crop-livestock into the farming systems in the Guinea savannah zone.

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