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Response of Lowland Rice to Biofertilizesr Inoculation and their Effects on Growth and Yield in Southwestern Nigeria

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Abstract

Low input technology through the use of biofertilizers in rice has increased due to their potential as plant growth regulator and ability to increase yield on an economical and sustainable basis. Field trials were conducted at the Federal University of Technology, Akure during the dry season of 2012/2013 in the tropical rainforest agro-ecology of south west Nigeria. The objective was to investigate the response and performance of some selected lowland rice varieties to the application of biofertilizers. A 5 x 3 factorial experiment was conducted; five lowland rice varieties selected with and without the application of biofertilizer (mycorrhizae and rhizobium), laid out in split plot arrangement, with mycorrhizae and rhizobium in the main block, while variety was in the sub-plot. Each treatment was replicated three times. Result show significant ($P < 0.05$) effect of biofertilizer inoculation observed on vegetative, reproductive growth and development parameters in the order + biofertilizers > - biofertilizers. There was no significant ($P > 0.05$) varietal variability on grain yield/ha. N-L-19 recorded higher grain yield (6090t/ha), higher panicle/m2 (111.63), highest filled spikelet (567) and highest grain weight (32.8g).

Keywords: biofertilizer, lowland rice, low input technology, growth, grain yield

1. Introduction

Food security challenges in Nigeria are made worse by increasing demographic pressures in the context of dwindling resources. Rice forms a major part of most people's diet in Nigeria and by extension most population in the developing part of the world (Sakariyawo et al., 2013).

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In Nigeria, rice is the sixth major crop in cultivated land area after sorghum, millet, cowpea, cassava and yam (Dauda and Dzivama, 2004; Olaleye et al., 2004). It is the only crop grown nationwide and in all agro ecological zones from Sahel to the coastal swamps. Rice could be cultivated in about 4.6 - 4.9 million ha of land in Nigeria, but the actual area under cultivation is only 1 million/ ha representing 22% of the total potential available area (Kehinde, 1997). Rice is the most rapidly growing food commodity in demand across Nigeria, but the productivity of its production system is very low due in part to poor access to technologies and poor use of external inputs. National demand for rice is rising because of population growth, increasing affluence and changing dietary habits. The UN/FAO forecasts that global rice production will need to increase by over 40% by 2030 and 70% by 2050 (FAO, 2009). It will be difficult for Nigerian farmers to meet up with this demand due to escalating cost of chemical fertilizers. Application of synthetic fertilizer for increased production in required quantity is slowly becoming unaffordable for small-scale farmers in Nigeria; chemical fertilizer use also come with an environmental cost and applying them contributes half the carbon footprint of agriculture and causes environmental pollution. The use of pesticides and burning of rice crop residues (straws and husks) might be beneficial to the enhancement of productivity of major rice varieties but increases methane emission (IRRI, 2011); most methane emission by human activity (300 - 400 million ton a year) originates from rice fields (Fuehrer, 2011). In addition, climate change has reduced the reliability of food supply through altered weather patterns and increased pressure from pests and diseases.

Also, the use of improved rice varieties exhausts soil fertility more rapidly than traditional varieties; farmers usually compensate these nutritional losses, especially macro-elements, with chemical fertilizers while neglecting some essential secondary and micro nutrients. In the long run, the micro-elements become deficient and cause an imbalance in soil nutrition affecting the ultimate grain yield.

Local rice growers will have to produce more rice from lesser land, using less water, energy and other inputs in harmony with the fragile environment (CRRI, 2013).

The exploitation of biofertilizers through microbial sources such as *rhizobium* and *arbuscular mycorrhizae* for rice growth promotion, environmental changes, abiotic and biotic stress endurance through conventional and intensive use of molecular tools would alleviate the serious production constraints for the present and future.

Application of rhizobium has been extensively explored in the root nodules of legumes where they fix atmospheric nitrogen, but recent studies also suggest that rhizobium can exhibit plant growth promoting (PGP) activities with nonlegumes (Yanni *et al*., 1997).

Certain mechanisms are attributed towards rhizobium which may be involved in their PGP activities i.e. mobilization and efficient uptake of nutrient (Biswas *et al*., 2000a, enhancement in stress resistance (Mayak *et al.,* 2004), solubilization of insoluble phosphates (Alikhani *et al*., 2006), induction of systemic disease resistance (Tuzun and Kloepper, 1994), production of phytohormones(Dakora, 2003), vitamins (Dobbelaere *et al*., 2003) and siderophores (Neiland and Leong, 1986). Also mycorrhizae, was reported to be responsible for the uptake of some essential macro and micro nutrients; especially the uptake of phosphorus, nitrogen, magnesium and zinc (Yeasmin *et al.,* 2007).

In the light of the prevailing constraints to increased rice production in a sustainable and affordable way, a cheaper alternative source of nutrient input is needed for sustainable food security and rice production in Nigeria, there is a need to put in place ameliorative strategies to improve the performance of lowland rice in tropical region of Nigeria. Hence, the objective of this study was to evaluate the response of some selected lowland rice varieties to inoculation of rhizobium and mycorrhizae on their growth performance and yield in the tropical region of Nigeria.

2. Materials and Method

2.1 Description of Location and Experimental Site

The studies were carried out on a submerged lowland area (fadama site) at the Federal University of Technology, Akure. Ondo State Nigeria.

It is located between latitude 50 081 10.51E and 70171 59.21N, at elevation of 140 m above the sea level. The mean annual rainfall range between 1500 and 1613mm for year 2012 and 2013 respectively. The mean annual temperature were 27°C .

The Soil was submerged with water throughout the duration of the experiment, it's a sandy clay loam which is an alfisol classified as clayey skeletal oxic-paleustaif (USDA/ NRCS,2003), while the vegetation is tropical rain forest with an average relative humidity of between 56 and 59% during the dry season and 51 - 82% during the wet season (IITA, 2002). Field experiments were conducted on rice with biofertlizer inoculation under lowland condition during the 2012 and 2013 dry seasons. Prior to transplanting, the nursery stage was conducted at the screen house of the Department of Crop Soil and Pest Management of the Federal University of Technology, Akure. Small polythene pots of about 5cm in diameter and 10cm in length were filled with topsoil and prepared Mycorrhizae/Rhizobium innoculum with soil as carrier at 50g per pot; this was done to ensure maximum colonization of the roots before transplanting. Rice seeds were sown at 2-3 seeds per pot, the pots were made moist and maintained for about 21-25 days before germinated seedlings were transplanted to the field. Soil samples were collected for the determination of chemical properties before planting and after harvest, Soil pH was determined in 1:2.5 (soil: water) and KCl solution (1:1) using glass electrode pH meter. Soil organic matter was determined according to Walkey and Black (1934) method. Total nitrogen in the soil was analysed using Kjeldahl method (Bremner, 1960). Available phosphorus was extracted using Olsen's extract while the P in the extract was determined by the use of spectrophotometer. Exchangeable cation (K, Ca, Mg) were extracted with 1 N Ammonium Acetate K in the extract was determined by flame photometry, Ca and Mg were determined by atomic absorption spectrometer (AAS).

2.2 Experimental Design and Treatment

The experiment was a 3 x 5 factorial experiment with *Arbuscular mycorrhizae*,*Rhizobium*, without *AMF/Rhizobium*(control) and five varieties of lowland rice (NERICA L-19, NERICA L- 34, TOOX4004, WITA 4 and FARO 44). The study was a split plot arrangement in Randomized Complete Block Design (RCBD), with AMF and rhizobium inoculation in the main plot, while varieties were in the sub-plot, replicated three times.

2.3 Source and Application of planting materials

The different rice seeds (varieties) were acquired from Africa Rice Centre, International Institute of Tropical Agriculture, Ibadan (IITA). The varieties are the improved high yielding varieties commonly grown by farmers in the ecological zone.

Prepared *Arbuscular mycorrhizal fungi(Glomus intaradices*) inoculum with soil as carrier and cultured *Rhizobium* strains (RACA 3/5/12) were obtained from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. The inoculants were applied to the potting medium where rice seeds were planted at the rate of 50 g per pot just after the seeds were planted.

2.4 Field Layout and Planting

There were three main plots, each plot consist of 15 sub-plots with a size measurement of 2m x 1m and inter sub-plot spacing of 0.5m in between plots. A total of 132 plants were planted per sub plot and each sub-plot consists of 21 plants per row. Transplanted seedlings were planted with the ball of earth into planting holes in the field at two seedlings per stand, according to their respective plot at a spacing of 20cm x 20cm^3. Minimal weeding was done throughout the duration of the experiment to prevent weed infestation on the field.

2.5 Sampling and Data Collection

Five plants per plot were randomly selected from the net plot (2 x 1 m) for the collection of agronomic parameters (growth, development, yield and yield components) of lowland rice varieties. Plant height, number of leaves and number of tillers were recorded at 2, 4, 6, 8, 10 and 12 weeks after planting (WAP). Plant height was determined using a ruler from soil surface to the tip of the tallest leaf. Development parameters (Days-to-50% flowering and days-to-90% maturity) were determined by standard procedures. Number of panicle per meter square was determined with the aid of one meter quadrant by counting the number of panicle in the quadrant three weeks before harvesting. Other yield components parameters were determined by standard procedures.

2.6 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA), mixed model at 5% probability level. All data were checked prior to statistical analysis for the violation of ANOVA assumption, Means were separated using DMRT. Genstat statistical package was used for the analysis.

3. Result and Discussion

Table 1. Physio-Chemical Properties of the Soil Before Planting

Soil properties	Values
Sand (%)	82.78
Silt (%)	6.38
Clay (%)	10.84
Nitrogen (%)	0.47
Organic Carbon (%)	2.78
Organic Matter (%)	4.79
Calcium (cmol/kg)	5.5
Magnessium (cmol/kg)	2.9
Potassium (cmol/kg)	1.08
Phosphorus (cmol/kg)	4.35
pH	5.94
CEC	11.54
Al^2	0.7
H	0.47

Table 2. Chemical Properties of the Soil After Harvest

Treatments	N (%)	OM (%)	OC (%)	K (cmol/kg	P (cmol/kg	Mg (cmol/kg)	Ca (cmol/kg)	Na (cmol/kg	pH
MHI	0.70	5.13	3.2	0.03	3.89	2.0	4.03	0.17	6.04
RHI	0.83	5.48	3.18	0.02	4.69	1.2	2.3	0.04	5.55
NI	0.63	2.30	1.33	0.005	2.73	0.8	1.7	0.02	5.27

N: Nitrogen; OM: organic matter, OC: organic carbon, K: potassium, P: phosphorus, Mg: Magnessium, Ca: Calcium, Na: Sodium.

MHI: Mycorrhizae inoculation, **RHI**: Rhizobium inoculation, **NI**: Not-inoculated
*mean values are presented in the table

3.1 Reponses with Respect to Plant Height

The heights of rice during the vegetative, developmental and ripening stages of the treatments are given in Figures 1, 2 and 3 with detailed graphs.

Plants inoculated with biofertilizers were not significantly ($P < 0.05$) taller than those without biofertilizer.Significant ($P < 0.05$) varietal interaction was however observed in plant height of varieties inoculated with mycorrhizae and rhizobium at 8 WAP, while at 12 WAP significant interaction was only observed in varieties inoculated with rhizobium. TOX 4004 had the highest plant height and FARO 44 had the lowest plant height across all treatments. This agree with the findings of Ashrafuzzaman *et al*. (2009), Sakthivel and Gnanamanickam (1987), and Isahak *et al*. (2012) who all stated that biofertilizers significantly improved rice plants growth by increasing soil nutrients such as nitrogen and phosphorus which influences rice seedlings growth, and significantly enhancing plant height which leads to high photosynthesis rate. Similarly, Chi *et al.* (2005) observed up to 23.63% increase in plant height of rice over un-inoculated control and argued indole acetic acid and gibberellins production as the key mechanism for that improvement.

With higher plant height, there would be a better canopy architecture for the interception of both direct and diffuse radiant energy for carbon assimilation, which will be reflected in increased accumulation of dry matter in biofertilizer treated rice plants

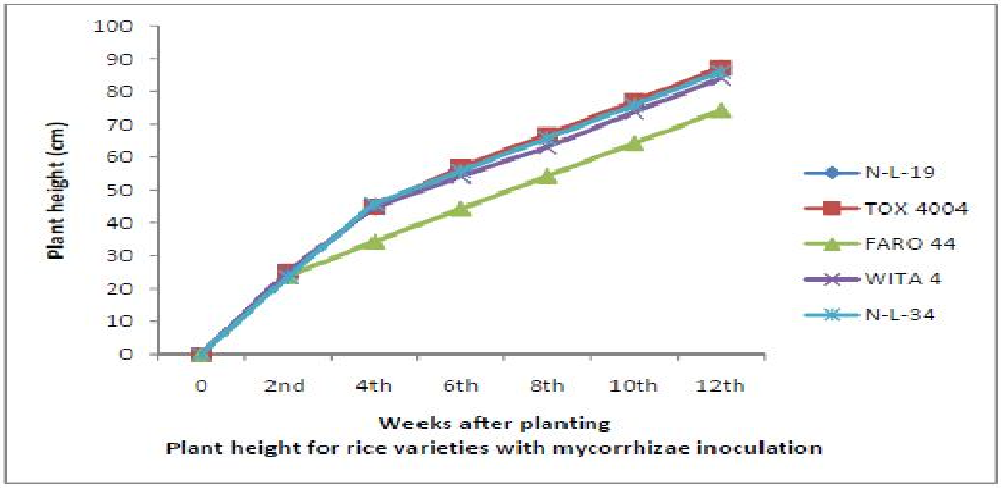


Figure 1.Response of Rice Varieties to Mycorrhizae Inoculation with Respect to Plant Height

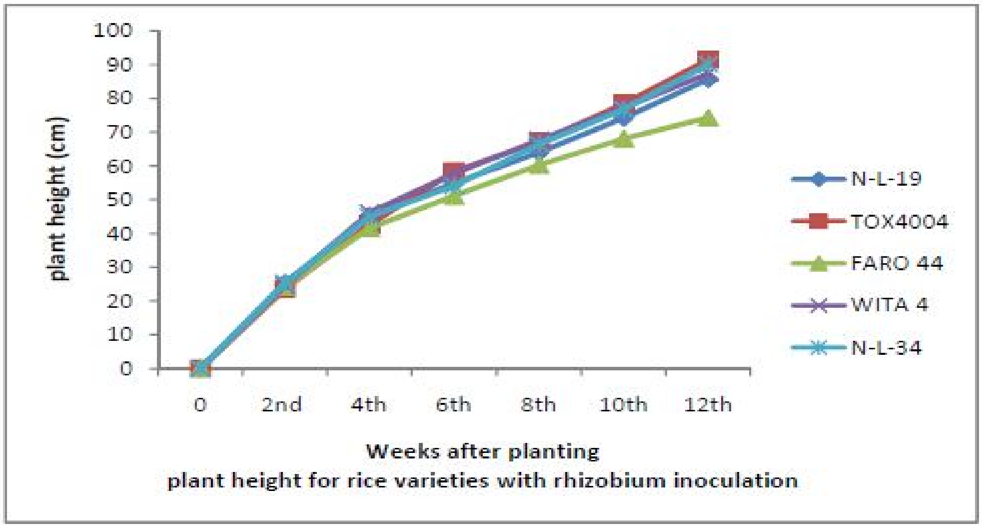


Figure 2.Response of Rice Varieties to Rhizobium Inoculation with Respect to Plant Height

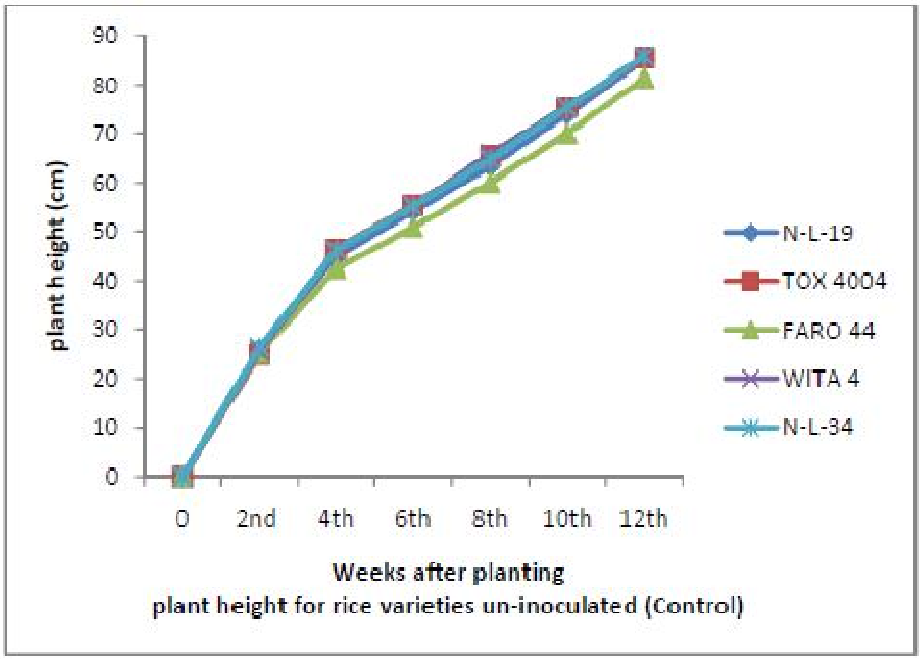


Figure 3. Response of Un-Inoculated Rice Varieties (control) with Respect to Plant Height

3.2 Responses with Respect to Number of Leaves

The numbers of leaves of the crop throughout the entire growing season are as shown in Figures 4,5 and 6.The plants inoculated with biofertilizers had the highest number of leaves. WITA 4 had the highest number of leaves amongst plant inoculated with mycorrhizae, while N-L-34 had the highest number of leaves amongst plant inoculated with rhizobium. Plants inoculated with biofertilizers significantly ($P < 0.05$) had more leaves than those without biofertilizer at 8WAP (weeks after planting) and 12 WAP. Significant ($P < 0.05$) mycorrhiza x variety interaction was observed at 12WAP during the phenological period of investigation, significant ($P < 0.05$) rhizobium x variety interaction was also observed at 12WAP. This agrees with the findings of Dar and Bali (2007) who stated that application of biofertilizers on rice under low land conditions, proved significantly beneficial in increasing number of leaves and improving leaf area index (LAI) and all yield attributing aspects.

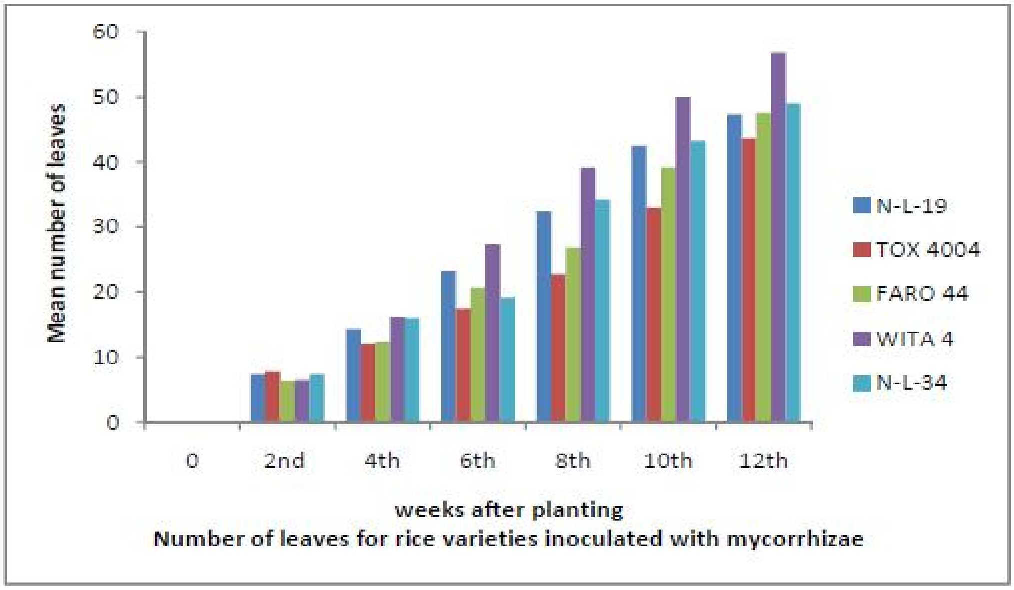


Figure 4.Response of Rice Varieties to Mycorrhizae Inoculation with Respect to Number of Leaves

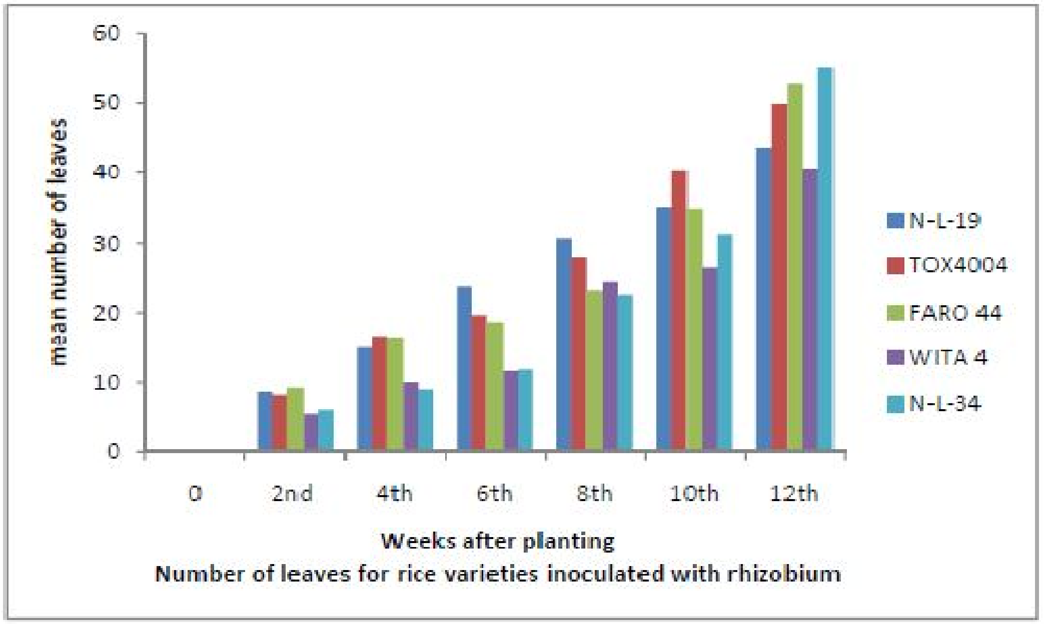
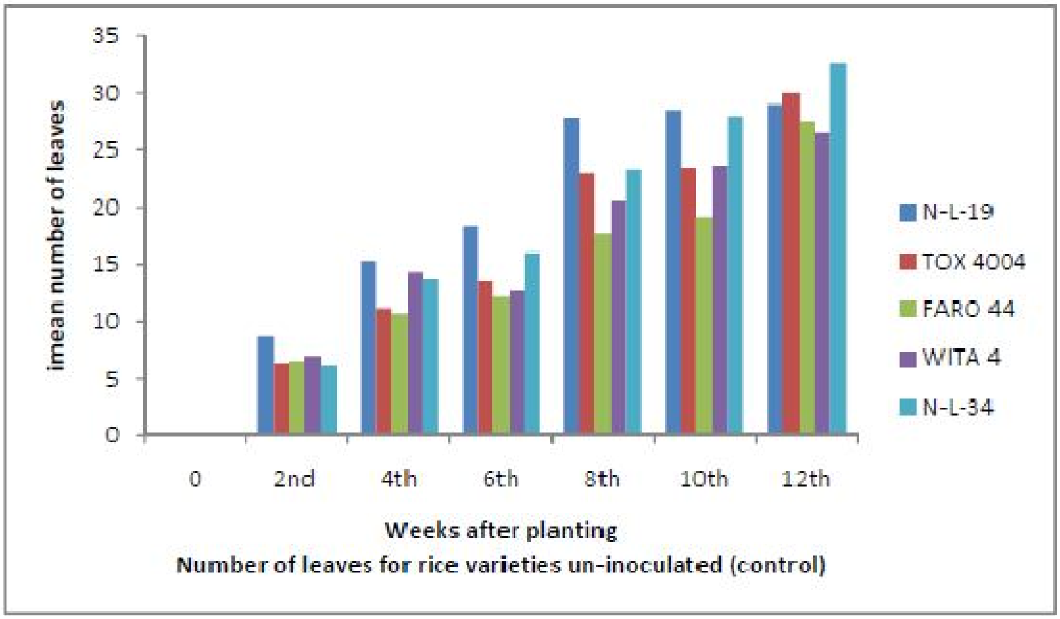


Figure 5.Response of Rice Varieties to Rhizobium Inoculation with Respect to Number of Leaves



`Figure 6.Response of un-inoculated rice varieties (control) with respect to number of leaves.

3.3 Effect of Biofertilizers on the Number of Tillers

Number of tiller was significantly (P < 0.05) increased by mycorrhizae application at 8 and 12 WAP in both seasons (figure 7, 8 and 9), while rhizobium application was not significantly higher (P < 0.05) when compared to control although it has higher value. There was no significant difference (P > 0.05) in the number of tillers among the varieties. There were no significant (P < 0.05) mycorrhizae x variety interaction observed across the varieties during the phenological period of investigation, but significant (P < 0.05) rhizobium x variety interaction was observed at 4 WAP during phenological period of investigation. WITA 4 had the highest number of tillers amongst plant inoculated with mycorrhiza, while N-L-19 had the highest n mber of tillers amongst plant inoculated with rhizobium. This agree with the findings ofMohammadinejhad-Babandeh *et al*. (2012), Vahed *et al*. (2012) and Gopalakrishnan *et al*.

(2012) who all stated that use of biofertilizers on rice plant significantly improve plant height, number of tillers and grain yields. Also, an increase of 27.11% in number of panicles per plant of rice due to biofertilizer inoculation over un-inoculated control was recorded by Peng *et al*.

(2002) who have suggested efficient nutrient and water uptake as important mechanisms. Biswas *et al*. (2000b) also reported 16% increase in number of panicles per plant of rice and suggested that the improvement was due to increased availability of nutrients and phyto hormones like indole acetic acid and ethylene. This is a clear indication that increase in the number of tillers would have resulted in increased assimilatory surface towards the interception of radiant energy thereby leading to better growth and yield.

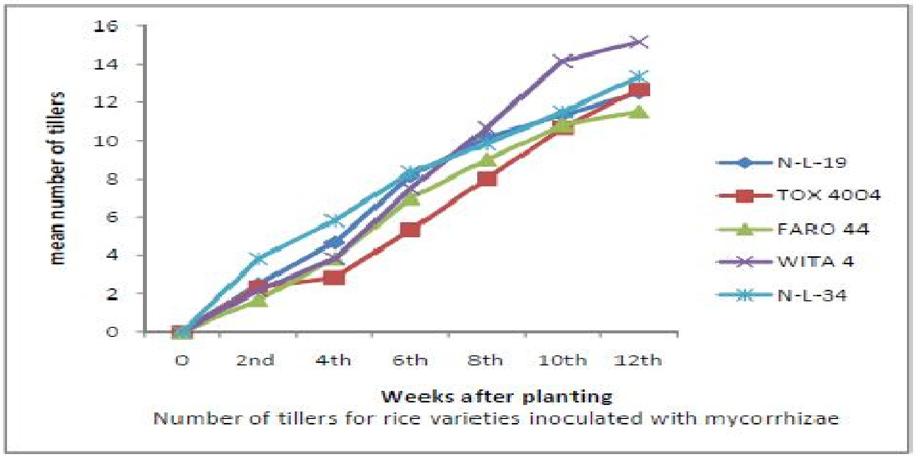


Figure 7. Response of rice Varieties to Mycorrhizae Inoculation with Respect to Number of Tillers

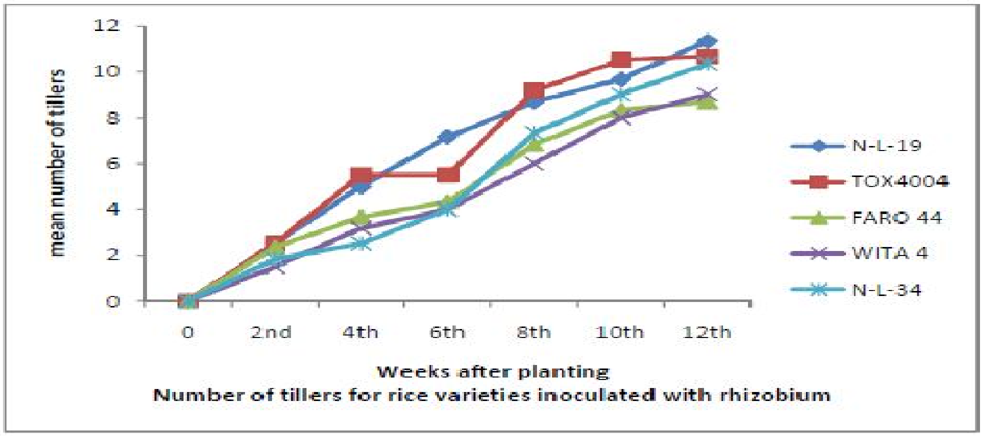


Figure 8.Response of rice Varieties to Rhizobium Inoculation with Respect to Number of Tillers

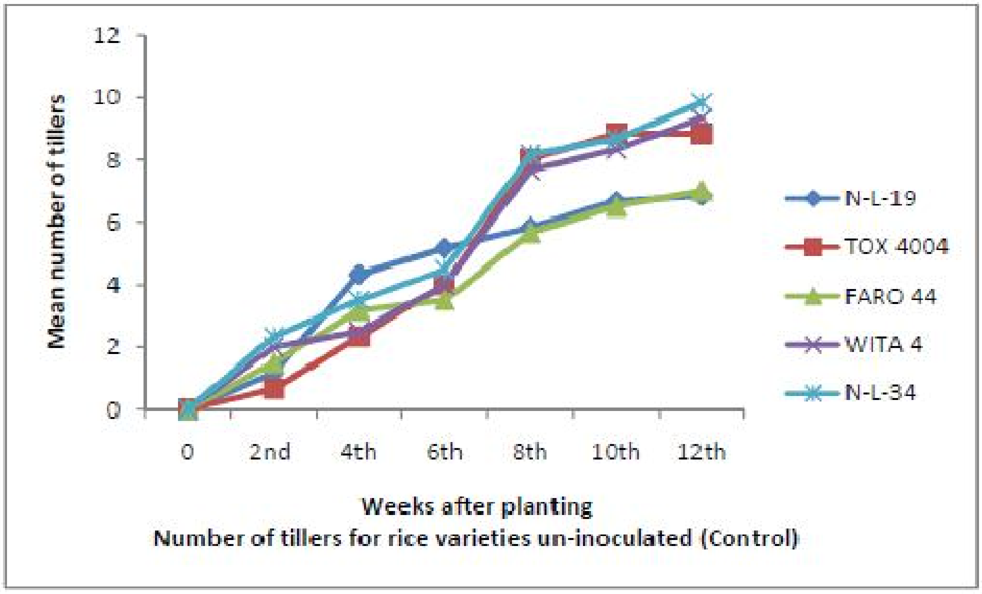


Figure 9.Response of Un-Inoculated Rice Varieties (control) with Respect to Number of Tillers

3.4 Effect of Biofertilizers on the Plant Biomass

As summarized in Table 3, mycorrhizae and rhizobium inoculation highly increased shoot and root growth. The greatest rice shoot and root development was reached in rice plants inoculated with mycorrhizae, closely followed by those inoculated with rhizobium (50 % of increase over un-inoculated control plants). Application of biofertilizers did influence shoot and root growth; length, fresh weight and number of roots. Plants inoculated did have higher significant weight to those un-inoculated (control). No varietal variability was observed across the varieties examined. There was no significant interaction ($P < 0.05$) of rhizobium x variety observed across varieties, significant interaction ($P < 0.05$) of mycorrhizae x variety observed as well. WITA 4 had the highest fresh root weight but was not significantly different from other varieties. N-L-34 had the highest shoot weight but wasn't significantly different from other varieties, N-L-34 had the highest tap root length and number of roots but not significantly different other varieties, while N-L-19 had the highest lateral root length.

Induction of longer roots with increased number of root hairs and root laterals is a growth response attributed to IAA production by inoculation of plant with biofertilizers this triggers plant growth stimulation and vigor of young seedlings which leads to more productive plants resulting in higher yields at maturity (Biswas et al., 2000) The positive response observed with inoculation of rhizobium in all growth parameters (viz. shoot length, root length, shoot fresh weight, root fresh weight of both vegetative and reproductive stages of rice plants can be attributed to its ability to fix atmospheric nitrogen. Nitrogen is usually the nutrient that limits plant production in wetlands (Buresh *et al.,*1990) and, under N-limited conditions, plant roots excrete compounds with high C/N ratios, favoring rhizospheric N2 fixation (Klein *et al.* 1990). Plant growth promotion in terms of shoot length, root length, shoot fresh weight, fresh root weight of both vegetative and reproductive stage over the control by rhizobium inoculation may be due to synergistic effects of several factors. The rice plants inoculated with mycorrhizae also showed significant beneficial effect in all the growth parameters in both vegetative and reproductive stages over the un-inoculated control plants. This is because my corrhizae improves the growth and biomass of wide host range including rice plant and is an efficient phosphate solubilizer and transporter.

AMF is able to enhance the absorption of nutrients from the soil which could have moved to the roots principally by mass flow, in addition to those, which could have diffused through the soil slowly. It is envisaged that AM fungal mycelium acts as a key component in a close cause and effect interchange of mineral nutrients, carbon compounds, and signal between the plant and rhizosphere population and soil aggregation. Its beneficial effect on host plant as a result of mycorrhizal infection is usually associated with improved plant nutrition, especially phosphorus by virtue of extensive root system that extend the functional mycelium into surrounding soil, making a greater pool of nutrients available to the plant. This leads to increased plant growth, often as high as several hundred-fold increases in biomass (Menge 1983).

Table 3. Effects of Mycorrhizae and Rhizobium Inoculation on Plant Biomass of Lowland Rice Varieties

Treatments	Fresh root weight(g)	Fresh shoot weight (g)	Taproot length (cm)	Lateral root length (cm)	No of roots
Mycorrhizae	60.41b	113.62c	15.11c	11.97c	77.72c
Rhizobium	44.95a	64.71b	13.55b	10.10b	68.51b
Control	42.50a	50.49a	10.92a	8.80a	37.12a
Varieties					
N-L-19	52.24a	83.18a	14.10a	11.72a	63.33a
N-L-34	51.52a	88.04a	14.58a	11.53a	70.50a
FARO 44	48.68a	80.61a	13.39a	10.70a	59.06a
WITA 4	52.60a	83.09a	13.68a	10.89a	65.35a
TOOX 4004	47.43a	77.75a	13.09a	10.44a	54.64a
M*V	ns	ns	ns	ns	ns
R*V	ns	ns	ns	ns	ns

For each variable, means followed by the same letter in the column are not significantly different by DMRT test
ns: no significant interaction at (P < 0.05)
*: significant interaction at (P < 0.05)

Table 4. Effects of Mycorrhizae and Rhizobium Inoculation on Growth Parameters of Lowland Rice Varieties

Treatments	Plant height (cm)			Number of tillers			Number of leaves		
	4WAP	8WAP	12WAP	4WAP	8WAP	12WAP	4WAP	8WAP	12WAP
Mycorrhizae	43.53a	57.18ab	87.64a	4.17a	9.38b	12.50b	13.98a	29.78b	43.58b
Rhizobium	46.97b	70.04b	89.59a	3.70a	7.13a	9.47a	12.93a	24.05a	40.70b
Control	46.12b	66.52a	77.22b	3.33a	7.23a	8.25a	12.93a	21.50a	27.22a
Varieties									
N-L-19	44.89b	64.56b	85.97b	4.67a	8.22a	10.22a	14.89ab	30.28a	40.00ab
N-L-34	45.63bc	65.61b	87.22b	3.94a	8.44a	11.17a	12.89ab	26.67a	45.61b
FARO 44	39.39a	58.17a	76.62a	3.56a	7.17a	9.07a	13.17ab	22.56a	42.67ab
WITA 4	45.62bc	65.56b	85.56b	3.17a	8.11a	11.17a	13.50ab	28.00a	41.33ab
TOOX 4004	44.64b	66.50b	87.94b	3.56a	8.39a	10.72a	13.28ab	24.50a	41.17ab
M*V	ns	*	ns	ns	ns	*	ns	ns	ns
R*V	ns	*	*	ns	ns	*	*	ns	ns

For each variable, means followed by the same letter in the column are not significantly different by DMRT test.
ns: no significant interaction at (P < 0.05)
*: significant interaction at (P < 0.05)

3.5 Effect of Biofertilizers on the Plant Development, Yield and Yield Components

The result presented in table 4 shows that all development and yield components were significantly ($P < 0.05$) affected by the application of biofertilizers, days-to-50% flowering and days-to-95% physiological maturity were significantly higher in plants without biofertilizer inoculation compared to inoculated plants. Also, number of grains per panicle, panicle/m^2, panicle length, number of filled spikelet, number of un-filled spikelet, grain weight and plot yield were significantly higher in inoculated plants. In fact the yield of rice in inoculated plants was 100% higher than the yield of non-inoculated plant.N-L-34 had significantly ($P < 0.05$) higher panicle length (21.58cm) than other varieties examined, while N-L-19 had significantly higher grain weight than other varieties examined. Significant interaction ($P < 0.05$) of rhizobium x variety was observed on number of grains/panicle, panicle length, filled spikelet, days to maturity, grain weight and plot yield.

Significant interaction ($P < 0.05$) of mycorrhizae x variety was also observed on panicle length, days to flowering, days to maturity, grain weight and plot yield. significant ($P > 0.05$) varietal variability was observed in days to flowering, days to maturity and grain weight in varieties examined, with FARO 44 having the lowest days to flowering and maturity, while N-L-19 higher grain weight (32.8g) and WITA 4 had the lowest grain weight (27.6g).No varietal variability was observed on plot yield across varieties examined, but N-L-19 had the highest plot yield (6090t/ha) and closely followed by FARO 44 with (5880t/ha).

The earlier positive phenotypic responses (growth and development) of lowland rice varieties to mycorrhiza and rhizobium treatments were reflected on the yield and yield components, suggesting effective partitioning of the assimilates for biofertilizer treated lowland rice. This could be ascribed to the ameliorative effects of mycorrhizae and rhizobium on rice (osmo-regulatory, osmo-protective) (Ruiz-Lozano, 2003; Ruiz-Lozano et al., 1996) and the soil nutrient availability. Increased nutrient availability in the presence of biofertilizer application was also reported by Solaiman and Hirata (1997) especially nitrogen, which is the most important nutrient requirement for rice plants, which was supplied by inoculation with rhizobium a nitrogen fixer, these results demonstrate that inoculating rice seedlings with rhizobium is beneficial to growth and yield. Comparative better performance of all varieties could be ascribed to the positive influence of applied biofertilizers on rhizosphere for better water and nutrient uptake.

The increment in the development and yield parameters in response to mycorrhizae/rhizobium inoculation endorsed the fact that biofertilizers do have one or more growth promoting mechanisms including mobilization and efficient uptake of nutrients (Biswas *et al*., 2000a, enhancement in stress resistance (Alami *et al*., 2000), solubilization of insoluble phosphates (Alikhani *et al.,* 2006), induction of systemic disease resistance (Tuzun and Kloepper, 1994), inhibition of fungal growth (Nautiyal et al.,2000), production of phytohormones (Dakora, 2003), vitamins (Dobbelaere *et al.,* 2003) and siderophores (Neiland and Leong, 1986).The demand for rice production in Nigeria is still rising because of the continuous increase in population one possible way for local growers to enhance rice production is to improve yield and tolerance to stresses by means of rhizosphere microbial manipulation.

Among the microbial groups, rhizobia and AM fungi are able to promote activities which can improve agricultural development (Barea et al., 2005)

Table 5. Response of Mycorrhizae and Rhizobium Inoculation on Development Parameters, yield Component and Yield of Lowland Rice Varieties

Treatments	Grains/panicle	Panicle/m²	Panicle length (cm)	Filled spikelet	Un-filled spikelet	Days to 50% flowering	Days to 90% maturity	1000 grain weight (g)	Plot yield (t/ha)
Mycorrhizae	785.98c	135.39c	22.56c	630.79c	155.19c	72.57c	90.27c	31.80c	6997.5c
Rhizobium	514.06b	104.68b	20.56b	459.49b	58.23b	80.90b	97.73b	32.80b	5640.0b
Control	359.12a	62.08a	16.65a	271.11a	88.04a	89.17a	105.10a	27.00a	3787.5a
Varieties									
N-L-19	652.11d	111.63a	21.17b	567.00d	85.11a	80.89c	97.22bcd	32.8d	6090.00a
N-L-34	628.83cd	103.50a	21.58c	527.94d	102.00a	77.44bc	93.78bcd	31.6cd	5502.23a
FARO 44	642.88cd	105.37a	20.23abc	550.18d	92.64a	71.33a	87.78a	32.3cd	5880.00a
WITA 4	637.28cd	102.75a	20.17abc	536.01d	101.22a	80.89c	96.44bcd	27.6b	5500.00a
TOOX 4004	578.22bcd	100.33a	19.33ab	473.62cd	104.62a	79.44c	95.00bcd	31.1cd	5490.00a
M*V	ns	ns	ns	ns	ns	*	*	*	*
R*V	*	ns	*	*	ns	ns	*	*	*

For each variable, means followed by the same letter in the column are not significantly different by DMRT test.
ns: no significant interaction at (P < 0.05)
**: significant interaction at (P < 0.05)

3. Conclusion

This study reveals that application of biofertilizers resulted in comparatively better performance (growth, development and yield) in all the lowland rice varieties investigated. Genotypic variability was observed across investigated varieties only at the growth stage, while there was no genotypic variability observed during development and yield stage. N-L-19 and FARO 44 varieties had higher yield and developmental rate in the presence of biofertilizers; this could be attributed to their constitutive response to improved chemical/nutrient composition of the soil nutrients in the presence of applied biofertilizers.

N-L-19 and FARO 44 among other investigated rice varieties responded better to the application of biofertilizer in the tropical rainforest zone of south-west Nigeria, hence it could be recommended to farmers in the zone. This could serve as a low input technology in the quest for sustainable rice production system on an economical and sustainable basis.

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