Effect of good agricultural practices on Fonio (*Digitaria exilis* Stapf) across agro-ecological zones of Mali

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1. ABSTRACT

Digitaria exilis **Stapf is the most cultivated type of Fonio in Mali, but its culture is still practiced in the traditional way on pour soil reserved to women with very low yield and low income. Many results and information on agricultural practices are used by farmers to increase production of major crops like rice, maize, sorghum etc. while plants of African origin such as Fonio have not been the subject of much research however, these species show-interesting characteristics in food security, in balancing the local biodiversity and adaptation to climatic change. Previous studies have shown that the main agronomic problem of Fonio in Mali was its low yield. Therefore, this study was carried out at three farmer's fields of three climatic areas with an aim to propose to farmers a good agricultural practice of fonio fertilization. The specific objectives were to assess effect of NPK 15-15-15 and Farm Yard manure on growth and yield of Fonio. The design was the split split plot. The measured characters were plant height, number of tillers, number of leaves, number of roots, length of roots, fonio fresh and dry matter weight and grain yield of fonio. This study showed that: except for length of roots NPK, significantly influenced all the studied growth and yield characters of Fonio. The maximum growth and grain yield were obtained with NPK at 100 kg/ha which was at par with NPK at 150 kg/ha, but significantly higher than NPK at 50 kg/ha and the control (0kg/ha). Effect of manure was inconsistent on growth and grain yield of fonio but in most cases, increase in manure led to proportional increase in Fonio yield up to 10t/ha. Compared to the national average Yield (less than 600kg/ha), the results of this study recommend application of NPK at 100kg/ha followed by weeding which gave the maximum yield 1969 kg/ha in Sudanian zone, 1469 kg/ha Sudano - sahelian zone and 1185 kg/ha in semi-arid zone of Mali. Incorporation by ploughing of Farm Yard Manure at 10t/ha gave an average yield of 1509 kg/ha in the three study areas.**

RESUME

Digitaria exilis **Stapf est le type de fonio le plus cultivé au Mali mais sa culture est toujours pratiquée traditionnellement sur des sols pauvres réservés aux femmes avec de très faible rendement et de faibles revenues. Beaucoup de résultats de recherche agronomiques sont disponibles pour les céréales considérées comme majeures comme le riz, le maïs, le sorgho et le mil ce qui permet aux producteurs d'avoir de bons rendements avec ces cultures alors**

que des plantes d'origine africaines telles que le fonio n'ont pas fait l'objet de beaucoup d'investigations agronomiques en dépit de leur importance dans la sécurité alimentaire, l'équilibre de la biodiversité locale et sa résilience au réchauffement climatique. Cette étude fait suite à une recommandation d'un diagnostic auprès des producteurs dans le but de les proposer de bonnes pratiques culturales de fertilisation permettant d'accroitre le rendement du fonio. Elle a été réalisée en milieu paysan de trois zones agro-climatiques du Mali. L'objectif spécifique était d'évaluer l'effet du fumier de petits ruminants et du complexe céréale NPK 15-15-15 sur la croissance et le rendement de Fonio. Le dispositif était le split plot. Les caractères mesurés étaient la hauteur de la plante, le nombre de talles, le nombre de feuilles, le nombre de racines, la longueur des racines, le poids de matière fraîche et sèche de fonio le rendement grain de fonio. Les résultats ont montré que mise à part la longueur des racines, NPK influence de manière significative tous les paramètres de croissance et de rendement étudiés. La croissance maximale et le rendement grain maximum ont été obtenus avec NPK à 100 kg/ha qui était similaire au rendement de NPK à 150 kg/ha, mais sensiblement supérieur à NPK à 50 kg/ha et au témoin (0kg/ha). L'effet du fumier était contradictoire sur la croissance et le rendement grain de fonio mais dans la plupart des cas, l'augmentation de fumier conduisait à l'augmentation proportionnelle du rendement de Fonio jusqu'à 10t/ha. Comparativement au rendement moyen national (moins de 600kg/ha), les résultats de l'étude recommandent l'application de NPK à 100kg/ha au moment du désherbage qui a donné les meilleurs rendements 1969 kg/ha, 1469 kg/ha et 1185 kg/ha respectivement dans les zones Soudanienne, Soudano – sahélienne et semi-aride du Mali. L'incorporation au sol de fumure organique à 10t/ha par le labour permet d'avoir un rendement moyen de 1509 kg/ha dans les trois zones d'étude.

2. INTRODUCTION:

Fonio (*Digitaria exilis* Stapf) is regarded as the oldest indigenous cereal in West Africa. According to Cruz et al (2016), the first references to Fonio as a food are reported from the mid-14th Century by the Berber explorer Ibn Battuta in his "Voyage to Sudan" (modern-day Mali). Nowadays, Fonio production area is still conformed zones reported by Portères (1946) and Cruz (2011) produced in about sixteen African countries including fourteen countries of West Africa from Senegal to Nigeria and two countries of Central Africa (Cameroon and Chad). Africans use Fonio in many recipes Fonio is rich in essential amino acids such as methionine (2 times and 3 times more than millet and rice, respectively). It is light, easy to digest and studies on the nutritional factors carried out at CIRAD and by KONE (2000), Sylla (2016) have given some characteristics that partially explain the advantage of the consumption of Fonio recommended as nutritive and medicines food, especially for diabetic people, for people suffering from obesity and women after delivery. In urban Mali, Fonio is considered as a luxury product. It consumption is more frequent during religious parties and during other ceremonies. SWOT Analysis of Fonio production system by Konaté (2018) confirms that low yield is an important problem limiting crop extension. Comparative yield of one ha Fonio is proximate ½ ha millet, 1/3 sorghum, 1/4 ha maize, 1/5 ha rice. Compared to total surface area for five regions of Mali (3752702 ha), the rate of surfaces by cereal in those five Regions of Mali 2010 are: millet 39%, sorghum 28%, rice 19% maize 12%, Fonio 2% . Compared to total production (5411478 t), production by cereal in five Regions of Mali 2010 are: millet 24%, sorghum 25%, rice 29% maize 21%, Fonio 1% (EAC CPS/SDR 2001-2010). Fonio does not profit from much attention on behalf of agronomic research in Mali the main agronomic problem is its low yield (less than 600kg/ha), is it culture still practiced

by the traditional way the cause? Is the poor performance of Fonio largely due to poor farming practices, such as lack of information on the correct dose of fertilizer, optimum seed rate and other extension services? In view of these constraints and challenges, this study was conceived with the general aim to evaluate the effect of good cultural practices on growth and yield of Fonio across agro- ecological zones of Mali and the specific objectives were to assess the effect of Farm Yard manure and NPK fertilizer on growth and yield of Fonio.

3. MATERIALS AND METHODS

The investigation was carried out at three farmer's fields of three climatic areas in Mali. Kolondiéba in Sudanian-type climate with average rainfall of 1200 mm in 72 rainy days , Sanankoroba with Sudano –Sahelian type of climate and average rainfall of 900 mm in 50 rainy days and Baroueli in semi-arid area with average rainfall of 600 mm in 44 days. The experimental design was a split-split plot with three factors including three seed rates three doses of farm yard manure(0, 5and 10t/ha) and four levels of NPK 15- 15- 15 (0, 50, 100 and 150g/ha). Soil sample of the three locations and manure sample analysis was done at Bayero University Kano soil science laboratory. A monthly follow-up was been carried out starting from germination date, on five selected plants randomly selected in each treatment. The measurement were relate to: Height of plant (HP), Number of tiller per plant (NTP), Number of leaf per plant, Average length of roots (LR), Number of roots per plant, plant fresh and dry matter weight, total yield by treatment and Weight of thousand seeds. The Genstat software was used for the analysis of variance. Significant difference means were separated at 5% level of probability using Duncan Multiple Range Test (DMRT 1955).

4. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Chemical analysis of Farm Yard manure used in both cropping season: Table 1 showed that manure use in first year was superior in nutrient (nitrogen and phosphorus) but inferior in potassium compared to the one used in second year.

Table 1: Chemical composition of Farm Yard Manure used in both years

Years	First year	Second year
Chemical composition		
N (%)	3.85	2.45
P (mg/kg)	45.59	39.45
K (mg/kg)	8.55	9.08

4.1.2. Mechanical composition of soil sample (Table 2)**:** In Baroueli, the soil contained very high proportion of sand (83% and 79%) but low in clay content (14%) and very low in silt (3% and 7%). At Sanankoroba, the soil contained an important quantity of sand (49 % and 61%), a significant quantity of silt (21% and 31%) and a little clay 16% and 18%. At Kolondiéba the composition of the soil was dominated by sand (61% and 67%), a significant quantity of clay (18% and 20%), and silt (13% and 21%). In both years, Nitrogen, phosphorus, potassium, organic carbon, organic matter and effective cat ion exchange capacity (ECEC) were low in the soil. However, in all the three locations the soil was acidic in nature (5.12 – 4.32).

Table 2: Results of Laboratory Analysis of Soils of the Study Areas at Depth 0-20 cm before Cropping in Both Years

Years	First year			Second year		
Locations	KBA	SANA	BRLI	KBA	SNABA	BRLI
Properties						
Mechanical composition						
% Clay	20	18	14	18	16	14
% Silt	13	21	3	21	35	7
% Sand	67	61	83	61	49	79
TEXTURE	Sandy Loam	Sandy Loam	Loamy Sand	Sandy Loam	Sandy Loam	Loamy Sand
physical composition						
pH (Water)	5.3	5.28	5.48	4.57	5.12	4.89
pH ($CaCl_2$)	4.78	4.96	5.12	4.14	4.85	4.32
EC (dS/m)	0.03.	0.038	0.015	0.065	0.024	0.062
% O/C	0.120	0.200	0.200	0.299	0.359	0.299
% O/M	0.2.06	0.344	0.344	0.516	0.619	0.516
% T/N	0.035	0.105	0.07	0.07	0.105	0.035
AVP (mg/kg)	13.929	17.143	15.357	16.250	12.143	15.893
Ex.Acidity (mol/kg)	0.167	0.334	0.167	0.668	0.334	0.501
Ca (mol/kg)	3.097	2.963	3.231	2.670	2.493	2.581
Mg (mol/kg)	0.969	0.732	0.899	0.756	0.833	0.684
Na (mol/kg)	0.834	0.922	0.672	0.747	0.966	0.878
K (mol/kg)	1.239	1.111	0.464	1.154	1.197	1.026
ECEC (mol/kg)	6.356	6.111	5.483	6.044	5.873	5.720

Available phosphorus (Avp), potential hydrogen (pH), Electric Conductibility (EC), Total nitrogen (TN), Effective Cation Exchange Capacity (ECEC), Organic Carbon (O/C), Organic Matter (OM) KBA: Kolondiéba; SNABA: Sanankoroba; BRLI: Baroueli

4.1.3 Height of Fonio as influenced by, manure and NPK 15-15-15 (Table 3)**:** Manure was observed to increase plant height up to 10t/ha in all the three locations but manure was significant on Fonio height only in two trials over six (at Sanankoroba in 2018 and Baroueli in 2019). Application of manure at 10t/ha gave the maximum plant height and the minimum plant height was given by the control (0t/ha). NPK (15-15-15) significantly affected height of Fonio at the three locations. In most of the cases effect of NPK at 100kg/ha was similar to NPK at 150kg/ha but significantly higher than those of NPK at 50kg/ha also significantly Higher than the control.

Table 3: Mean plan height (cm) of Fonio as affected by manure and NPK fertilizer in 2018 and 2019

Rainy season	2018			2019		
Treatments	**KBA**	**SNABA**	**BRLI**	**KBA**	**SNABA**	**BRLI**
Manure (M)						
0	66.91	64.24c	76.17	66.26	65.56	56.62**c**
5	76.47	67.82b	78.75	69.20	68.53	61.41**b**
10	79.38	71.98a	80.33	70.73	69.62	66.09**a**
NPK (F)						
0	70.36**b**	64.76**b**	75.56**c**	63.50**d**	63.27**d**	58.91**c**
50	73.81**a**	67.99**a**	78.79**b**	68.09**c**	67.07**c**	61.07**b**
100	75.74**a**	69.76**a**	78.95**b**	70.04**b**	68.78**b**	62.83**a**
150	77.09**a**	69.55**a**	80.38**a**	73.29**a**	72.49**a**	62.68**a**
Interactions						
M*F	ns	ns	ns	ns	ns	ns

Means followed by the same letters among treatments are not
Significantly different at 5% level of probability using DMRT KBA: Kolondiéba; SNABA: Sanankoroba; BRLI: Baroueli

4.1.4 Number of tillers per plant (NTP) (table 4): In 2018, application of manure was significant across the three locations. Increasing manure was observed to increase number of tillers per plant up to 10 t/ha. In 2019 manure did not significantly affect number of tillers, but effect of manure 10t/ha was higher than manure 5t/ha, also higher than the control at Kolondiéba and Baroueli will, increasing number of tillers up to 5t/ha at Sanankoroba, Application of NPK fertilizer significantly affected number of tillers per plant across the three locations in both years. In 2018, NPK at 100 kg/ha and 150 kg/ha were similar but significantly higher than 50kg/ha which was also higher than the control. The trend was the same in 2019 at Sanankoroba but at Kolondiéba and Baroueli there was a linear increase of number of tillers with increase in NPK dosage. All the interactions had no effect on number of tillers.

Table 4: Number of tillers per plant as affected by Manure NPK and their interaction in 2018 and 2019

	2018			2019		
Treatments	**KBA**	**SNABA**	**BRLI**	**KBA**	**SNABA**	**BRLI**
Manure (t/ha)						
0	3.117**c**	3.433**c**	3.311**b**	2.733	3.361	2.806
5	3.428**b**	3.911**b**	3.550**a**	3.000	3.389	2.961
10	3.656**a**	4.428**a**	3.700**a**	3.144	2.978	3.006
s. e.d	0.1501	0.0769	0.1070	0.1665	0.4879	0.1894
NPK (kg/ha)						
0	3.148	3.407**c**	3.074**c**	2.593**d**	2.585**c**	2.526**d**
50	3.407	3.822**b**	3.422**b**	2.807**c**	3.067**b**	2.815**c**
100	3.511	4.215**a**	3.696**a**	3.119**b**	3.600**a**	3.044**b**
150	3.533	4.252**a**	3.889**a**	3.319**a**	3.719**a**	3.311**a**
s. e.d	0.1575	0.1389	0.1289	0.1605	0.3246	0.1876
Interactions						
M*F	ns	ns	ns	ns	ns	ns

Means followed by the same letters among treatments are not
Significantly different at 5% level of probability using DMRT

4.1.5 Number of roots per plant (fig1; 2) **:** Manure was significant at Sanankoroba in 2018(fig 3) and 2019 , at Kolondiéba and Baroueli in most cases the higher plant numbers of roots was obtained with manure at 10t/ha, while the lowest number was observed with the control. NPK15-15-15 was observed to increase fonio number of roots,

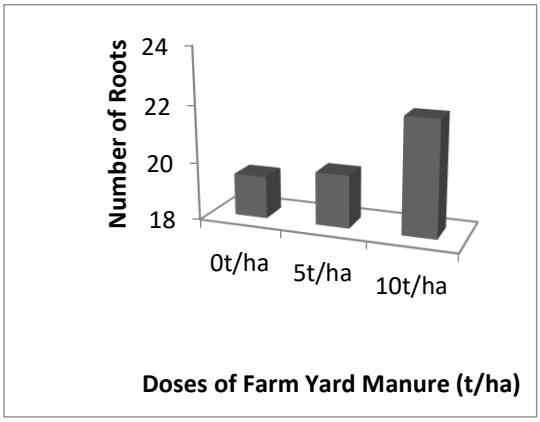

Fig 1: Number of Roots per plant as affected by Manure in 2018 at Sanankoroba

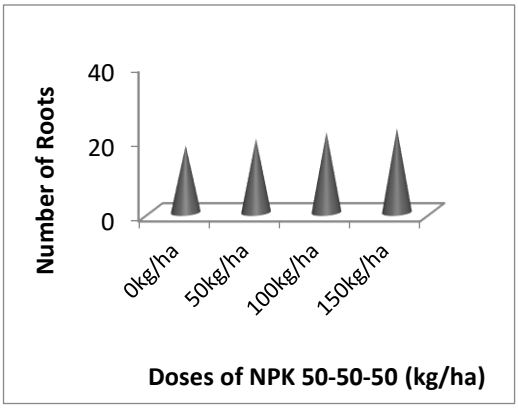

Fig 2: Number of Roots per plant as affected by NPK 15-15-15 in 2018 at Sanankoroba

4.1.6 Length of roots as affected by manure and NPK 15-15-15 (figures 3; 4): No significance of manure was observed in five trials over six but only at Kolondiéba the longest length of roots was obtained with the control while the shortest was with manure at 10t/ha. NPK 15-15-15 did not influenced Fonio length of roots only at Kolondiéba the longest length of roots was with the control, while, the length of roots of the other doses of NPK were similar.

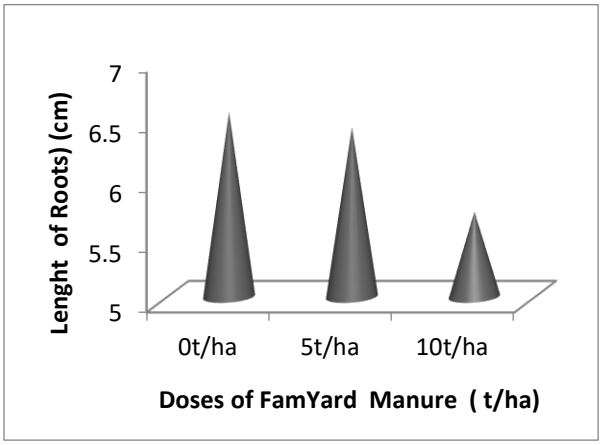

Figure 3: Length of roots (cm) per plant of Fonio as affected by Seed Rate at Kolondiéba in 2018 rainy season

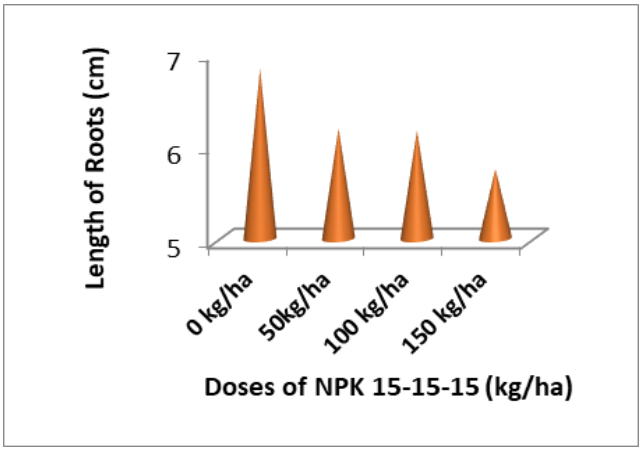

Figure 4: Length of roots (cm) per plant of Fonio as affected by NPK 50-50-50 at Kolondiéba in 2018 rainy season

4.1.7 Plant Fresh weight and dry matter weight: Manure significantly influenced fresh and dry weight of Fonio at Sanankoroba and Baroueli in 2018 rainy season. Increasing manure was observed to increase fresh weight and dry weight of Fonio in both locations up to 10t/ha **(Fig 5)**, but manure did not affect significantly Fonio fresh and dry matter weight at Kolondiéba in 2018 and 2019. Application of NPK fertilizer was observed to be significant on plant Fresh and dry weight of Fonio at all the three locations in both 2018 and 2019 rainy seasons **(Fig 6)**. In most of the cases, application of NPK at 150 and 100kg/ha gave statistically similar dry weights, but higher than NPK at 50kg/ha and the control.

Picture 1: Fresh Fonio after harvest

Picture 2: Fonio after Drying

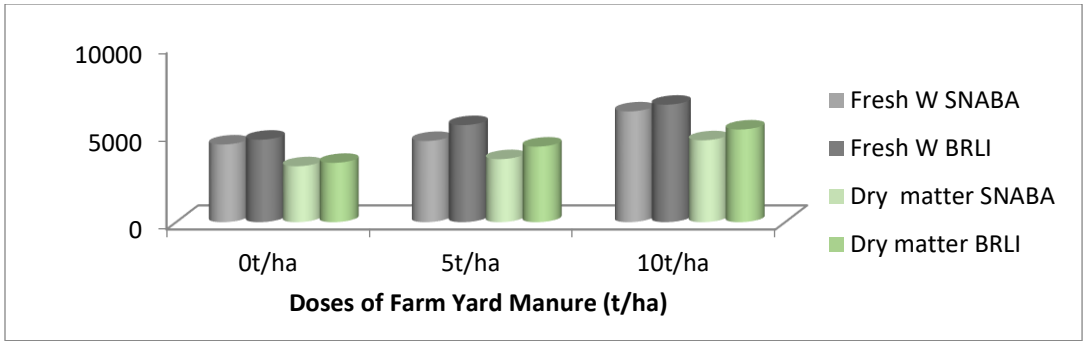

Fig 5: Mean Fresh and Dry matter Weight (kg/ha) of Fonio Crop as Affected by Manure at SNABA and BRLI in 2018

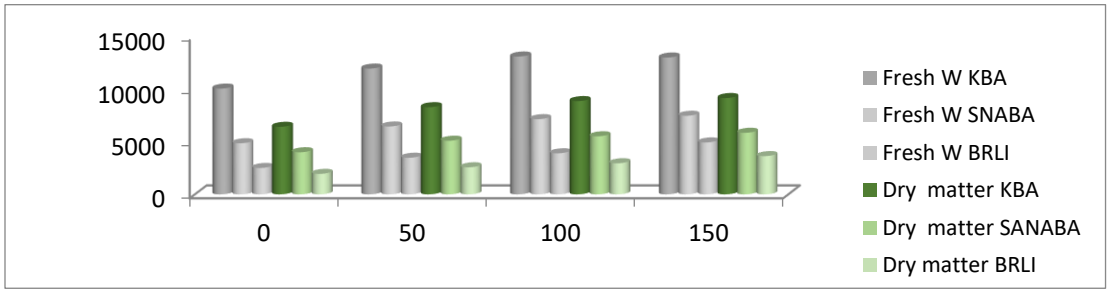

Fig 6: Mean Fresh and Dry matter Weight (kg/ha) of Fonio as Affected by NPK across the three locations in 2019

4.1.8 Yield of Fonio as affected by Manure and NPK 15-15-15 (Table 5)**:** The effect of manure was observed to be significant at Sanankoroba and Baroueli. At Sanankoroba the increase in manure led to proportional increase in Fonio yield up to 10t/ha. At BRLI, manure at 5 t/ha was at par with the control, but significantly lower than manure at 10 t/ha. NPK significantly influenced Fonio grain yield, the maximum grain yield was obtained with NPK at 100 kg/ha which was at par with NPK at 150 kg/ha, but significantly higher than NPK at 50 kg/ha and the control. Interactions were not significant on yield of Fonio.

Table 5: Yield **(**kg/ha) as affected by Manure and NPK at the Three Locations

Treatments	KBA	SNABA	BRLI	Combined
Manure (M)				
0	1759	1214**c**	1101**b**	1358**b**
5	1812	1299**b**	1107**b**	1406**b**
10	1874	1426**a**	1228**a**	1509**a**
s. e.d	88.16	64.03	53.88	44.60
NPK (F)				
0	1565**c**	1045**c**	1009**d**	1206**c**
50	1767**b**	1285**b**	1144**c**	1398**b**
100	1969**a**	1452**a**	1244**a**	1555**a**
150	1960**a**	1469**a**	1185**b**	1538**a**
s. e.d	60.95	50.97	32.34	24.85
Interactions				
M*F	Ns	ns	ns	ns

Means followed by the same letters among treatments are not
Significantly different at 5% level of probability using DMRT

5 DISCUSSION

The study confirmed that Fonio could grow in a wet site, sunny, and semi-arid area as reported by CIRAD-GRET-MAE (2002). Manure was observed to increase plant height linearly number of tillers, number of leaves, plant fresh and dry matter weight, at all the three locations the maximum plant growth characters were obtained with manure at 10t/ha. At Sanankoroba using of manure at 10t/ha was justified, Similar results were reported by Ndor *et al* (2016) with application of three levels of poultry manure 0, 5 and 10t/ha on two species of "Acha" in Nasarawa State of Nigeria. Morales-Payan (2002) reported that organic manure or farmyard fertilizer (FYM) (cow or goat manure) has been used to increase plant biomass and grain yield. Significant effect of manure on number of roots of Fonio was observed, number of roots linearly increased with increasing manure. Ouattara (2011) reported that manure improved the chemical properties of soil through the process of mineralization. The microbial activity allows a better development of roots. Ndor et al (2016) reported that the application of compound fertilizer NPK at 3 levels (0, 60 and 120kg/ha) significantly enhanced growth parameters in both two seasons. This finding is in tandem with the works reported by Manga (2010) and Mustapha (2010) on effect of organic and inorganic fertilizer on yield and Yield components of *Digitaria exilis* Stapf. NPK 15-15-15 had a significant influence on height of Fonio, plant number of tiller, number of leaf, leaf area, number of roots and grain yield. Manga *et al* (2010) reported that number of leaves was significantly affected by the application of NPK fertilizer. The application of 300kgNPK/ha brought about a significant increase in number of leaves when compared to the control during most of the sampling periods in both locations. The increase in number of leaves may be attributed to the increase in tiller due to the application of NPK fertilizer, an observation

earlier made by Tanaka (1959) and Magaji (1994) on rice. Sissoko (2013; 2014) used DAP and urea at eight levels, the results showed that the output gap between the treatment without fertilizer and the treatment with the best yield was 243kg/ha. All conditions being equal, the use of fertilizer on Fonio enables the farmer to obtain a profit margin. Using large quantities of fertilizer did not result significantly higher biomass production. Diagnostic Analysis of the Fonio Sector in Guinea / PASAL-BCEPA (1998) reported that 75kg / ha of superphosphate plus 25kg / ha of urea before or during sowing was shown to increase yield of Fonio to 1.600kg / ha, more than 587kg the control. Growth and yield of NPK at 100kg/ha was similar to NPK at 150kg/ha, Kanfany (2009) reported similar results and according to FAO (2005), "there is a technical threshold beyond which the yield decreases by effect of toxicity (overdose)…"

6 CONCLUSION

NPK 15-15-15 significantly increased all the studied plant growth and yield characters. It significantly influenced grain yield of fonio at the three locations. The maximum growth and grain yield were obtained with NPK at 100 kg/ha. The study revealed a maximum grain yield of fonio of 1965 kg/ha at Kolondiéba with application of NPK at 100kg/ha, 1469 Kg/ha at Sanankoroba with application of NPK at 150kg/ha and 1244kg/ha at Baroueli with NPK at 100kg/ha. Effect of Farm Yard Manure was inconsistent on number of tillers, number of leaves length of roots, height of fonio, plant fresh and dry matter weight but it was significant on number of root and increasing in Farm Year Manure led to proportional increase in yield of fonio up to manure at 10 t/ha. 1869 kg/ha were the maximum grain yield at Kolondiéba, 1426 Kg/ha the highest grain yield of fonio at Sanankoroba and 1228 Kg/ha at Baroueli with application of manure at 10t/ha. This study confirmed that in Mali despite its cultural role; fonio is a neglected crop cultivated by traditional way by women on poor soil. Application of fertilization at indicated rates increases grain yield of fonio, three times and two times respectively at Kolondiéba Sanankoroba and Baroueli compare to the national average grain yield.

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