

Original Research Article

Agronomic adaptability of some selected Nerica rice varieties in response to biofertilizer application in northern Cameroon

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 some selected Nerica rice varieties to biofertilizer application on their growth and yield performances in the field. The experimental setup was factorial (4x5x3), in which the type of fertilization was the main factor or treatments, each of which was repeated thrice, while the rice variety (FKR56-N, FKR58-N, FKR60-N, FKR62-N, DIR-95) was considered as the second factor. Treatments were: T0, which has received none of the fertilizers; TE, which has received only the chemical fertilizer NPK (14-24-14); TEM, which has received chemical fertilizer (NPK) and biofertilizer (mycorrhizae); TM, which has received only biofertilizer. From this experiment was as biofertilizer effective as the commercial chemical fertilizer on rice growth and yield, but at different degrees depending on the seed variety. Seed varieties FKR60-N and FKR62-N significantly expressed the highest degree of root colonization by biofertilizer at Yagoua ($p=0.001$) and Wakwa ($p=0.004$) compared to other varieties. This differed between varieties of the first ($p=0.002$) and the second cropping seasons ($p=0.0001$). Rice plants that received each of the fertilizers exhibited an important height when compared to the control. The number of tillers was significantly ($p<0.05$) increased 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 grain yield/ha and panicles/m² within each of the agro-ecological zone. On the overall, there was a significant ($p<0.05$) varietal changes on growth parameters and grain yield/ha. Results reveal the contribution of this biofertilizer in sustaining the intensification of safe and environmentally friendly rice culture in northern Cameroon.

Keywords: Nerica rice, biofertilizer, growth and yield performances, Yagoua, Wakwa

1. Introduction

Rice of the genus *Oryza* is a cereal cultivated worldwide, and where it constitutes the main component of human nutrition [1]. It is a nutritional food source for which the 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 in rice 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», 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 culture in lowland, even with bad water management practices. Hence, the possibility of adapting the varieties known as flexible or polyvalent, that also support high temperature fluctuations opens new

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Comment [M10]: These are P values. Use factual findings.

Comment [M11]: state the actual increase that was highest in degree of root colonization, number of tillers, highest grain yield. Kindly state the actual figures.

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44 interesting perspectives.

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

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51 The fast growing population in northern Cameroon invites thoughts on long term
52 environmentally friendly solutions for a strategic rehabilitation of agricultural surfaces for
53 high yields. Hence, restoration of soil fertility, and the socio-economic criteria have to be
54 taken into account prior to any sustainable agricultural development operation. The utilization
55 of chemical fertilizers has been preconized as one of the solutions, but its high cost and
56 availability to the common poor farmer, as well as its hazardous effect on population and
57 environment [6] are the main constraints. In addition, the bad cultural practices lead our
58 tropical soils to multiple erosions, and mineral leaching that intensify the low soil productivity
59 [7].

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60 The «Agenda 21» adopted at Rio-De-Janeiro has suggested the necessity for third
61 world countries to establish agricultural production systems that take into account the
62 ecological equilibrium [8]. Biological agriculture techniques seem to be appropriate and
63 adapted to a given region at low cost, and without harmful effect to the environment [9,10].

64 In fact, more than 90% of cultivated plants can establish a symbiotic relationship with
65 mycorrhizal fungi, in which each of the partners gains benefit from the other [11]. Mycorrhizae
66 have proven their potentials as biological control agents against certain plant pathogens [12],
67 or pests [13]. To many known advantages of mycorrhizae on plant growth, can be added their
68 positive impact on soil microflora, reduction of abiotic and biotic stresses [14]. Based on this

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69 wide advantages related to plants and environment, one could think that mycorrhizae can be a
70 solution to several problems linked to agricultural production and plant protection [15]. The
71 unequal distribution of efficient mycorrhizal strains in cultivated soils justifies the introduction
72 of inoculation techniques ([9,16,17]) that could improve rice yields attributes, as well as the
73 physico-chemical properties of harvested seeds. From our basic knowledge, although few
74 studies have recently focused on interactions between *NERICA* and mycorrhizal inoculation [18,
75 19], none has yet compared mycorrhizae as biofertilizer to chemical inputs as far as the plant
76 growth and yield improvement are concerned. Therefore, the main objective of this study was

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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 riziculture program in this part of the country.

2. Material 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, less leached and indurated on hard mother rock, average depth with 82% of granulometry on the soil surface. Their texture is sandy within the first 15 cm depth (67.2% sand; 30.1% limon; 2.7% clay). In zone II, soils are also less leached with spots and concretions, average 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/g 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 rice grains 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.

108 **Table1.**CharacteristicsofNericaricevarietiesusedinthisstudy

Varietalnames	Geneticorigin (parents)	Geographicorigin	Homologated names	Sowing- fruitset Cycle (DAP)	Sowing- maturity cycle (DAP)
WAS161-B-9-3	TOG5681/4*IR64	WARDA(ADRAO) StLouis,Senegal	FKR56-N	86	116
WAS191-9-3	IR64/TOG5681// 4*IR64	WARDA(ADRAO) StLouis,Senegal	FKR58-N	86	116
WAS122-IDSA-1-WAS-1-1-B	TOG5681/.3*IR64	WARDA(ADRAO) StLouis,Sénégal	FKR60-N	85	115
WAS122-IDSA-1-WAS-6-1	TOG5681/3*IR64	WARDA(ADRAO) StLouis,Senegal	FKR62-N	88	118
IR46	//	Adamawa(Mbe, Cameroon)	DIR-95	80	115

109 FKR:Farako-BâRice; DIR: localvarietyfromMbeinAdamwa;N=Nerica*;NewRiceforAfrica;DAP:DaysAfter
110 Planting
111
112

113 2.3.Preparationofriceseedlingsfortransplantation.

114 Toobtainseedlingsforfieldexperiment,1kgofeachseedvariety(**figure 1a**)wasstored in20cmx 40
115 cmbags,andsoakedfor48hwithin15Lplasticbasketscontainingtapwater (figure1b).Thepre-
116 germinatedseedsforeachvariety(**figure 1c**)wereevenlydistributedon1
117 m²plots,halfofwhichhasreceiveda smalllayerofbiofertilizerpriorto sowing.Allthe
118 plotswerethencoveredwitha layerofdriedhay(**figure 1d**)tomaintainhumidityandsecure seeds
119 fromdevastating birds. Pre-germinated seeds wereallowed to grow under wet
120 conditionsfor21days,beforetransplantationinthe field.

121 2.4.Experimental field,designandtreatments

122 Fieldexperimentswereconductedandrepeatedin eachstudysiteduringthegrowingseason extending
123 from mid-February to June 2008 and 2009 in Yagouaand Wakwa. The
124 experimentalsoilwasmanuallycleared,ploughedanddelimitedinelementaryplotswith
125 dikes.**The trial was a factorial (4x5x3), in which the type of fertilization was the main factor or**
126 **treatments, each of which was repeated thrice, and 5 rice varieties (FKR56-N, FKR58-**
127 **N, FKR60-N, FKR62-N and IR-95) these second factor.** Transplantation of plantlets
128 was effected two per planting hole with 0.20mx 0.20m within and between the lines. An
129 elementary plot was a 16m² area, each of which comprises 20 lines of 4m length, with an
130 averagedensity of 250.000 plantlets/ha⁻¹. Weeding was manually performed twice after every
131 two months. Plant growth parameters and seed yield were estimated on the middle line to
132 avoid bordering effects.

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The main treatments were: biofertilizer (TM), in which experimental unit was inoculated by dipping nursery plants roots into biofertilizer (containing 10×10^8 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 10×10^8 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 panicle emergence.



Figure 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 48 h 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 [20] by Phillips and Hayman (1970), but modified [21] by Kormanik and McGraw (1982). 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 [22,23] by McGonigle *et al.* (1990) and Brundrett *et al.* (1996). Hence, 10 stained root fragments with intact cortex were arranged on to slides and protected with a coverslip. The mounted slides were observed at 20X–40X under a light microscope. The presence or absence of mycorrhizal 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 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 was measured using a graduated ruler.

At maturity, yield components were assessed on 10 randomly selected plants per experimental unit. Thus, the panicle number/plant, the grain number/panicle were determined by counting the grain per panicle [24] (Ngakou *et al.*, 2013). An electronic balance PGW153i (Max 150g, 0.001 sensibility) was used to evaluate the weight of 1000 grains. From the weight of grains per experimental unit, the grain yield per hectare as estimated by extrapolation for each of the rice varieties. Seedy 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 compared between treatments through the Least Significant Difference (LSD) procedure. Correlations between parameters were assessed using the Statistical Package for Social Science (SPSS) program.

3. Results and discussions

3.1. Influence of fertilization type on root colonization, growth and maturity cycles of selected NERICA rice varieties

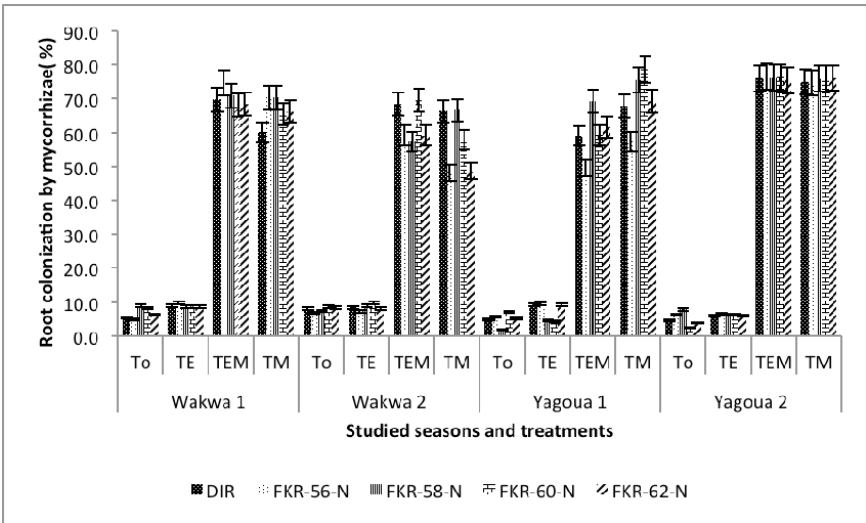
Figure 2 illustrates the variations in the degree of root colonization by mycorrhizae (biofertilizer) as influenced by different treatments within the studied sites of the two agro-ecological zones I (Yagoua 1, 2) and II (Wakwa 1, 2). The degree of roots colonized by

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187 biofertilizer was different between treatments and varieties at both experimental sites. Hence,
 188 plant roots from treatment T0 (4.34-5.94% at Yagoua, 5.73-8.38% at Wakwa), and TE (5.25-
 189 7.97% at Yagoua, 8.44-9.15% at Wakwa) were significantly less colonized by biofertilizer
 190 than those of treatment TEM and TM (62.96-77.23% at Yagoua, 59.29-69.05% at Wakwa)
 191 that expressed the highest degree of colonization in both experimental sites for each of the
 192 repeated cropping seasons.



193 **Figure 2.** Degree of root colonization by biofertilizer as influenced by treatments in
 194 cropping seasons within sites (Yagoua, Wakwa)
 195

196 At Yagoua, TEM-planted seed varieties FKR60-N and DIR-95 responded significantly
 197 ($p=0.006$) to biofertilization than all the other varieties, whereas no difference was observed at Wakwa.
 198 As far as treatment TM is concerned, seed varieties FKR60-N and FKR62-N
 199 significantly expressed the highest degree of root colonization by biofertilizer at Yagoua ($p=$
 200 0.001) and Wakwa ($p=0.004$) compared to the other varieties. Similarly, the degree of root
 201 colonization by biofertilizer differed between varieties of the first ($p=0.002$) and the second
 202 cropping season ($p=0.0001$).
 203

204 The decrease in root colonization by biofertilizer in negative control (T0) and
 205 chemical fertilizer (TE) treatment lines with recent results [17] that claimed that efficient strains of
 206 biofertilizer are not homogeneously distributed in cultivated soils. The present
 207 results confirm the infestation of rice varieties by incoming strains of biofertilizer, but also reveal that
 208 the indigenous strains were present in the soil, although less competitive/efficient [9].
 209

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Figure3 illustrates the variation expressed in days of sowing-panicle cycle of the rice varieties responding to various treatments conducted at Yagoua and Wakwa. Generally, treatments have significantly ($p < 0.001$) affected the sowing-panicle cycle of all varieties, the longest (over 90 days) accounting for the negative control (T0) when variety FKR62-N was sown. On the reverse, treatment TEM contributed to shortening the cycle of local variety DIR-95 to 69 days in Yagoua. At Wakwa, there was also a significant difference between treatments for this parameter. In such, where the longest sowing-panicle cycle was ascribed to treatment T0 (91, 91, 90 days respectively for FKR62-N, FKR58-N and FKR56-N seed varieties), the shortest accounted for treatment TEM of the local DIR-95 variety (69 days).

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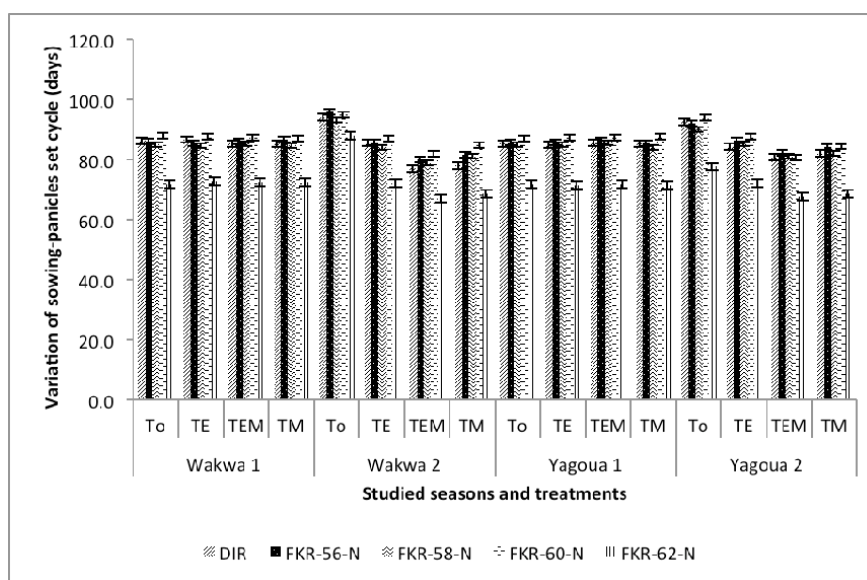


Figure3. Sowing-panicles set cycle of NERICA rice varieties as influenced by treatments in cropping seasons within the sites (Yagoua, Wakwa).

The sowing-panicle cycle did not vary between the first and the second cropping seasons, neither at Wakwa, nor at Yagoua. This cycle issue was highly significant ($p < 0.001$) between NERICA seed varieties in the first and second cropping seasons, varying from 72-87 days for the local DIR-95 and FKR62-N varieties the first year, and from 72-87 days for the same varieties the second year. As far as the sowing-maturity cycle is concerned (Figure 4), there was a highly significant difference ($p < 0.001$) between treatments at each of the experimental site. Hence, 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. A consistent and significant ($p < 0.001$) variation of the sowing-maturity cycle was observed at Yagoua between NERICA seed varieties of the same cropping season, from 110-116 days the first year, and 112-119 days the second year. At Wakwa, these values varied between 111-117 days for the first cropping season, to 114-118 days for the second.

The maturity phase that runs from flowering to complete seed set lasted for approximately 30 days. The flowering period was seed variety dependent, and could be considered as a secondary selection criteria as previously pointed out [25]. The reduction of maturity cycle (days) of several varieties by biofertilizer was also seen as a pre-dilection criteria that positively affects the cultural calendar. This precocity lines with reduction of climate change [25]. The shortening of cultural cycle in an adaptation to season 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 [26, 27].

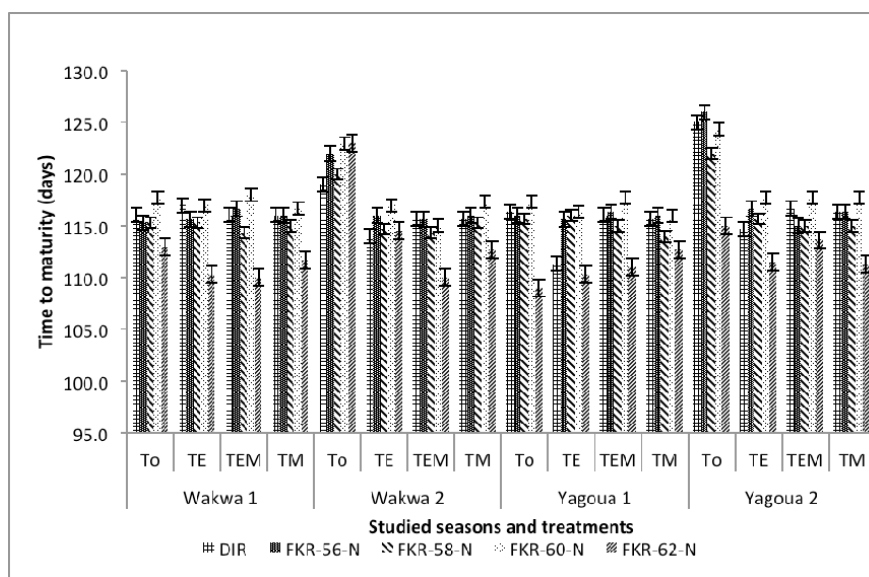


Figure 4. Variation in the sowing-maturity cycle of rice varieties as influenced by cropping seasons within the sites

3.2. Effect of fertilization on productive and yield parameters of selected Nerica rice varieties

Table 2 indicates that at Yagoua during the first cropping season, the number of fertile tillers/m² varied from one seed variety to another, and within a seed variety, from one treatment to another. For all the varieties, treatment TE and TEM significantly ($p < 0.001$) increased the number of fertile tillers/m² 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 seed variety FKR62-N significantly ($p \leq 0.0004$) produced more fertile tillers than any other variety, the less performing variety being FKR58-N. The number of fertile tillers was consistently ($p < 0.001$) more elevated in the first (Yagoua1) than the second cropping season (Yagoua2) (See table 3).

Table 2. Variation of growth parameters between varieties as affected by treatments at Yagoua1 (during the cropping season 1).

Growth parameters		Rice varieties					p-value (LSD)
		FKR56-N	FKR58-N	FKR60-N	FKR62-N	DIR-95	
Tiller number/m ²	T0	103.63 ^a	104.57 ^a	100.00 ^a	152.72 ^b	100.00 ^a	0.001(47.65)
	TE	238.72 ^c	225.57 ^c	270.22 ^b	221.01 ^c	202.00 ^b	<0.0001(39.41)
	TEM	251.39 ^{ab}	227.25 ^c	272.22 ^{bc}	202.51 ^d	200.22 ^{cd}	0.0009(30.17)
	TM	196.27 ^a	101.44 ^b	100.45 ^b	210.76 ^b	200.00 ^a	0.027(17.48)
	p-value (LSD)	<0.0001 (42.65)	<0.0001 (44.08)	<0.0001 (73.88)	<0.0001 (62.12)	<0.0001 (89.33)	
Plant height at maturity (cm) ^{abbbb}	T0	96.04 ^a	104.00 ^b	100.72 ^a	100.07 ^a	107.07 ^a	0.027(5.62)
	TE	106.09 ^b	112.80 ^b	105.45 ^b	104.66 ^b	105.47 ^b	0.016(6.71)
	TEM	104.01 ^a	112.29 ^b	106.88 ^b	106.88 ^a	106.98 ^a	0.017(6.31)
	TM	102.00 ^a	110.00 ^b	104.70 ^a	104.00 ^a	104.07 ^a	0.006(5.01)
	p-value (LSD)	0.0003 (7.84)	0.0113 (7.41)	0.0014 (5.44)	0.022 (7.43)	0.005 (7.64)	
Panicle number/m ²	T0	92.13 ^b	80.42 ^a	85.59 ^b	142.16 ^b	94.50 ^b	0.003(47.65)
	TE	236.83 ^c	222.22 ^a	270.00 ^b	210.57 ^c	201.75 ^b	<0.0001(40.13)
	TEM	247.3 ^{ab}	235.06 ^a	271.96 ^c	301.13 ^c	288.06 ^{bc}	0.0009(29.16)
	TM	194.63 ^a	187.32 ^a	194.43 ^a	216.0 ^b	198.76 ^a	0.016(17.26)
	p-value (LSD)	<0.0001 (42.2)	<0.0001 (46.01)	<0.0001 (77.53)	<0.0001 (85.13)	<0.0001 (89.33)	
Panicle length (cm)	T0	18.56 ^{ab}	18.62 ^b	17.73 ^{ab}	19.5 ^b	15.07 ^a	0.012(3.55)
	TE	25.18 ^a	26.11 ^a	26.23 ^a	27.03 ^a	26.75 ^a	0.837(ns)
	TEM	24.89 ^a	25.86 ^a	28.20 ^a	27.79 ^a	26.18 ^a	0.379(ns)
	TM	27.00 ^b	27.00 ^b	28.47 ^b	26.88 ^a	27.08 ^a	0.0001(8.86)
	p-value	0.0001	0.012	0.0003	0.0004	<0.0001	

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For both years, the seed variety FKR58-N exhibited 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 these varieties, the

the planted seed varieties was significantly ($p \leq 0.0003$) shorter than that of all the other treatments (TM, TEM and TE), the tallest (113.94 cm) being observed in treatment TE and TEM for variety FKR58-N. Apart from the seed variety FKR58-N for which no difference was noticed in the plant height between cropping seasons, plants of the first cropping season were significantly ($p \leq 0.03$) taller than those of the second for these seed varieties FKR56-N, FKR60-N, FKR62-N and DIR-95.

Table 3. Variation of growth parameters between varieties as affected by treatments at Yagoua2 (during the cropping season 2)

Growth parameters		Treatments					Rice varieties		p-value (LSD)	
Tiller number/m ²										
Plant height at maturity (cm)										
Panicle number/m ²										
Panicles length (cm)										

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 row, values affected by the same upper case letter are not significantly different between

Biofertilizer and chemical fertilizers significantly ($p < 0.001$) improved the panicle number/m² contrary to the control, and from one seed variety to another for a given treatment. The length of panicles was enhanced by treatments TEM and TE in all the seed varieties. For all the assessed growth parameters, the result of the first cropping season was always significantly greater than that of the second, except for the plant height in the seed variety FKR62-N that did not differ between the cropping seasons (table 2 and 3).

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The replication of growth parameters at Wakwa (Table 4 and 5) also indicated a consistent enhancement of the number of fertile tillers, the plant height and the panicle number/m², all attributed to treatments TE, TEM and TM, compared to the control. Apart from the plant height ($p < 0.0001$) and the panicle length ($p \leq 0.0001$) that showed significant difference between varieties for each treatment, only treatment TM contributed to increasing the number of panicles/m². For each of the growth parameters, the significant difference between the cropping seasons 1 (Wakwa 1) and 2 (Wakwa 2) was only observed on seed variety FKR56-N (table 5).

Table 4. Variation of growth parameters between varieties as affected by treatments at Wakwa 1 (during the cropping season 1).

Growth parameters	Treatments	Rice varieties					p-value (LSD)
Tiller number/m ²		FKR56-N	FKR58-N	FKR60-N	FKR62-N	DIR-95	
	T0	298.51 ^c _a	150.75 ^a _a	205.20 ^{bc} _b	255.12 ^b _b	272.12 ^{bc} _b	0.0001(40.08)
	TE	300.43 ^b _a	234.29 ^a _b	272.14 ^{ab} _b	272.48 ^{ab} _b	285.17 ^{ab} _b	0.013(66.14)
	TEM	348.18 ^c _b	225.14 ^a _b	200.50 ^{bc} _b	200.22 ^{ab} _b	200.14 ^{bc} _b	0.015(63.44)
	TM	307.76 ^c _a	240.20 ^b _b	220.20 ^b _a	220.22 ^b _a	141.57 ^a _a	0.0001(58.06)
	<i>p-value</i>	0.034	0.020	0.020	0.014	0.004	
	<i>LSD</i>	40.41	66.39	51.74	35.07	130.91	
Plant height at maturity (cm)	T0	40.86 ^a _a	84.71 ^b _a	97.33 ^d _a	91.81 ^c _a	99.10 ^d _a	<0.0001(5.52)
	TE	78.04 ^a _c	107.02 ^d _c	101.16 ^b _b	104.90 ^{cd} _b	102.66 ^{bc} _{bc}	<0.0001(3.74)
	TEM	78.78 ^a _c	103.84 ^b _b	104.24 ^b _b	102.32 ^b _b	102.63 ^b _b	<0.0001(23.85)
	TM	59.97 ^a _b	103.86 ^b _b	101.27 ^b _b	101.43 ^b _b	100.71 ^a _b	<0.0001(40.73)
	<i>p-value</i>	<0.0001	0.0001	0.006	0.0006	0.0006	
	<i>LSD</i>	18.06	19.12	3.82	9.62	1.92	
Panicle number/m ²	T0	254.65 ^b _a	134.8 ^a _a	243.10 ^{ab} _b	208.32 ^a _b	220.63 ^b _b	0.009(73.52)
	TE	296.15 ^b _{ab}	231.47 ^b _b	271.56 ^{ab} _{ab}	268.57 ^{ab} _{ab}	281.85 ^{ab} _{ab}	0.017(64.67)
	TEM	343.13 ^b _b	224.66 ^a _b	287.98 ^{ab} _{ab}	279.07 ^{ab} _{ab}	296.15 ^{ab} _{ab}	0.018(63.31)
	TM	295.81 ^c _{ab}	240.17 ^b _b	210.02 ^b _a	210.57 ^b _a	124.02 ^a _a	<0.0001(5.90)
	<i>p-value</i>	0.0287	0.002	0.011	0.004	0.003	
	<i>LSD</i>	88.48	89.86	68.05	49.01	95.70	
Panicle length (cm)	T0	14.29 ^a _a	13.93 ^a _a	27.52 ^c _c	23.98 ^{ab} _{ab}	22.25 ^{ab} _{ab}	0.0104(13.23) TE
		19.88 ^a _b	31.57 ^c _c	27.93 ^{bc} _{bc}	28.03 ^{bc} _{bc}	25.14 ^b _b	0.0007(5.26) TEM
		20.34 ^a _b	20.08 ^a _b	27.69 ^b _a	18.32 ^{ab} _a	19.88 ^a _a	0.042(7.35) TM
		29.68 ^c _c	20.83 ^a _b	14.59 ^a _a	19.48 ^{ab} _{ab}	0.0007(5.90)	14.92 ^a _a
	<i>p-value</i>	0.0024	<0.0001	0.4044	0.0247	0.6085	
	<i>LSD</i>	4.95	6.14	ns	9.39	ns	

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 row, 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 seed variety, but is influenced by cultural practices. The rice variety FKR62-N had the greatest number of tiller/m² in treatments TE and TEM at Yagoua, whereas the lowest was variety FKR58-N in different treatments. The number of tillers was significantly ($p < 0.05$) increased by biofertilizer application at Yagoua

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and Wakwa during both cropping seasons, similar to other reported results [19]. Rice plants that received each of chemical or biological fertilizer exhibited 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 [28,29]. Similarly, mycorrhizae were revealed to contribute to 23.63% enhancement of plant height as compared to unfertilized plants [30]. This is in agreement with significantly improvement of rice plants height, number of tillers and grain yields by biofertilizer [31,32, 33]. Increment of 27.11% in panicle number/plant due to biofertilizer inoculation over uninoculated plants was reported [34], and suggested efficient nutrient and water uptake as underlining mechanisms.

Table 5. Variation of growth parameters between varieties as affected by treatments at Wakwa 2 (during the cropping season 2)

Growth parameters	Treatments	Rice varieties					p-value (LSD)
		FKR56-N	FKR58-N	FKR60-N	FKR62-N	DIR-95	
Tiller number/m ²	T0	195.12 ^a	240.42 ^{ab}	241.55 ^{ab}	219.64 ^b	201.75 ^{ab}	0.012(115.51)
	TE	254.21 ^a	227.0 ^a	220.43 ^b	221.07 ^a	225.55 ^{ab}	0.202(ns)
	TEM	265.13 ^a	266.77 ^b	272.76 ^{ab}	277.03 ^a	220.41 ^b	0.007(89.75)
	TM	256.34 ^a	264.04 ^a	277.66 ^a	220.20 ^a	244.54 ^a	0.974(ns)
	p-value	0.227	0.282	0.045	0.272	0.015	
Plant height at maturity (cm)	LSD	ns	ns	97.87	ns	93.87	
	T0	28.87 ^a	97.85 ^b	94.15 ^b	98.23 ^b	93.86 ^b	<0.0001(64.9)
	TE	96.96 ^a	101.6 ^{ab}	105.69 ^b	101.47 ^{ab}	106.06 ^b	0.037(8.73)
	TEM	96.20 ^b	105.61 ^c	103.38 ^{bc}	102.64 ^b	104.14 ^b	0.003(6.64)
	TM	92.30 ^b	105.0 ^c	99.98 ^b	100.22 ^b	102.03 ^b	<0.0001(2.97)
Panicle number/m ²	p-value	<0.0001	0.0001	0.007	0.021	0.016	
	LSD	63.34	3.40	5.83	3.23	8.17	
	T0	148.75 ^a	202.04 ^{ab}	205.42 ^{ab}	257.02 ^b	269.51 ^{ab}	0.029(106.26)
	TE	250.25 ^a	224.44 ^a	221.41 ^a	210.96 ^a	274.54 ^{ab}	0.206(ns)
	TEM	262.69 ^b	329.52 ^a	270.77 ^{ab}	275.29 ^a	337.07 ^b	0.015(54.23)
Panicle length (cm)	TM	253.26 ^b	250.7 ^a	222.20 ^a	221.22 ^a	221.03 ^a	0.899(ns)
	p-value	0.034	0.139	0.033	0.484	0.047	
	LSD	101.49	ns	101.12	ns	125.23	
	T0	27.6 ^b	15.24 ^a	22.31 ^{ab}	26.97 ^b	26.87 ^b	0.046(11.62)
	TE	18.20 ^{ab}	13.16 ^a	28.8 ^c	17.34 ^{ab}	22.22 ^b	0.001(6.58)
Panicle length (cm)	TEM	26.73 ^a	26.41 ^a	24.65 ^a	22.52 ^a	24.63 ^{ab}	0.914(ns)
	TM	27.60 ^{ab}	25.77 ^b	31.29 ^b	29.39 ^{ab}	16.26 ^a	0.0001(5.51)
	p-value	0.002	0.0001	0.351	0.05	0.013	
	LSD	8.53	10.52	ns	12.05	10.60	

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 row, values affected by the same upper case letter are not significantly different between varieties at the level indicated.

Increase in panicle number/plant was attributed to improvement and enhanced availability of nutrients and phyto-hormones like indole-acetic acid and ethylene [35,36]. The plant height and the panicle number/m² obtained from this study were respectively 1.5 and 3.5 fold higher than the values reported in Nigeria [37].

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The yield expressed in t/ha at 14% moisture significantly varied between varieties respectively for treatment T0 ($p < 0.001$), TE ($p < 0.001$), TEM ($p = 0.003$) and TM ($p = 0.011$). For each seed variety, the yield was significantly ($p \leq 0.001$) lower in the control than any other treatments (TE, TEM, TM).

Table 6 summarizes the yield components related to different treatments considered at maturity phase at Yagoua 1 and 2. The seed number/panicle significantly varied between the varieties from 15 to 47 for T0 ($p < 0.001$), 42 to 48 for TE ($p = 0.079$), 34 to 40 for TEM ($p = 0.003$), and 26 to 36 for TM ($p < 0.001$). However, for each seed variety, the seed number/panicle was consistently ($p \leq 0.005$) lower in the control than other treatments, the greatest value accounting for treatments TE or TEM. Treatment did not affect the 1000 seed weight of varieties FKR62-N, DIR-95 and FKR58-N, but biofertilizer and chemical fertilizer significantly increased ($p < 0.0001$) the seed weight of varieties FKR56-N and FKR60-N.

At Wakwain the agro-ecological zone II, a significant enhancement of the seed number/panicle was revealed by treatments TE and TEM for all the seed varieties as compared to each of the treatments control or TM alone (Table 7). Apart from treatment T0 for which the seed number/panicle was averagely the same for all the planted varieties, FKR56-N, FKR58-N, FKR60-N and DIR-95 produced more seeds/panicle than FKR62-N for treatments TE and TEM. In contrast, varieties FKR62-N and FKR60-N were the most performing in seeds/panicle production following inoculation at sowing with biofertilizer (TM). As far as weight of 1000 seeds is concerned, no significant difference was observed between seed varieties for treatments T0 and TE. Instead, the 1000 seed weight of varieties FKR60-N and DIR-95 was consistently increased by treatments TEM and TM compared to other varieties. Unlike treatment T0, all treatments improved the 1000 seed weight of each rice variety.

375 **Table6.**Changesinyieldcomponentsbetweenvarietiesas affectedbytreatmentsatYagoua

Yield components		Treatments Seed varieties sp-value				
		FKR56-N	FKR58-N	FKR60-N	FKR62-N	DIR-95
Seed/panicle	TE	41.89 ^b	45.79 ^c	47.66 ^c	48.07 ^a	43.69 ^c
	TEM	39.75 ^a	34.25 ^a	43.73 ^a	44.66 ^a	40.70 ^b
	TM	31.73 ^a	28.20 ^a	28.20 ^b	26.49 ^c	36.00 ^{ab}
	Pvalue	0.0001	0.0002	<0.0001	<0.0001	0.013
	LSD	8.02	9.33	10.26	6.40	11.65
1000-seedweight (g)	T0	25.41 ^a	27.75 ^{ab}	29.59 ^b	29.46 ^a	29.38 ^b
	TE	29.36 ^{bc}	27.75 ^{ab}	26.67 ^a	30.42 ^c	27.86 ^{ab}
	TEM	31.53 ^b	27.75 ^{ab}	27.50 ^{ab}	26.53 ^a	28.06 ^{ab}
	TM	29.35 ^b	29.12 ^a	29.12 ^a	27.75 ^a	28.75 ^a
	Pvalue	0.008	0.815	0.226	0.09	0.92
	LSD	3.93	ns	ns	ns	ns
Yield(t/ha)at 14%moisture	T0	0.41 ^a	0.48 ^a	0.68 ^a	1.25 ^b	1.49 ^b
	TE	3.31 ^a	3.30 ^a	4.22 ^b	4.76 ^b	4.54 ^b
	TEM	3.24 ^{ab}	2.52 ^a	3.77 ^b	4.32 ^b	3.77 ^b
	TM	2.90 ^a	2.12 ^a	2.20 ^a	1.79 ^a	2.79 ^b
	Pvalue	0.0001	0.0001	0.0001	0.0001	0.0002
	LSD	1.04	0.78	1.56	0.79	0.96
376		Yagoua2				
Seed/panicle	T0	14.07 ^a	17.07 ^a	16.14 ^a	18.3 ^a	45.87 ^b
	TE	40.10 ^d	44.06 ^d	45.07 ^c	46.29 ^c	44.06 ^{ab}
	TEM	37.90 ^{ab}	32.46 ^c	40.94 ^b	42.87 ^b	38.91 ^{ab}
	TM	22.69 ^b	26.41 ^b	26.41 ^{ab}	24.70 ^b	34.55 ^a
	Pvalue	0.0001	0.0001	0.0001	0.0001	0.0001
	LSD	10.55	9.33	10.26	18.16	11.32
1000-seedweight (g)	T0	28.16 ^a	30.50 ^{ab}	32.34 ^b	32.21 ^b	32.13 ^b
	TE	32.11 ^{ab}	30.50 ^{ab}	29.42 ^a	39.83 ^b	30.61 ^{ab}
	TEM	32.61 ^a	30.50 ^{ab}	30.25 ^a	34.95 ^a	30.81 ^a
	TM	31.43 ^b	31.87 ^a	31.87 ^a	30.50 ^a	31.50 ^a
	Pvalue	0.045	0.815	0.299	0.564	0.924
	LSD	3.27	ns	ns	ns	ns
Yield(t/ha)at 14%moisture	T0	0.22 ^a	0.25 ^a	0.30 ^{ab}	0.43 ^b	0.89 ^c
	TE	1.78 ^a	1.73 ^a	2.27 ^c	3.75 ^b	2.22 ^c
	TEM	2.05 ^{ab}	1.36 ^b	1.90 ^{ab}	2.68 ^b	2.03 ^{ab}
	TM	1.17 ^a	0.86 ^a	0.92 ^a	0.96 ^a	1.16 ^a
	p-value	<0.0001	<0.0001	<0.0001	0.0028	0.0014
	LSD	0.61	0.36	0.61	1.72	0.87

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 378 differentbetweentreatmentsatthelevelindicated.Foreachyieldparameterandeach treatmentwithinaraw,
 379 valuesaffectedbythesameuppercaseletterarenotsignificantlydifferentbetweenvarietiesatthelevelindicated.

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381 **Table7.**Changesinyieldcomponentsbetweenvarietiesas affectedbytreatmentatWakwa

Yield components		Treatments Seedvarietiesp-value					
		FKR56-N	FKR58-N	FKR60-N	FKR62-N	DIR-95	
Wakwa1							
Seed/panicle	T0	17.25 ^a	17.81 ^a	19.85 ^a	17.29 ^a	22.37 ^a	0.40(ns)
	TE	41.02 ^{bc}	45.57 ^c	39.78 ^b	24.44 ^a	40.19 ^{bc}	0.0001(13.23)
	TEM	41.85 ^c	26.07 ^c	20.41 ^b	21.54 ^a	24.06 ^{bc}	0.0009(13.23)
	TM	14.74 ^a	20.58 ^a	19.43 ^a	22.37 ^a	20.62 ^a	0.397(13.23)
	Pvalue	<0.0001	<0.0001	<0.004	0.411	<0.0001	
	LSD	23.76	8.70	9.98	ns	5.39	
1000-seedweight (g)	T0	23.69 ^a	25.76 ^a	26.67 ^a	32.07 ^{bc}	33.18 ^c	0.024(6.3)
	TE	28.14 ^a	28.68 ^a	30.09 ^a	30.30 ^{ab}	29.04 ^a	0.361(ns)
	TEM	26.60 ^a	26.58 ^a	31.95 ^b	28.32 ^a	28.47 ^a	0.023(3.48)
	TM	23.15 ^a	29.10 ^b	28.92 ^{ab}	29.79 ^b	40.18 ^c	<0.0001(5.95)
	Pvalue	0.214	0.504	0.0005	0.018	0.77	
	LSD	ns	ns	1.86	0.022	0.026	
Yield(t/ha)at 14%moisture	T0	1.17 ^{ab}	0.56 ^a	1.33 ^b	1.16 ^{ab}	1.67 ^c	0.05(0.76)
	TE	3.18 ^{bc}	2.55 ^{ab}	3.75 ^c	1.77 ^b	2.92 ^{bc}	<0.0001(1.15)
	TEM	3.81 ^c	2.24 ^b	3.12 ^{bc}	1.18 ^a	2.81 ^b	0.001(1.00)
	p-value	0.001	0.002	0.002	0.048	0.0001	
	LSD	2.01	0.92	1.65	0.59	0.69	
	Wakwa2						
Seed/panicle	T0	15.33 ^a	17.36 ^a	19.56 ^a	23.20 ^a	16.85 ^a	0.33(ns)
	TE	29.91 ^b	39.68 ^c	38.13 ^c	22.79 ^a	38.95 ^c	0.002(7.12)
	TEM	32.86 ^a	39.88 ^a	36.93 ^a	38.53 ^b	38.20 ^b	0.60(ns)
	TM	14.88 ^a	16.86 ^a	22.60 ^b	40.19 ^c	19.09 ^{ab}	<0.0001(5.74)
	Pvalue	0.0006	0.0001	0.0004	0.005	0.0001	
	LSD	14.58	22.50	14.32	15.33	19.11	
1000-seedweight (g)	T0	30.33 ^a	27.47 ^a	26.60 ^a	27.78 ^a	24.88 ^a	0.415(ns)
	TE	27.87 ^a	29.99 ^a	26.15 ^a	28.86 ^a	28.50 ^a	0.70(ns)
	TEM	27.21 ^{ab}	22.46 ^a	30.27 ^b	26.76 ^{ab}	27.86 ^{ab}	0.025(7.81)
	TM	27.33 ^{ab}	23.15 ^a	29.40 ^{bc}	27.90 ^{ab}	33.42 ^c	0.019(5.52)
	Pvalue	0.036	0.161	0.226	0.541	0.339	
	LSD	ns	ns	ns	ns	ns	
Yield(t/ha)at 14%moisture	T0	0.68 ^a	1.01 ^a	1.06 ^b	1.88 ^b	1.19 ^{ab}	0.05(0.81)
	TE	2.10 ^a	3.99 ^c	3.34 ^b	1.66 ^a	3.05 ^{bc}	0.002(1.23)
	TEM	2.38 ^a	2.88 ^c	2.99 ^{at}	3.20 ^b	3.68 ^b	0.024(1.29)
	TM	1.05 ^a	1.05 ^a	1.63 ^{at}	2.64 ^c	1.33 ^b	0.001(1.01)
	p-value	0.0007	0.0004	0.0006	0.023	0.002	
	LSD	1.05	1.10	1.35	0.98	1.72	

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 383 differentbetweentreatmentsatthelevelindicated.Foreachyieldparameterandeach treatmentwithinaraw,
 384 valuesaffectedbythesameuppercaseletterarenotsignificantlydifferentbetweenvarietiesatthelevelindicated.

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Although the seed yield (t/ha) at 14% moisture was significantly ($p < 0.001$) influenced by treatment 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 variety FKR62-N. These seed yields significantly varied from one planted seed variety to another, the best yields accounting for 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, TM, were respectively taken into consideration. In all the cases, the number of seeds/panicle and the seed yield (t/ha) not only consistently differed between varieties of the same season, but also varied from one season to another.

Yields from different varieties were by far lower than the potentialities indicated by FAO [38]. This event could be justified by the reduced solar arrays during the cultural season. It has been reported that solar radiation is the energy source for photosynthesis, which of course are important for a good seed yield [39]. 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 [40]. 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 [41,42], as well as solubilization of insoluble phosphates [43]. Elsewhere, upland rice was revealed to exhibit increased yield (2.51 t/h) for 1 t/ha + 20 kg N/ha compared to one application of any of the organic and inorganic fertilizers [44], justifying the dependence of rice to the best fertilizers combination for yield improvement.

Conclusion

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

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