FUDMA Journal of Sciences (FJS)
ISSN Online: 2616-1370
ISSN Print: 2645-2944
Vol. 2 No.3, September, 2018, pp 105 - 111

PRODUCTIVITY OF SORGHUM (*Sorghum bicolor* L.) UNDER INCORPORATED LEGUMES AND NITROGEN FERTILIZATION IN SEMI-ARID ENVIRONMENT

[*1]Adesoji, A. G., [2]Ogunwole, J. O. and [3]Ojoko, E. A.

[1]Department of Crop Production and Protection, Federal University, Dutsin-Ma, Katsina State, Nigeria.
[2]Department of Soil Science & Land Resource Management, Federal University, Oye-Ekiti, Ekiti State, Nigeria
[3]Department of Agricultural Economics and Extension, Federal University, Dutsin-Ma, Katsina State, Nigeria.

*Corresponding Author E-mail: aadesoji@fudutsinma.edu.ng

ABSTRACT

Sustainable crop production can be achieved in a cropping system that facilitates a renewable source of nutrients for sustainable soil fertility and productivity. The study was carried to evaluate the influence of incorporated legumes and nitrogen application on productivity of sorghum (*Sorghum bicolor* L.). Field experiments were carried out in the wet seasons of 2015 and 2016 at the Research Farm of Federal University Dutsin-Ma, Nigeria. The treatments consisted of four levels of N (0, 30, 60 and 90kg N ha -1), and four legumes (Lablab (*Lablab purpureus*), Mucuna (*Mucuna pruriens*), Soybean (*Glycine max* L. Merrill), and Cowpea (*Vigna unguiculata* L.)) and no legume. SAMSORG 40 variety was used in this experiment. The experiment was laid out in a randomized complete block design and replicated three times. Nitrogen application significantly ($P<0.05$) increased yield components and grain yield of sorghum. In combined mean, application of 30, 60 and 90kg N ha^{-1} gave 32.3, 89.2 and 75.5% increases in sorghum grain yield over zero N treatment, respectively. Increasing N rate beyond 60 kg N ha^{-1} did not significantly increased sorghum grain yield. Application of 60kg N ha^{-1} was adequate for sorghum productivity in the study area. Incorporation of lablab, mucuna, soybean and cowpea significantly ($P<0.05$) influenced yield components and grain yield of sorghum. In combined mean, incorporation of lablab, mucuna, soybean and cowpea gave 17.9, 2.1, 25.7 and 21.7% increases in sorghum grain yield over no legume treatment, respectively. Incorporated soybean produced significantly higher sorghum grain yield than no legume control.

Keywords: Incorporation, Legume, Nitrogen, Sorghum, grain yield.

INTRODUCTION

Sorghum is one of the dominant cereals in Sudan and Guinea savanna zones of Nigeria. These zones are characterized with more favourable production conditions which include solar radiation intensity, lower night temperature and low incidence of diseases and pests (Kassam *et al*., 1975). Despite these potentials, average yield per hectare in 2016 is 11931 hectograms per hectare (1193.1kg ha^{-1}) (FAO, 2018) which is still relatively low. This may be attributed to poor soil fertility, low or no inorganic fertilizer input leading to soil mining, no organic input, grown on marginal soils and use of local varieties with poor yield potentials. It has been observed that farmers in this area apply little or no fertilizer to sorghum. Hence, low yield and soil nutrient mining become apparent in this production area. Soil degradation is a militating factor in Nigerian agricultural systems because most farmers add little fertilizers and the crops in turn absorb much from the soil 'reservoir' without commensurate effort to revitalise the soil (Adesoji *et al*., 2011). However, the bane of low yield is as a result of low or no fertilizer input either as inorganic or organic source. For best to come of mineral fertilizers, it must be used judiciously with accurate rate. The use of mineral fertilizers is the quickest and surest way of boosting crop production, their cost and other constraints frequently deter farmers from using them in recommended quantities and in balanced proportions (Roy, 1995). The use of inorganic fertilizers to alleviate the problems of low soil fertility for successful crop production in the Savanna region is limited by high costs and unreliable availability of inorganic fertilizers, even the few farmers who use fertilizers cannot afford the recommended rates (Loks *et al*., 2016). Therefore, technologies must be put in place to restore soil fertility, to reduce erosion and environmental degradation in order to increase food production and mitigate chronic hunger in the zone (Vagen *et al*., 2005). Hence, green manure, which is a cheap and renewable generator of plant nutrients, can serve as a good alternative to reduce afore mentioned challenges.

On the other hand, organic manures have been reported to be cheap and could serve as substitute for chemical fertilizers (Delate and Camberdella, 2004). Legumes have ability to biologically fix nitrogen through rhizobia bacteria in the nodules to the soil and when they are incorporated, they decompose and mineralize to generate organic matter which is the main factor in the sustainability of soil fertility and productivity and release nitrogen and other nutrients into soil. The green manure has an advantage over other organic manures in that it can be grown directly in the field and can be incorporated during land preparation or regular weeding operation (Ventura and Watanabe, 1993). Unlike synthetic N fertilizers, legumes utilized as green manure represent a potentially renewable source of on-farm, biologically fixed nitrogen and may also fix and add large amount of carbon to the cropping systems (Hargrove, 1986; Sharma and Miltra, 1988). Green manure has been reported to increase soil organic matter, available nitrogen, concentration of nutrients near the soil surface in available form and reduces the N loses through leaching and soil erosion (Sultani *et al*., 2007). In the light of the above, it is therefore important to adopt a legume based cropping system that is a renewable source of nutrients and environmentally friendly, and has capacity to reduce the reliance on inorganic fertilizers for sorghum production. Therefore, this study was designed to assess the influence of incorporated legumes and nitrogen fertilization on yield and yield components of sorghum.

MATERIALS AND METHODS

Experimental Site and Soil Characteristics

The research was conducted in the wet seasons of 2015 and 2016 at the Research Farm of Federal University Dutsin-Ma, at Badole (Longitude 07^{0}29'29" E and Latitude 12^{0}27'18" N) with altitude of 605 m in the Sudan savanna ecological zone of Nigeria. The annual rainfall for the duration of the study was 582 and 684.9mmfor 2015 and 2016, respectively. The physico-chemical parameters of the top soil (0-30cm depth) of the experiment site was collected before planting in 2015 as determined by standard procedures is presented in Table 1

Treatments and Experimental Design

The treatments consisted of four levels of N (0, 30, 60 and 90kg N ha $^{-1}$), and four legumes (Lablab (*Lablab purpureus*), Mucuna (*Mucuna pruriens*), Soybean (*Glycine max* L. Merrill), and Cowpea (*Vigna unguiculata* L.)) and no legume. SAMSORG 40 variety was used in this experiment. This is an early maturing variety (75-80days) adaptable to Sudan and Sahel savanna zones of Nigeria. The experiment was laid out in a randomized complete block design with factorial combinations of nitrogen levels and various legumes (Treatments consisted of a 5x4 factorial arrangement in a randomized complete block design). The experiment was replicated three times.

Table 1: Physico-chemical characteristics of soil experimental site during rainy season of 2015

Soil Characteristics	Value
Particle size (g/kg)	
Clay	62
Silt	74
Sand	864
Textural class	Loamy Sand
Chemical property	
pH (0.01MCacl$_2$; 1:2.5w/v)	4.65
pH in H_2O	4.76
Organic carbon (g kg^{-1})	2.7
Total nitrogen (g kg^{-1})	0.4
Available phosphorus(mg kg^{-1})	6.14
Exchangeable base (cmol kg^{-1})	
Ca	4.84
Mg	1.17
K	0.26
Na	0.62
CEC	7.54

Crop Management Practices

The study was conducted on the same field and the plots were maintained throughout the two years of the experiment. The experimental field was harrowed and ridged at 75cm apart. Sorghum seeds, 5-7 seeds per hole were sowed at a spacing of 50 cm on the ridges of 75 cm spacing. After two weeks of sowing, the sorghum seedlings were thinned to two seedlings per stand. The legumes were planted sorghum seedlings was thinned to two seedlings per stand at two weeks after sowing. The legumes were planted simultaneously with sorghum at a space of 16.7cm from the sorghum stands for lablab, mucuna and cowpea while soybean was planted drilled in between the sorghum stands. The legumes were incorporated at seven weeks after sowing during earthen-up cultural practice. The experimental plot consisted of four (4) ridges of 3m apart and 5m long (gross plot) and net plot was 5m x 1.5m (7.5m^2). Application of nitrogen fertilizer as urea (46%N) to the sorghum plants was done at 2 and 6 weeks after sowing (WAS) according to the treatment. Basal applications of 30 kg of P_2O_5, and 30 kg of K_2O were done at sowing. Weeding was done at 3, 6 and 9WAS using hoe.

Data Collection

The observations recorded during the course of study were panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g), panicle yield (kg ha^{-1}) and grain yield (kg ha^{-1}). Length of panicles from the five tagged plants in each plot was measured with ruler from the tip of the panicle to its base and the average was recorded. Panicle diameter of five randomly selected panicles from the net plot was determined and the average was recorded. One thousand grains were counted from each net plot and weighed with Mettler-P 1210 weighing balance. The weight was recorded as 1000-grain weight. Grain weight per panicle of five randomly selected panicles from the net plot was determined and the average was recorded. Panicles of sorghum from each net plot were removed, sun-dried and weighed. The mean weight was recorded and panicle yield per hectare was calculated. The grain yield was determined at harvest. The harvested panicles from the net plots were sun-dried, shelled, winnowed and the clean grains weighed. The total weight per plot was expressed in kilogram per hectare and recorded.

Statistical Analysis
Data obtained were subjected to statistical analysis of variance (ANOVA) to test for significance of difference among means as described by Gomez and Gomez (1984) using SAS package version 9.0 of statistical analysis (SAS, 2002) and the differences among treatment means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1955) at 5% level of probability.

RESULTS

Panicle Diameter
Legume incorporation significantly (P<0.05) influenced panicle diameter in 2016 and combined (Table 2). Incorporation of mucuna significantly reduced panicle diameter in both 2016 and combined while there was no significant difference between no legume incorporation and legume incorporation. In combined means, incorporation of lablab, soybean and cowpea increased panicle diameter of sorghum by 2.4, 2.4 and 4.8% over no legume incorporation, respectively. Nitrogen fertilization significantly (P<0.05) increased panicle diameter in 2015 and combined (Table 2). Application of 60kg N ha^{-1} produced significantly higher panicle diameter than the control. In combined means, application of 60 and 90 kg N ha^{-1} increased sorghum panicle diameter by 7.3 and 9.8% over zero N control, respectively.

Panicle Length
Legume incorporation was significant only on combined (Table 2). Incorporation of cowpea significantly (P<0.05) increased panicle length while there was no significant difference between no legume incorporation and other incorporated legumes on panicle length. In combined means, incorporation of lablab, mucuna, soybean and cowpea increased panicle length by 4.7, 2.0, 2.0 and 5.1% over no legume incorporation, respectively. Nitrogen application significantly (P<0.05) increased panicle length in 2015 and combined (Table 2). Application of 60kg N ha^{-1} produced significantly longest panicle which was at par with application of 90 kg N ha^{-1}. In combined means, application of 30, 60 and 90 kg N ha^{-1} increased length of sorghum panicle by 2.0, 5.9 and 4.7% when compared with no zero N, respectively.

Table 2: Influence of incorporated legumes and nitrogen on panicle diameter and panicle length of sorghum in 2015, 2016 and combined.

	Panicle diameter (cm)			**Panicle length (cm)**		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	3.8	4.6ab	4.2ab	24.3	26.6	25.5b
Lablab	4.0	4.6ab	4.3ab	25.8	27.6	26.7ab
Mucuna	3.9	4.2b	4.1b	25.4	26.6	26.0ab
Soybean	3.7	4.8a	4.3ab	24.6	27.4	26.0ab
Cowpea	4.0	4.7a	4.5a	26.1	27.5	26.8a
SE±	0.12	0.16	0.09	0.61	0.4	0.39
Nitrogen(N) Kg ha^{-1}						
0	3.6c	4.6	4.1b	23.7c	27.0	25.4c
30	3.7bc	4.5	4.1b	24.8bc	26.9	25.9bc
60	4.0ab	4.8	4.4a	26.4a	27.4	26.9a
90	4.2a	4.8	4.5a	26.1ab	27.2	26.6ab
SE±	0.11	0.11	0.08	0.54	0.36	0.35

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

1000 Seed Weight
Incorporation of legumes showed a significant (P<0.05) effect on 1000 seed weight in 2015, 2016 and combined (Table 3). Incorporation of mucuna, soybean and cowpea produced significantly heaviest seeds but at par with incorporation of lablab. In combined means, incorporation of lablab, mucuna, soybean and cowpea increased 1000 seed weight by 2.3, 8.8, 7.4 and 7.9% over no legume incorporation, respectively. 1000 seed weight was significantly (P<0.05) increased by application of 60kg N ha^{-1} in both years of study and combined but statistically similar with application of 90kg N ha^{-1} (Table 3). In combined means, application of 30, 60 and 90 kg N ha^{-1} increased 1000 seed weight by 2.3, 10.2 and 10.2% over no zero nitrogen, respectively.

Grain Weight per Panicle
Incorporation of lablab and soybean significantly (P<0.05) increased grain weight per panicle but statistically similar with incorporation of mucuna and cowpea in 2016 and combined (Table 3). In combined means, incorporation of lablab, mucuna, soybean and cowpea increased grain weight per panicle by 22.5, 10.5, 18.1 and 13.4% when compared with no legume incorporation, respectively. Increasing nitrogen rate from 0kg N ha^{-1} to 30kg N ha^{-1} did not significantly increase grain weight per panicle but a further increase of nitrogen rate

to 60kg N ha^{-1} significantly (P<0.05) increased grain weight per panicle and a further increase of nitrogen rate to 90kg N ha^{-1} produced no significant difference (Table 3). In combined means, application of 30, 60 and 90 kg N ha^{-1} increased grain weight per panicle by 1.8, 31.9 and 23.4% over no zero nitrogen, respectively.

Table 3: Influence of incorporated legumes and nitrogen on 1000 seed weight and grain weight per panicle of sorghum in 2015, 2016 and combined.

	1000 seed weight (g)			**Grain weight panicle^{-1}(g)**		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	22.4b	20.7b	21.6b	25.3	30.0b	27.6b
Lablab	22.7b	21.5ab	22.1ab	30.0	37.2a	33.8a
Mucuna	25.5a	21.5ab	23.5a	24.5	35.6ab	30.5ab
Soybean	24.2ab	22.3a	23.2a	25.1	37.9a	32.6a
Cowpea	25.2a	21.1b	23.3a	27.1	35.6ab	31.3ab
SE±	0.80	0.36	0.48	1.96	1.91	1.5
Nitrogen(N) Kg ha^{-1}						
0	21.9b	21.1b	21.5b	23.2b	31.3c	27.3b
30	22.9b	21.2b	22.0b	22.3b	33.4bc	27.8b
60	25.2a	22.2a	23.7a	29.6a	42.4a	36.0a
90	26.0a	21.4ab	23.7a	30.5a	36.8b	33.7a
SE±	0.71	0.29	0.43	1.75	1.54	1.34

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Panicle Yield

Legume incorporation was significant only on panicle yield in 2016 (Table 4). Incorporation of soybean produced significantly (P<0.05) higher panicle yield of sorghum than no legume incorporation and incorporation of mucuna but at par with incorporation of other legumes. Increasing nitrogen rate from 0kg N ha^{-1} to 30kg N ha^{-1} did not significantly increase panicle yield per hectare but a further increase of nitrogen rate to 60kg N ha^{-1} significantly (P<0.05) increased panicle yield and a further increase of nitrogen rate to 90kg N ha^{-1} produced no significant difference on panicle yield in 2015 and combined (Table 3). In combined means, application of 30, 60 and 90 kg N ha^{-1} increased panicle yield per hectare by 23.4, 97.4 and 71.3% over no zero nitrogen, respectively.

Grain Yield

Incorporation of soybean significantly (P<0.05) increased grain yield per hectare of sorghum but statistically similar with no legume incorporation and mucuna incorporation in 2016, and no legume incorporation in combined (Table 4). In combined means, incorporation of lablab, mucuna, soybean and cowpea increased grain yield per hectare by 17.9, 2.1, 25.7 and 21.7% when compared with no legume incorporation, respectively. Application of nitrogen significantly (P<0.05) increased sorghum grain yield per hectare up to 60kg N ha^{-1} in 2015 and combined (Table 4). However, a further increase of nitrogen beyond 60kg N ha^{-1} did not significantly increase grain yield per hectare. In combined means, application of 30, 60 and 90 kg N ha^{-1} increased grain yield of sorghum per hectare by 32.3, 89.2 and 75.5% when compare with no zero nitrogen, respectively.

Table 4: Influence of incorporated legumes and nitrogen on panicle yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of sorghum in 2015, 2016 and combined.

	Panicle yield (kg ha^{-1})			**Grain yield(kg ha^{-1})**		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	1240	491b	873	1099	503c	801b
Lablab	1457	670ab	1122	1124	754ab	944ab
Mucuna	1332	505b	948	1025	611bc	818ab
Soybean	1396	749a	1132	1189	785a	1007a
Cowpea	1477	664ab	1107	1243	644abc	975ab
SE±	103.8	65.3	82.3	74.8	48.2	52.1
Nitrogen(N) Kg ha^{-1}						
0	692c	707b	700b	564c	654	609c
30	1069b	660bc	864b	969b	643	806b
60	1931a	832a	1382a	1544a	759	1152a
90	1829a	570c	1199a	1466a	671	1069a
SE±	92.8	39.1	74.5	66.9	40.1	55.5

Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

DISCUSSION

Response of Sorghum Yield and Yield Components to Incorporated Legumes

Sorghum plants in plots that received incorporated legumes produced bigger panicle diameter (cm), longer panicle length (cm), heavier 1000-seed weight (g), higher grain weight per panicle (g) and larger panicle yield (kg ha^{-1}) compared with sorghum plants in plots without legume incorporation. This could be attributed the ability of legumes to biologically fix nitrogen into the soil and when buried into soil, generate organic manure, nitrogen and other nutrients from decomposition and subsequent mineralization of the incorporated legumes. Seo *et al*. (2000) observed that green manure is an environmental friendly agricultural technology which could provide better conditions of soil by improving the physical properties, fertilization of soil and micro flora of soil. The better performance observed on sorghum yield attributes as a result of legumes incorporation could be equally attributed to the capacity of incorporated legumes to maintain and renew the soil organic matter and improve the soil physical and chemical characteristics (Tiwari *et al*., 1980), increase soil nitrogen (Pushpavalli *et al*., 1994) and release P (Singh *et al.*, 1992; Palm *et al.*, 1999). Shuaibu *et al.* (2015) reported that there was a significant difference on 1000 seed weight of sorghum after legume residues treatment which was attributed to the increase in soil fertility through nitrogen fixed and addition of organic matter by the legumes.

The higher increase in grain yield of sorghum in incorporated legumes treated plots over the control plots could be attributed to the capacity of incorporated legumes to generate organic matter and Adesoji (2015) reported that organic matter is a best friend of soil and a promoter of good soil behaviour and environment-friendly for remarkable crop yield. This increase in grain yield in legume treated plots could also be attributed to the decomposition and subsequent mineralization of incorporated legumes for generation of N, P, K and other embedded nutrients in the buried legumes. The better grain yield could also be attributed to the better performance observed in panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g) and panicle yield (kg ha^{-1}) of sorghum in plots that received incorporated legumes. This is in line with Shuaibu *et al*. (2015) who reported grain yield increase following soybean and cowpea residues and attributed this to significance of legume in nitrogen fixation and in improving the physico-chemical properties of the soil. The better performance observed on soybean incorporation at earthen-up operation in this experiment could have been that soybean fixed higher N than other legumes and better dry matter accumulation for enhanced mineralized N than other legumes. Usman *et al*. (2013) reported that the main effect of legumes incorporation on sorghum grain yield showed that, higher yield of sorghum could be produced from incorporating cowpea varieties than other legumes. This was attributed to the fact that these legumes were sown 3 weeks after the cowpeas and might not have exhibited their full potential for N-fixation.

Response of Sorghum Yield and Yield Components to Nitrogen Fertilization

The significant increases exhibited in panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g) and panicle yield (kg ha^{-1}) of sorghum after nitrogen fertilization could be explained on the important role nitrogen plays in enhancing formation and production of chlorophyll for enhanced photosynthetic ability which could have improved the production of photosynthates in sorghum leaves for subsequent translocation to sorghum grains. Application of 60kg N ha^{-1} gave the highest response on these yield attributes. The better performance exhibited by nitrogen application on sorghum yield components could be attributed to the fact that nitrogen is the most critical element of plant growth and plays a major role in many metabolic and physiological functions in plants (Balasubramaniyan and Palaniappan, 2001). Gebremariam and Assefa (2015) reported that application of N-fertilizer significantly increased panicle length, yield per panicle, 1000 grain weight, stover yield and harvest index over the control and affirmed that application of 150kg N ha^{-1} produced the highest response of these parameters. Similarly, Moosavi *et al*. (2013) reported that N fertilization levels significantly influenced grain number per panicle, 1000 grain weight, biological yield, grain harvest index and grain harvest index per panicle.

The significant higher grain yield of sorghum obtained after nitrogen fertilization could be that increase in nitrogen fertilization positively enhanced the photosynthetic activities of sorghum which could have led to higher assimilate production and subsequent translocation to the grains for adequate filling and production in sorghum plants in plots that received nitrogen than plants in the zero N control plots. The significant increase in grain yield of sorghum plants in N-treated plots could be attributed to the favourable effect of nitrogen application on panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g) and panicle yield (kg ha^{-1}). Application of 60 kg N ha^{-1} and 90 kg N ha^{-1} were similar in their effects on sorghum grain yield. This result showed that increasing N rate beyond 60kg N ha^{-1} did not result in corresponding sorghum grain yield increase that would merit the extra cost incurred for the additional 30 kg N ha^{-1}. Fertilization of sorghum with 60kg N ha^{-1} gave most favourable response on sorghum grain yield. Similarly, Buah and Mwinkaara (2009) reported that increasing N level from 40 to 80 or 120 kg N ha^{-1} did not result in corresponding increase in sorghum grain yield and concluded that application of 40 kg N ha^{-1} was adequate for sorghum production in the zone. This resulted in improved rooting depth, leaf area expansion, nutrient availability and uptake as well as increased N use efficiency, which optimized grain yield and net benefits. Moosavi *et al*. (2013) reported that increase in sorghum grain yield caused by the increase in N fertilization level is attributed to the generation of strong sinks, i.e. more number grains, and the activity of source i.e. higher leaf area index and duration. Application of 23, 41, 64 and 87 kg ha^{-1} N was found by Melaku *et al*.(2018) to give a sorghum yield increase of 40, 53, 62 and 69% over the control (0 kg N ha^{-1}), respectively.

CONCLUSION

Better productivity of a crop is guaranteed when plant nutrients either organic or inorganic are added appropriately at a rate that ensures optimum performance of the crop for higher yield. Based on the results obtained from this study, it can be concluded that application of nitrogen significantly increased panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g), panicle yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of sorghum. Application of 60kg N ha^{-1} seems to be adequate to meet the N requirements of sorghum in the study area. Incorporation of lablab, mucuna, soybean and cowpea significantly influenced increased panicle diameter (cm), panicle length (cm), 1000-seed weight (g), grain weight per panicle (g), panicle yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of sorghum. Incorporated soybean although at par with other incorporated legumes produced significantly higher sorghum grain yield than no legume control.

ACKNOWLEDGEMENT
The researchers wish to acknowledge the award of institutional research grant by Tertiary Education Trust Fund (TETFund) in conjunction with the Management of Federal University Dutsin-Ma, Nigeria, to carry out this research.

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