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Response of Fonio (*Digitaria exilis*) Accessions to Fertilizer Application

I.K. Addai [1], B.K. Bisuki [2] and A. Bawa [3,*]

[1]*Department of Crop Science, Faculty of Agriculture Food and Consumer Sciences, UDS, Nyankpala Campus, Ghana*
[2] *Ministry of Food and Agriculture (MoFA), Bolgatanga, Ghana*
[3]*Department of Sustainable Agriculture, Faculty of Agriculture and Natural Resources, Tamale Technical University, Tamale, Ghana*
[*]*Corresponding Author Email address: abawai1@yahoo.com/ or abawa@tatu.edu.gh*

Abstract— Fonio is one of the lost crops of Africa, and part of the reasons it has been neglected is inadequate information on Fonio growth and yield potential across its growing areas, hence the need to assess the response of available germplasm to fertilizer application. The objectives of the study were to determine the growth and yield response of Fonio accessions to fertilizer application, and to evaluate the interactive effect of fertilizer and Fonio accession on growth and yield. The study was conducted in Northern Ghana, during the 2019 cropping season. The research used a 4 x 5 (four fertilizer levels and five accessions) factorial experiment in a randomized complete block design with three replications. The finding showed that growth and yield parameters were significantly ($P< 0.05$) affected by fertilizer application. The result also revealed that accession OUSAI recorded the highest grain yield of 1015.10 kg/ha and NFAS4 recorded the least grain yield of 713.23 kg/ha. Also, the most lodged accession was OUAS1 which recorded 65% lodging of its total plant population and the least lodged accessions (NFAS4 and EYAS5) recorded about 10% lodging each. There were significant ($P < 0.05$) variations among accessions for most of the attributes measured. The interactive effect of fertilizer and accession was significant (($P<0.05$) for most of the traits studied.

Keywords— **Fonio, Accessions, Savannah agro-ecology, Morphological traits, Ghana**

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INTRODUCTION

Nations in Africa will progressively rely on cereals of Africa, with approximately 30% of the total population of the continent suffering from chronic hunger and malnutrition. Finding ways of redeeming food crises remains a challenge to all stakeholders throughout the continent and beyond (Danladi *et al*., 2003). Food security in developing communities has been dependent on traditional food products produced and consumed in different geographical settings within the continent (Danladi *et al*., 2003). Unfortunately, some of these traditional crops including Fonio that sustained the continent and beyond for centuries have been gradually forgotten due to a lack of research information on these crops for improvement leading to food insecurity which threatens peace and security across the continent (Danladi *et al*., 2003, Okeme *et al.,* 2017).

Fonio (*Digitaria exilis* Stapf) is an indigenous cereal of the Saharan Africa (Annegers, 1973). It is also known as acha, hungry rice or petit mil. Fonio belongs to the class Monocotyledoneae, order Dactyloctenium and the grass family *Poaceae* (Chapman and Peat, 1992). The genus *Digitaria* has two known cultivated species: *D. exilis* Stapf and *D. iburua* Stapf (Dalziel, 1937). *D. exilis* is widely grown throughout West Africa, while *D. Iburua* is reported to be restricted to Nigeria and the northern parts of Benin and Togo (NRC, 1996). Fonio yields well on poor soils with low rainfall (Wrigley, 1981). The crop is now grown as a staple, major complementary cereal or cash crop in parts of the West African Savannah. The seed is richer in protein than other known cereals in West Africa. The gel filtration profiles of the albumin, globulin, prolamin and glutelin fractions of fonio show a similar number of peaks to durum wheat (Jideani *et al*., 1994).

Fonio is a small-scale farmers' crop with numerous nutritional properties and is very vital as a source of food to many people on the continent and the world as a whole. Little input in its cultivation provides quite a substantial income and food to many households thereby giving possible developmental options to the rural poor. The crop is crucial to food security, particularly in seasons of hunger and critical periods when food reserves in the households are low (Vodouhe *et al.,* 2003).

Despite the importance of Fonio as a traditional African crop with many nutritional benefits, inadequate attention by researchers and policymakers has resulted in under exploitation of the genetic potential of Fonio, which encourages continuous genetic erosion of the crop. The traditional husbandry practice such as broadcasting seeds at

unspecified rates depending on seeds availability and farmers' proficiency often leads to low yields and is liable to uncertainties and therefore needs improvement. In Ghana, Fonio is gaining popularity, particularly in the Northern Region as it is in other parts of sub-Sahelian Africa. Therefore, it is important to assess its response to a supplementary nutrient application to promote and enhance sustainable production of Fonio in the continent (Okeme *et al.*, 2017).

MATERIALS AND METHODS

A. Experimental site

The experiment was conducted in the northern part of Ghana, Rainfall was erratic during the study period. The Savannah agro-ecological region of Ghana is characterized by a unimodal tropical monsoon with a single cropping season. This single cropping season is constrained by the harmattan period which commences in December and ends in April. The soils of Ghana are developed from highly weathered parent material. Percent organic matter and nitrogen are particularly low in the savannah and the transition zones. Alluvial and eroded shallow soils are common to the Savannah agro-ecological zones of Ghana (Oppong-Anane, 2006), most soils are inherently infertile (Table 1).

Table 1. Average soil fertility status of seven administrative regions of Ghana

Region	Soil P^H	OM (%)	Total N (%)	Available P (mg/kg soil)	Available Ca (mg/kg soil)
Greater Accra	5.40-8.20	0.10-1.70	0.05-0.90	0.80-144.00	14.00-147.00
Western	3.8.0-7.10	1.00-5.70	1.0-7.50	0.4-11.30	28-420.00
Ashanti	4.3-7.80	1.50-3.00	0.10-0.30	0.10-12.00	50.00-100.00
Brong Ahafo	3.50-6.70	0.30-1.70	No data	0.1-64.30	16-140.00
Northern	4.50-6.70	0.60-2.00	0.02-0.05	2.50-10.00	45.00-90.00
Upper West	6.00-6.80	0.50-1.30	0.01-0.07	2.00-7.40	52.00-152.00
Upper East	5.10.0-6.80	1.10-2.50	0.06-0.14	1.80-14.80	44-152.00

Source: Wood, 2013

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B. Experimental materials

Germplasm was collected from three countries including Ghana, Ouagadougou and Togo, and used for the study (Table 2).

Table 2. List of Accessions and their Attributes

Name of accession	Place of collection	Attributes
Ouagadougou (OUAS1)	Burkina Faso	Very early maturing (takes 70 days to physiological maturity), short, small leaves, and high yielding.
Namba (NAAS2)	Ghana	Early maturing (takes 80 days to physiological maturity) and high yielding.
Kpenteke (KPAS3)	Ghana	Early maturing (takes 80 days to physiological maturity) and high yielding.
Nfonikpa (NFAS4)	Ghana	Late maturing (takes 98 days to physiological maturity), broad leaves and grows very tall.
Eyadema (EYAS5)	Togo	Late maturing (takes 98 days to physiological maturity), grows very tall and high yielding.

C. Field preparation and planting

The field was ploughed and harrowed prior to planting. Seedbeds of 4 m^2 with 0.75 m between beds and 1 m between replications were used. Sowing was done in July 2019 in furrows of 0.25 m apart on each bed with a farrow depth of 0.003 m. A seed rate of 25 kg/ha was used and the seeds were gently spread in the furrows and covered with a thin film of soil.

D. Experiment design

The experiment was a 4 x 5 factorial experiment laid out in a Randomized complete block design replicated three times (Plate 1); 4 levels of fertilizers [NPK: 15:15:15 = 60 kg/ha, compost = 10 tons per hectare, 30 kg/ha of NPK plus 5 tons/ha of compost and control (no fertilizer application)] and five 5 accessions.

Fig.1. Plate 1: Fonio growing in experimental field (UDS research field, Nyankpala)

E. Data collection and analysis

The number of leaves at reproductive maturity: Ten plants were randomly selected for each plot at 50% emergences of flag leaves and the number of leaves per plant counted. This was repeated at the complete emergence of flag leaves and the average computed. The number of racemes per plant: The racemes of ten tagged plants in each plot were counted and the averages were computed to represent each plot. Plant height at maturity: The heights of ten tagged plants in each plot were measured at maturity with a meter rule and the average computed. Days to physiological maturity: This was counted as the number of days it took for plants on each experimental unit to mature by counting the number of days from sowing till physiological maturity was observed. Number of tillers per plant: Ten plants were randomly selected at 50% flowering from all experimental units, and the number of tillers was counted. Days to 50% flowering: Days to 50% flowering were obtained as the number of days taken for half of the total plant population in each plot to flower.

Lodging: Lodging was scored at the reproductive stage on a scale of 1 to 5. Where: 1= zero lodging, 2=Less Lodging about 1-10% of plant population, 3=Moderate lodging of about 10-40%, 4=High lodging of about 40-70% and 5= severe lodging tendency (70-100%) of plant population. This was repeated three times at one-week intervals and the average was taken to represent each treatment. Plate 2 shows lodged tillers of accession OUAS1.

Fig.2. Plate 2: Lodged OUAS1 tillers lying on the ground

The number of panicles per stalk: Panicles of ten plants were randomly selected, and tagged plants for each treatment were counted at complete flowering.

Leaf area: Leaf area was estimated by measuring the width and length of four leaves at the mid-trunk portion per plant of ten selected plants per experimental unit. The actual leaf area was then computed using the formula suggested by Ashley *et al*. (1963). b = a/l*w.

1000-seed weight: Thousand seeds were randomly collected from each plot and weighed in grams using an electronic balance at 12% moisture content. Total grain yield: The weights of seeds obtained from each experimental unit were weight in grams and expressed in kilogram/ha at 12% moisture content. Harvesting: Harvesting was done by cutting mid-stalk using sickle at physiological maturity. Data collected were subjected to analysis of variance (ANOVA) using Genstat statistical package edition 12. The means were separated using LSD (5%).

RESULTS AND DISCUSSION

Growth parameters

Plant height

The interaction effect of fertilizer and Fonio accessions was not significant (P > 0.05) (Table 3). However, the individual accessions and fertilizer application had a significant (P<0.001) influence on plant height at physiological maturity. Plants applied with 60 kg/ha NPK recorded a peak mean plant height of 87.06 cm followed by those applied with the combination of NPK (30 kg/ha) and compost (5 tons/ha) with a plant height of 83.47 cm (Table 4). Plants applied with sole compost (10 tons/ha) also had a mean plant height of 83.47 cm and the control recorded the shortest mean plant height of 77.48 cm at physiological maturity. The late-maturing accession NFAS4 with 98 days to physiological maturity (DPHM) recorded the highest average plant height of 93.79 cm and KPAS3 with 80 DPHM recorded the shortest mean plant height (72.66 cm) among all the accessions at maturity.

Table 3. Analysis of variance for yield and yield components as influenced by accession, fertilizer, and accession x fertilizer interaction effects during the 2019 cropping seasons

Source of variation	df	*F probability (*0.05*)*							
		Number of leaves per plant	Plant height (cm)	Tiller number per plant	Leaf area (cm^2)	1000-grain weight (g)	Grain yield (kg/ha)	Panicle number per plant (PNP)	Lodging in Fonio (LG)
Accession	4	< 0.0.001	< 0.001	< 0.001	< 0.001	< 0.048	< 0.003	< 0.001	< 0.027
Fertilizer	3	< 0.001	< 0.001	< 0.001	< 0.120	< 0.433	< 0.127	< 0.001	< 0.052
Accession x Fertilizer	12	< 0.651	< 0.250	< 0.410	< 0.245	< 1.000	< 0.150	< 0.113	< 0.050
Residual	41								
Total	60								
SEM		0.235	1.794	0.195	0.222	0.007	62.123	0.185	0.01
CV (%)		13.50	10.60	11.4	19.20	7.00	35.80	11.05	10.50

SEM = Standard error of means

This observation means that Fonio accessions might have efficiently responded to chemical fertilizers (NPK 15:15:15) and the combination of NPK and compost than sole compost, hence the difference in plant height at maturity. The control registering the shortest plant height meant that the accessions responded positively to NPK and compost fertilizers in terms of plant height. These observations support the results of Priyadarshani *et al*. (2000) who recorded significant influence of fertilize in Fonio plant height. However, it does not agree with the work of Cruz *et al*. (2011) who found no significant influence of NPK on Fonio plant height. Also, the difference in maturity date among accessions might have affected their response to fertilizer application hence the difference in height between late and early maturing accessions. The average plant height recorded for the five accessions was 82.61 cm, this is similar to the findings of Cruz *et al*. (2011) who reported that Fonio reached a height of about 30 cm to 80 cm at maturity.

Peduncle length

Fertilizer application significantly (P < 0.01) influenced peduncle length (Table 4). Sole compost at 10 tons/ha recorded the longest peduncle length (29.37 cm) among all the levels of fertilizer applied and was closely trailed by sole NPK 15:15:15 at 60 kg/ha which recorded a peduncle length of 29.07 cm. But in all cases, the control (plots without fertilizer application) recorded the shortest peduncle length (26.71 cm). There was an observed statistical (P<0.001) difference among Fonio genotypes for peduncle length. The grand mean for peduncle length was 28.51 cm, the late-maturing genotypes were observed to have the longest peduncle length compared to the early maturing genotypes. The genotype EYAS5 recorded the longest peduncle length (31.91 cm) followed by NFAS4 and the shortest peduncle length was recorded by NAAS2.

Number of leaves per plant

The interactive effect of fertilizer and Fonio accession had no significant (P > 0.05) influence on the number of Fonio leaves per plant (Table 3). Conversely, the individual

effects of accession and fertilizer varied significantly (P<0.001) for the number of leaves per Fonio plant. The late-maturing accessions EYAS5 and NFAS4 with 98 DPHM registered the highest mean number of leaves per plant (10.07 and 10.31 respectively) compared to the three early maturing accessions, OUAS1 (70 DPHM), NAAS2, and KPAS3 (80 DPHM each) whose highest mean number of leaves was 7.580 (Table 4).

These findings suggest that the fertility status of soil does not affect the number of Fonio leaves as does the choice of accession. Also, the number of leaves in this work did not positively affect Fonio grain yield as the best yielding accession OUAS1 was among accessions that recorded a lesser number of leaves. The significant diversity observed among the accessions is in line with the report of Ibrahim *et al*. (2020) who observed statistical differences among Fonio accessions for leave number per plant.

Leaf Area

The interaction effect of all the levels of fertilizer and accession as well as the individual effect of the fertilizer levels were not significant (P > 0.05) on the leaf area in fonio (Table 3). The accession had a significant (P<0.001) influence on leaf area in Fonio. Accession NFAS4 recorded the largest leaf area of 8.28cm^2 and the least leaf area was recorded by OUSA1 (Table 4). The diversities observed validate the morphological difference noticed for canopy architecture among accessions which were noticeably grouped into two; accessions EYAS5 and NFAS4 had longer and broader leaves while the other three accessions (OUAS1, NAAS2, and KPAS3) had narrow and shorter leaves. This suggests that the expression of Fonio growth potential with respect to leaf area is greatly controlled by the genotypes.

Number of tillers per plant

The Interaction effect of fertilizer and accession produced no significant (P > 0.05) difference in the number of tillers per plant. However, the individual effects of fertilizer and accessions on number of tillers produced per plant were highly significant (P< 0.001) (Table 3). Sole compost registered the highest average number of tillers, and the control registered the least average number of tillers per plant (Table 4). Accession NFAS4 recorded the highest average number of tillers per plant (11.480) and NAAS2 recorded the least average number of tillers (7.460**)** among all accessions.

The results of this work imply that tillering in Fonio is increased with the application of either NPK or compost, this can potentially increase grain yield. This finding is in line with that of Priyadarshani *et al*. (2000) and who established that tillering in Fonio was significantly enhanced by poultry manure and NPK. The significant diversity among accessions observed for tiller number per plant averaging 8.19 tillers for five accessions supports the report of Clottey *et al*. (2006). Similarly, Dachi and Gana (2008) reported significant variation among black Fonio (*Digitaria iburua*) accessions for the number of tillers per plant. This observation suggests that the Fonio genotypes uniquely responded to fertilizer application with respect to tiller number per plant. This again validates the genotypes diversity that exists among Fonio accessions which could be exploited for improvement of the crop.

Grain yield and yield components

Thousand-grain weight

A significant difference (P<0.05) was observed among accessions for thousand-grain weight (Table 3). However, the interaction of fertilizer and accession, as well as the individual influence of the fertilizer levels did not significantly affect 1000-grain weight of fonio. Accession KPAS3 recorded the heaviest 1000GW of 0.53 g and the least accessions in terms of grain weight were EYAS5 and NFAS4 which recorded the same grain weight of 0.51 g (Table 5). The observation made in this study means that 1000GW in Fonio is not affected by the fertility status of the soil or the application of fertilizer but by the genotype. It also suggests that 1000GW in Fonio is an inherent trait. This result resonates with the results of Priyadarshani *et al. (*2000) in which it was discovered that organic and inorganic fertilizer application did not influence Fonio grain weight statistically.

Table 4. Influence of fertilizer and accession on plant height at maturity (PHM), number of leaves per plant (NLP), leaf Area (LA), peduncle length (PL) and tiller number per plant (TNP)

Traits	Fertilizer					Accessions						
	NPK	CP	NPK+ CP	CT	LSD (5%)	OUAS1	NAAS2	NFAS4	EYAS5	KPAS3	LSD (5%)	CV (%)
PHM	87.00	83.47	82.42	77.48	4.52	76.89	76.75	93.79	92.94	72.66	5.1	10.6
NLP	8.41	8.52	8.58	8.70	0.59	7.40	7.40	10.31	10.70	7.58	0.66	13.5
LA	6.33	5.98	5.89	4.47	0.56	3.80	3.99	8.28	8.23	4.04	0.62	19.2
TNP	0.21	0.44	0.78	1.44	1.23	6.79	7.04	10.54	8.21	7.50	1.37	27.1
PL	29.07	29.37	28.89	26.71	1.75	25.91	25.57	30.19	31.91	28.95	1.96	12.0

CT=control, CP= compost (10 tons/ha), NPK=60 kg/ha, NPK+ CP= 30 kg/ha + 5 tons/ha.

Table 5. Effects of Fertilizer and Accession on 1000-Grain Weight (1000gw), Number Racemes per panicle (NRP), Number of panicles per plant (NPP), Grain Yield (GY), and Lodging (LG) in Fonio

	Fertilizer					Accession						
Traits	CT	NPK	CP	NPK + CP	LSD (5%)	OUAS1	NAAS2	NFAS4	EYAS5	KPAS3	LSD (5%)	CV (%)
1000GW	0.52	0.51	0.52	0.51	0.02	0.51	0.52	0.51	0.51	0.53	0.02	7.00
NRP	3.05	3.35	2.92	3.33	0.21	3.28	2.88	3.17	3.38	3.10	0.23	12.70
NPP	6.60	8.10	8.27	9.10	1.12	6.79	7.40	10.54	8.21	7.50	1.25	27.10
GY (kg/ha)	799.58	929.17	844.75	829.83	156.38	1015.10	884.48	713.23	720.73	920.62	174.83	35.80
LG	2.80	4.07	3.80	3.90	0.51	4.75	4.04	2.75	2.88	3.79	0.14	6.60

CT=control, CP= compost (10 tons/ha), NPK=60 kg/ha, NPK+ CP= 30 kg/ha + 5 tons/ha.

Racemes number per panicle

The individual effect of fertilizer levels on the number of racemes per panicle was also observed to be significant (P<0.001). Plants applied with NPK 15:15:15 at 60 kg/ha recorded the highest number of racemes (3.35) per panicle and were closely followed by those applied with a combination of NPK (30 kg/ha) and compost (5 tons/ha) with 3.33 racemes per panicle (Table 5). The control outperformed plants applied with sole compost at 10 tons/ha which recorded the least average number of racemes (2.92) as compared to the control with 3.05 racemes per panicle. The number of racemes per panicle varied statistically among the five accessions (Table 5). The accession EYAS5 recorded the highest number of racemes (3.38) and accession NAAS2 recorded the least number of racemes per panicle (2.88).

The interaction between accession OUAS1 and a combination of NPK and compost (30 kg/ha + 5 tons/ha respectively) produced the highest mean number of racemes (3.65) per panicle (Table 6). This was closely followed by EYAS5 at 60 kg/ha NPK which recorded 3.60 racemes per panicle. The least influencer was the interaction between accession NAAS2 and control (no fertilizer application) which recorded 2.33 mean numbers of racemes per panicle.

Table 6. Interactive effect of fertilizer and accession on number of racemes in Fonio

Fertilizer	Accession							
	EYAS5	KPAS3	NAAS2	NFAS4	OUAS1	Mean	LSD (5%)	CV (%)
Control (CT)	3.33	3.13	2.33	2.87	3.58	3.05		
NPK	3.60	3.23	3.30	3.47	3.15	3.35		
Compost (CP)	3.13	2.93	2.77	3.00	2.75	2.91	0.46	12.7
CP + NPK	3.47	3.10	3.10	3.33	3.65	3.33		

CT=control, CP= compost (10 tons/ha), NPK=60 kg/ha, NPK+ CP= 30 kg/ha + 5 tons/ha.

The statistical difference observed in racemes number with regard to fertilizer application and accession implies that the application of fertilizer enhances or increases the number of racemes formation in Fonio. This however is dependent on the genotype. Linking the number of racemes to Fonio grain yield, it is as well noticed that this is much dependent on the variety; OUAS1 which recorded the second-highest number of racemes per panicle was judged the best yielding accession in terms of total grain yield in contrast to the yield recorded by EYAS5 which recorded the highest number of racemes. Many factors like the plant stand, length, and quality of filled racemes among others which were not considered in this work might have accounted for this disparity. Ibrahim *et al.(*2020) and Hilu *et al.* (1997) also reported diversity in racemes' number and length which reverberates this result. However, it is worth acknowledging that the diversity in racemes among the accessions is a trait to consider in a breeding programme for the improvement of grain yields in Fonio since it is influenced by both genes and the environment.

Panicle number per plant

The accession and fertilizer interaction for panicle number per plant was not significant (P > 0.05), but the individual effects of accession and fertilizer were highly significant for panicle number per plant (Table 3).

Plots applied with the combination of NPK and compost (30 kg/ha + 5 tons/ha) were the most yielding in terms of the number of panicles per plant (9.10), followed by those applied with sole compost (10 tons/ha) which recorded 8.27 panicles per plant and the control (no fertilizer application) recorded least number of panicles per plant (6.60) (Table 5). Significant (P<0.001) difference was observed among accessions for the number of panicles per plant. Accession NFAS4 recorded the highest mean number of panicles per

plant (10.54), and OUAS1 recorded the least mean number of panicles per plant.

The above findings meant that panicle formation in Fonio is highly dependent on the fertility status of the soil and the genotype. However, in this study the number of panicles per plant did not significantly affect grain yield in Fonio. However, several other factors like panicle length, lodging, and unfilled panicles, significantly affected grain yield among accessions studied as reported by Ibrahim *et al.* (2020).

Grain yield

The impact of fertilizer application and the interaction of fertilizer and accession on total grain yield was not significant (P > 0.05). On the other hand, accessions showed a significant (P< 0.05) difference in Fonio's total grain yield (Table 3). The grand mean for the five Fonio accessions was 850.83 kg/ha. OUAS1 recorded the highest grain yield (1015.10 kg/ha) while NFAS4 recorded the least grain yield of 713.23 kg /ha (Table 5).

This observation is indifferent to the finding of Priyadarshani *et al*. (2000) and Moralespayan (2002) which in both cases did not establish any significant impact of organic and inorganic (NPK) fertilizers on grain yield in Fonio. These observations are evident that the five Fonio accessions varied for grain yield. This finding proposes that the accession, as well as the husbandry practices (row planting, spacing between rows and plots, and weeding), were effective in increasing Fonio grain yield. Grain yields in general for all treatments oscillated between 713 kg/ha to 1015 kg/ha. This conforms with the finding of Cruz (2004) in which he indicated that Fonio regional average yield hovers around 0.600 tons/ha and 0.9 tons/ha and peaking at 1.50 tons/ha.

Lodging phenomenon

Fertilizer application showed a significant (P<0.05) influence on lodging tendency in Fonio (Tabe 3). Fonio accessions were also statistically diverse (P < 0.05) for lodging. Plots applied with NPK were the treatments that recorded the highest lodging in Fonio with a mean score value of 4.07 contributing to about 40% to 60% of lodging (Table 5). Plots applied with sole compost at 10 tons/ha and those applied with a combination of compost at 5 tons/ha and NPK at 30 kg/ha both caused moderate lodging in Fonio contributing about 30% to 38% lodging in Fonio and the control plots were the least lodged. Acession OUAS1 was the most lodged plants and recorded a score of 4.75 for lodging, representing about 65% of its total plant population. Two accessions (NFAS4 and EYAS5) scored the least lodging means of 2.75 and 2.88 respectively, representing about 10% of its total plant population each.

The interaction influence of fertilizer and accession was statistically significant (P<0.05) (Table 3). The interaction between OUSA1 and all the levels of fertilizer except the control caused the highest lodging in Fonio (Table 7), registering above 70% lodging followed by the interaction between NPK (60kg/ha) and NAAS2 which registered about 65% lodging. The interaction between the EYAS5 and control as well as NFAS4 and control caused the least lodging in Fonio.

Table 7. Interaction effect of Fonio accession and fertilizer treatment on lodging.

Fertilizer	Accession EYAS5	KPAS3	NAAS2	NFAS4	OUAS1	Mean	LSD (5%)	CV (%)
Control (CT)	2.00	3.00	3.00	2.00	4.00	2.80		
NPK	3.50	4.17	4.67	3.00	5.00	4.07		
Compost (CP)	3.00	4.00	4.00	3.00	5.00	3.80	0.28	6.60
CP plus NPK	3.00	4.00	4.50	3.00	5.00	3.90		

CT=control, CP= compost (10 tons/ha), NPK=60 kg/ha, NPK+ CP= 30 kg/ha + 5 tons/ha.

It is worth mentioning that fertilizer application in Foino has the potential to increase lodging up to about 60% rather than grain yield as the crop turns to lodge more on fertile soil. It was also detected that late-maturing accessions were less affected by lodging compared to the early accessions. These findings consolidate the report of Ibrahim *et al*. (2020) and Vodouhè *et al*. (2004) who indicated that lodging is a major setback in Fonio production as a result of its tender shoot which easily lodges leading to loss of grains and making it tedious to harvest.

CONCLUSIONS AND RECOMMENDATION

Conclusions

1. The response of all the accessions to compost and inorganic fertilizer applications was significantly. For instance, plant height, leaf area, number of panicles per plant, number of tillers per plant, number of racemes per panicle, lodging, and peduncle length were significantly affected by fertilizer application. However, fertilizer application did not significantly affect Fonio grain yields.
2. There were significant (P<0.05) variations among the five Fonio accessions for most of the morphological traits studied. For example, plant height, leaf area, number of leaves per plant, number of panicles per plant, number of tillers per plant, number of racemes per panicle, lodging, grain yield, and 1000-grain weight all exhibited significant differences among the accessions.

3. Accession by fertilizer interaction effect was statistically significant for the number of racemes per panicle and lodging in Fonio.

Recommendations

1. Row planting rather than broadcasting in Fonio production should be encouraged for the following reasons:
   - It allowed easy management and control of weeds.
   - It was effective in increasing grain yield in Fonio.
2. The results of this study revealed that fertilizer application in Fonio production does significantly increase lodging rather than yield and therefore should only be considered in extremely poorer soils.

SIGNIFICANT STATEMENT

Fonio is nutritionally important, and therefore plays an important role in food security in Africa. The crop also has high level of genetic and morphological variabilities among existing accessions. Therefore, there is the need to improve upon Fonio production. Scientists from the Universities and research institutions, through collaborative research, ought to improve upon the crop from all its production zones; targeting the following traits: higher number of racemes per plant, higher spikelet number per panicle, effective number of panicles per plant, larger seed size and resistance to lodging.

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DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest

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