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Effects of Different Types of Fertilizers on Rice Productivity in the Irrigated Perimeter of Toula (Niger)

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Authors' contributions

This work was carried out in collaboration among all authors. Author DHH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MMA and ZAM managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

AIM: Assessment of various fertilizers type effects on rice productivity in Niger.
Study Design: The experiment was laid by using a complete randomized block design with different types of fertilizers and was replicated four times.
Place and Duration of Study: The field experiment was conducted during the dry and wet season of 2020 on the irrigated perimeter of Toula (Niger).
Methodology: The experiment was performed with four treatments in complete randomized blocks. The treatments applied are: T1=Bokashi, T2=Compost, T3=Biochar and T4=NPK-Urea. The monitored parameters were the rice plant development cycle and agronomic characteristics. Observations of the crop evolution during the experimentation were recorded at regular intervals. The significance of treatment impact was examined by the statistical test.

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Results: The results showed that bio-fertilizers had significant effects on 1000 grain weight and the length of the vegetative cycle. As for the chemical treatments, the effects were significant on most of the rice growth parameters (height, number of grains per panicle, number of tillers per rice plant) as well as on paddy and feed biomass yield. These results also showed a positive correlation between rice growth parameters and yield irrespective of the type of treatment.

Keywords: Bio-fertilizers; performance; chemical fertilizers; agronomic characteristics; Toula.

1. INTRODUCTION

Rice is the world's main food source after wheat for the overwhelming majority of the population [1]. In Niger, rice cultivation is practiced mainly in the Niger River valley, particularly in the regions of Tillabéri, Niamey and Dosso [2]. National rice production is estimated at 132,030 ton of paddy rice, of which about 65,860 ton are produced on the irrigated perimeters of the Niger River valley [3].

Rice is one of the most consumed cereals in Niger, both in rural and urban areas, with a record in Niamey estimated at 41.27 kg/inhabitant/year [4]. As a result, rice is one of the main staple crops for human consumption and plays an important role in the fight against food insecurity [5]. However, many parameters interact on rice production, including soil and climatic conditions, accessibility of agricultural inputs, and post-production rice disposal [6]. Furthermore, dry matter production after heading and its synchronization with grain filling are key approaches to increase rice yield [7]. One of the problems of agricultural production in the tropics is that soils have a low fertility status [8,9].

As a result, the use of chemical fertilizers is one of the widely accepted means for increasing the productive capacity of soils in both temperate and tropical areas of the world [10]. However, the use of inorganic fertilizers to increase agricultural production has shown its limitations in the long run. These include a gradual decrease in yield per area, increased soil acidity, loss of organic matter through leaching, and the destruction of soil microorganisms by chemical fertilizers [11].

In response to these concerns, the use of bio-fertilizers could be an alternative to ensure good crop productivity and integrated water and soil management. Organic fertilizer improves the physical and biological properties of soils, thus promoting good vegetative growth and better production [12]. In addition to its role as a nutrient reservoir for plants, organic fertilizer contributes significantly to the cation exchange capacity and acts as a buffer against undesirable pH fluctuations [13]. Thus, the use of organic fertilizers is increasingly common on both irrigated and rainfed crops, as they are less expensive and have little impact on groundwater compared to chemical fertilizers [14,15]. It is with this in mind that the present study was initiated to assess the effects of bio-fertilizers on rice growth and yield.

2. MATERIALS AND METHODS

2.1 The Study Area

This study was conducted in the irrigated area of Toula located in the urban commune of Tillaberi. The geographical location of the study area is presented in the Fig. 1 below. The study site is located between latitude 14°11'10.1" North and longitude 01°20'1.9" East and covers an area of 131.5 m² or 0.013 ha.

2.2 Experimental Design

The trial was conducted during the two seasons of the year 2020 (Dry Season and Wet Season) of production. Complete randomized block design was used with four treatments and four replications. The four treatments used are: T1 = Bokashi, T2 = Compost, T3= Biochar, and T4 = NPK (15-15-15) + Urea (46%). Mineral fertilizers were applied by spreading in the plots at a rate of 0.16 kg/m². The mineral fertilizer treatment (NPK and Urea) corresponding to the farmer's practice was considered as a positive control in comparison to biofertilizers. As for Bokashi, Compost, and Biochar treatments, the quantity applied was 2 kg/m² (dose recommended by the technical data sheet being popularized). Weeding and maintenance operations were carried out manually before each fertilizer application. The trial was conducted during the two seasons of the year (Dry Season and Wet Season) of production. The trial plan is illustrated in Fig.2 below. The sizes of the device are as follows: *2m*2m= size of a sub-plot, 1m= distance between blocks, 0.5m= distance between plots.*

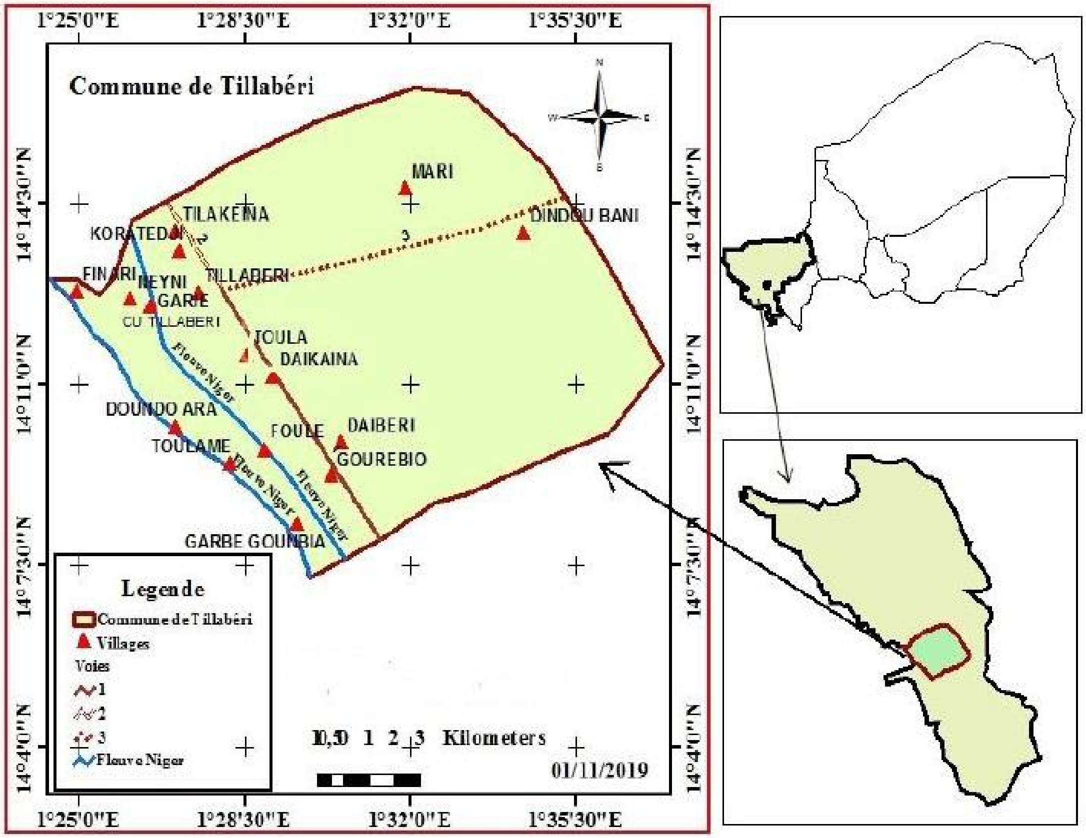

Fig. 1. Map of the study area

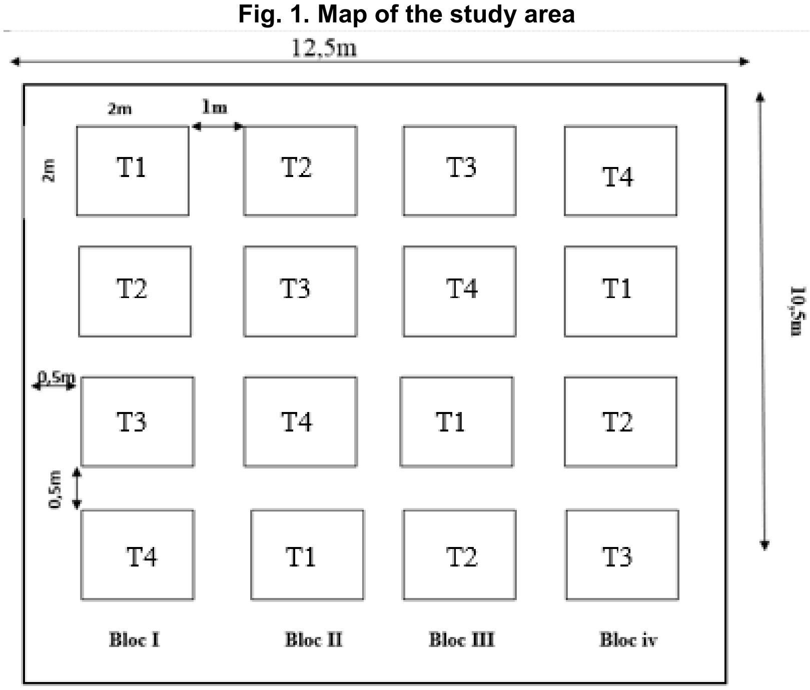

Fig. 2. Diagram of the experimental set-up

2.3 Monitoring of Crop Parameters

Regular monitoring of the vegetative stage of rice was carried out from transplanting to harvest. The parameters selected for monitoring were: duration of the vegetative cycle, number of tillers per treatments, the average height of rice plants per treatment, biomass, number of grain per panicle, 1000-grain weight, and grain yield.

2.4 Evaluation of Grain Yield

Yield evaluation was done by measuring yield at harvest through the yield square (1m*1m).

2.5 Analysis and Data Processing

The results obtained were subjected to an analysis of variance with ANOVA at the 5% level (*P*=.05). Discriminant and multivariate analyses were performed with Xlstat-2014 version 5.3 software. The Pearson correlation matrix was used to determine the correlation between the production variables and the associated factors.

3. RESULTS

3.1 Effects of Fertilizers on Rice Agronomic Parameters

3.1.1 Effects on cycle length

The effects of fertilizers on the length of the vegetative cycle were shown in Fig. 3.

The analysis of this figure shows that the length of the vegetative cycle varies slightly by a few days depending on the season and the type of treatment for the same rice variety. Indeed, we can see that the biological treatments (T1, T2 and T3) with an average of 145 days has a greater effect on the timing of the vegetative cycle than the chemical treatment (T4) (160 days on average). Moreover, for the same type of treatment, there are differences in cycle timing from one season to another (Table 1).

3.1.2 Effects on rice plant height

The effects of fertilizers on rice plant height were shown in Fig. 4 below.

The graph 4 shows that the height of the rice plants varies greatly according to the type of treatment from one season to another. Indeed, the chemical fertilizer treatment (NPK-Urea) had more effect on the height of the plants with a peak of 81 cm in the dry season against 56.08 cm in the wet season compared to the general average of 69.75 cm. The compost (T2) and bokashi (T1) treatments had plant heights ranging from 54 cm (dry season) to 71 cm (wet season) respectively, compared to a variation of 56.08 cm in the dry season to 66 cm in the wet season.

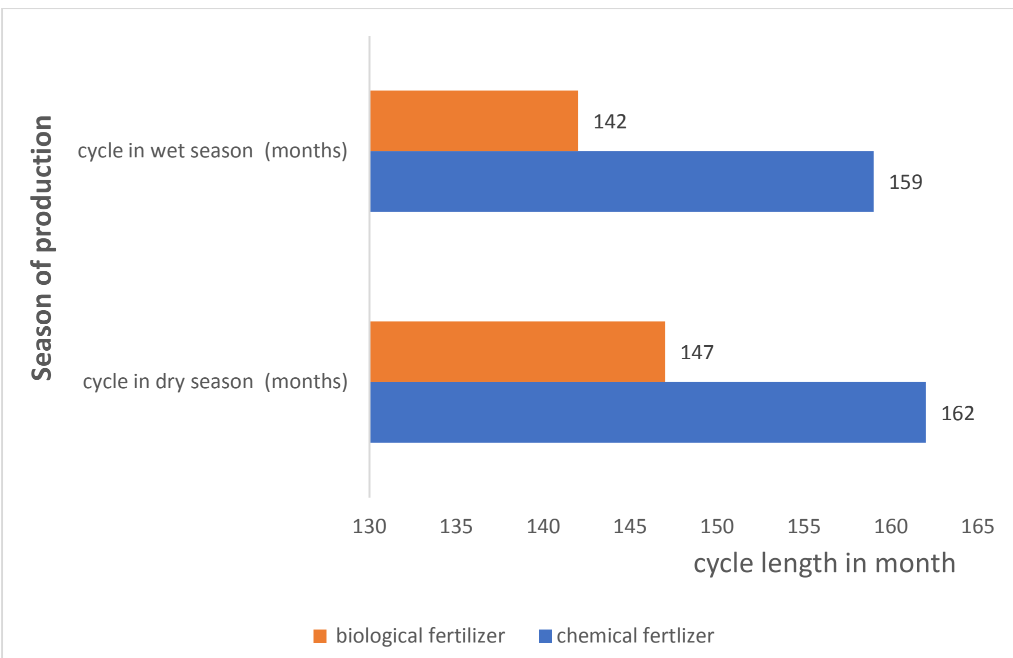

Fig. 3. Growing season length of rice (Gambiaca variety) by season and treatment type

Table 1. ***Chi-square Test (comparing rice cycle time between two season)***

	Values	df	Asymptotic significance (bilateral)
Pearson Chi-square	8,000[a]	7	0,333
Likelihood ratio	11,090	7	0,135
Number of valid observations	8		

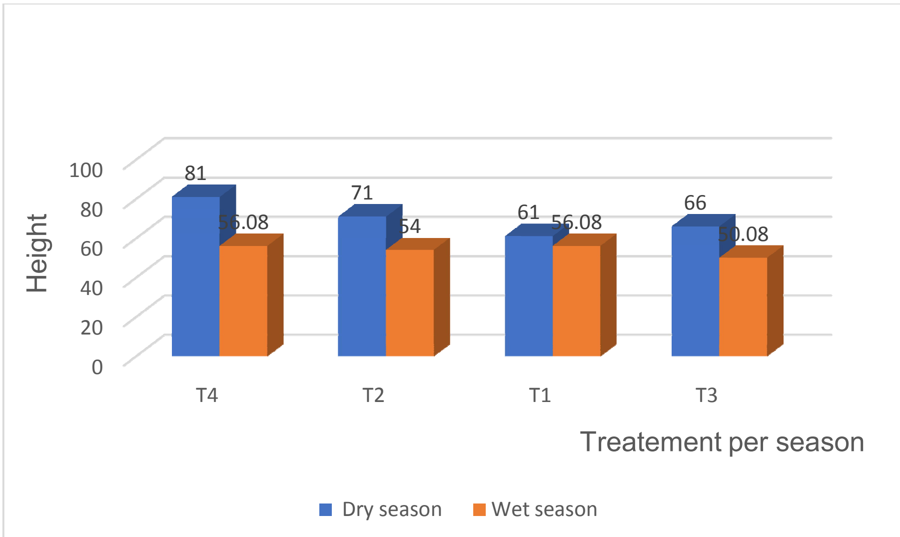

Fig. 4. Variation in plant height depending on the type of treatment and the season

The graph also shows that, there is a variation in height according to the type of treatment and the season with a significance of 0.588.

3.1.3 Effects on the degree of rice tillering

The effects of fertilizers on rice tillering were indicated in Table 2.

The Table 3 shows that the number of tillers per plant varies from one season to another according to the type of treatment. Similarly, it appears that the T4/NPK-urea has the highest number of tillers per plant in both dry and wet seasons with an average of 21.85 tillers in the dry season against 49.6 tillers in the wet season, followed respectively by the T2/compost with an average of 13.46 tillers, the T1/Bokashi with an average of 11.7 tillers in the dry season and 55.75 tillers in the wet season. The biochar treatment recorded an average of 9.47 tillers per plant in the dry season and 37 tillers per plant in the wet season.

Furthermore, the number of tillers was higher in the wet season than in the dry season, resulting in inter- and intra-seasonal variation (depending on the treatment) with a significance of 0.354 (Table 4).

3.2 Effects on Performance

3.2.1 Biomass yield

The effects of fertilizers on biomass yield were shown in Table 5 below.

The results of this table shows that the biomass yield varies according to the treatments and the season. It can be seen that the mineral fertilizer treatment (T4/NPK-urea) has the highest biomass yield in both seasons with a net production of 13.87 (t/ha) and 8.05 t/ha respectively in dry and wet season. The /compost treatment (T2) had the highest yield among the organic treatments with a net biomass yield of 6.06 t/ha in the dry season and 4.93 t/ha in the wet season, followed by the T1/bokashi treatment (5.6 t/ha) and the T3/biochar treatment with the lowest biomass yields, with net production ranging from 1.75 t/ha in the wet season to 2.18 t/ha in the dry season. The feed biomass yield for the chemical treatment (T4) is higher in the dry season than in the wet season unlike biological treatments (T2/compost, T1/bokashi, and T3/biochar).

Table 2. One-factor ANOVA (plant height)

	df	Frequency	Significance
between Group	5	0,939	0,588
Within Groups	2		
Total	7		

Table 3. Variation of the number of tillers according to the type of treatment and the season

Campaign	Treatment	Number of tillers per plant
Dry Season (DS)	NPK-Urea	21,85
	Compost	13,46
	Bokashi	11,7
	Biochar	9,47
Wet season (WS)	NPK-Urea	49,6
	Compost	45,75
	Bokashi	55,75
	Biochar	37

Table 4. One factor Anova (number of tillers per plant)

	df	Frequency	Significance
between Group	5	2,092	0,354
Within Groups	2		
Total	7		

Table 5. Biomass yield per season and per treatment

Campaign	Treatment	fresh Biomass (t/ha)	Dry Biomass (t/ha)
	NPK-Urea	22	8,125
Dry Season (DS)	Compost	10,125	4,0625
	Bokashi	8,9375	4
	Biochar	5,9375	3,375
	NPK - Urea	15,5	7,450
Wet Season (S)	Compost	9,68	4,75
	Bokashi	11,56	5,96
	Biochar	5,62	3,87

3.2.2 Number of grain per panicle

The effects of fertilizers on number of grain per panicle were shown inTable 5 below.

The table shows that the number of grain per panicle varies slightly per treatment. However, the NPK-urea treatment had the highest number of grains per panicle with an average of 142 grains per panicle in the dry season, followed by the bokashi treatment (140 grains per panicle), the compost treatment (128 grains per panicle), and the biochar treatment with 112 grains per panicle respectively. Table 7 shows the results of the variance analysis between the number of grainss per panicle and the 1000 grain weight.

Analysis of the variance results indicates that the first between groups sum of squares is 595.375 compared to 420.5 for the sum of squares within groups. The difference between the two is therefore not significant (df=7, *P*=0.915, and F=0.236). Therefore, the number of grains per panicle does not influence the grain weight. However, the value of the mean of squares shows that the difference in the number of grains per panicle between the treatments is significant at the 0.05 threshold with a mean of squares of 99.229.

3.2.3 Rice grain yield

The Fig. 5 below presents the effect of fertilizers on rice grain yields.

The graph 5 shows a variation in grain yield between seasons by treatment. Moreover, the NPK-urea treatment has the highest yield in both dry season (5.625 t/ha) and wet season (4.68 t/ha), followed by compost and bokashi respectively. The biochar treatment had the lowest yield with an average of 2.25 t/ha in the dry season and 3.75 t/ha in the wet season. The results also shown that the paddy yield during the wet season is almost double that of the dry season for the compost and bokashi treatments. For the biochar treatment, there was a slight increase in wet season yield (3.75 t/ha) compared to the dry season yield (2.25 t/ha). The NPK-urea treatment showed a drop in production in the wet season (4.64 t/ha) compared to that obtained in dry season (5.625 t/ha). The variance analysis results between paddy yield and grain weight indicate that the between group sum of squares value is 470.865, while the within group value is 546.812 (Table 7). The difference between the two groups is therefore not significant (df = 7, p = 0.961, f= 0.144).

Table 6. Variation in the number of grain per panicle

Season	Treatment	Number of grain per panicle
Dry season (DS)	NPK-Urea	142
	Compost	128
	Bokashi	140
	Biochar	112
Wet Season (WS)	NPK-Urea	146
	Compost	132
	Bokashi	136
	Biochar	117
General average		**131,62**

Table 7. One-factor ANOVA (number of grain per panicle)

	Sum of squares	df	Average of squares	Frequency	Significance
Between groups	595,375	6	99,229	0,236	0,915
within groups	420,500	1	420,500		
Total	1015,875	7			

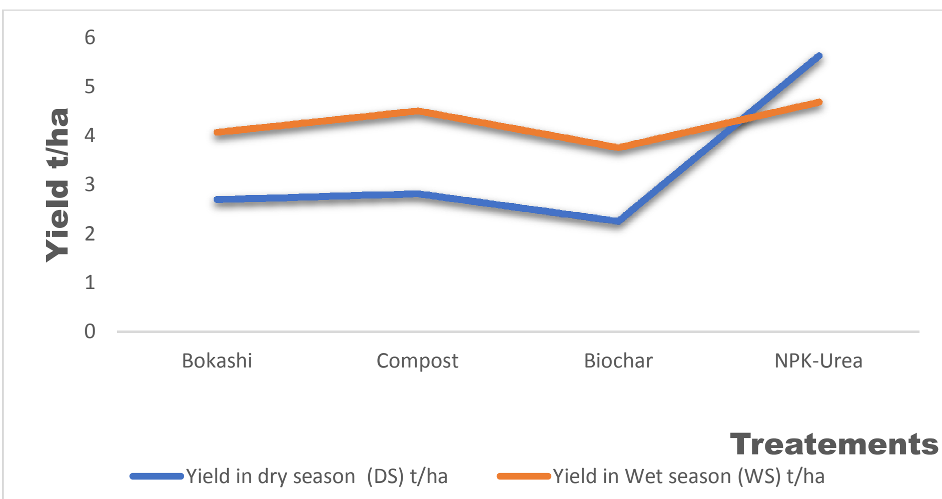

Fig. 5. variation in paddy yield

Table 8. One –factor Anova (paddy yield)

	Sum of squares	df	Average of squares	Frequency	Significance
Between groups	470,865	6	78,477	0,144	0,961
within-groups	546,812	1	546,812		
Total	1017,677	7			

However, the variation in grain yield shows a significant difference between the different treatments at the 5% threshold with a mean square of 78.477.

3.2.4 1000 grain Weight

The Fig. 6 presents the effects of fertilizers on 1000 grain Weight.

The Fig. 6 shows that, on the one hand the variation of the grain weight is more important from one campaign to another than between treatments and on the other hand, within the same campaign, the variation is more important between the various treatments. Thus, the bokashi treatment has the highest 1000-grain weight in the wet season (44.00 g), while in the dry season the compost treatment has the highest weight (22.75 g). Furthermore, this graph 6 shows that the variation in grain weight is disproportionately high in the wet season contrary to the dry season where grain weight varies slightly between treatments. This means that grain weight is higher in the wet season than in dry season and that in both seasons (dry and wet), the organic treatments (T1/bokashi, T2/compost, and T3/biochar) influence grain weight more than the chemical treatment (T4/NPK-Urea). The variance analysis results of 1000 grain weight shows that there is a difference between group and within group values of the sum of squares (527.208, and 108.667). The difference between the two groups is therefore significant (df=7, P=0.374, and F=1.94). The weight of 1000 grains, therefore, varies significantly by treatments and season.

3.3 Correlation between Variables

The table 9 below presents Pearson correlation matrix between rice growth and yield parameters.

The results of this matrix shows that there is a positive correlation between plant height and number of tillers per plant (0.48), between plant height and above-ground biomass (0.57), between height and number of grain per panicle, and between plant height and paddy yield. The number of tillers per rice plant, number of grain per panicle, and paddy yield are positively correlated with all other variables. Similarly, 1000-seed weight, number of tillers per plant, number of seeds per panicle and paddy yield were positively correlated. For fee biomass, it is positively correlated with all the other four variables (height, number of tillers, number of grain per panicle, and paddy yield). However, the number of tillers per rice plant and the number of seeds per panicle showed the best correlation ($r \geq 0.7$) at the 5% significance level.

4. DISCUSSION

4.1 Effects on Rice Growth Parameters (Height, Tillering)

The results of the field experiment showed that the application of biofertilizers on rice plants had significant effects on the weight of filled grain, the duration of the vegetative cycle and the degree of tillering while chemical fertilizer had more effects on the height of plants, paddy yield, feed biomass and number of grains per panicle.

The plant height variation per treatment (Fig. 2) shows that the NPK-urea treatment had the highest height numerically with an average of 81 cm in the dry season and 56.08 cm in the wet season, followed by the T2, T1, and T3 treatments respectively. Furthermore, the results of the analysis of variance showed that the difference in height between treatments was significant. Similarly, the analysis showed that plant height was correlated with forage biomass. These results are in agreement with those of FAO [16] who find that agronomic use efficiency, and internal use efficiency and apparent recovery efficiency have been frequently used to characterize the effects of nutrients on improving plant growth parameters. Similar results reporting variation in plant height with treatment type were reported [17,18]. Indeed, these authors asserted that the increase in plant growth parameters would result from effective use of fertilizers applied at reasonable rates and that a combination of inorganic fertilizers with organic manure, biofertilizers, and bio-agents significantly increases growth parameters. The leaf area index provides information on growth dynamics and is strongly correlated with crop biomass and productivity [19].

4.2 Effect on Biomass and Grain Yield (Number of Grain/Panicle, 1000 Grain Weight, Dry Matter)

The yield results showed that the NPK-urea (T4) treatment had the highest yield (Fig. 6) over the two seasons, followed by the compost, bokashi, and biochar treatments, respectively. In this study, it was found that paddy yield was strongly correlated with the number of tillers per plant, the number of grain per panicle, and the weight of

1000 seeds, respectively. This suggests that yield is largely determined by these parameters. These results corroborate those of [20,21], who states that there is a positive correlation between grain yield, harvest index, and biological yield. Besides, the improvement in rice yield potential could come from an increase in dry matter production [22]. However, a weak correlation was noted between paddy yield and feed biomass (Table 8). This suggests that a large amount of biomass does not always result in a good paddy yield. Indeed, excessive fertilizer use at the time of bolting could lead to the production of infertile panicles and a lot of fodder biomass. Thus, the yield of feed biomass recorded significant values in the different treatments. The chemical fertilizer treatment recorded a biomass yield of 13.00 t/ha in the dry season and 15.5 t/ha of fodder in the wet season, followed by the bokashi (11.56 t/ha), compost (9.68 t/ha), and biochar (5.62 t/ha) treatments respectively. Also, the results showed a variation in biomass yield from one season to another for the same treatments. This could be a result of climatic conditions (hygrometry, rainfall) and the adaptability of the rice variety to the season. These results corroborate those of several authors who noted a variation in yield parameters (feed biomass, 1000 grain weight, and paddy yield) depending on the rice variety used, the growing conditions, and the types of fertilizers [23,24,25]. The difference in 1000 grain of paddy rice weight observed between the different treatments compared to the average (30.77g) could be due to the degree of filling of rice hulls depending on the treatments. On the other hand, growth traits are functions of increasing dry weight or dry matter per unit time. The assimilated organic matter is a source of nutrition for various plant organs and contributes to the final yield. Growth and yield parameters are closely related and interdependent [26,27]. Therefore, the type of fertilizer and pesticide applied to rice are internal variables positively related to rice production.

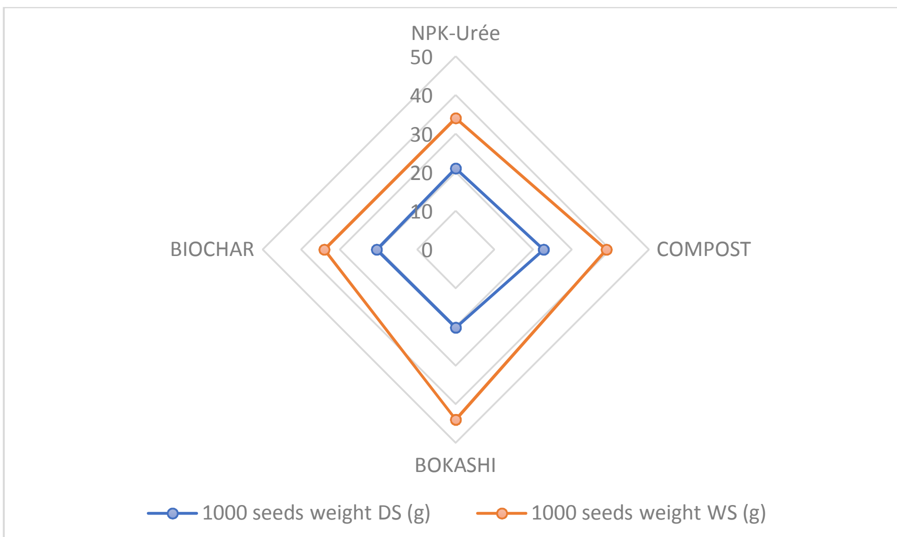

Fig. 6. variation in seed weight of paddy rice as a function of treatment

Table 9. Pearson correlation matrix (n) between variables

Variables	Height	Number of Tillers	Biomass (kg)	Number of grain/panicle	1000 grain weight	Grain yield (kg)
Height	**1**	0,4894	0,5721	0,5380*	-0,4423	0,0509
Number of tillers	0,4894	**1**	0,3966	0,7146*	0,4072	0,5831*
Biomass (kg)	0,5721*	0,3966	**1**	0,4645	-0,2365	0,2585
Grain/panicle	0,5380*	0,7146*	0,4645	**1**	0,2097	0,5321*
1000 grain Weight	-0,4423	0,4072	-0,2365	0,2097	**1**	0,6541*
grain yield (kg)	0,0509	0,5831*	0,2585	0,5321*	0,6541*	**1**

** Correlation significance level between the variables*

4.3 Correlation between Rice Growth and Yield Parameters

The correlation of the different variables (parameters) showed that the plant height of rice plants was positively correlated with the number of grain per panicle, feed biomass, paddy yield, and the number of tillers per plant, respectively (Table 8). As for the weight of 1000 seeds of paddy rice, it is positively correlated with the number of grain per panicle, the number of tillers per rice plant and the paddy yield. However, the number of tillers per rice plant and the number of grains per panicle showed the best correlation with a value of 0.71 at the 5% threshold. Similar results were reported by [19], who found that there was no correlation between the length of the vegetative cycle, yield, and yield components. However, agronomic characteristics and yield components are interrelated.

The results in Table 8 show that there is a correlation within variables and between the variables and the factors. These results are similar to those of [5], who states that the labour factor has a positive effect on rice production. Indeed, the growth, development, and yield of crops, as well as the factors that affect them, occupy a position of primary importance in crop production [28]. Moreover, growth and yield are physiologically correlated and depend mainly on the expansion of planting areas, the increase in the input of material factors, and the gradual growth of productivity [29]. To this end, biofertilizers can play a key role in the development of an integrated management system for crop productivity and sustainability with low environmental impact [30,31]. The application of biofertilizers in addition to their positive effects on grain weight, cycle length, number of fertile tillers, effectively contributes to the improvement of soil fertility, protection of biological diversity, mineral uptake, vegetative growth, and plant quality [32]. According to Richert et al. [33], the use of organic fertilizers (recycled urine) allows for an improvement in agronomic parameters of rice and soil fertility with less health risk for producers and consumers.

5. CONCLUSION

The study found that, bio-fertilizers (compost, bokashi, and biochar) had significant effects on the rice agronomic characteristics, including the 1000 grains weight and the length of rice development cycle. As for the chemical fertilizer, it showed high productivity on many growths and yield parameters. Furthermore, a positive correlation was observed between rice growth and yield characteristics. However, the number of seeds per panicle and the number of tillers per rice plant are weakly correlated with the other variables. These results show that the use of organic fertilizers is a sustainable option for improving rice production in Niger. The large-scale adoption of this fertilization technique requires technical support to move towards an ecological transition in rice cultivation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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