Responses of Upland NERICA Rice to Fertiliser Application and Fallow Management in Different Agro-Ecological Zones of Benin Republic

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Abstract

Recent findings reported that introduction of legumes as an intercrop or in rotation to minimize external inputs can reverse the declining of soil fertility in upland rice agrosystem and so improve the productive capacity of farms. The objectives of the study were to assess (1) the effects of rotation of upland rice with other crops, of fertiliser application and of rice varieties on rice yield and (2) the interaction effects of rotation, fertiliser application and variety on rice production. An experiment was carried out from 2011 to 2012 in 2 zones in Benin Republic, West Africa. Three rice rotation treatments were established where in the year preceding rice cropping the following pre-crops were grown: (1) natural fallow regrowth (2) sole cowpea crop and (3) cowpea/maize intercrop. The following year, 3 NERICA varieties were cultivated in the three pre-crop treatments with and without fertiliser application. With respect to combined effect of NP mineral fertiliser and rotation, a consistent increase in rice yield over all varieties was only observed with maize-cowpea intercrop preceding rice in the Guinean zone. Improved fallow with cowpea combined with fertiliser was beneficial for NERICA 2 and NERICA 4 in the Sudano –Guinean zone and with NERICA 1 and NERICA 4 in the Guinean zone. Rice in rotation with maize-cowpea intercrop and in combination with NP mineral fertiliser can easily fit into the current smallholder farming systems under rain-fed conditions in the Guinean zone, but is not recommendable for the Sudano- Guinean zone.

Keywords: Rice, rotation, fertiliser, NERICA, cowpea, added benefit

1. Introduction

The high yielding upland NERICA (New Rice for Africa) varieties developed from the crosses between the Asian *Oryza sativa*. L. and the African rice *Oryza glaberrima* Steud. have been disseminated since 1998 through the Participatory Varietal Selection (PVS) and some of the NERICA varieties were widely disseminated from 2006 to 2010 across Benin, West Africa (Yokouchi & Saito, 2016). These varieties combine desirable traits of both parents including high fertiliser input responsiveness (Dibba et al., 2012) and have been widely adopted by rice farmers in Benin. For instance by 2009, 74 % of farmers belonging to a farmer group had experience of growing NERICA (Yokouchi & Saito, 2016). However, yields are generally low as a consequence of limited and erratic rainfall and low soil fertility. Indeed, Koné et al., (2009) found out N, P, K deficiencies as limiting factors of low grain yield of upland rice on the dominant soils of savanna zones in Benin. As soil fertility is declining and so the productive capacity of farms is being eroded (Okeleye et al., 2013), recent findings reported that introduction of legumes as an intercrop or in rotation to minimize external inputs can improve soil fertility (Oikeh et al., 2010). For example, in earlier review, Carsky et al. (2002) highlighted the benefits for soil fertility restoration through soil N and potential grain yield increase in trials made of cereal-based cropping systems in short rotation with cowpea in the savanna regions of West Africa. The rotation systems integrating appropriate dual-purpose soybean with rice increased grain yield for NERICA in the moist savanna (southern) and in dry savanna (northern) of Benin Republic forest zone (Oikeh et al., 2010). Indeed, positive effects of short fallow rotation of NERICA with leguminous crops has already been demonstrated (Sokei et al., 2010). Another study showed that rice cultivation on soils with legume fallow residue results in a significant increase in rice yield compared to rice cultivation on soils with residue burning and mulching (Akanvou et al., 2000). In addition, traditionally, cereal farmers use cowpea to rotate or mix with their crops for edible and commercial purposes as well as for its contribution to maintaining the fertility of their farmlands (Adjei-Nsiah et al., 2012). Meanwhile Corbeels et al. (2016) indicated, under drought stress the practice of mulching affects simulated subsequent crop grain yield positively, as well as the residual benefits of legumes interacting with variable seasonal conditions.

Furthermore legume residues can enhance the effectiveness of mineral fertiliser application to increase crop yields. For instance, nitrogen derived from mineral fertiliser increased sorghum yield by 10%, 22% and 26% in monoculture, rotation with fallow and rotation with cowpea, respectively (Bado et al., 2012). Specifically Oikeh et al. (2012) showed that grain yield of a NERICA variety was increased with the supply of 20 kg N ha^{-1} after a short rotation (same season) with cowpea in degraded Savanna in Benin. If an interaction effect on yield between N applications with the use of rotation can be seen in those previous studies, a similar interaction effect of rotation with a legume and inorganic fertiliser on yield could be expected in other agro-ecological zones. To test this hypothesis, the present study assesses the sole effect of rotation, fertiliser and rice variety and their interactions on rice yield components and interaction between those factors in two major savannah zones (Guinea and Sudano-Guinea) in West Africa.

2. Materials and methods

2.1. Site description

The experiment was carried out from 2011 to 2012 during two crop growing seasons in the Guinean and Sudano-Guinean Savannah zones in Benin Republic, West Africa. These zones are the major rice growing zones in the country and are characterized by different agro-ecological conditions (Fig. 1; Table 1). One representative farmer's field was selected for the field trial in each zone. In the Sudano-Guinean zone, the experiment was conducted at Materi (10° 45´N 0° 59´E).

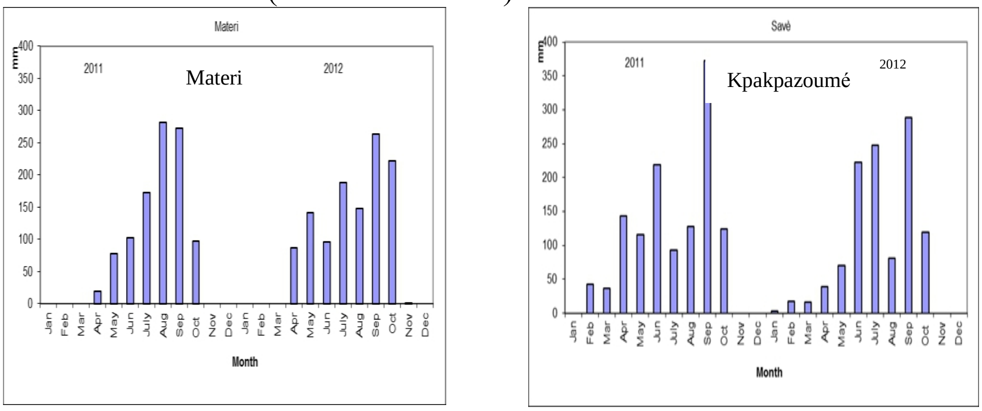

Figure 1. Rainfall patterns for two the experimental sites, Materi in the Sudano-Guinean agro-ecological zone and Kpakpazoumé in the Guinean zone in Benin Republic.

Table 1. Topsoil at 20cm depth properties of the two experimental sites in Benin Republic

	Materi	Kpapkazoumé
Coordinates	10° 45´N 0° 59´E	7° 55´N2°15´E
Agro-ecological zones	Sudano Guinea	Guinea

Soil type FAO	Dystric Plinthisol	Plinthic Luvisol
Physical properties		
Sand %	67	79
Clay%	9	9
Texture class	Sand-Loam	Sand-Loam
Chemical properties		
pH (H2O)	6.7	7
Corg %	0.7	0.7
N %	0.1	0.1
CEC (cmol kg^{-1})	8.5	7.7
Bases (cmol kg^{-1})		
K+	0.1	0.1
Ca2+	2.1	1.1
Mg2+	5.4	0.4
Na+	0.8	--
P Bray (mg/kg)	27	4

This zone represents a transition between semi-arid and semi-humid tropical climate and is dominated by a unimodal rainfall distribution. The average annual rainfall is between 1250 mm and 1500 mm with 180–270 rainy days. Kpakpazoumé (7° 55´N 2°15´E) was selected as the second experimental site in the Guinean zone, a location which extends from the coast up to about 8° N. The climate is tropically wet with usually two rainy seasons (Fig. 1), a longer season from May to July and a shorter one from September to November for about 250 rainy days and annual rainfall ranging from 1400 to 1800 mm, altogether (White, 1983).

Meteorological data were collected at the meteorological stations (Savé meteorological station for Kpakpazoumé and Materi gauging station for Materi) closest to the experimental fields (Fig. 1). In 2011 and 2012, annual amounts of rainfall were 1025 and 1147 mm, respectively, at Materi and 1273 and 1106 mm, respectively, at Kpapkazoumé. The rains were distributed over 7 months in Materi and over 9 months at Kpakpazoumé in both years.

In 2012, the rice growing cycle benefited of 919 mm of rain in Materi and 961 mm in Kpakpazoumé. Geologically, the two study sites are located on the crystalline basement, Kpakpazoumé on migmatite and Materi on schist. At both locations the experiment was conducted on a deep, slightly leached, tropical ferruginous soil (Alfisol) (Table 1) in which ferric hydrate particles are associated with few aluminum oxides (Igué, 2012).

2.2. Experimental design

2.2.1 Pre-rice crop experiment in 2011

The experiment included crop rotation as the main factor with three treatments preceding the rice crop: fallow (control), sole cowpea at a planting density of 66.000 plants per ha and cowpea intercropped with maize with 53.000 plants per ha each. The maize-cowpea intercrop was characterized by alternating rows of cowpea and of maize.

The experiments were conducted in 2011 and 2012 on plots where upland rice had been cultivated in the previous years. Plots had been tilled at the end of the dry season in May 2011. The variety DMR was used for maize and KVX396-18 for cowpea. All plots and crops were planted at the same time in June 2011 without any fertiliser applied. The plots were hand-weeded three times during the cropping season. Chemical insecticide, Decis 12.5 CE, (delthaméthrine) was applied regularly in monthly intervals from the seeding of the cowpea crop in both locations. Fallow vegetation residues and crop residues (shoot and root) from maize and cowpea were returned after harvesting cowpea.

2.2.2. Rice cropping

The following year, at the onset of the rainy season, main plots were divided into split plots with three replications where the second factor (main strip) was rice varieties (N1: NERICA 1, N2: NERICA 2, and N4: NERICA 4) and the third factor (sub-plots) was the fertiliser application (either no mineral fertiliser (0N0P) or N at 80 kg.ha^{-1} as urea combined with P at 80 kg P2O5 ha^{-1} as Triple Super Phosphate (TSP). Each main plot consisted of 12 rows, 3 m long, and each sub-plot had 9 m^2. These NERICA varieties were chosen in order to extend the evaluation done by Oikeh et al. (2008). A higher rate of fertiliser than farmers' practice was tested with respect to soil degradation status described in Worou (2012). Seeds of the NERICA varieties were sown at the rate of 4 seeds per hill (July 20th in Kpakpazoumé and July 5th 2012 in Materi) with a spacing of 20 cm x 20 cm and seedlings were thinned to 2 plants per hill. In order to avoid any interacting effect of drought spells, two weeks after planting, all fertilisers were applied at the full rate (no splitting). Weeding and pest controls were done when necessary (at least two times in 2011 and in 2012).

2.3. Data collection

The three central rows (3m of length) of each sub-plot were harvested at the end of the rainy season 2011 and 2012 to determine grain weight which was then oven-dried at 60 °C for 72 hours. In 2012, data collected in the rice crop were the number of tillers at 30 days after sowing (DAS), the plant height at 30 DAS, 60 DAS and at maturity. The number of panicles at maturity and rice total aboveground biomass was sampled at crop maturity during the harvest in Kpakpazoumé. HI (harvest index) was derived from measured total aboveground biomass and grain yields. Weed biomass was collected from the first weeding operation within the rice cropping season at 30 DAS in only Kpakpazoumé. At the beginning of the experiment in 2011, soil auger samples (0-20cm) were taken along a diagonal in each plot and combined into a composite sample. Total N was determined by the Kjeldahl method. The pH was determined using a soil water ratio of 1:2. Exchangeable bases (Mg, K, Ca and Na) were extracted with ammonium acetate of 1 mol. L^{-1}; Ca and Mg in the extract were measured using an atomic absorption spectrophotometer (AAS) while Na and K were determined by flame photometry. The potential cation exchangeable capacity was determined by extraction with barium chloride of 1 mol. L^{-1}. P concentration was determined using a method by Bray I. Results of soil analysis are presented in Table 1.

2.4. Data analysis

Data was analyzed by analysis of variance (ANOVA) with a generalized linear mixed model, at a 95% confidence level with three levels of errors: the first error to test fallow management/cropping systems (main effect); second error to test fertiliser application and interaction of the fertiliser application with the crop rotation system; and finally the pooled residual error to test variety effects and interactions of the variety with the other two factors. Means separation was performed with Tukey's Least Significant Difference (LSD) at the 0.05 probability level. The data analysis for this paper was carried out using SAS software, Version 6.1.176 of the SAS System for Windows.

The added value of legume rotation and applied fertiliser on rice grain yield was calculated with the following equation (Okeleye et al., 2013):

Added benefit (Mg ha^{-1}) = $Y_{T2orT3F} - (Y_{T1F} - Y_{T1O}) - (Y_{T2orT3O} - Y_{T1O}) - Y_{T1O}$

Where:

$Y_{T2orT3F}$ was the rice yield in legume rotation with 80N80P application (Mg ha^{-1})

Y_{T1F} was rice yield with 80N80P fertiliser application after natural fallow (Mg ha^{-1})

Y_{T1O} was rice yield without 80N80P fertiliser application (control) after natural fallow (Mg ha^{-1})
$Y_{T2orT3O}$ was rice yield in legume rotation without 80N80P fertiliser application (Mg ha^{-1})

3. Results

3.1. Pre-rice crops yields

In the Guinean zone at Kpapkazoumé, the sole cowpea yield was much higher than intercrop cowpea yield, while no difference was observed between them in the Sudano-Guinean zone of Materi (Fig. 2). Maize yield obtained without any fertiliser application remained below 0.18 Mg ha^{-1} in both sites.

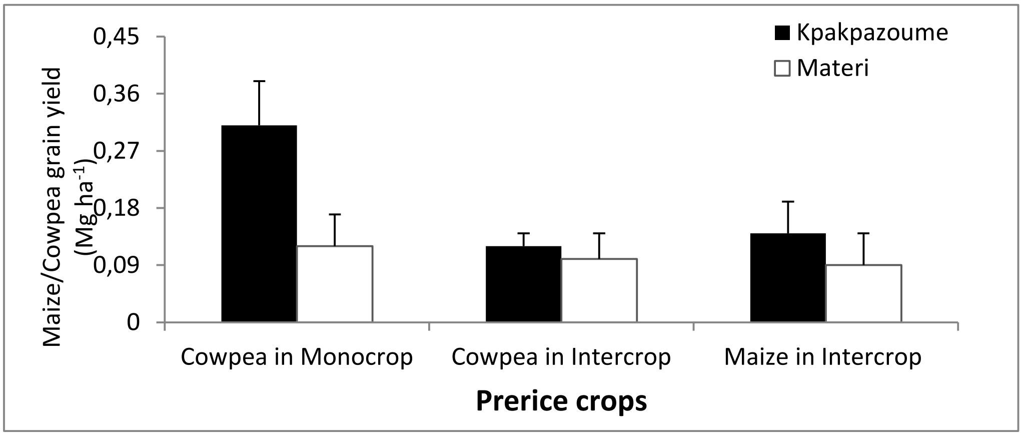

Figure 2. Pre-rice crops yield (maize and cowpea) at the Sudano-Guinean (Materi) and the Guinean (Kpakpazoumé) zones in Benin.

3.2. Rotation, fertiliser and variety and their interaction effects on rice yield and yield components

The study investigated the combined effect of a one year short-term fallow and fertiliser application on rice grain yield and its components of three NERICA varieties in the Guinean zone of Benin. In this zone, the number of tillers at early stage was significantly affected by inorganic fertiliser inputs and rotation (Table 2). Panicle number at maturity was significantly influenced by rotation, fertiliser, variety and by interactions between some of the factors (rotation x fertiliser and fertiliser x variety). For the case of total aboveground biomass at harvest, only fertilizer was significant. Weed biomass was significantly affected by all the factors involved in the study except rotation and fertiliser. Rice crop height at maturity was also affected by all the factors except rotation x variety.

In Sudano-Guinean zone of Benin, the number of tillers at early stage was significantly affected by inorganic fertiliser inputs (Table 2). For the case of plant height at maturity, significant factors were fertiliser, variety and the interaction between rotation x fertiliser x variety. Furthermore, there were significant effects of rotation, fertiliser, interaction variety x rotation, interaction fertiliser x variety and the three levels interaction rotation x fertiliser and variety on rice yield at harvest. Fertiliser particularly had a highly significant effect (p <0.001).

Table 2. Analysis of variance for grain yield, panicle and tillers number at maturity, plant height, total aboveground biomass of NERICA varieties and weed biomass as influenced by Variety, N and P fertiliser and Rotation factors.

Variable	DDF	Grain Yield	Tillers number at 30 DAS	Plant height at maturity	Panicle number at maturity	Total above ground biomass	Weed Biomass
P-value from ANOVA across 2 experiments. DDF: Denominator Degrees of Freedom							
Guinea zone							
Source							
Rotation	2	0.04	0.05	0.0002	0.009	0.05	0.25
Fertiliser	1	<.001	0.02	<.001	<.001	<.001	0.79
Rotation*Fertiliser	2	0.36	0.07	0.007	0.01	0.1	0.02
Variety	2	0.007	0.98	0.05	0.02	<.001	0.02
Rotation*Variety	4	0.25	0.69	0.21	0.07	0.24	0.002
Fertiliser *Variety	2	0.003	0.43	0.001	0.004	<.001	0.02
Rotation*Fertiliser *Variety	4	0.22	0.25	0.03	0.44	0.30	0.003
Sudano-Guinea zone							
Source							
Rotation	2	0.01	0.09	0.22			
Fertiliser	1	<.001	<.001	<.001			
Rotation*Fertiliser	2	0.86	0.59	0.15			
Variety	2	0.52	0.06	0.006			
Rotation*Variety	4	<0.001	0.59	0.82			
Fertiliser *Variety	2	0.03	0.75	0.66			
Rotation*Fertiliser *Variety	4	0.02	0.29	0.05			

In the Guinea zone, there were significant effects of N-P fertiliser, rotation and variety on crop yield at harvest and interaction of variety and fertiliser. Indeed results showed that fertiliser effect was highly significant (p <0.001) and allowed that yield attained 5.1 Mg ha^{-1} (Fig. 3a). Grain yields of the 3 cultivars ranged from 2.3 Mg ha^{-1} to 3.5 Mg ha^{-1} (Fig.3b), N1 and N4 gave the highest yield. Grain yields of different rotation treatments ranged from 2.66 Mg ha^{-1} after natural fallow to 3.52 Mg ha^{-1} after cowpea-maize intercrop, which was significantly higher than rice yield after natural fallow (Fig. 3c). In the Sudano- guinea, the highest grain yield of 3.07 Mg ha^{-1} was achieved in the fertilized plots (Fig. 3a). According to the rotation effect there was a significant decrease in yield by 31 % with cowpea-maize intercrop compared to the natural fallow (Fig. 3c).

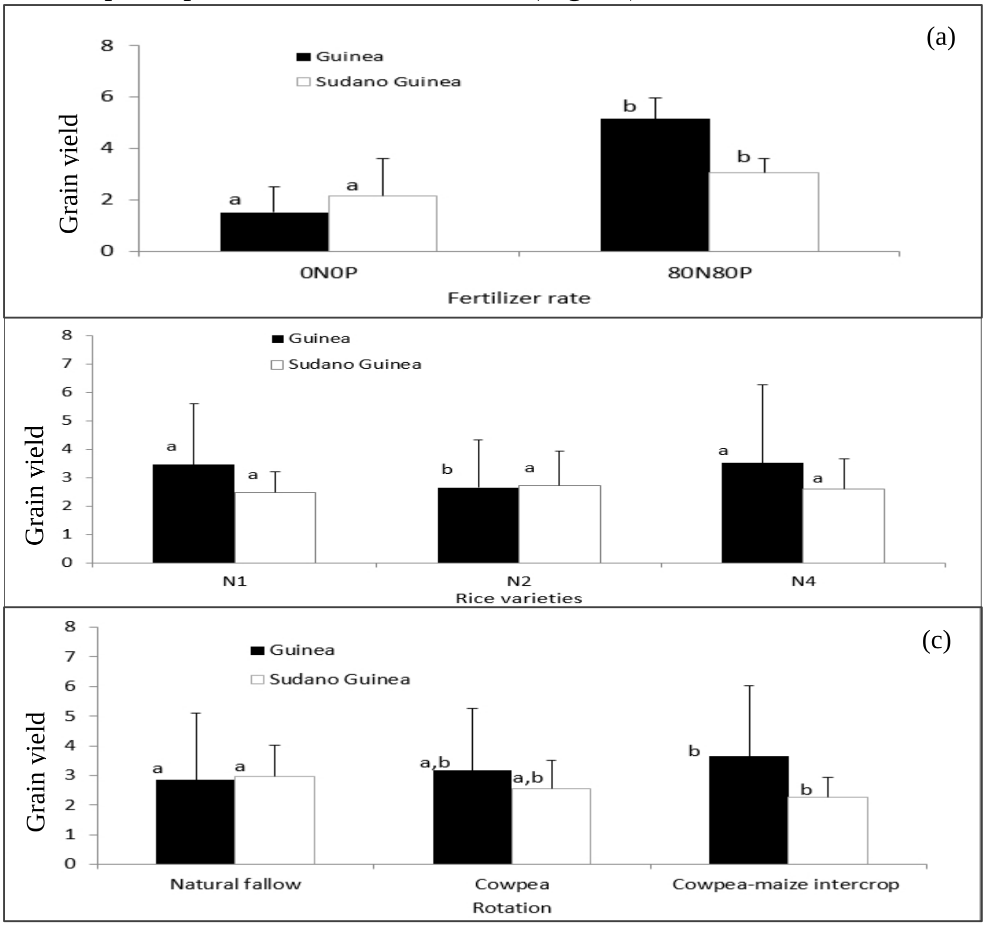

Figure 3. Influence of NP level (a); variety (b); and rotation (c) on rice yield in 2012. Means of yield according to Variety, Fertiliser and Rotation effects followed by the same letter are not significantly different at $P < 0.05$. N1, N2 and N4 refer to NERICA1, NERICA 2 and NERICA 4 respectively.0N0P and 80N80P refer to no fertiliser and 80 kg.ha^{-1} N with 80kg.ha^{-1} of P respectively.

Table 3 shows details of the significant interaction effects observed for variety x fertiliser. Under Guinea, N2 yield was significantly depressed by 24-32% compared with the yields of other NERICA varieties with fertilizer application, while the responses of the varieties were similar with grain yield of 1.1 – 1.5 Mg/ha when fertilizer was not applied. Under Sudano-Guinea, significant interaction effects were observed in variety x rotation and variety x fertilizer. Data showed that N4 performed best (3.7 Mg/ha) under natural fallow (T1), while N2 was the best (3 Mg/ha) under maize-cowpea intercrop (T3). But all the varieties had similar grain yield (2.3 – 2.9 Mg/ha). Also, under this agroecology, all the NERICAs responded significantly to NP fertilizer application by 21 – 47% compared with zero-fertilizer, and the grain yields of N2 and N4 were similar (3.54 vs. 2.93 Mg/ha) based on the statistics presented.

Table 3. Influence of Rotation x Variety and Variety x Fertiliser on grain yield (Mg ha^{-1}) in two agro-ecological zones of Benin Republic.

	N1	N2	N4
		Guinea	
T1	2.64b,c	2.43c	3.44a,b
T2	3.73a	2.29c	3.47a,b
T3	4.02a	3.26a,b,c	3.64a
O	1.53c	1.25c	1.05c
F	5.39a	4.08b	5.99a
		Sudano-Guinea	
T1	2.90b,c	2.22c,d	3.74a
T2	2.52b,c,d	2.86b,c	2.28b,c,d
T3	1.97d	3.04a,b	1.78d
O	2.18c	1.87c	2.28c
F	2.75b,c	3.54a	2.93a,b

Means within a column for Variety × Rotation or Variety x Fertiliser level interaction effect (averaged in each location) followed by the same letter are not significantly different at $P < 0.05$. N1, N2 and N4 refer to NERICA1, NERICA 2 and NERICA 4 respectively. T1, T2 and T3 refer to fallow, cowpea and intercropping cowpea-maize respectively, O and F refer to without fertiliser and with fertiliser respectively.

Significant varietal differences were also observed in some other traits like panicle number at maturity and total above ground biomass (Table 4). N2 exhibited the highest plant height at maturity in the Guinea, although the range in plant height between varieties was less wide. Besides, data showed that HI was higher with fertilizer (0.31) than without fertilizer (0.21). Also, weed biomass was significantly higher in N1 plots than in N4 plots, but the biomass was similar in N1 and N2 plots.

Plant height was also larger in fertiliser plots (124 cm versus 84 cm in the no fertiliser plots). Higher grain yields in the fertiliser treatments were associated with higher harvest index whereas there were no significant differences in the weed biomass neither with respect to fertiliser inputs nor with respect to rotation. In parallel, in the Sudano-Guinean zone, Varietal traits in the different treatments in Sudano-Guinea zone were also examined in Table 5. Plots with fertiliser application showed higher tillers number at 30 days after sowing, plant height at different growth stages. N1 was the tallest at maturity and N4 was the tallest at 60 DAS.

3.2. Added yield benefits of combined legume-fertiliser in different agro-ecological zones

Integrating cowpea into rice-legume systems could play a significant role in enhancing the performance of succeeding rice crop in upland rice production. Beside this, the additional contribution of combining improved fallow with inorganic fertiliser to rice yield was calculated (Table 6). Sole cowpea generated the lowest gains at balance across the agro ecological zones. For sole cowpea, in Guinea zone, only N1 substantially had an increment of its yield whereas in Sudano-Guinea zone, N2 and N4 obtained positive benefits in yield, up to 0.91 Mg ha^{-1} with N4. In Guinea zone, all verities were getting an increment of yield with the intercrops systems tested in the study. N1 was found to be on the best responsive to improved fertility management systems producing the highest gain yields in Guinea zone but N4 was particularly more adapted to both agroecological zones.

4. Discussion

4.1. Comparison of effect of fertiliser between Guinean and Sudano-Guinean zones

Fertiliser was the most significant factor at both agro-ecological zones. The results revealed the importance of soil fertility improvement for NERICA varieties production and were in same line with the study by Saito & Futakuchi (2009) who estimated the average grain yield across all upland cultivars in low fertility soils (low C_{org} content) to be 54% lesser of that in high fertility soils (1.56 vs. 3.40 Mg ha^{-1}) in irrigated fields. However, the study contrasts with earlier studies that moderate levels of both nutrients (60 kg N ha^{-1}and 26 kg P ha^{-1}) as optimum for some of the NERICAs in the highly P-deficient acidic Ultisols (Oikeh et al., 2008). In our study even with a moderately acidic Alfisol with one of the sites (Materi) having a very high soil-P level (27 mg.kg^{-1} Bray-P), the 80N80P rate seemed to generate enough response implying that the additional P application improved the effect of the N inputs. In the Guinea zone, our study showed an increase of yields with NP-fertiliser which could be associated with higher sink size (number of panicles) fertiliser. Saito et al. (2010) confirmed that the highest grain yields under fertiliser treatments were the result of large spikelet numbers per m^2.

Table 4. Influence of Rotation x Variety and Variety x Fertilizer on tillers number, plant height, aboveground biomass, harvest index and weed biomass in Guinean zone.

Treatment	Tillers number.m^{-2}	Panicle number .m^{-2}	Plant height(cm)			Above ground biomass (Mg.ha^{-1})	HI	Weed biomass (Mg.ha^{-1})
	Day 30	Maturity	Day 30	Day 60	Maturity			
N1	153	277a	48.02a,b	85.72b	102.48b	15. 77a	0.21a,b	1.70a
s.e	11.35	14.23	1.44	3.73	4.80	3.54	0.04	0.30
N2	150	308b	46.05b	90.77a,b	107.01a	9.19b	0.29a	1.54 a,b
s.e	9.11	9.51	1.47	3.55	4.96	1. 43	0.04	0.11
N4	151	284a	50.33a	91.27a	103.14a.b	19.43a	0.18b	1.40b
s.e	13.13	18.13	1.96	4.82	6.19	3.86	0.01	0.39
	ns							
F	166a	332a	50.40a	104.11a	124.22a	26.43a	0.19b	1.56
s.e	8.99	5.73	1.33	1.82	1.93	2.43	0.01	0.09
O	138b	247b	46.66b	74.4b	84.04b	3.11b	0.41a	1.53
s.e	8.47	10.55	1.26	1.38	2.06	0.28	0.02	0.02
								ns
T1	147a,b	274a	46.67	84b	99c	12.03b	0.23a	1.61
s.e	9.59	18.88	1.33	3.48	6.16	3.06	0.04	0. 25
T2	171a	309b	50.27	90a	110a	18.84a	0.16b	1.45
s.e	10.89	11.23	1.78	4.22	5.08	3.89	0.04	0.39
T3	137b	285a	47.67	92a	104b	15.52a,b	0.23a	1.59
s.e	11.76	11.46	1.80	4.36	4.40	3.52	0.04	0.30
			ns					ns

s.e is the standard error, ns non-significant at P<0.05. Means within a column Variety, Fertiliser and Rotation effects followed by the same letter are not significantly different at P < 0.05. N1, N2 and N4 refer to NERICA1, NERICA 2 and NERICA 4 respectively. T1, T2 and T3 refer to fallow, cowpea and intercropping cowpea-maize respectively, O and F refer to without fertiliser and with fertiliser respectively.

Table 5. Influence of Rotation x Variety and Variety x Fertiliser on tillers number at 30 DAS, plant height at different growth stages in Sudan Guinean zone.

Treatment	Number of tillers.m^{-2}	Plant height(cm)		
	Day 30	Day 30	Day 60	Maturity
Variety				
N1	84	14.87a,b	19.58b	25.66a
s.e	25	0.58	0.57	0.92
N2	81	15.93a	21.28a	25.13a
s.e	21	0.58	0.49	0.82
N4	79	14.01b	21.61a	23.56b
s.e	21	0.37	0.47	0.78
	ns			
Fertiliser				
F	95a	16.21a	21.71a	27.41a
s.e	17	0.4	0.34	0.50

O	67b	13.22b	19.94b	22.17b
s.e	18	0.34	0.38	0.50
Rotation				
T1	84	14.45	20.56	25.42
s.e	25	0.52	0.71	1.02
T2	82	15.51	21.3	24.55
s.e	21	0.64	0.49	0.77
T3	79	14.85	20.61	24.42
s.e	21	0.46	0.40	0.83
	ns	ns	ns	ns

s.e is the standard error, ns non-significant at $P<0.05$.Means within a column Variety, Fertiliser and Rotation effects followed by the same letter are not significantly different at $P < 0.05$. N1, N2 and N4 refer to NERICA1, NERICA 2 and NERICA 4 respectively. T1, T2 and T3 refer to fallow, cowpea and interaction cowpea-maize respectively, O and F refer to without fertiliser and with fertiliser respectively.

Table 6. Added benefit of legume/rice rotation types in combination with inorganic NP fertiliser on rice grain yield of 3 NERICA varieties.

Treatment	$Y_{T1orT2F}$ (Mg ha^{-1})	Y_{T1O} (Mg ha^{-1})	$Y_{T1orT2O}$ (Mg ha^{-1})	Y_{T1F}(Mg ha^{-1})	Added benefit (Mg ha^{-1})
Sole Cowpea					
Guinea					
N1	5.67	0.89	1.79	4.39	0.38
N2	3.51	1.09	1.08	3.78	-0.26
N4	5.61	0.87	1.32	6.01	-0.85
Sudano-Guinea					
N1	2.59	2.17	2.46	3.64	-1.34
N2	4.01	1.27	1.72	3.17	0.39
N4	2.61	3.87	1.95	3.62	0.91
Maize-Cowpea intercrop					
Guinea					
N1	6.12	0.89	1.91	4.39	0.71
N2	4.95	1.09	1.57	3.78	0.69
N4	6.33	0.87	0.96	6.01	0.23
Sudano-Guinea					
N1	2.03	2.17	1.91	3.64	-1.41
N2	3.46	1.27	2.63	3.17	-1.07
N4	2.55	3.87	1.02	3.62	1.78 n.a.

N1, N2 and N4 refer to NERICA 1, NERICA 2 and NERICA 4 respectively. $Y_{T1orT2F}$ was the rice yield in legume rotation with 80N80P application (Mg ha^{-1}), Y_{T1F} was rice yield with 80N80P fertiliser application after natural fallow (Mg ha-1), Y_{T1O} was rice yield without 80N80P fertiliser application (control) after natural fallow (Mg ha^{-1}), $Y_{T1orT2O}$ was rice yield in legume rotation without 80N80P fertiliser application (Mg ha^{-1}). n.a. not applicable when yield in Y_{T1O} is higher than in other treatments

4.2. Comparison of variety effect between Guinean and Sudano-Guinean zones

A significant variety effect was found in the Guinean zone in contrast to the Sudano-Gunean zone. Mandal et al. (2010) found smaller varietal variance for grain yield under low-input conditions in India, thus supporting our results in the Sudano-Guinea zone. Several kind of stresses may limit varietal selection progress under unfavorable environments and many studies reported that nutrient deficiencies in rice are very common in West Africa (Oikeh et al., 2009) which may constrain the expression of varietal differences.

The response of grain yield to fertiliser application was consistent across environments and across varieties but under fertilized conditions N2 yielded lower than the other two varieties in the Guinean zone indicating a slight interaction between fertiliser application and the performance of the varieties in this zone. As a result, N4 and N1 under 80N80P treatment gave the best yield of 5.39 Mg ha^{-1} to 5.99 Mg ha^{-1} in Guinean zone whereas N4 and N2 gave the best yield of 2.93 Mg ha^{-1} to 3.54 Mg ha^{-1} in Sudano-Guinean zone.

4.3. Comparison of rotation effects on grain yield between Guinea and Sudano-Guinean zones

In the Guinean zone, the effect of N supply on soil from the use of cowpea crop residues may have contributed to the maintenance of soil fertility in this agro-ecological zone resulting in the higher grain yield observed after cowpea as well as maize- cowpea intercrop. In this situation, the benefit of using pre-crop legumes is likely mediated by the N input from pre-crop residues into soils. Akanvou et al. (2000) found an increase up to 20-30 % of soil nitrogen from the use of crop residues inputs for three agro-ecological zones including the Guinean zone in Côte d'Ivoire. Igué (2006) reported that after 6 years of organic input (here rice residues incorporation) in the same agro-ecological zone, nitrogen, phosphorus and potassium availability changed positively as well as soil organic matter content from 1.23% to 3.15%.

Further a contrast between the Guinean and Sudano-Guinean zones was the interaction that existed between rotation and variety at one side and interaction between rotation, fertiliser and variety at the other side in the Sudano-Guinea zone. Meanwhile, when taking rotation factor alone there were highest yield was obtained with natural fallow in the Sudano-Guinea zone. Saidou et al. (2004) reported that the cereals production in the

Sudano-Guinea region is sustained when cereals benefit from the residual effect of fertiliser applied to the previous crops. In our study, there was no fertiliser application in the preceding crop to rice possibly inducing higher soil nitrogen mining by the pre-crops and consequently no yield benefits by the following rice. Indeed this was evidenced with the very low pre-crop maize and cowpea yields obtained due to the non-application of fertilizer. While comparing the rainfall distribution, the number of wet days appeared relatively lower in Sudano-Guinea compared to Guinea and in the period between the growing season in 2011 and 2012 which may not provide enough moisture for legume residues decomposition. Furthermore, although Adjei-Nsiah et al. (2004) attributed the yield increase in maize after cowpea to an increase in fertility of the soil as a result of the decomposition of the cowpea foliage that is left on the land after harvest, they remarked that if the land is not immediately used for cropping after harvesting, the cowpea effect on soil is lost since cowpea leaves decompose fast.

Rice cultivar traits after the natural fallow, cowpea and cowpea/maize were relatively consistent except that in Guinea zone, tiller and panicle numbers were higher under T2 (cowpea fallow). Oikeh et al., (2012) reported that NERICA 8 after previous cowpea cultivation had the highest soil mineral-N content at tillering which persisted till panicle initiation stage, this may explain that contribution of additional N from the previous cowpea crop influenced the following rice crop in our experiment. Nevertheless in the Guinea zone, anticipate hypothesis can be raise up that NERICA high height with N4 is correlated with weed weight decrease. The study was in agreement with Kolleh (2016) that significant influence ($p < 0.05$) of weed management practices, varieties and some level of interactions exist on rice plants height at maturity.

However, the ideotype approach that has been used in global rice breeding programs rather rely one large panicle size, reduced tillering capacity and improved lodging resistance (Tadele , 2017). In our study, such relationship cannot be obtained.

4.4. Effectiveness of rice-based systems with the combination of cowpea and cowpea/maize rotation in Benin

When no mineral fertiliser was applied after natural fallow, rice produced low (Guinean zone) to moderate (Sudano-Guinean zone) yields, except for N4 in the Sudano-Guinean zone where yields after natural fallow where quite high (see Y_{T1O} in Table 6). The added benefit of combining mineral NP fertiliser with a maize-cowpea pre-crop was positive in the Guinean zone for all three NERICA varieties and whereas at the Sudano-Guinean site, it was negative in all cases (Table 6). On the other hand, the added benefit of combining mineral NP fertiliser with a sole cowpea pre-crop, was slightly positive with N1 in the Guinean zone and N2 in the Sudano-Guinean zone. For these last outcomes, similar results were reported that rice seeded after cowpea cv. IT97-568-11 and supplied with 20N gave the greatest grain yield of about 2.0 Mg ha^{-1}, accounting for 500% heavier grains than fallow-rice rotation with zero-N (Oikeh et al., 2012). But in our study we can show that the positive effect of NP fertiliser after sole cowpea pre-crop depends strongly on the rice variety. On the other hand, N4 seems to be most responsive to NP fertiliser in the Guinean zone (Tables 4 and 7). This is supported by a previous study in a similar climate zone (Oikeh et al., 2009), where N4 was found to be highly responsive to improved fertility management producing the highest yield of 1.2 Mg ha^{-1} with the nitrogen application of 30 $kg.ha^{-1}$ only on highly degraded coastal savanna (Oikeh et al., 2009).

Sole cowpea showed no significant effect on rice yield (Figure 3b) when pooling all NERICA varieties together. This observation may be explained by Toomsan et al. (2000) who showed that poorer N_2 fixation rate in sole legumes might lead to a negative balance of N. In contrast, cowpea intercropped with maize as pre-crop gave a positive N balance. The results are also confirmed by Rusinamhodzi et al. (2006) who found that residues from intercrops with cowpea could increase subsequent maize yields. In their study, maize grain yield after sole cotton was 1.4 Mg ha^{-1}, after sole cowpea (4.6 Mg ha^{-1}), after 1:1 intercrops (4.4 Mg ha^{-1}) and after 2:1 intercrops (3.9 Mg ha^{-1}) and these were significantly different from each other. These results on rotation effects with legume or cereal/legume intercropping requires critical investigation to identify areas where rice farmers can effectively benefit from rotations with sole or intercropped legumes. If several field studies indicate that production risk for small-scale rice farmers in the Guinean zone is lower in rotations with maize/legume intercrops compared to rotations with sole legumes (Stiger and Weiss, 1986), it should have consequences for the recommendations by the extension services. Rotation of rice with maize/cowpea intercrops in the Sudano-Guinean zone seems to be not recommendable. However, the findings from this study may be limited by the length of fallow duration and should be extended.

Conclusion

The objective was to study effects of rotation systems in combination with fertiliser application on NERICA varieties in rain-fed upland cropping system of two West African environments—Guinean and Sudano-Guinean zones—under the assumption that previous cowpea crop residues may release additional nitrogen to the soil that will be beneficial to the subsequent rice crop. Overall, our study found in both agroecosystems, that N4 showed the highest yield with NP mineral fertiliser application after natural fallow compared to N2 and N1. Application of mineral NP fertiliser after a maize-cowpea intercrop had added benefits on rice yield beyond the pure rotation or fertiliser effect in the Guinean zone and can therefore be recommended regardless of the rice variety. Mineral NP fertiliser application in a rotation with maize-cowpea intercropping system are likely to be useful for improving rice production in Central Benin (Guinean zone). In, Northern Benin (Sudano-Guinean zone), the only rotation with positive added benefit for rice yields was with sole cowpea as pre-ceding crop combined with NP mineral fertiliser application on N4 and N2.

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