Growth and yield of maize as affected by fertilizer types in the Southern Guinea Savannah, Nigeria

Afe, A.I.[1*], Fasakin, K.[1], Ogunbosoye, D.O.[2] & Kolade, U.[1]

[1]Department of Crop Production, Kwara State University, Malete, Nigeria
[2]Department of Animal Production, Kwara State University, Malete, Nigeria
*Corresponding author: adeafe22@yahoo.com

Abstract

A field trial was carried out at the Teaching and Research Farm, Kwara State University, Malete, in the 2017 cropping season to investigate the growth and yield of maize as affected by fertilizer types. The five fertilizers tested were four organic-based fertilizers (KOBF-1, KOBF-2, Aleshinloye Grade A, and poultry manure), inorganic NPK fertilizer, and the control without soil amendment. The fertilizers, except poultry manure, were applied at the rates of 100 kgN/ha and the treatments arranged in a Randomized Complete Block Design (RCBD) with three replicates. Application of poultry manure, which was applied at 10 t/ha, was found to be superior compared to all other treatments in all the parameters measured. The three formulated organic-based fertilizers were Aleshinloye Grade A (a commercially available fertilizer formulated with household wastes and cow dung), KOBF-1 and KOBF-2 (Kwara Organic-Based Fertilizers in development by Kwara State University and formulated with poultry manure and tithonia plants). Aleshinloye Grade A produced inferior growth and yield and yield components of maize compared to the other organic-based fertilizers. The control took a significantly longer number of days to tasseling and silking (62 and 68 days, respectively) compared to the other treatments. The results indicated that, in terms of overall grain yield in kg/ha, poultry manure produced the highest yield (4,633 kg/ha), followed by the inorganic fertilizer (4,096 kg/ha), then KOBF-1 and KOBF-2 with similar values (3,163 and 2,923 kg/ha, respectively), followed by Aleshinloye Grade A (2,160.00 kg/ha). The control treatment gave the least grain yield (1,148.20 kg/ha). The organic fertilizers tested all proved to be effective in raising yields. Organic fertilisers have known ecological and environmental benefits and are recommended for inclusion in the development of national fertilizer programmes for sustainable crop production.

Keywords: Organic-based fertilizer, inorganic fertilizer, poultry manure, tithonia, corn, grain yield, Africa.

Introduction

Maize (Zea mays L.) is an important cereal crop in tropical and sub-tropical agro-ecological zones, particularly in West Africa. It is the preferred staple food for about 50% of the sub–Sahara Africa population including 120 - 140 million farm families and children (IITA, 2009; CIMMYT-IITA, 2010). As a versatile crop, it is cultivated in virtually all the

agro-ecological zones of Nigeria as a commercial crop, and to meet staple food demands and the supply of raw materials for agro-allied industries (IITA, 2009; Iken & Amusa, 2004).

Nigeria, like other countries having a tropical climate, is characterized by high rainfall and insolation with the attendant problems of nutrient leaching and a low level of organic matter in the soil, both of which limit maize production (Azeez et al., 2006). Soil fertility depletion is a constraint on food security in Africa. The poor nutrient status of most soils in Nigeria necessitates the use of fertilizers for improved crop yield. Unfortunately, the use of inorganic fertilizer is gradually becoming problematic due to its rising cost and its adverse effects such as increase in soil acidity, reduction of soil organic matter, degradation of soil physical properties, and an increased rate of soil erosion due to instability of soil aggregates (Avery, 1995; Palm & Sanchez, 1991). Organic manures are a cheaper source of plant nutrients in maize production and the use of organic manures increases the nutrient density of maize (Naikwade, 2014). In view of such issues, the use of fertilizer that is organic-based has been advocated in recent times.

Organic-based fertilizers are obtained from plant and animal residues. Studies carried out on these fertilizers have shown their potential in crop growth as well as in the sound management of tropical soils (Olowoake, 2014). Olowoake & Adeoye (2010) have observed that several types of organic materials and residues in Nigeria can be processed, packaged and made available as organic-based fertilizers at a relatively cheaper rate compared to synthetic fertilizers for sustainable crop production. Among several organic-based fertilizers available in the market, Sunshine Grades A and B and Aleshinloye Grade A have been evaluated and found to promote crop growth and yield. To expand the range of available organic-based fertilizers in Nigeria, poultry manure and the aerial part of tithonia (Tithonia diversifolia L.) plant were combined with available organic residues, in two formulations, and called Kwara State University (Kwasu) Organic-based Fertilizers (KOBF-1 & KOBF-2).

The choice of tithonia is based on reported effects of tithonia alone on growth and yield of crops (Achieng et al., 2000; Jama et al., 2000). The studies recognized tithonia as a weed having vigorous growth habits and with the potential of raising the status of major elements in nutrient-depleted soils, and hence it could be considered an affordable component in formulating organic-based fertilizers. Earlier studies on existing organic-based fertilizers have shown their potential in boosting crop growth and yield in tropical soils. However, there is no available information on KOBF after its formulation; hence, research was therefore initiated to study the response of maize growth and yield as affected by KOBF in comparison with other fertilizers.

Materials & methods

Study location

The study was carried out at the Teaching and Research Farm of the Kwara State University, Malete located on Latitude 8.71^{o}N and Longitude 4.44^{o}E in the Southern Guinea Savannah agro-ecological zone of Nigeria. The climate of the study location is characterized by distinct wet and dry seasons. The wet season commences in March or April and terminates in October with a dry spell in August. The dry season starts in October and lasts till March or April. Meteorological data of the study location during the cropping season of 2017 is presented in Table 1.

Collection and analysis of soil, poultry manure and organic-based fertilizers

Sample of the soil at the experimental site was collected at a depth of 30 cm for determination of physico-chemical properties. Dried poultry manure and KOBF were taken to the laboratory for analysis. The nutrient compositions of the experimental site soil, KOBF, Aleshinloye Grade A, and poultry manure are presented in Table 2.

Table 1. Meteorological data of the study location during 2017

Relative Humidity	Relative Humidity (%)	Relative Humidity (%)	Relative Humidity (%)
January	2.2	27.06	20.96
February	0	28.54	21.78
March	33.50	30.60	25.01
April	12.73	29.15	25.08
May	8.44	27.62	24.65
June	12.32	27.03	23.83
July	4.30	29.09	23.57
August	18.74	25.01	22.65
September	20.27	25.66	22.41
October	12.73	26.85	23.24
November	0	28.05	23.14
December	14	27.79	21.75

Source: Lower Niger River Basin Development Authority, Ilorin, Hydrology Section, 2017.

Table 2. Composition of the experimental site soil, organic-based fertilizers, and poultry manure

	Experimental site soil	KOBF-1	KOBF-2	Aleshinloye Grade A	Poultry manure
Physical properties					
Sand (%)	58.69				
Silt (%)	19.31				
Textural class	Sandy loam				
Chemical properties					
pH (H_2O)	6.29	6.57	6.48		6.1
Organic carbon g/kg	1.54	3.24	3.59		5.02
Available P mg/kg	8.48	4.34	5.55	0.8	6.02
Total N g/km	1.82	8.50	4.41	1.2	1.08
Exchangeable bases					
K (mg/kg)	0.88	3.72	3.21	2.9	0.98
Na (mg/kg)	1.98	1.72	1.28		2.87
Mg (mg/kg)	1.82	2.26	1.21		1.52
Mn (mg/kg)	1.02				2.09
Zn (mg/kg)	2.87				2.98
Cu (mg/kg)	0.87				3.02
Ca (mg/kg)	2.46	10.53	8.48		3.44
Fe (mg/kg)	3.01				-

KOBF-1 = Kwasu Organic-Based Fertilizer type 1
KOBF-2 = Kwasu Organic-Based Fertilizer type 2

Treatment combinations

The treatments tested in this study were: KOBF type 1 (KOBF-1), KOBF type 2 (KOBF-2) (two organic fertilizers based on the plant tithonia, and formulated by the Kwara State University with the view to possible future commercialisation), Aleshinloye Grade A (a commercially available organic-based fertilizer produced by Oyo State Government, Nigeria), poultry manure (which is readily available to farmers), inorganic NPK fertilizer, and the control without soil amendment. The treatments were arranged in a Randomized Complete Block Design (RCBD) and replicated three times.

Cultural practices

The experimental site was ploughed and harrowed twice. Each plot size measured 4.0 m x 4.0 m with 0.5 m between plots and 1.0 m between blocks. Planting was carried out at intra- and inter-row spacings of 0.75 m and 0.50 m, respectively, with two plants per stand. Poultry manure was applied at two weeks before planting while KOBF, Aleshinloye, and NPK were applied at 3 and 6 weeks after planting (WAP). Pendimethalin [N-(ethylpropyl)-3, 4 dimethyl-2,6- dinitrobenzeneamin] mixed with atrazine (80WP) were applied at the rates of 1.5 litre and 2.0 kg/hectare, respectively, as pre-emergence herbicide immediately after planting. This was supplemented with manual hoe weeding at 5 WAP to keep the experimental site weed free. Dichlorvos (dichlorovinyl dimethyl phosphate, DDVP) insecticide was applied at four and six WAP against army worm infestation.

It should be noted that the two herbicides (atrazine and pendimethalin) and the insecticide (dichlorovos) are excluded under organic certification and their use is restricted in other jurisdictions due to health concerns; the use of atrazine has been banned in Europe for well over a decade.

Data collection and analysis

Ten tagged plants at the two innermost rows of each plot were sampled and the following data collected: plant height and number of leaves per plant at 4 and 8 WAP, leaf area and stem girth per plant at 8 WAP, days to 50% tasselling and silking, and number of cobs per plant. Cob length and circumference, number of grains per cob, weight of one thousand grains and aggregate grain yield were also taken. Data collected were subjected to analysis of variance (ANOVA) using SAS statistical package and the treatment means, where significant, were separated by means of Duncan's Multiple Range Test at 5% level of probability.

Results

Climatic elements during the period of the experiment

Rainfall, temperature and relative humidity observed during the period of the experiment were adequate for maize cultivation. Statistics obtained from the hydrology section of the Lower Niger River Basin Development Authority, Ilorin, a few kilometers from the experimental location, shows that, in 2017, rain commenced in March and lasted till October. Relative humidity ranged between 21.8% and 25.1%, and temperature, between 25.0^{o}C and 30.7^{o}C.

Analysis of soil, organic based fertilizers, and poultry manure

Table 2 shows the physical and-chemical properties of the experimental site soil and the nutrient compositions of the organic-based fertilizers (KOBF-1 & 2 and Aleshinloye) and

poultry manure used in this study. The soil was sandy loam and slightly acidic with pH in water of 6.9, low in N (1.82 mg/kg), with 8.48 mg/kg and 0.88 mg/kg for available P and exchangeable K, respectively. Analysis of the KOBF fertizers indicated the following major nutrients: KOBF-1: N (8.5 mg/kg), P (4.3 mg/kg), K (3.7 mg/kg) and KOBF-2: N (4.4 mg/kg), P (5.6 mg/kg), K (3.2 mg/kg) in addition to other vital micro-nutrients. These values are all higher than Aleshinloye Grade A (Table 2).

Growth parameters

Irrespective of fertilizer type, vegetative growth (plant height, number of leaves, leaf area, and stem girth) of maize increased with the application of soil amendments at the two sampling periods (Table 3). Among the treatments, poultry manure was superior to the others in terms of number of leaves and plant height, except number of leaves at 8 WAP. The two formulated KWASU Organic-based Fertilizers were also superior to Alesinloye fertilizer in the number of leaves and plant height at 4 and 8 WAP. In turn, KOBF-1 was superior to KOBF-2 in the growth parameters measured, except for plant height at 4 WAP. Significantly lower numbers of leaves and plant height than the other treatments tested were recorded at the control treatment (Table 3).

The applications of poultry manure and the inorganic fertilizer were superior for stem girth and leaf area per plant compared to other treatments. The lowest leaf area and stem girth were recorded at the control treatment. Days to 50% taselling and silking did not follow similar trends compared with other growth parameters. The number of days to tasselling and silking in the control were more than the other treatments. There were no significant differences in number of days taken to tassel and silk between poultry manure and inorganic fertilizer treatments (Table 3).

Table 3. Effects of fertilizer type on vegetative growth parameters and days to 50% taselling and silking of maize.

Treatments	No. of leaves plant^{-1}		Plant height plant^{-1}		Stem girth (cm)	Leaf area plant^{-1} (cm^2)	Days to 50% taselling	Days to 50% silking
	4 WAP	8 WAP	4 WAP	8 WAP	8 WAP	8 WAP		
KOBF-1	11.78c	15.34c	76.33d	149.30b	26.47c	340.0b	57.33d	63.0d
KOBF-2	11.44d	14.55d	86.34c	129.2c	23.86d	264.5c	58.0d	65.33b
Aleshinloye Grade A	10.89e	14.53d	53.17e	72.7d	21.50e	255.9d	59.33b	65.0bcd
Inorganic fertilizer (NPK)	12.67b	16.18a	87.89b	150.01b	41.48a	346.4a	56.33c	63.37d
Poultry manure	13.0a	16.0b	95.17a	160.40a	30.82b	346.5a	56.33c	63.33d
Control	10.11e	14.89e	53.17f	100.9e	16.81f	228.4e	61.67a	68.33a

Values in the same column with the same letter(s) are not significantly different at 5% probability level.
KOBF-1 = Kwasu Organic-Based Fertilizer type- 1.
KOBF-2 = Kwasu Organic-Based Fertilizer type -2.

Yield

Yield and yield parameters were significantly influenced by the fertilizer types tested. The application of 10t/ha poultry manure was found to be superior to the other treatments in yield and yield components, except for inorganic fertilizer on cob length (where there was

no significant difference) (Table 4). The longest and thickest cobs were produced with poultry manure, while inorganic fertilizer produced a similar cob length, the cob circumference was significantly lower, compared to poultry manure (Table 4). Among the three other organic-based fertilizers, KOBF-1 was superior in yield and yield components. The lowest number of grains per cob (142) and weight of one thousand grains (172.6g) were recorded for the control treatment.

Table 4 : Effects of fertilizer type on grain yield and yield components of maize.

Treatments	Cob length (cm)	Cob circumference (cm)	Number of grains cob^{-1}	Weight of 1000 grains (g)	Grain yield (kg/ha)
KOBF-1	12.29b	9.30b	253.3c	266.2b	3,163.15c
KOBF-2	11.60c	7.90d	217.95d	224.3c	2,923.33c
Aleshinloye grade A	8.08d	8.04c	218.0d	195.6d	2,160.00d
Inorganic fertilizer	14.64a	9.29b	403.0b	242.3b	4,096.23b
Poultry manure	14.62a	9.51a	455.6a	293.3a	4,633.10a
Control	5.95e	5.87e	142.0d	172.6e	1,148.20e

Values in the same column with the same letter(s) are not significantly different at 5% probability level.
KOBF-1 = Kwasu Organic-Based Fertilizer type 1.
KOBF-2 = Kwasu Organic-Based Fertilizer type 2.

The results showed that, in terms of overall grain yield in kg/ha (Table 4 and Figure 1), poultry manure produced the highest yield (4,633 kg/ha) followed in order of by the inorganic fertilizer (4,096.23), with KOBF-1 and KOBF-2 giving similar values (3,163 and 2,923 kg/ha, respectively), which were greater than Aleshinloye Grade A (2,160 kg/ha). The control treatment gave the least grain yield (1,148 kg/ha) (Table 4).

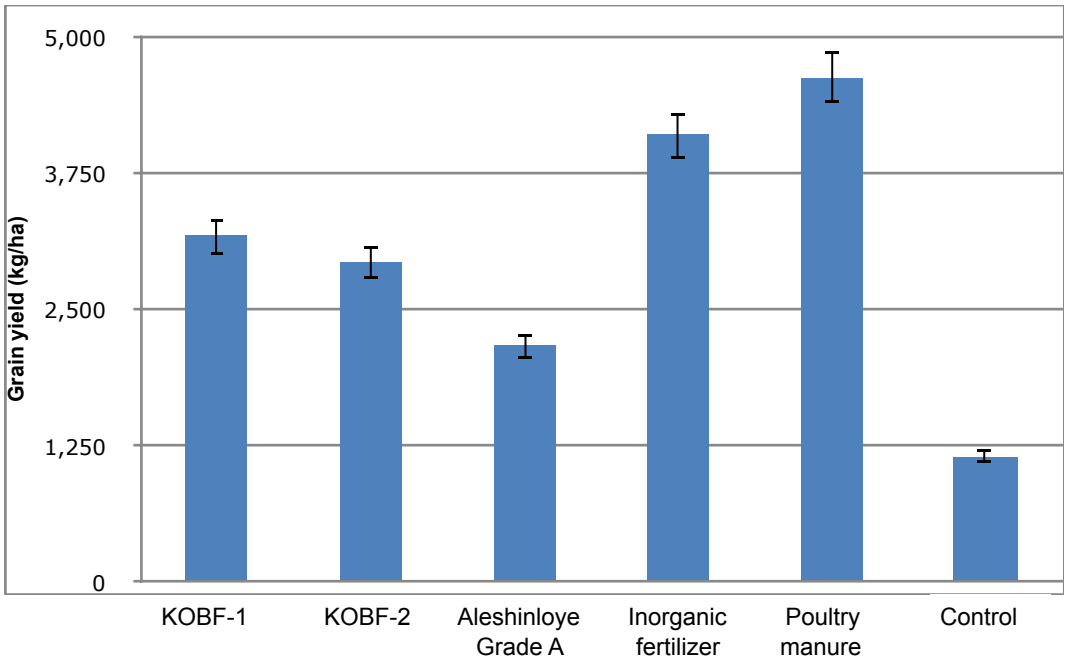

Figure 1. Maize grain yield as affected by fertilizer types.

Discussion and conclusion

The inherent low nutrient status of the experimental site suggests the need for soil amendment in order to achieve optimum crop growth and yield. The observed soil nutrient levels in the experimental site are below the recommended critical values for the Guinea Savannah ecological zone of Nigeria (Aduloju, 2004; Olowoake & Ojo, 2014). This poor nutrient status could be attributed to continuous farming in the study area. The study area has been under cultivation of various arable crops in the previous years and as expected the nutrients are lost through plant uptakes. Chhogyel et al (2015) have reported that the application of organic fertilizers leads to improved grain yields and to sustainable soil and farm productivity.

The positive response of maize growth and yield to the application of various fertilizer types as observed in this study can be attributed to adequate nutrients supplied by the applied soil amendments. Earlier studies (Garge & Bahla, 2008; Abdulmaliq et al., 2015; Afe & Oluleye, 2016) have reported the superiority of poultry manure over inorganic fertilizers on the growth and yield of crops. Poultry manure has excellent and balanced essential macro- and micro-nutrients, which are made available for plant use during their growing periods. In another study, Maheshbabu (2007) stated that manure acts as a nutrients reservoir and when decomposed the nutrients present are gradually released during the entire crop growing period, thus improving the growth and yield of the crop. Similarly, in another study, Amanullah et al (2008) recognized poultry manure as a good alternative to synthetic fertilizer. Fasina (2016) has identified the need to encourage Nigerian farmers to adopt organic fertilizers and in preference to inorganic fertilizers. Paull & Hennig (2016) have reported the under-performance of the African continent as a whole in achieving recognition for organic agriculture.

Improved growth and yield of maize with the application of organic-based fertilizer as observed in this study is consistent with reported works of Olowoake & Ojo (2014), Olowoake et al. (2016), and Olowoake & Lawal (2016), on the response of okra and grain amaranth to organic-based fertilizer. The superiority of the KOBF fertilizers over the Aleshinloye Grade A could be attributed to differences in the rate of release of nutrients by component materials used in the formulation of these organic-based fertilizers. Aleshinloye fertilizer is formulated from household wastes and cow dung whereas KOBF is formulated from poultry manure and tithonia plants. According to Abdulmaliq (2016), nutrients are released about three weeks earlier in poultry manure than in cow dung, suggesting that the rate of nutrient release from the component organic materials used in the formulation of the organic-based fertilizers tested in the current work probably differs. In another study, Masariambi et al. (2010) reported the superiority of poultry manure over cow dung in plant height and the number of leaves per plant in red lettuce (Lactuca sativa L.).

Effects of tithonia alone on growth and yield of crops have been reported (Achieng et al., 2000; Jama et al., 2000). The studies recognized tithonia as a weed having vigorous growth habits and an affordable alternative to expensive synthetic fertilizers, with the potential of raising the status of major elements in nutrient-depleted soils.

Both the organic-based fertilizers and the inorganic fertilizer (NPK) were found to enhance the growth and yield of maize. Among the fertilizer types tested, the KOBF fertilizers appreciably enhanced maize growth and yield, and therefore, are

recommended for consideration in the development of national fertilizer programmes for sustainable crop production. In the meantime, poultry manure, which is readily available to farmers, proved to be the most efficacious fertilizer for raising yields, compared to the other organic and inorganic fertilizers tested (at the application rates of the present study).

Acknowledgement

The authors wish to express their gratitude to KWASU Center for Sponsored Projects for approving TETFUND Research Grant Award with which this work was carried out.

References

Abdulmaliq, S.Y., Isah, M.K., Bello, O.B. & Ahamood, J. (2015). Effects of time of application and rate of poultry manure on the performance of Okra (Abelmoschus esculentus L.) in southern guinea Savanna ecology of Nigeria. Journal of Organic Agriculture and Environment, 3: 84-94.

Abdulmaliq, S.Y.,Isah, M.K. Loko, A. M.,Bello, O.B. & Mahamood, J. (2016). Growth and yield of Lagos spinach (Celosia argentia L.) as influenced by intra-row spacing and cowdung rates in Lapai, southern Guinea savannah of Nigeria. Journal of Organic Agriculture and Environment, 4:(1):79-88.

Achieng, J.O., Ouma, G., Odhiambo, G. & Muyekho, F. (2007). Effect of Tithonia diversifollia Chemsley as organic fertilizer on maize yield on ultisols of Western Kenya. Biennial Conference, Kenya, pp. 259 -261.

Aduloju, M.O. (2004). Acid exractable micro nutrients (Mn and Zn) in selected soils of vegetable producing areas of Kwara State, Nigeria. Nigerian Journal of Horticultural Science, 9: 116-199.

Afe, A.I. & Oluleye, F. (2017). Response of okra (Abelmuschus esculenthus L.) to combined organic and inorganic foliar fertilizers. International Journal of Recycling of Organic Wastes in Agriculture, 6(3): 189-193.

Azeez, J.O., Adetunji, M.T. & Lagoke, S.T.O. (2006). Response of low-nitrogen tolerant maize genotypes to nitrogen application in a tropical alfisol in northern Nigeria. Soil Tillage Research, 91: 181-185.

Avery, D. T. (1995). Saving the planets with pesticides and plastic: The environmental triumph of high-yield farming. Indianapolis, IN: Hudson Institute.

Chhogyel, N., Zamora, O. B., & Espiritu, B. M. (2015). Soil microbial counts and performance of lowland rice (Oryza sativa L) under two water regimes and organic soil amendments. Journal of Organics, 2(1): 33-48.

CIMMYT-IITA. (2010). Maize global alliance for improving food security and the livelihood of the resource-poor in the developing world. Draft proposal submitted by CINMYT and IITA to the CGIAR Consortium Board. El Batan, Mexico. 91pp.

Fasina, O. O. (2016). Comparative analysis of the use of organic and inorganic fertilizers by arable crop farmers in Ondo State, Nigeria. Journal of Organics, 3(1): 3-15.

Garge, S. & Bahla, G. S. (2008). Bioresources Technology, 99(13): 5773 - 5777.

IITA. (2009). International Institute of Tropical Agriculture. Research for development: Cereals and legume system. Palo Alto, CA.

Iken, J.E & Amusa, N.A. (2004). Maize research and production in Nigeria. African Journal of Biotechnology, 3(6): 302-307.

Jama, B., Palm, C.A., Buresh, R.J., Niang, A., Gachengo, C. & Nziguheba. (2000). Tithonia diversifollia as a green manure for soil fertility improvement in Western Kenya: A review. Agroforestry Systems, 49(2): 202 - 204.

Maheshbabu, H.M., Ravs, H., Biradar, N. K. & Babalad, H.B. (2007). Effect of organic manure on plant growth, seed yield and quality of soybean. Karnataka Journal of Agricultural Sciences, 21: 219 - 221.

Masariambi, M., Hlawe, M., Oseni, O. & Sibiya, T. (2010). Effects of organic fertilizer on growth, yield, quality and sensory evaluation of red lettuce (Lactuca sativa L.). Veneza Roxa, Agriculture and Biology Journal of North America, 1(6): 1319 - 1324.

Naikwade, P. V. (2014). Response of fodder maize to the application of various organic manures prepared from Ipomoea muricata weed. Journal of Organics, 1(1), 31-38.

Olowoake, A. A. & Lawal, O.I. (2016). Effect of organomineral and NPK fertilizer application on the growth and yield of grain amaranth (Amaranthus cruenthus L.). Tropical Agriculture, 93(2): 139 - 146.

Olowoake, A.A. (2014). Influence of organic, mineral and organomineral fertilizers on growth, yield and soil properties in grain amaranth (Amaranthus cruenthus L.). Journal of Organics, 1 (1): 39 - 47.

Olowoake, A. A. & Ojo, J.A. (2014). Effect of fertilizer types on the growth and yield of Amaranthus caudatus in Ilorin, Southern Guinea Savanna Zone of Nigeria. Advances in Agriculture, ID 947062:1-5.

Palm, C. A. & Sanchez, P. A. (1991). Nitrogen release from the leaves of some tropical legumes as affected by their lignin and poly-phenolic contents. Soil Biology and Biochemistry, 23(1): 83 - 88.

Paull, J., & Hennig, B. (2016). Atlas of Organics: Four maps of the world of organic agriculture. Journal of Organics, 3(1): 25-32.