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Influence of Legume/Rice Sequence and Nitrogen on NERICA® Rice in Rainfed Upland and Lowland Ecologies of West Africa

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ABSTRACT

One major limitation in tropical agriculture is the loss of productivity of soils due to continuous cultivation. This is often due to leaching losses of nutrients, erosion or crop removal. There is need to explore improving productivity of soils by using grain legumes complemented with low-use of applied nitrogen. Modern interspecific rice hybrids called New Rice for Africa (NERICA®) are low input cultivars developed to overcome environmental stresses including low soil fertility. The productivity of these NERICA®s under legume/rice rotation and low-nitrogen (0 vs. 30 kgN ha^{-1}) was evaluated in farmers' fields in 2007 and 2008 in rainfed upland in Kasuwa Mangani northern Guinea savanna (10° 24′ N, 7° 42′ E) and lowland at Edozhigi, southern Guinea savanna (09° 45′ N, 06° 7′ E) ecologies in West Africa. Preceding plots of incorporated soybean and mucuna (*Mucuna utilis*) after harvest, gave 33% increments in rice yield over the previous control-fallow plots in the upland ecology. While, in the lowland, plots with previously incorporated grain soybean (cv. 'TG× 1485 – 1D') and dual-purpose cowpea (cv. 'IT 98K–131–2') residues gave about 0.8 Mg ha^{-1} greater rice yield than plots with previous mucuna or dual-purpose soybean. Although NERICA L-42® produced over 25% more tillers and panicles than the farmers' cultivar, both cultivars had similar yield of 3.6 Mg ha^{-1}, possibly because of the severe effects of iron- toxicity that limited their potentials. Results showed that upland NERICA® rice would perform better after soybean or mucuna rotation, and the lowland NERICA® after soybean cultivation than traditional fallow. Also, the low N at 30 kg ha^{-1} applied was adequate to enhance the effect of incorporated legume on rice yield.

Keywords: cropping system, cereal, mucuna, soybean, yield

INTRODUCTION

One important limitation facing the stability of crop production in West Africa is the declining soil productivity after a few years of cultivation. Nutrients are removed from the soil through crop absorption, loss by leaching, erosion and immobilization. Nutrients so removed have to be replaced to ensure good crop performance. However, these conditions are not met under the present land use system in West Africa. Therefore, nutrient losses are manifested in the form of nutrient deficiencies. Thus, fertilizers need to be supplied to provide the needed nutrients.

Most smallholder farmers have limited resources to purchase fertilizers. Hence, exploring management strategies to use low inorganic N combined with suitable grain legumes could sustain crop productivity. However, the potential contribution of grain legumes to crop production by subsistence farmers in Africa is largely becoming known (Adjei-Nsiah *et al.* 2008; Yusuf *et al.* 2009). Nitrogen-fixing legumes have been shown to have positive impact on soil fertility by enhancing nitrogen availability and therefore benefiting a cereal crop grown in the subsequent season (Adjei-Nsiah *et al.* 2008). In solving the multifaceted problem of food shortage, efforts have been made to develop crop varieties with higher yield potentials. Rice is the third most widely consumed food crop worldwide after wheat and maize. The problems limiting local rice production include poor nutrition, low productivity of local varieties, insect pests and diseases (Oikeh *et al.* 2008a, 2009). A decade has passed since NERICA® (New Rice for Africa; *Oryza sativa x O. sativa x O. glaberrima*) was released from the Africa Rice Center (then West African Rice Development Association or WARDA, now AfricaRice). Because of its high-yielding potential, NERICA® was expected to bring about a rice Green Revolution in sub-Saharan Africa (Somado *et al.* 2008; Kisho *et al.* 2012). NERICA® has attracted a lot of attention by researchers and policy makers, and some literature has been accumulated (Kijima *et al.* 2008; Fujiie *et al.* 2010; Kijima *et al.* 2010), including some recent literature that casts doubt over the potential of NERICA® (Kijima *et al.* 2011).

Information exists in the literature on the nutrient requirements of upland NERICA® (Oikeh *et al.* 2008a, 2009). But, information on fertilizer recommendations for the NERICAs® in rainfed upland and lowland ecologies in the savannas are grossly lacking.

Consequently, there is need to harmonize the use of both organic and inorganic fertilizer sources for soil improvement to sustain yield over a long period as inorganic fertilizer not only promotes mineral elements in the soil, but has been found to be essential for growth enhancement and maximizes yield production in crops (Aynehband *et al.* 2010b).

The objective of this study, therefore was to determine the effect of preceding grain legume crops combined with inorganic N on upland and lowland NERICAs® in the savannas.

MATERIALS AND METHODS

NERICA® varieties developed for rainfed upland and lowland ecologies by Africa Rice Center (AfricaRice) were screened for

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their responses to nitrogen and phosphorus fertilization in 2006 and 2007. From these trials, the best performing NERICA® varieties in terms of yield response to the applied nutrient rates were selected and advanced to on-farm trials in legume/rice rotation experiments in 2007 and 2008 herein reported.

Location and time of studies

1. Rainfed upland

On-farm field experiments were conducted in 2007 and 2008 in Kasuwa Mangani village near Kaduna in the northern Guinea savanna (NGS) (10° 24′ N, 7° 42′ E). Rainfall pattern was unimodal, with a total of 1140 mm per annum. The soil at the selected three experimental sites was classified as Typic Haplusalf (Kowal and Knabe 1972). The average chemical analysis of topsoil 0–30 cm showed pH (H_2O) of 4.5, total organic carbon of 7.9 g kg^{-1}, total N 0.9 g kg^{-1}; Mehlich's available P (mg kg^{-1}) of 1.96, exchangeable K of 0.10 mol_c kg^{-1}, exchangeable Mg 10.73 mol_c kg^{-1} and Ca 1.55 mol_c kg^{-1}, sand 537 g kg^{-1}, silt 163 g kg^{-1} and clay 300 g kg^{-1} (IITA 1989). The sites were under fallow for about six years due to unproductiveness.

2. Rainfed lowland

The rainfed lowland experiment was conducted in 2007 and 2008 at the Africa Rice Center (AfricaRice) fields within the Research farm of the National Cereals Research Institute at Edozhigi (09° 45′ N, 06° 7′ E, 70.5 m elevation) southern Guinea savanna [SGS]), Bida, Nigeria. Rainfall was unimodal. The three selected experimental sites were waterlogged acid soil with pH (H_2O) 4.6 and classified as Typic Haplusalf (Kowal and Knabe 1972). Average chemical analysis of top soil (0–30 cm) indicated organic carbon of 7.8 g kg^{-1}, total N of 0.7 g kg^{-1}, Mehlich III-available P of 1.98 mg kg^{-1}, exchangeable Mg of 0.29 mol_c kg^{-1}, and Ca of 1.26 mol_c kg^{-1}, and Fe of 28.56 mg kg^{-1}. Soil textural analysis indicated sand 540 g kg^{-1}, silt of 280 g kg^{-1} and clay of 180 g kg^{-1} (IITA 1989). The fields were under fallow for about three years before the trials.

Treatments

Five sources of organic N and their control used were:
i. 'IT 98K – 131 – 2' (dual purpose cowpea (*Vigna unguiculata* (L.) Walp);
ii. 'IT 93K – 52 – 1' (grain cowpea (*V. unguiculata*);
iii. 'TGx 1844 – 18E' (dual purpose soybean (*Glycine max* (L.) Merril);
iv. 'TGx 1485 – 1D' (grain soybean (*G. max*);
v. Mucuna (*Mucuna utilis* L.);
vi. Fallow (no legume).

In the NGS the legumes were sown on marked plots in October 2007, while in the SGS, they were seeded in November 2007. The grains were harvested upon maturity by removing the pods, but the stovers were incorporated *in situ* immediately after harvesting. In 2008, the selected rice varieties were planted in each of the agroecologies on the legume incorporated plots and fallow (control).

The NERICA® cultivar selected for the upland (NGS) was 'NERICA 14®', and 'Yar China' (farmers' check), while 'NERICA L-42®' and an 'Edozhigi' variety (farmers' check) were used in the lowland (SGS).

Experimental design

1. Rainfed upland rice

The experiment was laid out in a randomized complete block in split-split plot arrangement in each of the sites. Each site served as a replication. The main plot was the grain legume plots previously incorporated with legume stovers in 2007. The sub-plot was the N rates at two levels (0 and 30 kg N ha^{-1}). Basal P and K were applied at the rate of 13 kg P ha^{-1} as triple super phosphate (20% P) and 25 kg K ha^{-1} as muriate of potash (KCl, 60% K_2O) were given to all plots except the control plots. The N was applied as topdressing in two splits with one-half at 21 days after planting and the remaining half at about panicle initiation stage (45–50 DAS). The sub-sub-plot was rice cultivars. The main plot size was 5 × 21 m (105 m^2) while the sub-subplot size was 3 × 5 m (15 m^2). The upland plots were seeded directly by dibbling 5–7 seeds hole^{-1} at 20 × 20 cm spacing and later thinned to 4 seedlings stand^{-1} to give a plant density of 1×10^6 plants ha^{-1} (Oikeh *et al.* 2009). All plots were weeded manually by hoeing just before top dressing of N fertilizer.

2. Rainfed lowland rice

The experiment was laid out in a randomized complete block in split-split plot arrangement in each of the sites. Each site served as a replication. The main plot was the grain legume plots previously incorporated with legume stovers in 2007. The sub-plot was the N rates at two levels (0 and 30 kg N ha^{-1}). Basal P and K were applied at the rate of 13 kg P ha^{-1} as triple super phosphate (20% P) and 25 kg K ha^{-1} as muriate of potash (KCl, 60% K_2O) were given to all plots except the control plots. The N was applied as topdressing in two splits with one-half at 21 days after planting and the remaining half at about panicle initiation stage (45–50 DAS). The sub-sub-plot was rice cultivars. The rice varieties in the rainfed lowland were transplanted at 3 seedlings stand^{-1} at 20 × 20 cm on flats that were later bunded. The bunds were maintained throughout the period of the studies to retain water in the plots needed for lowland rice production.

Sampling and measurements

Data were collected on number of tillers, number of days to 50% flowering and 80% maturity. Yield data taken from the net plot included harvest index, number of panicles m^{-2}, 1000-grain weight, and grain yield corrected to a 140 g kg^{-1} moisture basis.

Statistical analysis

Data collected were subjected to analysis of variance using the mixed model procedure with the restricted maximum likelihood method (REML) for variance estimates (SAS Institute 2001). Data analysis was done by rice ecology. The fixed effects were previous crops, N, and cultivars, while sites (replications) were random effects. Mean separation was performed using the SAS least square means test (PDIFF) at $P \leq 0.05$.

The added benefits of the combined use of legume rotation and applied urea-N on rice grain yield were calculated using the following equation (Vanlauwe *et al.* 2001):

$$\text{Added benefits (Mg ha}^{-1}\text{)} = Y_{comb} - (Y_{30N} - Y_{0N}) - (Y_{rot} - Y_{0N}) - Y_{0N}$$

where:
Y_{comb} was the rice yield in legume rotation plus 30N urea (Mg ha^{-1});
Y_{30N} was rice yield in 30N urea (Mg ha^{-1});
Y_{0N} was rice yield in 0N (control) (Mg ha^{-1});
Y_{rot} was rice yield in legume rotation without urea (Mg ha^{-1}).

RESULTS AND DISCUSSION

Rainfed upland rice

1. Growth of rice as influenced by legume in legume/rice rotation

Plant height and number of tillers of rice were not significantly influenced by preceding legume and fallow plots at 28 DAS, days to 50% flowering and 95% maturity of rice. Although not significant, preceding dual cowpea increased the height (90.4 cm) and number of tillers at maturity (20 cm), while plots with previous grain cowpea had the shortest plants at maturity (80.1cm). Also, rice plants that succeeded grain soybean though not significant ($P < 0.05$), had the lowest number of tillers per hill at 95% maturity (16). Although Okonji *et al.* (2011) reported a significant influence of cowpea residue on the growth of rice, this could

Table 1 Influence of legume/rice rotation, fallow and inorganic fertilizer and variety on plant height and tiller number at 28 DAS, days to 50% flowering and days to 95% maturity of upland rice.

Sources	**Plant height at**			**Number of tillers per hill at**		
	28 DAS	**Days to 50% flowering**	**Days 95% maturity**	**28 DAS**	**50% flowering**	**95% maturity**
Organic-nitrogen						
IT 98K – 131 – 2 (DC)	43.4	65.5	90.4	11	13	20
IT 93K – 452 - 1 (CC)	45.1	59.7	80.1	11	13	18
TGX 1485 – 1D (GS)	45.2	64.8	84.6	8	12	16
TGX 1844 – 18E (DS)	41.9	63.1	83.7	9	13	18
Mucuna	42.9	61.6	84.2	12	13	18
Fallow	41.7	64.7	83.7	12	13	18
LSD$_{0.05}$ (5 df)	NS	NS	NS	NS	NS	NS
Inorganic						
0	42.9	63.1	84.5	10	13	18
30	43.8	63.4	84.3	11	13	18
LSD$_{0.05}$ (6 df)	NS	NS	NS	NS	NS	NS
Variety						
YAR CHINA (farmers' rice)	42.9	62.6	85.8a	11	14	19
NERICA® 14	43.8	63.8	83.1b	10	12	17
LSD$_{0.05}$ (12 df)	NS	NS	0.25	NS	NS	NS

NS = not significant
DAS = days after sowing
Means with different letters of the alphabet are significantly different from one another at $P < 0.05$ using the pair-wise difference of least square means (PDIFF).

have resulted from the continuous cropping of cowpea in the field for as long as five years.

The inorganic N fertilizer showed no significant ($P < 0.05$) influence on plant height and number of tillers per hill at the three stages of rice growth (28 DAS, 50% flowering, and 95% maturity). Among the rice varieties, the farmers' rice (Yar China) at 95% maturity was significantly ($P < 0.05$) taller than NERICA 14® (**Table 1**). Although not significant ($P < 0.05$), the local check had higher number of tillers per hill at the three stages of rice plant growth than 'NERICA 14' as shown in **Table 1**. The three factors used in the trial showed no significant interaction, the possible reason for this being that the factors used (Organic source, inorganic source and rice varieties) acted individually as their interaction was not significant. However, the factors used had no significant influence on the traits measured but increases in the traits could be observed.

2. Yield and yield components of rice as influenced by legume in rice/legume rotation

Preceding legumes, inorganic-N and varieties had no significant ($P < 0.05$) influence on the yield and some yield components of rice (**Table 2**). However, previous plots of mucuna, grain and dual soybean planted with rice had the highest grain yield among the legume plots (0.8 Mg ha^{-1}), that is, 30% increase in the yield of rice compared to the control-fallow plots without N application (**Table 2**).

Also, rice in preceding grain soybean plots had the highest value (49.6%) in the partitioning of dry matter into grain yield as measured by the harvest index and 1000-grain weight (29.7 g). Incorporating grain soybean before planting rice in this study appeared to increase the HI by 49.6% over other treatments. Harvest index is an inherent ability of varieties to partition assimilates to the sink (grains). Rice in previous mucuna plots had the least harvest index (42.4%), though this was not significantly ($P < 0.05$) different from other previous legume plots. NERICA 14® though not significant ($P < 0.05$) had higher HI (45.9%) and 1000-grain weight (28.3 g) than the farmers' variety.

Also, number of panicles/m^2 was not significantly ($P < 0.05$) influenced by the preceding legume plots (**Table 2**). Nevertheless, preceding fallow plots with rice had high influence on the number of panicles/m^2 of rice (168) while the preceding dual soybean fields with rice had the least number of panicle/m^2 (119).

Inorganic N was observed to have significant ($P < 0.05$) influence on the number of panicles/m^2 of rice as 30 kg N ha^{-1} significantly ($P < 0.05$) increased the number of panicles/m^2 of rice (168) over 0 kg N ha^{-1}. No significant ($P < 0.05$) difference in panicle production between the rice varieties was observed. However, the local check had more panicles per meter square (152) than NERICA 14® (**Table 2**).

Grain yield was not significantly influenced by preceding legume, inorganic N, rice varieties, and their interactions (**Table 2**). The yield values ranged from 0.6 to 0.8 Mg ha^{-1}. However, the farmers' rice had significantly higher total dry matter (TDM) (1.7 Mg ha^{-1}) than NERICA 14® (1.2 Mg ha^{-1}). Although not significant ($P < 0.05$), the preceding soybean and *Mucuna* plots gave 33% increments in grain yield over the previous control-fallow plots (**Table 2**), and the previous dual-purpose soybean plots had the highest TDM of 1.9 Mg ha^{-1}, while the previous grain-soybean plots gave the highest HI of about 50% (**Table 2**). Also no significant interaction was observed among the factors on yield and yield components measured. This suggests that the factors – legume incorporation, inorganic N and rice varieties – could act independently to produce the observed results. The lack of interaction noticed could be as a result of the very degraded nature of the farmers' field used for which levels of both legume incorporation and inorganic manure may need to be higher.

The treatments in this study involved imposing the use of nitrogen-fixing dual-purpose/grain soybean and cowpea, limited use of inorganic N and a resilient rice variety to enhance rice productivity on a highly degraded soil. Incorporating mucuna and soybean (dual-purpose or grain) before sowing rice had the best advantage by increasing grain yield by more than 30% over the control and ranked among the highest in added benefits (0.3–0.6 Mg ha^{-1} grains). A similar advantage of legume had earlier been reported by others (Egbe *et al.* 2009; Yusuf *et al.* 2009; Okonji *et al.* 2011; Adjei-Nsiah 2012; Hamdollah 2012). The yields of rice following soybean rotation in the current study in which the residues were incorporated after harvest was much lower than the yields earlier reported in the study of Oikeh *et al.* (2008b) in which the residues were exported from farmers' fields in the NGS of Benin. Our result could be attributed to the highly degraded and acidic nature of the site used which had been left under fallow by farmers for about six years due to limited productivity. However, application of 30 kg N to a legume incorporated plot significantly (P <0.05) increased grain yield of rice over control (**Table 2**). This suggests that the low N applied was adequate to enhance the effect of incorporated legume on rice yield (Mosavi *et al.* 2009). This yield level of 0.9 Mg ha^{-1} is low when compared to performance on fertile soils. Our results suggest that the level of N used to supplement organic N source in this highly degraded soil would need to

Table 2 Influence of legume/rice rotation and inorganic N on yield and yield component of rainfed upland NERICA 14® rice.

Sources	Panicle m^{-2}	1000-grain (g)	Total dry matter	HI (%)	Grain yield (Mg ha^{-1})	Added benefit (Mg ha^{-1})
Organic-N sources						
IT 98K – 131 – 2 (DC)	137	27.0	1.1	48.4	0.7	0.3
IT 93K – 452 - 1 (GC)	145	25.7	1.2	47.1	0.7	0.1
TG× 1485 – 1D (GS)	128	29.7	1.4	49.6	0.8	0.1
TG× 1844 – 18E (DS)	119	25.5	1.9	39.4	0.8	0.2
Mucuna	141	25.7	1.8	42.4	0.8	0.6
Fallow	168	30.5	1.4	43.3	0.6	-
$LSD_{0.05}$ (5 df)	NS	NS	NS	NS	NS	-
Inorganic-N						
0	112b	27.3	1.2b	48.3	0.6b	-
30	168a	27.4	1.7a	41.8	0.9a	-
$LSD_{0.05}$ (6 df)	65.04*	NS	0.3*	NS	0.2*	-
Varieties						
YAR CHINA (farmers' rice)	152	26.4	1.7a	44.2	0.7	-
NERICA® 14	128	28.3	1.2b	45.9	0.8	-
$LSD_{0.05}$ (12 df)	NS	NS	0.3*	NS	NS	-

* = significant at $P < 0.05$
NS = not significant at $P < 0.05$
HI = Harvest Index
Mg ha^{-1} = mega gram per hectare
Means with the same letter of the alphabet are not significantly different at $P < 0.05$

Table 3 Influence of legume/rice rotation and inorganic N on growth of rainfed lowland NERICA L-42® rice.

Sources	LAI			Tillers $hill^{-1}$			Plant height (cm)		
	Mid -tillering	Flowering	Maturity	Mid -tillering	Flowering	Maturity	Mid -tillering	Flowering	Maturity
Organic-N sources									
IT 98K – 131 – 2 (DC)	1.49	0.95	1.59	18	14	13	56.08	109.56	114.58
IT 93K – 452 - 1 (GC)	1.51	1.15	1.78	18	15	15	61.55	114.22	111.30
TG× 1485 – 1D (GS)	1.51	1.07	1.68	19	14	13	59.30	111.44	115.86
TG× 1844 – 18E (DS)	1.33	1.06	1.92	19	15	16	57.42	113.97	113.62
Mucuna	1.71	0.95	1.70	20	13	14	60.55	111.83	114.11
Fallow (control)	1.58	0.92	1.70	17	14	13	59.72	112.99	111.39
$LSD_{0.05}$ (10 df)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Inorganic-N									
0	1.44	1.00	1.80	17.6b	14	14	56.79b	111.69	112.00b
30	1.60	1.03	1.66	19.4a	14	14	61.41a	112.98	114.95a
$LSD_{0.05}$ (12 df)	NS	NS	NS	1.2	NS	NS	3.8	NS	2.4
Varieties									
EDOZHIGI (farmers' variety)	1.73a	1.15a	1.72	18	13.3b	12.6b	66.99a	138.41a	135.38a
NERICA® L – 42	1.31b	0.88b	1.74	19	14.9a	15.8a	51.21b	86.25b	91.57b
$LSD_{0.05}$ (24 df)	0.2	0.5	NS	NS	0.7	2.4	3.8	17.4	7.8

NS = not significant at $P < 0.05$
LAI = Leaf Area Index
Means with the same letter of the alphabet are not significantly different at $P < 0.05$

be higher in order to achieve a significant yield increase and a much longer rotation would not be needed to reclaim the productivity of this soil.

Integrating mucuna and soybean into legume-rice systems could play a significant role in enhancing the performance of the succeeding rice crop in upland rice production because in this study mucuna plots preceding rice ranked among the highest contribution (33%) to the yield of rice. It has been suggested that farmers are very reluctant to devote their land solely to legume cover crops that would not provide food value for human consumption, although there is an impact on restoring soil fertility. The use of dual-purpose soybean which has a good potential for surface cover to suppress weed, conserve soil and with its grain being sold for economic benefit should be advocated and promoted widely to smallholder farmers.

Rainfed lowland rice

1. Physiological traits of lowland rice

Plant height was significantly ($P < 0.05$) affected by applied inorganic nitrogen at mid-tillering (21 DAT) and maturity stages of growth (63 DAT). Application of 30 kg N ha^{-1} was superior to 0 kg N ha^{-1} producing plant heights of 61.41 and 114.95 cm at the first and second sampling periods, respectively (**Table 3**).

Both varieties tested (NERICA L-42® and farmers' variety ('Ebagichi') at all sampling periods differed significantly ($P < 0.05$) with respect to height in this trial. The farmers' variety ('Ebagichi') at all the sampling periods was observed to have significantly ($P < 0.05$) taller plants than NERICA L-42® (**Table 3**). All interactions of treatments were not statistically significant with respect to plant height in this trial.

Number of tillers was significantly ($P < 0.05$) affected by applied nitrogen at mid-tillering (21 DAT) stage of growth. Applied rate of 30 kg N ha^{-1} recorded more tillers compared with 0 kg N ha^{-1} (19.44 and 17.58, respectively) (**Table 3**). NERICA L-42® at flowering (42 DAT) and physiological maturity (63 DAT) stages of growth produced significantly ($P < 0.05$) more tillers (14.94 and 15.77) than the farmers' variety (13.25 and 12.55, respectively) (**Table 3**). Application of 30 kg inorganic-N enhanced number of tillers by 10% only at 21 days after transplanting (DAT) over zero-N (**Table 3**). Our result is in agreement with previous studies which reported a significant influence of N on number of tillers and plant height in upland rice with increments in inorganic-N compared with zero-N (Oikeh *et al.* 2008a). Leaf area index at mid-tillering (21 DAT) and

Table 4 Influence of legume/rice rotation and inorganic N on yield and yield component of rainfed lowland NERICA L-42$^{®}$ rice.

Sources	Panicle m^{-2}	1000-grain wt (g)	Harvest index (%)	Panicle weight (g)	Panicles length (cm)	Grain yield (Mg ha^{-1})	Added benefit (Mg ha^{-1})
Organic-N sources							
IT 98K – 131 – 2 (DC)	154	35.3	54.2	3.61	24.54	3.9	-0.1
IT 93K – 452 – 1 (GC)	159	33.3	51.0	3.58	25.04	3.4	0.1
TG× 1485 – 1D (GS)	161	33.9	51.9	3.78	25.42	3.2	0.3
TG× 1844 – 18E (DS)	155	34.2	49.8	3.90	25.44	4.0	0.3
Mucuna	173	35.4	51.4	3.30	25.95	3.2	0.1
Fallow (control)	137	35.2	51.5	3.76	24.38	3.6	-
LSD$_{0.05}$ (5 df)	NS	NS	NS	NS	NS	NS	-
Inorganic-N							
0	152	36.7	51.5	3.65	25.03	3.5	-
30	161	34.5	51.8	3.66	24.89	3.6	-
LSD$_{0.05}$ (6 df)	NS	NS	NS	NS	NS	NS	-
Varieties							
EDOZHIGI (farmers' variety)	137b	36.6a	50.3	3.85a	24.61b	3.6	-
NERICA$^{®}$ L – 42	176a	32.5b	52.9	3.46b	25.31a	3.6	-
LSD$_{0.05}$ (12 df)	20.1	1.1	NS	0.03	0.03	NS	-

NS = not significant at $P < 0.05$

Mg ha^{-1} = mega gram per hectare

Means with the same letter of the alphabet are not significantly different at $P < 0.05$

Table 5 Interaction of organic nitrogen × varieties on panicle weight of rice.

Organic × Varieties	Farmers' variety (Ebagichi)	NERICA L-42$^{®}$
Dual cowpea	3.63 b	3.60 b
Grain cowpea	4.16 a	3.00 c
Dual soya	3.78 b	3.78 b
Grain soya	4.16 a	3.63 b
Mucunna	3.68 b	2.93 c
Fallow	3.68 b	3.85 a
LSD$_{0.05}$	0.17	

Means with the same letter of the alphabet are not significantly different from one another at $P < 0.05$ using the pair-wise difference of least square means (PDIFF).

flowering, and number of tillers evaluated at flowering and maturity were significantly influenced by variety (**Table 3**). The farmers' variety had 31% higher LAI at mid-tillering and flowering, but with 11–25% significantly lower tiller production than 'NERICA L-42$^{®}$' at flowering and maturity (**Table 4**). There was no significant interaction of treatments with respect to LAI.

2. Grain yield and yield components

Only varieties showed a significant ($P < 0.05$) effect with respect to panicle and 1000-grain weights of rice in this trial. The farmers' variety produced statistically ($P < 0.05$) heavier panicles (3.85 g) than 'NERICA L-42$^{®}$' (3.46 g). Similarly, one thousand grain weight was also signifi-cantly ($P < 0.05$) higher with 'Ebagichi' (36.57 g) than 'NERICA L-42$^{®}$' (32.54 g) (**Table 4**).

Sources of organic nitrogen by rice varieties interaction on panicle weight was significant ($P < 0.05$). Grain cowpea (4.16 g) and grain soybean (4.16 g) were observed to produce highest or similar panicle weights of rice with the farmers' variety (**Table 5**). Next to these were dual soybean (3.78 g), dual cowpea (3.63 g), mucuna (3.68 g) and fallow (3.68 g) with comparable panicle weights with the farmers' variety. 'NERICA L-42$^{®}$' with dual soybean (3.78 g), dual cowpea (3.60 g) and grain soybean (3.63 g) had statistically similar panicle weights but significantly ($P < 0.05$) higher than grain cowpea (3.00 g) and mucuna (2.93 g) which recorded significantly the least panicle weights. However, 'NERICA L-42$^{®}$' had the highest panicle weight (3.85 g) under fallow.

Organic residues from various grain legumes when incorporated have been found to supply more than sufficient organic nitrogen for the first crop of rice in the lowland which can also benefit a second crop of upland cultivars with more N reserve using supplementary irrigation in the lowland during the off-season (Ncube *et al.* 2007). The individual contribution of different legume incorporation revealed that dual purpose soybean, mucuna and grain soybean contributed 0.33, 0.3 and 0.3 Mg ha^{-1}, respectively. Oikeh *et al.* (2008b) has reported the beneficial impact of incorporated residues of promiscuous dual purpose soybean varieties on grain yield of 'NERICAs$^{®}$'.

Although grain yield of rice as influenced by sources of organic nitrogen was not significant ($P < 0.05$) in this study, grain yields were apparently high generally. Dual purpose soybean (4.01 Mg ha^{-1}) followed by dual purpose cowpea (3.90 Mg ha^{-1}) as organic sources of nitrogen produced the highest grain yield of rice (**Table 4**). Inorganic nitrogen at 30 kg N ha^{-1} had superior grain yield of (3.6 M ha^{-1}) compared with 0 kg N ha^{-1} (3.5 Mg ha^{-1}). 'NERICA L-42$^{®}$' and the farmers' variety produced similar grain yields (3.6 Mg ha^{-1}) in this study. The on-farm trial revealed that individual additional contribution of the different legume incorporation from dual purpose soybean, mucuna and grain soybean to rice grain yield in rotation was 0.30 to 0.33 Mg ha^{-1}. Generally, lowland 'NERICAs$^{®}$' performed better after incorporating soybean or mucuna residues with 30 kg N ha^{-1} urea than after cowpea with the same level of N.

However, despite the fact that the soil of the fields used in the legume/rice rotation trial was poor in available N (0.07%) and organic carbon (0.8%), the release of N from incorporated legumes and weed fallow plus the 30 kg N ha^{-1} supplement applied as urea could have supplied over and above the N requirement for rice (Yusuf *et al.* 2009 and Aynehband *et al.* 2010b); hence, the lack of a significant response to both organic and inorganic N sources on grain yield and most growth and the yield components in this study.

CONCLUSIONS

It is a common practice for smallholder farmers to harvest their legumes and export them from the fields; and they are reluctant in growing sole mucuna. This study has shown that the incorporation of legume back into the soil immediately after harvest with an addition of 30 kg N to the succeeding rice in rotation would enhance rice yield in both rainfed upland and lowland agroecologies. However, for the highly degraded acidic uplands similar to the site used in this study, the succeeding upland rice will benefit from greater rate of inorganic N than the 30 kg ha^{-1} and a longer rotation to restore the productivity of the soil may not be required.

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