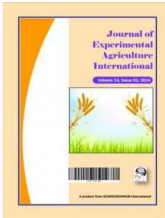

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Agronomic Adaptability of Some Selected Nerica Rice Varieties in Response to Biofertilizer Application in Northern Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Author GM designed the study, performed the work in the field and in the laboratory, wrote the protocol and the first draft of the manuscript. Author NA managed the statistical analysis of the study and reviewed the second draft of the manuscript. Author NR managed the literature searches and reviewed the third draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A field study was conducted in agro-ecological zone I (Yagoua) and II (Wakwa) in Cameroon during the 2008 and 2009 cropping seasons. The objective of this research was to evaluate the responses of four selected Nerica rice varieties to biofertilizer application on their growth and yield performances in the field. The experimental setup was a split-plot (4x5)x3, in which the type of fertilization was the main factor or treatments, each of which was replicated thrice, while the rice varieties (FKR56-N, FKR58-N FKR60-N, FKR62-N, DIR-95) were considered as the secondary factor or sub-treatment. Treatments were: T0, which received none of the fertilizers; TE, which was applied with only the chemical fertilizer NPK (14-24-14); TEM, which was applied with chemical fertilizer (NPK) and biofertilizer (mycorrhizae); TM, which was applied with only biofertilizer. Biofertilizer was revealed as effective as the chemical fertilizer on rice growth and yield, but at different ranges varying with rice varieties. Rice varieties FKR60-N and FKR62-N significantly

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expressed the highest degree of root colonization by biofertilizer at the range of respectively 62.96-77.23% at Yagoua and 59.29-69.05% at Wakwa compared to other varieties, and for the first and the second cropping seasons. Rice plants that were applied with each of the fertilizers showed an important height (103.88-112.80 cm) when compared to the control (96.04-104.06 cm). The number of tillers was significantly increased 1.5-2 folds by biofertilizer application at Yagoua and Wakwa during both cropping seasons. Nerica varieties FKR58-N, FKR60-N, as well as the local variety DIR-95 recorded higher seed yield, respectively (1.73-3.32; 2.27-4.42; 2.22-4.54) t/ha in studied agro-ecological zones. On the overall, there were significant varietal changes on growth parameters and grain yield/ha. Results revealed the contribution of this biofertilizer in sustaining the intensification of safe and environmentally friendly rice production in northern Cameroon.

Keywords: Nerica rice; biofertilizer; growth and yield performances; Yagoua; Wakwa.

1. INTRODUCTION

Rice of the genus *Oryza* is a cereal crop cultivated worldwide, and where it constitutes the main component of human nutrition [1]. It is a nutritional food source for which its consumption is more important, and rises up more than the demographic explosion. Cultivation of rice «*Oryza glaberrima*» has an ancient origin, anterior to introduction of Asiatic origin rice «*Oryza sativa L*.» [2]. Farmers have found some organoleptic qualities greater than those of Asiatic rice [3]. Therefore, the African Initiative for Rice (AIR) was launched in 2002 to promote diffusion of Nerica rice which means «New Rice for Africa», which is an interspecific hybrid from the crossing between the local rice (*Oryza glaberrima)* and the exotic Asian rice (*Oryza sativa*). Nerica rice is well adapted to Sub-Saharan Africa, due to its brief growth period, which allows rice growers to benefit from the short rainy season within the zones exposed to drought [4]. This rice is particularly indicated for securing rice cultivation in lowland, even with bad water management practices. Hence, the possibility of adapting the varieties known as flexible or polyvalent, but that also supports high temperature fluctuations opens new interesting perspectives.

Like other African countries in Central Africa, Cameroon possesses the agro-ecological conditions favorable for intensive rice production [5]. Despite this enormous potential that can ensure its self-dependence, the country still lines up with the sub-regional tendency of importing rice. With a prevision of 60000 ha of irrigated surface toward the 2030 horizon, which is equivalent to an average production of 120000 tons of paddy within the actual conditions, Cameroon could not satisfy the overgrowing demand in rice [5].

The fast growing population in northern Cameroon invites thoughts on long-term environmentally friendly solutions for a strategic rehabilitation of rice cultivation surfaces for high yields. Hence, restoration of soil fertility and the socio-economic criteria have to be taken into account prior to any sustainable agricultural development operation. The utilization of chemical fertilizers has been preconized as one of the solutions, but its high cost and availability to the common poor farmer, as well as its hazardous direct and indirect effects on human population and environment [6] are the main constraints. For instance, Inhalation or exposure to methomyl, malathion, methyl parathion, DDT have revealed a high occurrence of generalised symptoms including headache, nausea, vomiting, fatigue, irritation of skin and eyes, besides psychological, neurological, cardiorespiratory and gastrointestinal symptoms [7,8]. In addition, one can point out the poor cultural practices that lead our tropical soils to multiple erosions, and mineral leaching that intensify the low soil productivity [9].

The «Agenda 21» adopted at Rio-De-Janero has suggested the necessity for third world countries to establish agricultural production systems that takes into account the ecological equilibrium [10]. Biological agriculture techniques seem to be adapted to a given region at low cost and have no harmful effect to the environment [11,12]. In fact, more than 90% of cultivated plants can establish a symbiotic relationship with mycorrhizal fungi, in which each of the symbiont benefits from the other [13]. Mycorrhizae have proven their potentials as biological control agent against certain plant pathogens [14], or pests [15]. In addition to its many known avantages on plant growth, mycorhizae have been reported to positively impact the soil microflora or reduce the abiotic and biotic stresses [15]. Based on this wide advantages related to plants and environment, one could think that mycorrhizae can be a solution to several problems linked to agricultural production and plant protection [17].

The unequal distribution of efficient mycorhizae strains in cultivated soils justifies the introduction of inoculation technics ([13,16,18,19]) that could improve rice yields attributes, as well as the physico-chemical properties of harvested seeds. Although recent studies have focused on interactions between Nerica and mycorrhizal inoculation [20,21], none has yet compared mycorrhizae as biofertilizer to chemical input as far as the plant growth and yield improvement are concerned. Therefore, the main objective of this study was to improve Nerica rice production through low cost and safe strategies that increase the soil fertility and the income of rice growers.

It is expected that biofertilizer-rice symbiosis could increase Nerica rice growth and yield components, as a response to its adaptation to selected agro-ecological zones in Cameroon. The results from study sites in northern Cameroon are discussed, preliminary to the establishment of a biological rice production program in this part of the country.

2. MATERIALS AND METHODS

2.1 Description of Location and Experimental Site

Field experiments were located in Yagoua within the SEMRY plantation along the Logone river in agro-ecological zone I (sudano-sahelian, 10°30' of latitude north and 5°30' of longitude west), and Wakwa-Ngaoundere in agro-ecological zone II (12°30' of latitude north and 8°30' of longitude west). In zone I, soils are ferruginous lessiviated and indurated on hard mother rock, averagely deep with 82% of granulometry on the soil surface. Their textures is sandy within the first 15 cm depth (67.2% sand; 30.1% limon; 2.7% clay). In zone II, soils are also lessiviated with spots and concretions, averagely depth with 4% of granulometry on the soil surface with sandy texture within the first 15 cm depth (82.1% sand; 11.7% limon; 6.2% clay).

2.2 Biological and Chemical Inputs

Mycorrhizae used as biofertilizer was produced at the University of Ngaoundere, and was a mixture of soil, root fragments and spores of the genus *Glomus* and *Gigaspora* (10-25 spores/1g of soil). The chemical fertilizers NPK (fertilizer ®), with the formula 14:24:14, was purchased from an agricultural chemical fertilizer store in Ngaoundere and Yagoua, the two main towns of respective study sites. Nerica seeds were provided by Africa Rice Centre and were a composite of four Nerica varieties namely: FKR56-N; FKR58-N; FKR60-N; FKR62-N, and one local variety named DIR-95. The names, origins and growth cycles of the selected seed varieties are detailed in Table 1.

2.3 Preparation of Rice Seedlings for Transplantation

To obtain seedlings for field experiment, 1 kg of each seed variety (Fig. 1a) was stored in 20 cm x 40 cm bags, and soaked for 48 h within 15L plastic baskets containing tap water (Fig. 1b). The pre-germinated seeds for each variety (Fig. 1c) were evenly distributed on 1m^2 plots, half part of which has received a small layer of biofertilizer prior to sowing. All the plots were then covered with a layer of dried hay (Fig. 1d) to maintain humidity and secure seeds from devastating birds. Pre-germinated seeds were allowed to grow under wet conditions for 21 days, before transplantation in the field.

Table 1. Characteristics of Nerica rice varieties used in this study

Varietal names	Genetic origin (parents)	Geographic origin	Homologated names	Sowing-fruits set cycle (DAP)	Sowing-maturity cycle (DAP)
WAS 161-B-9-3	TOG 5681 / 4*IR 64	WARDA (ADRAO) St Louis, Senegal	FKR 56-N	86	116
WAS 191-9-3	IR 64 / TOG 5681 // 4*IR 64	WARDA(ADRAO) St Louis, Senegal	FKR 58-N	86	116
WAS 122-IDSA-1-WAS-1-1-B	TOG 5681 /.3*IR 64	WARDA(ADRAO) St Louis, Sénégal	FKR 60-N	85	115
WAS 122-IDSA-1-WAS-6-1	TOG 5681 / 3*IR 64	WARDA(ADRAO) St Louis, Senegal	FKR 62-N	88	118
IR 46	//	Adamawa (Mbe, Cameroon)	DIR-95	80	115

*FKR: Farako-Bâ Rice; DIR: local varietyfrom Mbe in Adamwa; N=Nerica * : New Rice for Africa ; DAP: Days After Planting*

2.4 Experimental Field, Design and Treatments

Field experiments were conducted and repeated in each study site during the growing season extending from mid-February to June 2008 and 2009 in Yagoua and Wakwa. The experimental soil was manually cleared, ploughed and delimitated in elementary plots with dikes. The trial was a split-plot (4 x 5) x 3, in which the type of fertilization was the main factor or treatments, each of which was replicated thrice, whereas the 5 rice varieties (FKR56-N, FKR58-N, FKR60-N, FKR62-N and IR-95) were the secondary factors or sub-treatments. Transplantation of plantlets was effected two per planting hole with 0.20 m x 0.20 m within and between the lines. An elementary plot was a 16 m² area, each of which comprises 20 lines of 4 m length, with an average density of 250.000 plantlets/ha^{-1}. Weeding was manually performed twice after every two months. Plant growth parameters and seed yield were estimated on the middle lines to avoid bordering effects.

The main treatments were: biofertilizer (TM), in which experimental unit was inoculated by dipping nursery plants roots into biofertilizer (containing 10 à 25 spores *Glomus* and *Gigaspora*/1 g of soil) before transplantation; chemical fertilizer (TE), in which each plant of the experimental unit received 150 kg.ha^{-1}of fertilizer ® NPK (14-24-14) and 75 kg.ha^{-1} of 46% urea at 30 days after planting (DAP); biofertilizer-chemical fertilizer (TEM) in which nursery plants roots were dipped into biofertilizer (containing 10 à 25 spores *Glomus* and *Gigaspora*/1 g of soil) before transplantation, with additional 75 kg.ha^{-1} of fertilizer ® NPK (14-24-14) and 25 kg.ha^{-1} of 46% urea at 30 DAP; control (T0) in which no experimental unit received none of the fertilizer type. Chemical fertilizers were applied twice during the plant growth cycle: one at sowing, and the other 50 DAP corresponding to panicles emergence.

(a)

(b)

(c)

(d)

Fig. 1. Growing steps of seedlings for field experiment

Breaking of dormancy by storing seeds in bags (a) and soaking in water (b); pre-germinated seeds 48h later (c); sown seeds covered with dried biomass to maintain humidity and secure seeds from devastating birds (d)

2.5 Assessment of the Degree of Root Colonization by Biofertilizers

The method used was that of root colonization described [22], but modified [23]. Stained roots provide a contrast allowing easy visualization of fungal structures (mycelium, vesicles, arbuscules). The degree of biofertilizer root colonization was expressed using the intersection line method described [24,25]. Hence, 10 stained roots fragments with intact cortex were arranged onto slides and protected with a cover slide. The mounted slides were observed at 20X-40X under a light microscope. The presence or absence of mycorhizal structures was evidenced on each and every fragment. The degree of root colonization by biofertilizer was determined as the ratio between the number of fragments bearing mycorrhizal structures and the total number of fragments.

2.6 Evaluation of Growth and Yield Parameters

Growth parameters were evaluated at 60 days after planting (DAP) on 10 randomly selected plants per experimental unit. The number of productive tillers at 60 DAP was assessed by visual counting, whereas the height of plants were measured using a graduated ruler. At maturity, yield components were assessed on 10 randomly selected plants per experimental unit. Thus, the seed number/panicle was determined by counting the seeds per panicle [26]. An electronic balance PGW 153i (Max 150 g, 0.001 sensibility) was used to evaluate the weight of 1000 seeds. From the weight of seeds per experimental unit, the seed yield per hectare was estimated by extrapolation for each of the rice varieties. Seed yield expressed in t/ha was estimated at 14% relative humidity.

2.7 Statistical Analyses

All the obtained data were subjected to an analysis of variance (ANOVA) using the Stagraphic plus Program version 5.00. Means were separated between treatments using the Least Significant Difference (LSD) procedure.

3. RESULTS AND DISCUSSION

3.1 Influence of Fertilization Type on Root Colonization and Maturity Cycles of Selected Nerica Rice Varieties

Fig. 2 illustrates the variations in the degree of root colonization by mycorrhizae (biofertilizer) as influenced by different treatments within the studied sites of the two agro-ecological zones I (Yagoua 1, 2) and II (Wakwa 1, 2). Plant roots from treatments T0 (4.34-5.94% at Yagoua, 5.73-8.38% at Wakwa), TE (5.25-7.97% at Yagoua, 8.44-9.15% at Wakwa) were significantly less colonized by biofertilizer than those of treatment TEM and TM (62.96-77.23% at Yagoua, 59.29-69.05% at Wakwa) that expressed the highest degree of colonization in both experimental sites for each of the repeatedcropping seasons.

At Yagoua, TEM-planted rice varieties FKR60-N and DIR-95 responded significantly ($p = 0.006$) to biofertilization than all the other varieties, whereas no difference was observed at Wakwa. As for treatment TM, rice varieties FKR60-N and FKR62-N expressed the highest degree of root colonization by biofertilizer at Yagoua ($p = 0.001$) and Wakwa ($p = 0.004$) compared to other varieties. Similarly, the degree of root colonization by biofertilizer differed between varieties of the first ($p =0.002$) and the second cropping season ($p = 0.0001$). The decrease in root colonization by biofertilizer in negative control (T0) and chemical fertilizer (TE) treatments lines with the non-homogeneous distribution of efficient strains of biofertilizer in cultivated soils [19]. The present results confirm the infestation of rice varieties by incoming strains of biofertilizer, but also reveal that the indigenous strains were present in the soil, although less competitive or efficient [12].

The time to maturity varied from 112-121, 110-117, 112-117, and 112-116 days, respectively for treatments T0, TE, TEM and TM at Yagoua. At Wakwa, this variation was similar, with respectively 117-120, 111-117,111-116 and 112-117 days attributed in this order to the same treatments. Between Nerica varieties of the same cropping season at Yagoua, sowing-maturity cycle ranged between 110-116 days the first year, and 112-119 days the second year. At Wakwa, the variation held between 111-117 days for the first, to 114-118 days for the second cropping seasons. The maturity phase that runs from flowering to complete seed set lasted for approximately 30 days. The flowering period was rice variety dependent, and could be considered as a secondary selection criterium as previously reported [27]. The reduction of maturity cycle (days) of several varieties by biofertilizer was also seen as predilection criteria positively affecting the cultural calendar. This precocity lines with reduction of climate change [27]. The shortening of cultural cycle in an adaptation to seasonal length was reported as a classical most used method for breeders, and probably remains nowadays, one of the most efficient methods recommended for yield improvement [28,29].

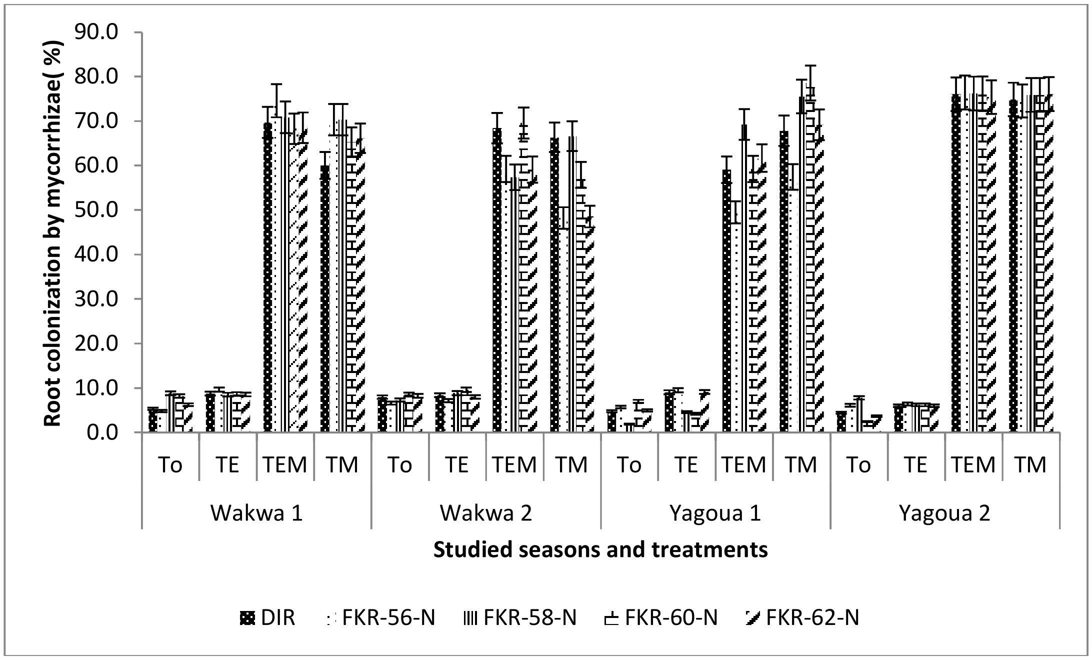

Fig. 2. Degree of root colonization by biofertilizer as influenced by treatments in cropping seasons within sites (Yagoua, Wakwa)

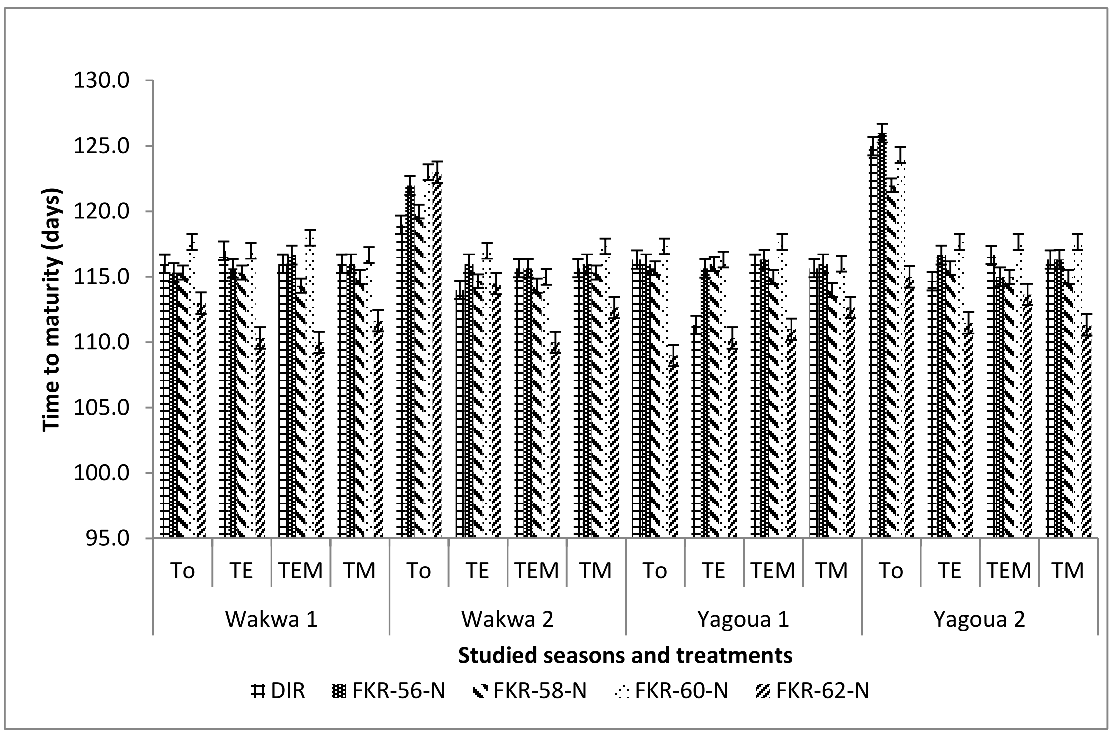

Fig. 3. Variation in the sowing-maturity cycle of rice varieties as influenced by cropping seasons within the sites

3.2 Effect of Fertilization on Productive and Yield Parameters of Selected Nerica Rice Varieties

Table 2 indicates that during the first cropping season at Yagoua, the number of fertile tillers/m^2 varied from one rice variety to another, and within a rice variety, from one treatment to another. For all the rice varieties, treatments TE and TEM increased the number of fertile tillers/m^2 more than treatment TM and T0. In all the cases, the control treatment produced less fertile tillers than any other treatment. When considering each treatment, the most producing fertile tillers was the rice variety FKR62-N, whereas the less was rice variety FKR58-N. The number of fertile tillers was more elevated in the first (Yagoua 1) than the second cropping season (Yagoua 2).

For both years, the rice variety FKR58-N produced the highest number of fertile tillers, whereas the lowest accounted for variety FKR56-N. Similarly, the plant height differed from one variety to another and was affected by treatments. For each of the rice variety, the plant height of controlled plants was shorter than that of other treatments, the tallest (113.94 cm) being observed in treatments TE and TEM for rice variety FKR58-N. Apart from the rice variety FKR58-N for which no difference was noticed in the plant height between cropping seasons, plants of the first cropping season were significantly taller than those of the second for the rice varieties FKR56-N, FKR60-N, FKR62-N and DIR-95.

The assessment of growth parameters at Wakwa (Table 3) also indicated an important increment of the number of fertile tillers and the plant heights, all attributed to treatments TE, TEM and TM, compared to the control. There was a significant difference ($p < 0.0001$) between varieties for each treatment for plant height. For each of the growth parameters, the significant difference between the cropping seasons 1 (Wakwa 1) and 2 (Wakwa 2) was only observed on rice variety FKR56-N (Table 3).

Table 2. Variation of growth parameters between varieties as affected by treatments at Yagoua

Growth parameters	Treatments	Rice varieties					*LSD*
		FKR56-N	**FKR58-N**	**FKR60-N**	**FKR62-N**	**DIR-95**	
		Cropping season 1(Yagoua 1)					
Tiller number/m^{-2}	T0	103.63^{a}_{a}	94.52_{a}^{a}	99.69_{a}^{a}	156.26_{a}^{b}	108.60_{a}^{a}	47.65
	TE	238.72^{a}_{c}	235.52_{c}^{a}	278.33_{c}^{b}	$321.91c^{c}$	293.89_{c}^{b}	39. 41
	TEM	251.39^{ab}_{c}	237.25_{c}^{a}	273.33_{c}^{bc}	303.51_{c}^{d}	290.22_{c}^{cd}	30.17
	TM	196.27^{a}_{b}	191.44_{b}^{a}	199.45^{a}_{b}	218.38_{b}^{b}	200.89_{b}^{a}	17.48
	LSD	42.65	44.08	73.88	62.12	89.33	
Plant height at maturity (cm)	T0	96.04^{a}_{a}	104.88_{a}^{b}	99.26_{a}^{a}	96.83_{a}^{a}	97.83_{a}^{a}	5.62
	TE	106.09^{a}_{b}	112.80_{b}^{b}	105.45_{b}^{a}	104.66_{b}^{a}	105.47_{b}^{a}	6.71
	TEM	104.01^{a}_{b}	112.29_{b}^{b}	106.88_{b}^{a}	106.88_{b}^{a}	106.98_{b}^{a}	6.31
	TM	103.88^{a}_{b}	110.69_{ab}^{b}	104.70_{b}^{a}	104.88_{b}^{a}	104.07_{b}^{a}	5.81
	LSD	7.84	7.41	5.44	7.43	7.64	
		Cropping season 2 (Yagoua 2)					
Tiller number/m^{-2}	T0	64.27^{ab}_{a}	56.21_{a}^{a}	60.79_{a}^{ab}	77.51_{a}^{b}	68.67_{a}^{ab}	21.30
	TE	184.0^{a}_{c}	180.99_{c}^{a}	218.88_{c}^{b}	$257.44c^{c}$	232.89_{c}^{b}	24. 79
	TEM	195.04^{ab}_{c}	182.53_{c}^{a}	214.46_{c}^{bc}	241.16_{c}^{d}	229.40_{c}^{cd}	26.70
	TM	146.25^{a}_{b}	141.98_{b}^{a}	149.14^{a}_{b}	165.82_{b}^{b}	150.34_{b}^{a}	15.47
	LSD	37.75	40.54	65.31	75.34	79.05	
Plant height at maturity (cm)	T0	$60..47^{a}_{a}$	107.85_{a}^{c}	96.67_{a}^{b}	95.57_{a}^{a}	101.03_{a}^{b}	6.81
	TE	106.3^{bc}_{b}	115.06_{b}^{d}	101.2_{b}^{a}	104.40_{b}^{a}	109.05_{c}^{c}	4.64
	TEM	108.48^{c}_{b}	115.03_{b}^{d}	102.29_{b}^{a}	104.29_{b}^{a}	108.19_{c}^{c}	2.00
	TM	108.37^{b}_{b}	112.77_{b}^{c}	100.11_{b}^{a}	102.60_{b}^{a}	103.30_{b}^{a}	4.4
	LSD	45.82	4.92	3.44	7.02	2.27	

For each growth parameter and each seed variety within a column, values affected by the same lower case letter are not significantly different between treatments at the level indicated. For each growth parameter and each treatment within a raw, values affected by the same upper case letter are not significantly different between

Table 3. Variation of growth parameters between varieties as affected by treatments at Wakwa

Growth parameters	Treatments	Rice varieties					*LSD*
		FKR56-N	**FKR58-N**	**FKR60-N**	**FKR62-N**	**DIR-95**	
Cropping season 1 (Wakwa 1)							
Tiller number/m^{-2}	T0	298.51^{c}_{a}	158.75_{a}^{a}	285.28_{b}^{bc}	255.43_{b}^{b}	272.43_{b}^{bc}	40.08
	TE	300.43^{b}_{a}	234.29_{b}^{a}	272.14_{b}^{ab}	272.48_{b}^{ab}	285.17_{b}^{ab}	66.14
	TEM	348.18^{c}_{b}	225.14_{b}^{a}	288.59_{b}^{bc}	280.33_{b}^{ab}	300.44_{b}^{bc}	63.44
	TM	307.76^{c}_{a}	249.70_{b}^{b}	220.39_{a}^{b}	220.36_{a}^{b}	141.52_{a}^{a}	58.06
	LSD	40.41	66.39	51.74	35.07	130.91	
Plant height at maturity (cm)	T0	40.86^{a}_{a}	84.71_{a}^{b}	97.33_{a}^{d}	91.81_{a}^{c}	99.10_{a}^{d}	5.52
	TE	78.04^{a}_{c}	107.02_{c}^{d}	101.16_{b}^{b}	104.90_{b}^{cd}	102.66_{bc}^{bc}	3.74
	TEM	78.78^{a}_{c}	103.84_{b}^{b}	104.24_{b}^{b}	102.32_{b}^{b}	102.63_{b}^{b}	23.85
	TM	59.97^{a}_{b}	103.86_{b}^{b}	101.27_{b}^{b}	101.43_{b}^{b}	100.71_{a}^{b}	40.73
	LSD	18.06	19.12	3.82	9.62	1.92	
Cropping season 2 (Wakwa 2)							
Tiller number/m^{-2}	T0	195.12^{a}_{a}	240.43_{a}^{ab}	241.55_{a}^{ab}	318.64_{a}^{b}	281.75_{ab}^{ab}	115.51
	TE	254.21^{a}_{a}	33.62_{a}^{a}	339.42_{b}^{a}	221.07_{a}^{a}	275.55_{ab}^{a}	ns
	TEM	265.13^{a}_{a}	366.77_{a}^{b}	272.79_{ab}^{a}	277.02_{a}^{a}	338.41_{b}^{ab}	89.75
	TM	256.34^{a}_{a}	264.04_{a}^{a}	237.66_{a}^{a}	238.391_{a}^{a}	244.54_{a}^{a}	ns
	LSD	ns	ns	97.87	ns	93.87	
Plant height at maturity (cm)	T0	28.87^{a}_{a}	97.85_{a}^{b}	94.15_{a}^{b}	98.23_{a}^{b}	93.86_{a}^{b}	64.9
	TE	96.96^{a}_{b}	101.6_{b}^{ab}	105.69_{c}^{b}	101.47_{b}^{ab}	106.06_{b}^{b}	8.73
	TEM	96.20^{a}_{b}	105.61_{c}^{b}	103.38_{bc}^{b}	102.64_{b}^{b}	104.14_{b}^{b}	6.64
	TM	92.30^{a}_{b}	105.0_{c}^{c}	99.98_{b}^{b}	100.22_{b}^{b}	102.03_{a}^{b}	2.97
	LSD	63.34	3.40	5.83	3.23	8.17	

For each growth parameter and each seed variety within a column, values affected by the same lower case letter are not significantly different between treatments at the level indicated. For each growth parameter and each treatment within a raw, values affected by the same upper case letter are not significantly different between varieties at the level indicated.

The importance of tillering is based on rice variety, but is influenced by cultural practices. The rice variety FKR62-N had the greatest number of tiller/m^2 in treatments TE and TEM at Yagoua, whereas the lowest accounted for variety FKR58-N in different treatments. The number of tillers was significantly ($p < 0.05$) increased by biofertilizer application at Yagoua and Wakwa during both cropping seasons, similar to previous reported results [21]. Rice plants that were applied with each of chemical or biological fertilizers responded by an important height when compared to the control. These findings line with improved plant growth by mycorrhizae through increase nutrient uptake, particularly nitrogen and phosphorus [29,30]. Similarly, mycorrhizae were revealed to contribute to 23.63% enhancement of plant height as compared to unfertilized plants [31]. This is in agreement with significantly increased rice plants height, number of tillers and grain yields by biofertilizer [32-34]. The plant height obtained from this study was 3.5 folds greater than the values reported in Nigeria [35].

Table 4 summarizes the yield components related to different treatments considered at maturity phase at Yagoua. The seed number/panicle varied between rice varieties from 15-47 for T0, 42-48 for TE, 34-40 for TEM, and 26-36 for TM. However, for each rice variety, the seed number/ panicle was lower in the control (148-268 seeds/panicles) than in other treatments, the greatest value accounting for treatments TE (250-334 seeds/panicles) or TEM (262-337 seeds/panicles). Treatments did not affect the 1000 seed weight of varieties FKR62-N, DIR-95 and FKR58-N, but biofertilizer and chemical fertilizer contributed to increase the seed weight of varieties FKR56-N and FKR60-N.

At Wakwa in the agro-ecological zone II, an enhancement of seed number/panicle was revealed in treatments TE and TEM for all the rice varieties as compared to each of the treatments control or TM alone (Table 5). Apart from treatment T0 for which the seed number/panicle was averagely the same for all the rice varieties, FKR56-N, FKR58-N, FKR60-N and DIR-95 produced more seeds/panicle than FKR62-N for treatments TE and TEM. In contrast, rice varieties FKR62-N and FKR60-N were the most performing in seeds/panicle production following inoculation at sowing with biofertilizer (TM).

Table 4. Changes in yield components between varieties as affected by treatments at Yagoua

Yield components	Treatments	Seed varieties					p-value
		FKR56-N	**FKR58-N**	**FKR60-N**	**FKR62-N**	**DIR-95**	
		Yagoua 1					
Seeds/panicle	T0	15.86^{a}_{a}	18.86^{a}_{a}	17.93^{a}_{a}	20.08^{a}_{a}	47.66^{a}_{a}	27.5
	TE	41.89^{b}_{b}	45.79^{c}_{b}	47.66^{c}_{b}	48.07^{a}_{a}	43.69^{c}_{b}	ns
	TEM	39.75^{a}_{b}	34.25^{a}_{b}	43.73^{a}_{b}	44.66^{a}_{b}	40.70^{a}_{b}	8.48
	TM	31.73^{a}_{a}	28.20^{a}_{a}	28.20^{b}_{a}	26.49^{c}_{b}	36.00^{ab}_{a}	5.23
	LSD	*8.02*	*9.33*	*10.26*	*6.40.*	*11.65*	
Yield (t/ha) at 14% moisture	T0	0.41^{a}_{a}	0.48^{a}_{a}	0.68^{a}_{a}	1.25^{b}_{a}	1.49^{b}_{a}	0.56
	TE	3.31^{a}_{c}	3.30^{a}_{c}	4.22^{b}_{c}	4.76^{b}_{b}	4.54^{b}_{c}	0.92
	TEM	3.24^{ab}_{b}	2.52^{a}_{b}	3.77^{b}_{c}	4.32^{b}_{b}	3.77^{b}_{c}	1.24
	TM	2.90^{a}_{b}	2.12^{a}_{b}	2.20^{a}_{a}	1.79^{a}_{a}	2.79^{b}_{b}	1.02
	LSD	1.04	0.78	1.56	0.79	0.96	
		Yagoua 2					
Seeds/panicle	T0	14.07^{a}_{a}	17.07^{a}_{a}	16.14^{a}_{a}	18.3^{a}_{a}	45.87^{b}_{b}	31.7
	TE	40.10^{a}_{d}	44.0^{c}_{d}	45.87^{a}_{c}	46.29^{a}_{c}	41.90^{a}_{ab}	ns
	TEM	37.90^{ab}_{c}	32.46^{a}_{c}	40.94^{b}_{c}	42.87^{b}_{c}	38.91^{ab}_{ab}	8.48
	TM	27.60^{a}_{b}	26.41^{ab}_{b}	26.41^{ab}_{b}	24.70^{a}_{b}	34.55^{c}_{a}	2.90
	LSD	*10,55*	*9.33*	*10.26*	*18.16.*	*11.32*	
Yield (t/ha) at 14% moisture	T0	0.22^{a}_{a}	0.25^{a}_{a}	0.30^{ab}_{a}	0.43^{b}_{a}	0.89^{c}_{a}	0.17
	TE	1.78^{a}_{c}	1.73^{a}_{d}	2.27^{a}_{c}	3.75^{b}_{b}	2.22^{a}_{c}	1.48
	TEM	2.05^{ab}_{c}	1.36^{a}_{c}	1.90^{ab}_{c}	2.68^{b}_{b}	2.03^{ab}_{b}	1.32
	TM	1.17^{a}_{b}	0.86^{a}_{b}	0.92^{a}_{b}	0.96^{a}_{a}	1.16^{a}_{a}	ns
	LSD	0.61	0.36	0.61	1.72	0.87	

For each yield parameter and each seed variety within a column, values affected by the same lower case letter are not significantly different between treatments at the level indicated. For each yield parameter and each treatment within a raw, values affected by the same upper case letter are not significantly different between varieties at the level indicated.

Table 5. Changes in yield components between varieties as affected by treatment at Wakwa

Yield components	Treatments	Seed varieties					p-value
		FKR56-N	**FKR58-N**	**FKR60-N**	**FKR62-N**	**DIR-95**	
		Wakwa 1					
Seeds /panicle	T0	17.25^{a}_{a}	17.81^{a}_{a}	19.85^{a}_{ab}	17.29^{a}_{a}	22.37^{a}_{a}	ns
	TE	41.02^{bc}_{b}	45.57^{c}_{c}	39.78^{b}_{c}	24.44^{a}_{a}	40.19^{bc}_{c}	13.23
	TEM	41.85^{c}_{b}	36.87^{c}_{b}	29.41^{b}_{b}	21.54^{a}_{a}	34.80^{bc}_{b}	13.23
	TM	14.74^{a}_{a}	20.58^{a}_{a}	19.43^{a}_{a}	22.37^{a}_{a}	20.62^{a}_{a}	13.23
	LSD	*23.76*	*8.70*	*9.98*	*ns*	*5.39*	
Yield (t/ha) at 14% moisture	T0	1.17^{ab}_{a}	0.56^{a}_{a}	1.33^{b}_{a}	1.16^{ab}_{a}	1.67^{c}_{c}	0.76
	TE	3.18^{bc}_{b}	2.55^{ab}_{c}	3.75^{c}_{b}	1.77^{a}_{b}	2.92^{bc}_{c}	1.15
	TEM	3.81^{c}_{b}	2.24^{b}_{bc}	3.12^{bc}_{b}	1.18^{a}_{a}	2.81^{b}_{c}	1.00
	TM	1.09^{a}_{a}	1.62^{a}_{b}	1.45^{a}_{a}	1.25^{a}_{b}	0.98^{a}_{a}	ns
	LSD	2.01	0.92	1.65	0.59	0.69	
		Wakwa 2					
Seeds /panicle	T0	15.33^{a}_{a}	17.36^{a}_{a}	19.56^{a}_{a}	23.20^{a}_{a}	16.85^{a}_{a}	ns
	TE	29.91^{b}_{b}	39.68^{c}_{b}	38.13^{c}_{b}	22.79^{a}_{a}	38.95^{c}_{b}	7.12
	TEM	32.86^{a}_{b}	39.88^{a}_{b}	36.93^{a}_{b}	38.53^{a}_{b}	38.20^{a}_{b}	ns
	TM	14.88^{a}_{a}	16.86^{a}_{a}	22.60^{b}_{a}	40.19^{c}_{b}	19.09^{ab}_{a}	5.74
	LSD	*14.58*	*22.50*	*14.32*	*15.33*	*19.11*	
Yield (t/ha) at 14% moisture	T0	0.68^{a}_{a}	1.01^{a}_{a}	1.06^{b}_{a}	1.88^{b}_{ab}	1.19^{ab}_{a}	0.81
	TE	$2.10a^{b}_{b}$	3.99^{c}_{c}	3.34^{c}_{b}	1.66^{a}_{a}	3.05^{bc}_{b}	1.23
	TEM	2.38^{a}_{b}	2.88^{ab}_{b}	2.99^{ab}_{b}	3.20^{b}_{c}	3.68^{b}_{c}	1.29
	TM	1.05^{a}_{a}	1.05^{a}_{a}	1.63^{ab}_{a}	2.64^{c}_{bc}	1.33^{b}_{a}	1.01
	LSD	1.05	1.10	1.35	0.98	1.72	

For each yield parameter and each seed variety within a column, values affected by the same lower case letter are not significantly different between treatments at the level indicated. For each yield parameter and each treatment within a raw, values affected by the same upper case letter are not significantly different between varieties at the level indicated. ns not significant

Although the seed yield (t/ha) at 14% moisture was significantly ($p < 0.001$) influenced by treatments TE, TEM, TM compared to the control (T0) for rice varieties FKR56-N, FKR58-N, FKR60-N and DIR-95, this parameter did not significantly ($p = 0.2591$) change from one treatment to another for rice variety FKR62-N. The seed yield significantly varied from one rice variety to another, the best yields accounting for rice varieties FKR62-N (1.88 t/ha), FKR58-N (3.99 t/ha), DIR-95 (3.68 t/ha), FKR62-N (2.64 t/ha), when treatments T0, TE, TEM and TM were respectively taken into consideration. In all the cases, the number of seeds/panicle and the seed yield (t/ha) did not only differ between varieties of the same season, but also varied from one season to another.

Yields from different rice varieties were by far lower than the potentialities indicated by FAO [36]. This could be justified by the reduced solarrays during the cultural season. It has been reported that solar radiation is the energy source for photosynthesis, which of cause is important for a good seed yield [37]. Shade, which is appropriate for vegetative growth exerts little influence on yield, but has a negative impact on the reproductive phase, acting on the panicle number, thus considerably reducing the seed yield and the fertile panicles. In short, the increment of yield was closely dependent on the length and number of panicles. This is understandable, since these parameters are used to directly or indirectly estimate the seed yield [38]. The increased plant development and yield parameters in response to inoculation endorsed the fact that biofertilizers do have one or more growth promoting mechanisms including mobilization and efficient nutrients uptake [39, 40], as well as solubilization of insoluble phosphates [41]. Elsewhere, inoculation of upland rice was revealed to increase yield by 10 to 29% compared to other types of fertilizers applied at 20 and 40 $kgN.ha^{-1}$ [42], justifying the dependence of rice to the best fertilizers combination for yield improvement.

4. CONCLUSION

This study has proven that application of biofertilizers resulted in comparatively better performance in terms of growth, development and yield in all Nerica varieties investigated. All the five Nerica varieties favorably responded to biofertilizers inoculation, with varieties FKR58-N, FKR60-N, as well as the local variety DIR-95 producing higher yield and developmental rate. Therefore, these two Nerica varieties could be recommended to farmers as alternative performant varieties to the local DIR-95.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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