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Adaptability and Response of NERICA Upland Rice Varieties to Fertilizer Application in the Mono Modal Rainfall Forest Zone of Cameroon

[1]Njiayouom Ibrahim, *[2]Ngome Ajebesone Francis, [3]Suh Christopher, [4]Misse Alain

Institute of Agricultural Research for Development (IRAD) Cameroon.

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Corresponding Author
Ngome Ajebesone Francis
E-mail: *ngomajebe@ yahoo.com*
Phone: *(+237)78967402*

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ABSTRACT

A study was conducted in Barombi-kang, in the forest agro-ecological zone with mono modal rainfall pattern in Cameroon to evaluate the adaptability of selected NERICA upland rice varieties and their response to fertilizer application. A factorial split plot experimental design in a randomized complete block with three replications was used. The first factor included: T0 (unfertilized control), T1 (200 kg NPK / ha + urea 100 kg/ha) and the second factor included 7 varieties of rice namely NERICA 1, NERICA 2, NERICA 3, NERICA 4, NERICA 8, NERICA 10 and Fofifa. Varieties tested were well adapted to the mono modal rain forest agro-ecological zone. Thus, average cycle duration was 100 days and grain yield ranged between 1.4 and 2.3 t/ha without fertilizer use. Yield and yield components were significantly ($p<0.05$) enhanced by fertilizer application particularly grain yield (146%), grain per panicle (59%), straw yield (50%). Highly significant correlations ($p<0.05$; $r = 0.60$ to 0.90) were observed between grain yield and most of the yield components. Further studies are warranted to address the yield gap existing between farmers' practice and on-station research before disseminating these varieties to farmers.

INTRODUCTION

Rice (*Oryza sativa* L.) is a major food crop in the world; it is the staple food for more than half of the world's population (Shimono, 2011). Production remains concentrated geographically, with over 90% in East and South Asia (IRTA, 2004). Rice is a food whose consumption is fast growing in Africa. In Cameroon, the national demand in 2009 was estimated at 300 000 tons, mostly covered by imports. This explains why over 72 billion francs CFA was spent on rice importation in 2007 (MINADER, 2009). The total area cultivated with rice in 2012 was estimated at 135 000 ha with a national production of approximately 139 000 tons (FAO, 2014). Thus, the productivity of rice in Cameroon is averagely 1.02 T/ha.

Efforts have been made by research to increase crop productivity in developing new improved rice varieties. The *New Rice for Africa* (NERICA) developed by AficaRice is a product of hybridization between *Oryza glaberrima* and *Oryza sativa* (ADRAO, 2008; Olembo et al., 2010). In addition to desirable agronomic traits (early maturity, resistance to drought, pests, diseases and high yields averaging 4 to 7 T/ha) of these improved varieties the protein content is very high (8 to 10%) (ADRAO, 2002; WARDA, 2003; ADRAO, 2008). The contribution of rice variety to its productivity is estimated at 21.7% (Liu et al., 2013). In addition to improved varieties, cultural practices play an important role in achieving yield potential of a variety. Thus, Alam et al. (2009) reported that the judicious use of fertilizers can remarkably increase the quantity and quality of harvested rice. This increase is mainly due to nitrogen, phosphorus and potassium availability which are the major elements for plant nutrition and the key input to increase yields (Dastan et al., 2012). Application of nitrogen fertilizer on rice plants significantly increases yield components (Dobermann and Fairhurst, 2000). This is because it contributes to the accumulation of carbohydrates in the stems and leaf sheaths during the pre-flowering stage and in the grain during the ripening stage of rice (Swain et al., 2010). Phosphorus promotes tilling, root development, early flowering and ripening (Dobermann and Fairhurst, 2000). Potassium increases tolerance to rice plants to pests and diseases, to various stress conditions and may also reduce the potential for lodging (Norman et al., 2002). Liu et al. (2013) estimated that improving soil fertility contribute to 12.7% on rice productivity. Crop plants require a certain amount of minerals for growth, development and grains production. Rice for example uptake 16-17 kg nitrogen to produce a yield of one ton of paddy rice including straw (Sahrawat, 2000). Some authors have found that improving soil fertility can reduce the spatial variation of rice yields from 13.7% to 7.4% (Liu et al., 2013). Fertilizer use has a significant effect on the growth of plants at different stages of development. It significantly increases the number of tillers per m^2, the number of fertile tillers, the total number of grains, 1000-seed weight, plant height and percentage of filled grains (Walker and Street, 2003; Chaturvedi, 2005; Gebrekidan and Seyoum, 2006; Yosef Tabar, 2012). Yield and yield components of rice respond much to nitrogen than phosphorus. However, the maximum grain yield and yield components are possibly obtained with combined application of nitrogen and phosphorus. Thus, Gebrekidan and Seyoum (2006) observed a 38.49% increase in yield with the combined application of 60 kg N/ha and 13.2 kg P/ha. Moreover, when the crop management is used to achieve a performance close to potential yield, a final application of nitrogen at flowering stage is an option to improve the milling and the nutritional quality of rice grains (Consuelo et al., 1996). However, the effect of fertilizer use on yield is not always positive in all cases. Excess or underutilisation of fertilizer as well as poor timing of fertilizer application could have a potential effect on reducing rice yields (Walker and Street, 2003). Thus, the application of more than 120 kg N/ha reduces the number of grains per panicle due probably to an increase in competition for metabolic reserves among the tillers thereby reducing the production of grains (Gebrekidan and Seyoum, 2006). However, other studies showed that high nitrogen application rates of over 225 kg/ha reduce percentage of mature grains (Zhang et al., 2008; Zhang et al., 2010). Elsewhere, positive correlations were noted between rice grain yield, number of panicle and harvest index (Yaser et al., 2011).

The production deficit observed in Cameroon justified in part by the low crop yield 1.02 T/ha (FAO, 2014) keeps the country in a strong dependence on imports; while the country has a considerable potential for rice production still unexploited. Moreover, the increase in rice productivity can be an important strategy to increase farmers' incomes and reduce poverty. Face with this situation, it is extremely important to find solutions to the problems plaguing Cameroon rice production. Among these problems, we can identify the lack of selected high yielding adapted varieties to production areas, low fertilizer use, poor farming practices, pests and diseases. To address the problem of low crop yield, research has decided to introduce NERICA varieties in Cameroon. That is why preliminary studies particularly on adaptability of varieties to different agro-ecologies are essential prior to dissemination to farmers. Thus, this study was conducted to select among NERICA upland varieties those that are best suited to the forest agro ecological zone of Cameroon with mono modal rainfall pattern and to evaluate the response of these varieties to fertilizer application.

MATERIALS AND METHODS

Description of the experimental site

The field experiment was conducted in 2012 during the second cropping season (August to November) at the Institute of Agricultural Research (IRAD) Station of Barombi-kang in the Southwest region of Cameroon. The research station is located in the forest agro-

ecological zone at an altitude of 211 m asl, longitude 25° E and latitude 4.39° N. The mean annual rainfall is about 2300 mm and mean temperature of 26 °C (Njiayouom, personal Communication). The experiment was conducted on a clayey soil whose characteristics are shown in Table 1.

Table 1: Selected soil parameters of the experimental field for rice variety adaptability trial in the forest zone with mono modal rainfall pattern in Cameroon

Parameter	Value
Total OM (gkg^{-1})	41.72
Organic C (gkg^{-1})	24.20
Total N (gkg^{-1})	01.97
C/N ratio	12.28
Available P ($mgkg^{-1}$)	06.19
CaO ($cmolkg^{-1}$)	01.21
MgO ($cmolkg^{-1}$)	0.318
K_2O ($cmolkg^{-1}$)	0.049
T (CEC) ($cmolkg^{-1}$) X31130	11.65
pH H_2O	04.63

Experimental Design and Treatments

A factorial split plot experimental design in a randomized complete block with three replications was used. The first factor included: T0 (unfertilized control), T1 (200 kg NPK / ha + Urea 100 kg/ha) and the second factor included 7 varieties of rice namely NERICA 1, NERICA 2, NERICA 3, NERICA 4, NERICA 8 , NERICA 10 and Fofifa. Each experimental unit had a size of 2 m x 4 m. Two rice seeds were sown at a spacing 30cm x 20cm on the 17th August 2012. Fertilizers were not applied in the unfertilized control. Fertilized plots received N-P-K (20-10-10) as basal fertilizer at a rate of 200 kg/ha applied two weeks after sowing at the beginning of tilling stage. Urea was applied later as top dressing during the phase of panicle initiation (6th to 7th week after sowing). Two manual weeding were carried out in all plots. The first weeding was done two weeks after planting before the first application of fertilizer, and the second weeding took place 4 weeks later. A net was installed on the plots just after sowing to control bird damage. The observations and measurements were made on 10 randomly selected plants in the two central rows in each plot to avoid edge effects. Yield components namely number of plants/m^2, number of panicles/plant, number of grains/panicle, rate of filled grain, weight of thousand grains were recorded. In each experimental unit plant height was determined by measuring the length from ground level to the insertion point of the panicle of 5 randomly selected plants. The beginning of flowering, 50% flowering time and the length of crop cycle were also recorded. At physiological maturity the plants were cut at ground level to determine the straw yield after drying. The harvest index was obtained as the ratio of grain yield over grain yield plus straw yield from each plot expressed in percentage (Gebrekidan and Seyoum, 2006).

Statistical Analysis

The data on yield, yield components, height and straw yield were subjected to analysis of variance using the SAS statistical software. When differences were significant by the F-test, the comparison of means was done by the Student Newman Keuls test (SNK) at 5% significance level (Toutenburg and Shalabh, 2009). Simple correlations were examined between yield and yield components.

RESULTS AND DISCUSSION

Yield and yield components

Significant differences ($P<0.05$) were not observed between yields of different rice varieties studied. However, all yields components except the rate of filled grains varied with variety. Fertilizer used had a very significant effect ($p <0.001$) on yield, yield components and other agronomic parameters that were studied (Table 2). The mean square of the fertilizer effect for each parameter of the plant (except weight of thousand grains) far exceeded the corresponding mean square of the variety. Interactions (Fertilization X Variety) were significant only for the straw yield, plant height and harvest index.

Table 2: Analysis of variance for yield and yield components of NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Yield/Yield components	Mean square of source of variation			
	Fertilization (Fert)	Variety (Var)	Fer x Var	Error
Grain yield (t/ha)	68.046***	0.601 ns	0.315 ns	0.278
Number of panicle/m^2	10786.267***	475.118 **	197.794 ns	109.447
Number of grain/panicle	33081.057***	883.584 **	155.777 ns	262.403
Rate of filled grain (%)	0.134***	0.005 ns	0.009 ns	0.004
Weight of thousand grain (g)	1.303 ns	46.667***	0.396 ns	0.555
Plant height (cm)	1385.177***	597.567***	20.256*	6.243
Straw yield (t/ha)	41.680***	0.864*	1.096*	0.315
Harvest index (%)	1357.180***	83.537***	35.554*	13.629

ns= non-significant; * Significant ($p < 0.05$) ; ** Highly significant ($p < 0.01$); ***Very highly significant ($p < 0.001$)

The effect of variety was not significant ($p<0.05$) on grain yield of rice (Table 3). This result was in contrast to findings of Liu et al. (2013) who in studying the impact of climate change, soil nutrient and cultural practices on different rice varieties found that there were differences in yield between these varieties. The six varieties of NERICA tested are well adapted to the environmental conditions of the study area. NERICA 8, NERICA 2 and NERICA 1 respectively gave a yield of 3.48 T/ha, 3.19 T/ha and 3.09 T/ha, which are not far from the potential yield of these varieties which are respectively 5 T/ha, 4 T/ha and 4.50 T/ha (ADRAO, 2008).

Table 3: Yield and yield components response to NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Variety	GY	NP/m^2	NG/P	RFG	WTG	PH	SY	HI
Nerica 1	3.09^{a}	117.72^{bc}	130.18^{ab}	59.00^{a}	31.71^{b}	84.60^{b}	5.20^{ab}	35.45^{b}
Nerica 2	3.19^{a}	136.22^{a}	115.90^{ab}	68.83^{a}	28.23^{d}	84.36^{b}	5.03^{ab}	37.46^{b}
Nerica 3	2.68^{a}	109.21^{c}	127.60^{ab}	61.66^{a}	28.58^{cd}	86.16^{b}	4.61^{b}	34.31^{b}
Nerica 4	2.54^{a}	120.68^{abc}	115.29^{ab}	62.50^{a}	27.91^{d}	87.06^{b}	4.97^{ab}	32.38^{b}
Nerica 8	3.48^{a}	131.42^{ab}	139.02^{a}	62.50^{a}	29.45^{c}	73.13^{c}	4.49^{b}	43.03^{a}
Nerica 10	3.05^{a}	121.05^{abc}	131.06^{ab}	65.16^{a}	28.45^{cd}	84.90^{b}	4.76^{ab}	37.92^{b}
Fofifa	3.07^{a}	121.05^{abc}	103.51^{b}	61.33^{a}	35.61^{a}	106.70^{a}	5.60^{a}	32.51^{b}
CV(%)	17.49	8.54	13.14	1 1.16	2.48	2.88	11.32	10.21

Means within a column followed by the same letter (s) are not significantly different according to Student-Newman-Keuls test at 5%.
GY= Grain yield (kg/ha); NP/m^2 = Number of Panicle per square meter; NG/P =Number of Grain per panicle; RFG = Rate of Filled Grain (%); WTG = Weight of Thousand Grain (g); PH =Plant Height (cm); SY = Straw Yield (t/ha); HI = Harvest Index (%)

NERICA varieties are early maturing and cycle duration is generally between 85 and 100 days (WARDA, 2008). In this study, it was observed that the cycle of different varieties tested ranged from 92 to 104 days (Table 4). These results showed that the cycle of the varieties increased by 2 to 12 days depending on the variety. Thus, NERICA 2 and NERICA 8 respectively had 95 days and 85 days (increase of 7 days) cycle duration. This variation in the duration of the vegetative cycle may be influenced by the agro-ecological conditions of the study area. In addition, these rice varieties were not sensitive to disease attack and lodging. Meanwhile the pressure from insect pests was below threshold to necessitate control measures.

Table 4: Duration of cycle of NERICA upland rice varieties in the forest agro ecological zone with mono modal rainfall pattern in Cameroon

Variety	Observed duration (days)	Reported duration (ADRAO, 2008) (days)
Nerica 1	102	95-100
Nerica 2	102	90-95
Nerica 3	103	95-100
Nerica 4	102	95-100
Nerica 8	92	75-85
Nerica 10	104	90-100
Fofifa	97	

The application of fertilizer (NPK) had a remarkable effect on grain yield of rice (Table 5). Grain yield of rice increased significantly ($p < 0.001$) from 1.74 T/ha in unfertilized plots (control) to 4.29 T/ha in the fertilized plots (Table 5a), representing an increment of 146% (2.55 T/ha) compared to the control. Deverin et al. (2005) reported that NERICA varieties in the presence of fertilizer can increase yields by 200% compared to traditional varieties. Gebrekidan and Seyoum (2006) also obtained a yield increment of 38.49% compared to the control with the combined application of 60 kg N/ha and 13.2 kg P/ha. In this study, the yield increase associated with fertilizer use is possibly due to increase in the number of panicles/m^2, the number of grain/panicle and the rate of filled grains. These results corroborate those of Dobermann and Fairhurst (2000); Gebrekidan and Seyoum (2006) and YosefTabar, 2012. Similarly, Norman et al. (2002); Swain et al. (2010) and Dastan et al. (2012) also noted enhanced rice productivity with the addition of NPK fertilizer.

However, in the absence of fertilizer application yield of NERICA varieties are observed to vary between 1.42 and 2.29 T/ha (Table 5a). This observation reveals that NERICA varieties have the ability to produce on acidic soils with low fertility, which also confirms earlier reports (WARDA, 2002).

Table 5: Effect of fertilizer use on yield and yield components of NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Treatment	GY	NP/m^2	NG/P	RFG	WTG	PH	SY	HI
Unfertilized	1.74^b	106.45^b	95.16^b	57.3^b	29.81^a	80.96^b	3.96^b	30.47^b
Fertilized	4.29^a	138.50^a	151.28^a	68.6^a	30.17^a	92.44^a	5.95^a	41.84^a
CV(%)	17.49	8.54	13.14	11.16	2.48	2.88	11.32	10.21

Means within a column followed by the same letter (s) are not significantly different according to Student-Newman-Keuls test at 5%.
GY= Grain yield (t/ha); NP/m^2 = Number of Panicle per square meter; NG/P =Number of Grain per panicle; RFG = Rate of Filled Grain (%); WTG = Weight of Thousand Grain (g); PH =Plant Height (cm); SY = Straw Yield (t/ha); HI = Harvest Index (%)

Table 5a: Yield of NERICA upland rice varieties with and without fertilizer use in the forest zone with mono modal rainfall pattern in Cameroon

Treatment	Variety							
	Nerica 1	**Nerica 2**	**Nerica 3**	**Nerica 4**	**Nerica 8**	**Nerica10**	**Fofifa**	**Mean**
Unfertilized	1.68^b	1.98^b	1.41^b	1.50^b	2.28^b	1.99^b	1.36^b	1.74
Fertilized	4.50^a	4.41^a	3.95^a	3.58^a	4.69^a	4.11^a	4.78^a	4.29
Mean	3.09	3.19	2.68	2.54	3.48	3.05	3.07	

*Means within a column followed by the same letter (s) are not significantly different according to Student-Newman-Keuls test at 5%. %.; CV(%) = 17.49

Yield Components

Number of Panicle/m^2 (NP)

Highly significant differences ($p<0.01$) were observed between the NP of the different NERICA varieties (Table 3). NERICA 2 had the highest NP (136) while NERICA 3 had the lowest (109). Lui et al. (2013) also found differences between the NP, the number of grains/panicle (NG/P) and weight of thousand grains (WTG) of different rice varieties tested. Highly significant differences ($p < 0.01$) were also noted between the NP in the fertilized and unfertilized plots. Application of fertilizer increased the NP by 30% (32.05 panicle/m^2) compared to unfertilized control. This result is in line with those of Gebrekidan and Seyoum, 2006 and Yosef Tabar, 2012. The NP is the most important yield component as it has a direct effect on yield (Chaturvedi, 2005; Gebrekidan and Seyoum 2006).

Number of grains/panicle (NG/P)

The NG/P was significantly different ($p < 0.01$) between the varieties (Table 3). NERICA 8 had the highest number of grain/panicle (139.1) while Fofifa had the lowest NG/P (103.5). These results demonstrated that NERICA varieties produce large NG/P. These observations are in agreement with the report of Deverin *et al*. (2005). These scientists stated that the panicles of NERICA varieties can produce up to 400 grains, compared to other African varieties that can produce only 75 to 100 grains.

The application of fertilizer (NPK) increased significantly ($p<0.01$) the NG/P, which was estimated at 59% over the control (Table 5). Similar observations were made elsewhere (Chaturvedi, 2005; Yosef Tabar, 2012).

Rate of Filled Grains (RFG)

There were no significant differences ($p<0.05$) between the RFG of different varieties of rice (Table 3). The average RFG of different varieties was between 61.33% and 68.83%.

However, the RFG increased significantly ($p<0.0001$) after the application of fertilizer (Table 5).

This result demonstrated that the RFG is not a varietal characteristic, but is a yield component that rather depends on soil fertility. Swain et al. (2010) reported that phosphorus and nitrogen contribute to accumulation of carbohydrate in stems and leaf sheaths during the pre-flowering stage and in grain during the ripening stage of rice.

Weight of thousand grains (WTG)

The effect of the variety was very highly significant ($p < 0.0001$) on the WTG (Table 3). The Fofifa variety presented the highest WTG (35.61 g) and the lowest (27.9 g) was observed with NERICA 4. These results are similar to those of Liu et al. (2013) who found that some varieties are described as heavy panicle type, while others are described as many panicle type.

Fertilizer application did not significantly ($p < 0.05$) affect WTG (Table 5), which is in accordance with Yaser et al. (2011) who observed that the effect of nitrogen and bacterial fertilization had no significant effect on WTG and NP. These results could demonstrate that the WTG is a varietal characteristic which is not influenced by soil fertility. However, Yosef Tabar (2012) found that the combined supply of nitrogen and phosphorus fertilization above 150 kg N/ha and 90 kg P/ha is likely to increase the WTG of rice.

Plant Height (PH)

The interaction Fertilization X Variety was significant ($p < 0.05$) for plant height (Table 2). The variety Fofifa recorded the highest plant height of 115.86 cm and 97.53 cm in the fertilized and unfertilized control plots, respectively (Table 6). Significant differences in PH were not also observed with the NERICA varieties both with- and without the use of fertilizer. However, NERICA 8 was the shortest (73 cm) among the varieties.

The application of fertilization significantly ($p < 0.0001$) increased PH of each variety (Table 6) compared to unfertilized control. These observations confirm those of Gebrekidan and Seyoum (2006) who reported that the increase in PH after application of N and P is due to the fact that N is an essential element for plant growth since it is a constituent of all proteins and nucleic acids while P is essential for the production and transfer of energy in plant.

Table 6: Interaction effect of fertilizer application and variety on plant height (cm) of NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Treatment	Variety							
	Nerica 1	**Nerica 2**	**Nerica 3**	**Nerica 4**	**Nerica 8**	**Nerica10**	**Fofifa**	**Mean**
Unfertilized	79.06^{d}	79.60^{d}	79.53^{d}	83.80^{d}	67.26^{e}	79.93^{d}	97.53^{b}	80.95
Fertilized	90.13^{c}	89.13^{c}	92.80^{c}	90.33^{c}	79.00^{d}	89.86^{c}	115.86^{a}	92.44
Mean	84.59	84.36	86.16	87.06	73.13	84.89	106.7	

Means across all rows and columns followed by the same letter(s) are not significantly different at P<0.0001; according to Student-Newman-Keuls test at 5%.; CV(%) = 2.88

Straw yield (SY)

The interaction between fertilization and variety was significant for SY (Table 2). Table 7 shows that the combination Fertilized X Fofifa gave the highest SY (6.77 T/ha). However, the combination; Unfertilized X NERICA 8 produced the lowest SY (3.15 T/ha). In unfertilized plots NERICA 4 gave the highest SY (4.57 T/ha) compared to other varieties (Table 7). These results corroborate those of Vadivelloo and Fadel (2009) who reported that the quality of SY in response to urea treatment depends on the variety of rice; varieties with wide leaf area will improve the quality of the straw with the supply of urea.

Table 7: Interaction effect of fertilizer and variety on straw yield (T/ha) of NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Treatment	Variety							
	Nerica 1	**Nerica 2**	**Nerica 3**	**Nerica 4**	**Nerica 8**	**Nerica10**	**Fofifa**	**Mean**
Unfertilized	3.63^{e}	4.11^{de}	3.52^{e}	4.57^{bcde}	3.15^{e}	4.27^{de}	4.44^{cde}	3.95
Fertilized	6.76^{a}	5.96^{ab}	5.70^{abc}	5.38^{abcd}	5.82^{abc}	5.24^{bcd}	6.77^{a}	5.94
Mean	5.19	5.03	4.61	4.97	4.48	4.75	5.60	

Means across all rows and columns followed by the same letter(s) are not significantly different at P<0.0001; according to Student-Newman-Keuls test at 5%.; CV(%) = 11.32

Moreover, each variety in the fertilized plot gave SY significantly higher ($P < 0.0001$) compared to unfertilized control plot. This result corroborates those of Gebrekidan and Seyoum (2006); Ali et al. (2009); Nogueira et al. (2011) who found that the application of fertilizer increased SY of rice compared to unfertilized control. According to Gebrekidan and Seyoum (2006) the increase in SY was due to the ability of nitrogen to increase the vigorous vegetative growth of rice plants. It was the case with Zhang et al. (2010) who found that

treatment with urea (225 kg/ha) could maintain a relatively high rate of translocation of dry matter and nitrogen use efficiency and economic benefits of rice.

Harvest Index (HI)

Regarding the HI, interaction between Fertilization X Varieties was significant (Table 2). It was observed that in the fertilized plots the HI in each variety increased compared to the same variety in unfertilized plot (Table 8). In contrats, Gebrekidan and Soyoum (2006) found that increasing nitrogen availability from 0 to 150 kg/ha reduced the HI from 44.93% to 37.22%. The combination Fertilized plot X NERICA 8 recorded the highest HI of 44.4% while the combinations Unfertilized Plot X Fofifa had the lowest rates of HI of 23.6 (Table 8).

Table 8: Interaction effect of fertilizer and variety on the harvest Index (%) of NERICA upland rice varieties in the forest zone with mono modal rainfall pattern in Cameroon

Treatment	Variety							
	Nerica 1	**Nerica 2**	**Nerica 3**	**Nerica 4**	**Nerica 8**	**Nerica10**	**Fofifa**	**Mean**
Unfertilized	31.05^{bc}	32.37^{abc}	27.73^{c}	24.63^{c}	41.63^{ab}	32.21^{abc}	23.65^{c}	30.46
Fertilized	39.85^{ab}	42.55^{ab}	40.89^{ab}	40.13^{ab}	44.43^{a}	43.63^{ab}	41.38^{ab}	41.83
Mean	35.45	37.46	34.31	32.38	43.03	37.92	32.51	

* Means across all rows and columns followed by the same letter(s) are not significantly different at P<0.0001; according to Student-Newman-Keuls test at 5%.; CV(%) = 12.43

A positive and significant correlation was observed between rice grain yield and NP (0.84), NG (0.90), RFG (0.69), SY (0.82) and HI (0.85). Meanwhile correlations between WTG and other yield components was not significant (Table 9). Similar results were observed by Gebrekidan and Seyoum (2006). However, in testing different doses of fertilizer on rice these scientists found that the correlation between PH and yield was not significant.

Table 9: Correlations between yield and yield components of NERICA upland varieties in the forest zone with mono modal rainfall pattern in Cameroon

Parameter	GY	NP/m^2	NG/P	RFG	WTG	PH	SY	HI
GY	-	-	-	-	-	-	-	-
NP/m^2	0.84***	-	-	-	-	-	-	-
NG/P	0.90***	0.66***	-	-	-	-	-	-
RFG	0.69***	0.47**	0.56***	-	-	-	-	-
WTG	0.09 ns	0.09 ns	0.13 ns	0.10 ns	-	-	-	-
PH	0.43**	0.33*	0.18 ns	0.29 ns	0.63***	-	-	-
SY	0.82***	0.80***	0.69***	0.38*	0.25 ns	0.66***	-	-
HI	0.85***	0.62***	0.82***	0.82***	0.09 ns	0.09 ns	0.43**	-

ns= non-significant; * Significant ($p < 0.05$) ; ** Highly significant ($p < 0.01$); ***Very highly significant ($p < 0.001$)

GY= Grain yield (kg/ha); NP/m^2 = Number of Panicle per square meter; NG/P =Number of Grain per panicle; RFG = Rate of Filled Grain (%); WTG = Weight of Thousand Grain (g); PH =Plant Height (cm); SY = Straw Yield (t/ha); HI = Harvest Index (%)

CONCLUSION

The NERICA upland rice varieties tested in this study were well adapted to forest agro-ecological zone with mono modal rainfall pattern in Cameroon. Fertilizer use significantly enhanced yield and yield components with the strongest response observed in FOFIFA and NERICA 1. Rice GY was highly significantly correlated to yield components notably NG/P and SY. Further studies are underway to confirm these preliminary results and to address yield gap between farmers' practices and potential yield obtained from on-station research to facilitate dissemination of results to users.

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COMPETING INTERESTS

No competing interests

AUTHORS' CONTRIBUTION

Author 1. Field data collection, preparation of draft MS

Author 2. Development of research topic, soil sampling, correction of draft MS
Author 3. Literature search, field lay out and correction of draft MS
Author 4. Experimental design, data analysis, correction of draft MS

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