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Effect of different fertilizer types on three millet crops grown in the humid tropics of Nigeria

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Abstract

Northern Nigeria is predominantly known to produce millet due to the low rainfall associated with the climate. However, Changes in climatic factors over the years has resulted in the shift in crop production as some crops that were adaptable to the semi-arid regions become increasingly adaptable to tropical rainforest regions. Hence there is the need to study millet in the humid tropics of Nigeria. The objectives of the studies was to determine the performance of 3 millet types treated with different fertilizers types in the humid tropics of Nigeria.

The experiment was conducted in the Department of Crop Science Screen-house situated at the Research and Teaching Farm of the Faculty of Agriculture, University of Benin, Benin City. The experiment was a 3 x 6 factorial set up in a completely randomized design which includes 3 millet crop types (Gero, Maiwa and Tamba) and 6 fertilizer types (*Abuscular mycorrhiza* (AM), *Trichoderma hazianum* (TH), NPK (15:15:15; 60 kg/ha), AM+NPK (15:15:15 at 30 kg/ha), TH+NPK and Control (C)). Growth and yield variables were measured every 3 weeks for 12 weeks and the data obtained were subjected to analysis of variance. Means were separated using Fishers-protected LSD at 5% level of probability.

Millet types were significantly different with Gero and Maiwa having higher mean performance over Tamba millet. However, Gero millet was the only plant to attain flowering and subsequent grain yield during the period of the study. The fertilizer types were significant only on yield and yield components. Grain yield of Gero millet with TH+NPK had the highest yield (>100g plant^{-1}) and wider grain diameter (>2.0 mm) than other fertilizer types. AM fertilized plants had the heaviest grain weight and was significantly heavier than the grains obtained from plants in control pots.

Millet types can be grown in the humid tropics of Nigeria under controlled condition as observed in the study. They can grow vegetatively with little or no fertilizer, but the grain yield could be enhanced with *Abuscular mycorrhiza* and *Trichoderma hazianum* as biofertilizers in combination with NPK fertilizer. Application of this finding will reduce the amount of inorganic fertilizer that will be solely required for millet production by 50% and consequently promote environmental sustainability. Under controlled conditions, Gero millet can be cultivated for both forage and grains whereas Maiwa and Tamba millets could be cultivated for forage in the humid tropics of Nigeria.

Keywords: Millet; Fertilizer; Biofertilizer; Growth; Cereals

1 Introduction

Millet is a common cereal crop commonly referred to as “small-seeded crop” belonging to the grass family Poaceae (1). It is ranked sixth among the cereal crops of the world after Maize, Rice, Wheat, Barley and Sorghum (2) in descending

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order. In the drier parts of Africa, it is among the staple food crops, particularly the arid and semi-arid regions of West Africa such as northern Nigeria (3). It is highly productive, short duration plant (120-180 days) that is resistant to drought, poor soils, variety of pests, and diseases (4). Millet, therefore, fits well into certain cropping systems with short seasons that can accommodate crops with short growing cycles (5).

Millets have been reported to grow and produce grains with little or no fertilizer application due to their tolerance for poor soils (5) (6). However, to achieve higher yields to meet increasing world food demand, organic or inorganic fertilizers are essential for millets (7). Biofertilizers such as Arbuscular mycorrhiza and *Trichoderma harzianium* (T22) applied alone and in combination with NPK fertilizer were reported to have significantly increased growth and yield of both finger millet and maize crops (8). Pearl and finger millet were reported to produce higher grains with fertilizer application rates of 50-120 $kgha^{-1}$ NPK (9).

Increasing the productivity of cereals including millet is one way of reducing global food shortages (10). Several studies (2,11,12) have been conducted with a view to improving pearl and finger millet yields in northern Nigeria. According to FAOSTAT (13) report, millet productivity is deficient in southern Nigeria and as such efforts geared towards millet adaptability in southern Nigeria will bring about new opportunities or modification of existing production systems (14) that may lead to increasing millet production needed to meet the increasing demand for food security. Such efforts could involve conducting research on the adaptability of millet to the humid tropics under controlled and uncontrolled environments (15). Hence, the purpose of this study with an objective to determine the effect of different types of fertilizers on the growth and yield of millet under controlled conditions.

2 Material and methods

The study was conducted in the screen house of the Department of Crop Science at the Teaching and Research Farm, Faculty of Agriculture, University of Benin, for a period of 120 days during the rainy season (May to August). The University of Benin is located on latitude 6.02 ^{o}N and longitude 5.06 ^{o}E in the humid rain forest zone of southern Nigeria. Annual temperature ranges between 24.5 to 32.7 ^{o}C with a mean temperature of 28.6 ^{o}C. Annual rainfall is between 1498mm to 3574mm with a mean rainfall of 2430mm. Relative humidity and daily sunshine ranges are 63.31 to 81.71% (with a mean of 73.5%) and 5.85 to 7.50 hours (with a mean of 6.68 hours), respectively.

The study was a two-factor experiment arranged in a completely randomized design replicated three times. Three millet types were used as test crops which were Gero and Maiwa (*Pennisetum glaucum*) and Tamba (*Eleucine corocana*) millets. Six fertilizer types were applied to 10 kg potted soil weight in which the crops were sown were, Control (no fertilizer) *Abuscular mycorrhiza* (AM), *Trichoderma hazianum* (TH), 60 kg/ha NPK (15:15:15) and a combination of 30 kg/ha NPK with AM (i.e., AM+NPK) and TH (i.e., TH+NPK) giving a total of 18 pots per replicate spaced 20 cm apart. 30 g of AM was applied to the upper surface of the soil and mixed gentle within the top 10 cm prior to sowing of seeds. 50 g of sawdust (Okwen wood) was inoculated with TH in a salad cream bottle of 19 cm height and 5 cm basal diameter for 12 days after sterilization. The content of the bottle was thereafter emptied into the assigned pots top-soil surface and mixed with 10 cm of the soil. Data was obtained on shoot height, stem diameter, apparent leaf area every 3 weeks and yield parameters at harvest. Data obtained on growth and yield variables were subjected to Analysis of variance using Genstat 12th edition software.

3 Results and discussion

Table 1 Routine soil Physio-chemical analysis

Variable	Result
pH (H_2O)	6.80
pH ($CaCl_2$)	6.00
Total nitrogen (g/kg)	2.80
Available P (mg/kg)	2.85
Organic matter (g/kg)	26.90
ECEC	6.04
Ca (cmol/kg)	1.55

Mg (cmol/kg)	2.48
K (cmol/kg)	0.46
Na (cmol/kg)	0.26
Exchangeable Acidity (cmol/kg)	1.28
Silt (%)	10.44
Sand (%)	73.96
Clay (%)	15.60
Textural class	Sandy loam

Routine soil analysis on the physiochemical properties of the soil samples obtained from the soil used for the study. Table 1 shows the result which indicates that the soil was sandy loam in texture, high in N, K and OM but low in P. This implies that the soil was generally of good fertility status at the commencement of the study.

3.1 Growth Response

Table 2 Effect of Millet and Fertilizer types on shoot height, stem diameter and Leaf area

Treatment	**Shoot height (cm)**				**Stem diameter (mm)**				**Leaf Area (cm^2)**			
	W3	**W6**	**W9**	**W12**	**W3**	**W6**	**W9**	**W12**	**W3**	**W6**	**W9**	**W12**
Millet-type (M)												
Maiwa	16.48a	25.30^{b}	48.20^{b}	102.20^{b}	6.45^{b}	9.43^{b}	11.60^{a}	10.74^{b}	76.40^{b}	124.70^{ab}	151.00^{a}	191.90^{a}
Gero	17.56a	45.90^{a}	143.40^{a}	155.30^{a}	7.10^{b}	7.89^{c}	8.85^{b}	5.12^{c}	97.00^{a}	203.80^{a}	150.80^{a}	142.20^{b}
Tamba	13.43b	17.80^{c}	21.50^{c}	44.10^{c}	8.90^{a}	11.05^{a}	12.53^{a}	14.74^{a}	35.00^{c}	41.60^{b}	46.60^{b}	64.00^{c}
LSD (0.05)	1.681	7.23	19.85	21.38	1.119	1.347	2.734	2.680	15.31	121.20	37.14	37.87
Fertilizer (F)												
Control	14.72	22.80	56.80	92.5	6.47	7.29^{d}	9.55	7.76	58.70	80.60	101.20	100.30
Abuscular	15.49	28.80	71.70	87.7	7.28	8.30^{cd}	10.02	9.14	68.20	89.50	109.50	136.90
Trichoderma	15.13	33.00	68.00	112.1	7.01	8.76^{cd}	11.84	12.02	63.10	241.90	131.60	153.50
NPK	15.90	28.60	75.70	99.9	7.79	11.69^{a}	12.60	11.53	74.90	115.70	105.00	140.90
Abuscular + NPK	16.06	28.90	70.80	97.7	7.73	9.72^{bc}	10.69	10.48	69.60	100.80	119.30	108.80
Trichoderma + NPK	17.64	36.00	83.10	113.20	8.61	10.97^{ab}	11.26	10.28	82.2	109.90	130.10	155.90
LSD (0.05)	ns	ns	ns	ns	ns	3.30	ns	ns	ns	ns	ns	ns
Interaction												
M x F	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means with similar alphabet are not significantly different from one another at 5% level of probability. ns = not significant; W3 = Week 3; W6 = Week 6; W9 = week 9; W12 = week 12

Table 2 shows the effects of Millet types, fertilizer types and their interactions on shoot height, stem diameter and leaf area of millet. There were significant differences ($p<0.05$) among millet-types for shoot height at the four sampling periods (W3, W6, W9, and W12). Generally, Gero was the tallest millet followed by Maiwa and then Tamba in decending order. This is attributed to genetic makeup by which Pennisetum species have a characteristically taller growth nature than *Eleucine corocana* which were shorter. Neither fertilizer types nor interaction between millet types did affect shoot height of millet significantly. This could be due to the initial nutrient status of the soil which had sufficient good amount of Nitrogen thereby limiting any significant observable effect vegetative growth of millet types because of fertilizer types applied. This implies that millet types can grow to maturity irrespective of whether fertilizer is applied or not in a relative fertile sandy loam soil. This agrees with the report of (5) that millet plants can grow and produce grains without fertilizer application.

Similarly, millet types differed significantly in terms of stem diameter at all sampling intervals. At week 3 (W3), Tamba produced significantly wider stem diameter than Maiwa and Gero that had similar stem diameter. At weeks 6 (W6) and 12 (W12), stem diameter followed the significant order of Tamba > Maiwa > Gero whereas, at week 9 (W9), Maiwa and Tamba had statistically similar stem diameter that was significantly wider than that of Gero millet which could also be attributed to morphological characteristics of Tamba. The effect of fertilizer on stem diameter was significant at W6. NPK fertilizer produced the significantly widest stem girth but was not different significantly from TH + NPK treatment combination effect on stem diameter. This implies that TH + 30 kg/ha NPK effect is equivalent to 60 kg/ha NPK. The interaction for stem diameter was not significant.

In addition, leaf area of millet differed significantly at all sampling intervals depending on variety. Generally, Maiwa and Gero produced significantly larger leaf area than Tamba which understandably is attributed to the difference in morphological features of the millet types. Fertilizer types did not significantly affect leaf area nor were the interactions significant. Millet is noted to perform well even when soil fertility is poor (5) This may have reduced the response of millet types to fertilizer types.

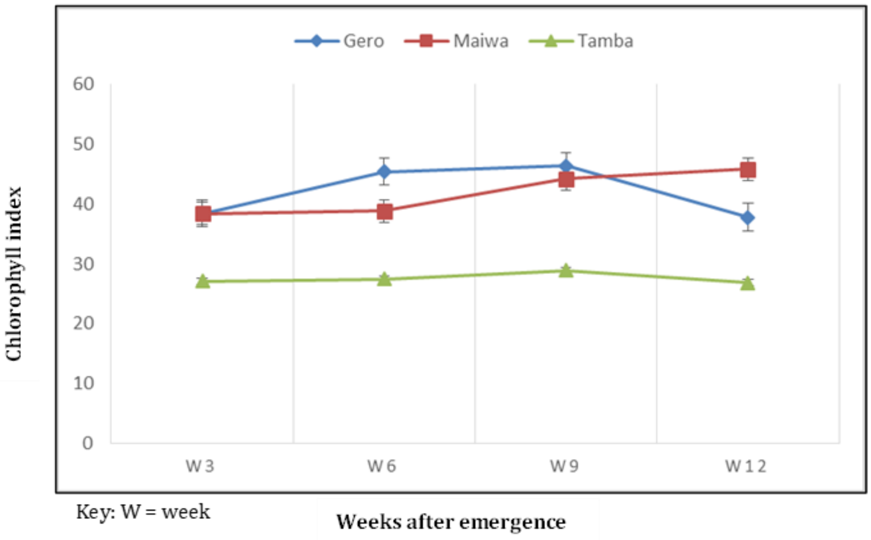

Figure 1 Chlorophyll index of the millet types at different periods

Chlorophyll index of millet types were seen to be significantly varied at the start only by millet types whereby Gero and Maiwa had higher chlorophyll than the Tamba millet type during the study. Between Gero and Maiwa, significant variability was observed at W6 and W12 as shown on Figure 1. Gero was higher than Maiwa during the 6^{th} week while the reverse was the case at 12^{th} week. Conversely it could be inferred that the marked difference in chlorophyll content between *Pennisetum sp.* and *Eleucine sp.* millet types was due to morphological differences whereas the significant difference observed within *Pennisetum sp*. varieties could be due to some inherent physiological processes influenced by environmental factors.

3.2 Relationship between some Growth and Variables

Correlation analysis among some measured variables showed a positive relationship between the variables with exception of Number of leaves that had no relationship with Chlorophyll index as shown in table 3. This implies that the increase in chlorophyll content of millet leaves do not relate to increased Number of leaves neither does the reverse imply reduction in Number of leaves. Increased stem diameter led to significant increase in all variables with exception of number of leaves. Significant Number of leaves relationship with Leave width and Panicle length only were observed by which 10% increase in number of leaves will lead to 5% increase in both Leave width and Panicle length. Similarly, chlorophyll content exhibited significant positive relationship with only Shoot height and Stem diameter. Panicle growth both in length and width were observed to be highly significantly related as a 10% growth in panicle length led to 8.3% growth in panicle width.

Table 3 Relationship between some measured variables of millet

Variables	Chlor. index	No. Lvs	Pan Lgt	Pan Wdt	Shoot hgt	Lv Lgt	Lv Wdt	Lv area	Stem dm
Chlor. Index	-								
No. Lvs	0.01	-							
Pan. Lgt	0.44	0.57*	-						
Pan. Wdt	0.47	0.30	0.83**	-					
Shoot hgt	0.59*	0.35	0.69**	0.61**	-				
Lv. Lgt	0.32	0.35	0.30	0.31	0.21	-			
Lv. Wdt	0.444	0.58*	0.79**	0.75**	0.58*	0.47	-		
Lv. Area	0.42	0.57	0.66*	0.65**	0.47*	0.81**	0.89**	-	
Stem dm.	0.53*	0.50	0.67**	0.58*	0.50*	0.48*	0.72**	0.70**	-

Key: Lv(s) = leave(s); lgt = length; wdt = width; No. = Number; dm =diameter; Chlor. = Chlorophyll; hgt = height; * = significant at 0.05; ** = significant at 0.01.

3.3 Number of Days from Sowing to Harvest

Table 4 Number of days from sowing to flowering and harvest

Millet type	No of Days to Flower	No. of Days to Harvest
Maiwa	nil	>120
Gero	65	105
Tamba	nil	>120

Table 4 shows the number of days from sowing to flower and harvest maturity for Gero millet. Gero millet was able to attain flowering and harvest maturity within the 120 days in which the study was conducted. Maiwa and Tamba millet types did not flower within the 120 days hence their actual days to harvest maturity was also not captured because the study was terminated at 120 days. This could be attributed to the climatic conditions prevailing at the time of the respective studies and the photosensitive characteristics of Maiwa and Tamba millet. These findings agree with that of (16) who reported that photosensitive millets attain maturity between 2.5 to 6 months. This implies that the day-length in the humid tropics of Benin City was not sufficient to bring about grain production and maturity within 120 days. Therefore, Gero millet could be incorporated in the early and late cropping season of the humid rainforest of Nigeria. It also infers that both Maiwa and Tamba millet types could produce grains in this region if there is sufficient day light. Also, it could be due to variations in suitable environmental factors. The higher the humidity in the environment the longer the time required to attain physiological maturity. Similarly, the lower the average temperature per day the more likely the more observed delayed physiological maturity which could explain why Maiwa and Tamba failed to flower within 120 days. This finding is in agreement with the statement of (17) who stated that temperature variations play a major role in the phenological development processes of plants.

3.4 Yield and Yield Components Response

Figure 2 shows the effect of fertilizer type on the grain yield of Gero millet. TH+NPK and AM+NPK produced similar but significantly higher grain yield than other fertilize types. The significantly lowest mean yield was recorded by AM fertilizer. *Trichoderma harzianium* (TH) plus NPK and A*rbuscular mycorrhiza* (AM) plus NPK, gave the highest grain yield when compared to the control. This could be attributed to the inherent ability of TH and AM products to reduce the concentration of substances that inhibit plant growth (8,18). The study also agrees with the findings of (19) who reported that several *Trichoderma sp*. products, used as biofertilizers, promoted the growth and yield of plants by enhancing the resistance to stress factors (biotic or abiotic). The study also affirms the work of (20) which revealed that the amount of chemical fertilizer used for cropping could be reduced by 50% when complimentary biofertilizers such as *Trichoderma sp* and *Arbuscular sp.* products are combined with them. High yields were recorded when 50% NPK were combined or mixed with biofertilizers compared to 100% NPK fertilizer alone.

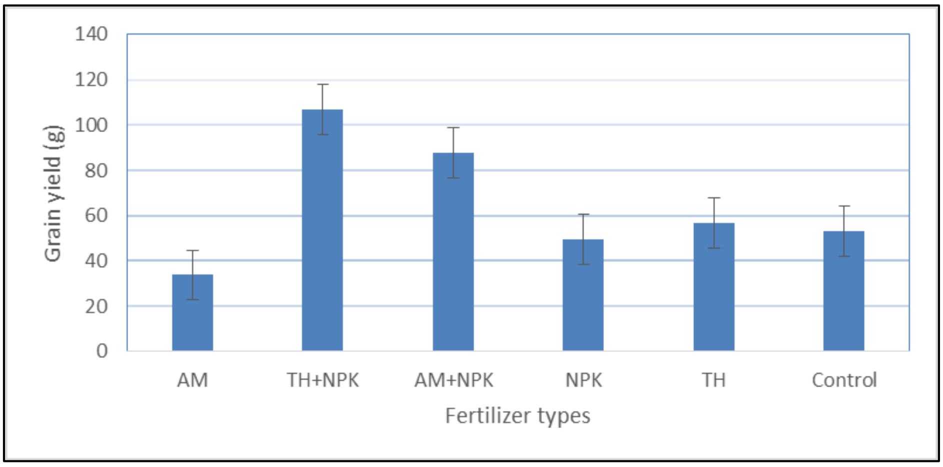

Figure 2 Effect of fertilizer type on grain yield of Gero Millet

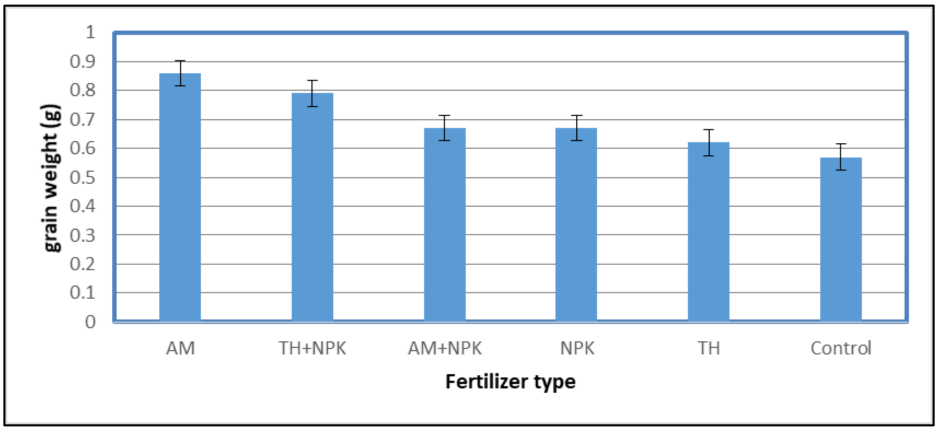

Figure 3 Effect of Fertilizer types on 100-grain weight of Gero millet

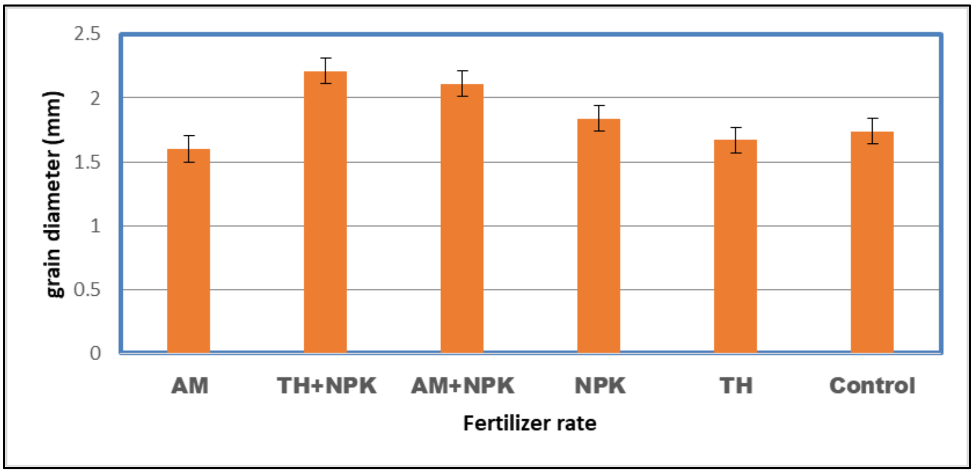

Figure 4 Effect of fertilizer types on grain diameter of Gero millet

Figure 3 shows the effects of fertilizer type on 100-grain weight of Gero millet. *Arbuscular mycorrhizae* (AM) and *T. Herzenium* plus 30 kg/ha NPK (15:15:15) (TH+NPK) fertilizers produced significantly heavier 100-grains than the other fertilizer types. AM recorded the heaviest grain weight per plant, which could imply that AM enhanced grain weight more than other fertilizer types. "This infers that the report of" (21) that AM effect on crop yield reduced with increased NPK application could be interpreted to mean AM is more effective applied alone than in combination with NPK (15:15:15) fertilizer with respect to increased grain filling and possibly early physiological maturity.

Figure 4 shows the effects of fertilizer type on grain diameter of Gero millet. The TH+NPK and AM+NPK produced significantly wider grain diameter than the other treatments. The AM fertilizer yielded narrowest grain diameter that was relatively at par with TH and the control.

4 Conclusion

Millet can be grown in a controlled environement such as Screenhouses in the humid tropics of Nigeria. Gero millet varieties can be cultivated for forage and grains during the rainy reason, whereas Maiwa and Tamba millets showed forage production potential. Gero attained harvest maturity in the rainy season which then implies that it can be incorporated into the early and late but short cropping period observed in the humid tropics of Nigeria. The yield performances of the millet types were enhanced by the fertilizer types applied. Biofertilizer in combination with 50% recommended NPK fertilizer rates (i.e. *Trichoderma harzianium* plus 30 kg/ha NPK fertilizer combinations) influenced better response of yield and yield components of Gero millet. Maiwa and Tamba millet had good vegetative growth fertilized with *Trichoderma hazianium* and *Arbuscular mycorrhiza*. The use of chemical fertilizer in cultivating millet can be supplemented with any of the biofertilizers and could enhance the yield performance. Further studies in uncontrolled environment is recommended to evaluate the response of the millet types to the different fertilizer types in the humid tropics of Nigeria.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known conflict of interest.

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