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SUSTAINABLE OKRA (*ABELMOSCHUS ESCULENTUS* L.) PRODUCTIVITY AS INFLUENCED BY FORTIFICATION OF GOAT MANURE WITH RICE HUSK ASH IN NORTHERN GUINEA SAVANNA ECOLOGY OF NIGERIA

Emmanuel Abraham SHITTU[1*], Moses Samuel BASSEY[2]

[1] Department of Agronomy, Bayero University Kano, PMB 3011, Kano State – Nigeria.
[2] National Cereals Research Institute, Badegi, P.M.B. 8, Niger State – Nigeria.
[*] Corresponding author. Email: seabraham.agr@buk.edu.ng. ORCID: 0000-0003-0639-009X

Abstract: To assess the agronomic effects of sustainable okra production as impacted by goat manure (GM) and rice husk ash (RHA) on a community-based demonstration farm in Gombe State, field trials were carried out during the wet seasons of 2017 and 2018. The trails consisted of four levels of GM and RHA, each measuring 0.0, 5.0, 7.5, and 10.0 t ha^{-1} which were used on Kwadon's local cultivar of okra in a Randomized complete block design (RCBD) replicated four times. Findings revealed that days to 50% emergence and establishment count were not significantly ($P>0.05$) influenced by the application of GM and RHA, regardless of rates of application. Other growth-related indices were significantly ($P<0.05$) higher due to GM, such as plant height at 4, 5, and 6 WAS, number of leaves plant^{-1} at 4 WAS, and pod diameter. On the other hand, RHA significantly ($P<0.05$) increased plant height, the number of leaves plant^{-1} at 5 and 6 WAS, leaf area, shortened days to 50% flowering, and the number of pods plant^{-1} across the sampling periods and seasons. Similar to this, due to adequate mineralization of organic material through time and space, fresh okra's marketable weight increased in the 2018 season compared to the previous year. Thus, the application of 10.0 t ha^{-1} of both GM and RHA can be adopted in the production of okra in the study area to reduce greenhouse gas emissions resulting from the use of inorganic agrochemical inputs.

Key words: fortification, goat manure, growth, okra, rice husk ash, yield characters.

Introduction

In an effort to combat hunger and meet the demand for food from the world's ever-increasing human population, as part of the Sustainable Development Goals (SDGs), farming system depends on the use of synthetic fertilizers, pesticides, and growth regulators for enhancing crop productivity [SEARCHINGER *&* al. 2019]. Despite the increase in yield brought about by using these methods, the rate of pest incidence and resistance, as well as the degradation of the ecosystem arising from global warming, is still at an alarming rate. The need to find more sustainable methods of producing food becomes essential in light of the SDGs' aim to guarantee food security in a holistic manner without lowering the quality of the ecosystem and causing a loss of biodiversity [FOLEY *&* al. 2011; PAUSTIAN *&* al. 2016; SHAKOOR *&* al. 2020 a, b]. Instead of using chemical pesticides, regenerative agriculture, which is a subset of sustainable agriculture, promotes the use of strategies like crop and animal rotation, composting, no-till farming, agroecology, and agroforestry. Regenerative agriculture increases the amount of fertile topsoil that is accessible for farming, leading to a more wholesome and long-lasting food system [REGENERATIVE ORGANIC ALLIANCE, 2020]. RHODES (2017)

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asserts that implementing regenerative agriculture towards integrating crop and livestock residue for food production could lessen environmental degradation and improve household sustainability. By incorporating organic and inorganic nutrients into the soil, enhancing the fertility of the soil, increasing the organic matter content, and increasing the soil's ability to hold water, soil amendments are used in agriculture to support plant growth and development.

According to extensive research, adding organic manure to the soil can increase crop productivity for a variety of crops, including okra [ADEKIYA *&* al. 2018; OKEE, 2020], eggplant [MOURSY *&* al. 2021], pepper [ANTONIOUS, 2014; ROSA-MARTÍNEZ *&* al. 2021], kale and collard greens [ANTONIOUS *&* al. 2014], cabbage and broccoli [ANTONIOUS *&* al. 2012] among other crops. Okra (*Abelmoschus esculentus* L.), also known as lady's finger is a valuable multifunctional crop in Nigeria and around the world valued for its tasty green seed pods, immature fresh leaves, and dried fruits [PATIL *&* al. 2015; SANDHAM *&* al. 2019]. It also contains high amount of dietary fiber, antioxidants, folate, and vitamins A, B, and C, as well as minerals including sodium, calcium, potassium, zinc, and iron [DHRUVE *&* al. 2015]. Because of its home and industrial utility, its production demand continues to outstrip supply [AWOLU *&* al. 2014; DONG *&* al. 2014]. Given that it is typically eaten as a succulent vegetable, it becomes essential to enhance its output utilizing a regenerative strategy. Compared to other animal manures, there is less information available on the cultivation of solanaceous crops utilizing goat manure. There has also been little research done on using rice husk ash to increase food output. In light of this, the current study was carried out with the aim of evaluating the impact of goat manure and rice husk ash on the productivity of okra.

Materials and methods

Experimental site

Field trials were conducted during 2017 and 2018 cropping seasons at a Community-Based Demonstration farm (11°03′0.0″ E, 10°18′59″ N) within Gombe using different levels of Goat manure and Rice husk ash.

Treatments and experimental design

The experimental treatment comprised of four levels of Goat manure (0.0, 5.0, 7.5 and 10.0 t ha^{-1}) and four levels of Rice husk ash (0.0, 5.0, 7.5 and 10.0 t ha^{-1}) which were factorially combined and applied to okra and replicated four times in a Randomized complete block design.

Land preparation and sowing

The land was ploughed and ridged before plots were marked out of size 4 m x 3 m. Four seeds of okra (*var*. Kwadon local, a predominant cultivar of okra cultivated by farmers in the experimental area) were sowed on intra row spacing of 30 cm on each ridge. The organic materials (Crop livestock) used were thoroughly incorporated into the soil based on treatment combination after marking the individual plots a week before sowing. Weeding was carried out twice manually using hoe on an interval of three weeks.

Data collection and Data analysis

Five plants per treatment were randomly selected and tagged from which growth and yield related characters were assessed. The data collected on growth and yield characters were subjected to analysis of variance and differences between means were determined by Duncan Multiple Range Test (DMRT) in General Linear Model (GLM) of SPSS.

Results and discussion

In the farming seasons of 2017 and 2018, levels of goat manure (GM) and rice husk ash (RHA) had no significant (P>0.05) impact on the number of days to 50% emergence and crop establishment count (Table 1). Similarly, treatment interaction was also not significant in both seasons.

Table 1. Effect of goat manure and rice husk ash on number of days to 50% emergence and establishment count of okra at Gombe during 2017 and 2018 wet cropping season

Treatment	Days to 50% emergence		Establishment count 3 WAS	
	2017	2018	2017	2018
Goat manure (t ha^{-1})				
0.00	4.31	4.06	79.90	71.09
5.00	4.06	4.31	71.09	74.22
7.50	4.31	4.31	74.22	77.03
10.0	4.37	4.38	77.03	79.92
LS	NS	NS	NS	NS
SE±	0.11	0.12	2.87	3.22
Rice Husk Ash (t ha^{-1})				
0.00	4.19	4.18	69.53	69.53
5.00	4.25	4.25	77.27	77.27
7.50	4.37	4.38	77.73	77.73
10.0	4.25	4.25	77.73	77.73
LS	NS	NS	NS	NS
SE±	0.11	0.12	2.87	3.22
Interaction				
Gm x Rh Ash	NS	NS	NS	NS

NS – not significant; WAS – weeks after sowing; LS – level of significance, SE – standard error.

Plant height was significantly (P<0.05) influenced by application of GM at 3, 4, 5 and 6 WAS in both 2017 and 2018 farming seasons, respectively (Table 2). Application of 0-10 t ha^{-1} of GM results in a significant (P<0.05) increase in plant height, with 10 t ha^{-1} producing the tallest plant in both seasons. The rise in plant height supports ANIEFIOK & al. (2013) findings, which indicated that adding poultry manure to water leaves increased plant height. Similar to this, NAJAH & al. (2021) found that the application of organic fertilizer increased the height of the okra plants. Application of RHA did not differ significantly due to plant height at 3WAS in both seasons. However, it significantly (P≤0.05) differs at 4, 5, and 6 WAS, respectively, where the application of 5.0-10.0 t ha^{-1} of RHA gave significantly taller plants at 4 WAS in the 2017 and 2018 seasons. Additionally, plants grown in response to 10.0 t ha^{-1} of RHA were substantially taller than those grown in response to other treatments, which were at par at 5 and 6 WAS during the farming seasons of 2017 and 2018, respectively. Treatment interaction with respect to plant height was not significant in 2017 and 2018 farming seasons, across the sampling periods.

Table 2. Effect of goat manure and rice husk ash on plant of okra at Gombe during 2017 and 2018 wet cropping season

Treatment	Plant height (cm)							
	3 WAS		4 WAS		5 WAS		6 WAS	
	2017	2018	2017	2018	2017	2018	2017	2018
Goat manure (t ha^{-1})								
0.00	9.56^{c}	19.56^{c}	15.50^{b}	25.50^{b}	21.44^{b}	31.44^{b}	24.19^{b}	34.19^{b}
5.00	9.81^{c}	19.81^{c}	17.38^{ab}	27.38^{ab}	24.50^{b}	33.75^{b}	24.75^{b}	34.75^{ab}
7.50	10.50^{b}	20.50^{b}	17.56^{ab}	27.56^{ab}	23.75^{b}	34.50^{b}	25.93^{ab}	35.94^{ab}
10.0	11.31^{a}	21.25^{a}	19.38^{a}	29.38^{a}	29.50^{a}	39.50^{a}	28.81^{a}	38.81^{a}
LS	*	*	*	*	*	*	*	*
SE±	0.11	0.18	0.71	0.75	0.97	1.02	1.12	1.21
Rice Husk Ash (t ha^{-1})								
0.00	10.37	20.38	14.69^{b}	24.69^{b}	23.06^{b}	33.06^{b}	23.31^{b}	33.31^{b}
5.00	10.13	20.13	19.38^{a}	27.63^{a}	23.31^{b}	33.31^{b}	25.31^{ab}	35.31^{ab}
7.50	10.19	20.13	18.13^{a}	28.13^{a}	25.81^{ab}	35.81^{ab}	27.38^{a}	37.38^{ab}
10.0	10.50	20.50	17.63^{a}	29.38^{a}	27.00^{a}	37.00^{a}	27.69^{a}	37.69^{a}
LS	NS	NS	*	*	*	*	*	*
SE±	0.11	0.18	0.71	0.75	0.97	1.02	1.12	1.21
Interaction								
Gm x Rh	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by common letter(s) in a column are not significantly different at 5% probability level, DMRT. NS – not significant; WAS – weeks after sowing; LS – level of significance; SE – standard error; * – significant at 5%

Number of leaves plant^{-1} was significantly affected by levels of GM at 4 WAS and rice husk ash at 5 and 6 WAS during 2017 and 2018 seasons (Table 3). At 4 WAS, application of 10.0 t ha^{-1} of GM ($P<0.05$) significantly resulted in highest number of leaves plant^{-1} compared with other levels which were at par in both years. However, number of leaves plant^{-1} due to levels of RHA at 10.0 t ha^{-1} significantly resulted in highest number of leaves plant^{-1} while other levels were at par at 5 and 6 WAS in both seasons, respectively. Nevertheless, treatment interactions due to number of leaves plant^{-1} were not significant in both years across the sampling periods. The increase in number of leaves due to GM application could be attributed to nutrient supplied by the manure compared with no nutrient as in control. ADESINA & al. (2014) who reported increase in pepper leaves number due to increase in levels of poultry manure application as organic soil amendment.

Table 3. Effect of goat manure and rice husk ash on number of leaves plant^{-1} of okra at Gombe during 2017 and 2018 wet cropping season

Treatment	Number of leaves plant^{-1}							
	3 WAS		4 WAS		5 WAS		6 WAS	
	2017	2018	2017	2018	2017	2018	2017	2018
Goat manure (t ha^{-1})								
0.00	4.37	18.75	6.50^{b}	21.00^{b}	6.06	21.06	6.81	21.38
5.00	4.44	19.13	6.00^{b}	21.00^{b}	6.31	21.06	6.75	21.50
7.50	4.13	19.44	6.00^{b}	21.63^{b}	6.06	21.13	6.19	21.75
10.0	4.44	19.44	8.00^{a}	23.00^{a}	6.13	21.31	6.13	21.81
LS	NS	NS	*	*	NS	NS	NS	NS
SE±	0.10	0.31	0.29	0.31	0.19	0.24	0.26	0.34

Rice husk (t ha^{-1})								
0.00	4.25	19.25	6.75	21.50	5.63^{c}	20.63^{b}	5.75^{b}	20.75^{b}
5.00	4.38	19.38	6.50	21.63	5.88^{bc}	20.88^{ab}	6.44^{ab}	21.75^{ab}
7.50	4.38	19.38	6.75	21.75	6.38^{ab}	21.38^{ab}	6.75^{a}	21.75^{ab}
10.0	4.38	18.75	6.50	21.75	6.69^{a}	22.69^{a}	7.19^{a}	22.19^{a}
LS	NS	NS	NS	NS	*	*	*	*
SE±	0.10	0.31	0.29	0.31	0.19	0.24	0.26	0.34
Interaction								
Gm x RH	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by common letter(s) in a column are not significantly different at 5% probability level, DMRT. NS – not significant; WAS – weeks after sowing; LS – level of significance; SE – standard error; * – significant at 5%.

Application of GM significantly influenced leaf area plant^{-1}and pod diameter of okra in the 2017 season only. However, there was no significant influence observed on leaf area and pod diameter in 2018, days to 50% flowering, number of pods plant^{-1} and pod length in 2017 and 2018 seasons (Table 4). Leaf area, days to 50% flowering, and number of pods per plant were significant ($P \leq 0.05$) due to the application of RHA in both seasons.

Rice husk ash at 10.0 t ha^{-1} produced the larger leaves in both years of the trial (Table 4). On the other hand, the application of 10.0 t ha^{-1} of rice husk ash significantly ($P<0.05$) decreased the number of days to 50% flowering in both seasons compared to other rates that were at par. The number of pods plant^{-1} was significantly higher arising from the application of 10.0 t ha^{-1} rice husk ash compared to other rates, which were at par in the 2017 and 2018 seasons, respectively. Further, pod length and pod diameter were not significant due to RHS in both the 2017 and 2018 seasons. Similarly, treatment interactions remained insignificant ($P>0.05$) across all parameters in both the 2017 and 2018 farming seasons.

Table 4. Effect of goat manure and rice husk ash on leaf area, days to 50% flowering, number of pods plant^{-1}, pod length and pod diameter of okra at Gombe during 2017 and 2018 wet cropping season

Treatment	Leaf area (cm)		Days to 50% flowering		Number of pod plant^{-1}		Pod length (cm)		Pod diameter (cm)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Goat manure (t ha^{-1})										
0.00	80.50^{b}	85.86	49.69	49.56	12.81	27.56	12.31	14.19	1.48^{b}	2.48
5.00	80.81^{b}	85.81	49.56	49.69	13.06	27.81	15.25	14.28	1.56^{ab}	2.56
7.50	84.81^{ab}	89.81	49.94	49.94	12.94	27.94	13.66	15.66	1.64^{ab}	2.64
10.0	102.69^{a}	107.81	50.13	50.13	12.56	28.06	12.28	17.13	1.73^{a}	2.73
LS	*	NS	NS	NS	NS	NS	NS	NS	*	NS
SE±	5.51	6.41	0.20	0.24	0.16	0.16	0.95	0.91	1.56	0.07
Rice Husk Ash (t ha^{-1})										
0.00	69.69^{c}	74.56^{b}	50.00^{a}	50.31^{a}	12.56^{b}	27.56^{b}	12.03	13.97	1.61	2.61
5.00	80.57^{bc}	85.75^{b}	50.31^{a}	50.00^{ab}	12.63^{ab}	27.63^{ab}	12.94	14.75	1.66	2.66
7.50	90.50^{ab}	95.69^{ab}	49.75^{ab}	49.75^{ab}	13.06^{ab}	28.06^{ab}	13.84	15.84	1.58	2.58
10.0	108.00^{a}	113.00^{a}	49.25^{b}	49.25^{b}	13.13^{a}	28.13^{a}	14.69	16.96	1.56	2.56
LS	*	*	*	*	*	*	NS	NS	NS	NS
SE	5.51	6.41	0.20	0.24	0.16	0.16	0.95	0.91	1.56	0.07
Interaction										
Gm x Rh Ash	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by common letter(s) in a column are not significantly different at 5% probability level, DMRT. NS – not significant; WAS – weeks after sowing; LS – level of significance; SE – standard error; * – significant at 5%.

Okra fresh marketable weight and dry weight were not significantly affected by the application of GM and RHA, irrespective of the rates of application, in the 2017 season, while in the 2018 season they were significantly influenced by both GM and RHA (Table 5). The application of 5, 7.5, and 10 t ha^{-1} of GM resulted in a higher fresh marketable weight of okra than the control, which resulted in a lower weight. On the other hand, application of RHA at 5.0 t ha^{-1} significantly produced heavier marketable pods, though statistically at par with 7.5 and 10.0 t ha^{-1} compared to the control that recorded a lower weight. Similarly, treatment interaction was not significant in both years (Table 5). Findings from this study can infer that the application of GM and RHA can significantly influence crop productivity, as depicted in the growth and yield attributes of okra. This corroborates the findings of GONZÁLEZ & al. (2023), who reported that goat manure fertilization resulted in an increase in grain yield and total protein content of two varieties of *Chenopodium quinoa* Willd. Grown at high altitude. Similarly, ABUKARI (2014) documented a higher number of nodules and nodule weight in cowpea arising from a 4.5 t ha^{-1} application of RHA. SARANYA & al. (2018) reported an increase in plant height, shoot and root weight, and dry matter due to the application of RHA at 10 t ha^{-1} + 50% of the recommended K rate. THIND & al. (2017) recorded a 25% increase in grain yield of wheat over control arising from a 10 t ha^{-1} RHA application. The 2018 growing season saw a marked improvement in growth and yield-related traits, which could be attributed to the organic materials' correct mineralization throughout time and space, which allowed the crop to utilize them for the formation of dry matter. Due to the rapid decomposition of organic materials, which influences how much rice husk ash is applied, this is the moment when nutrients are released. The results concurred with those of DE LA ROSA & al. (2023), who reported sustainable crop production by evaluating the agronomic impact of volcanic ash, rice husk ash, and other soil amendments as a means of lowering pollution and protecting the ecosystem.

Table 5. Effect of goat manure and intact rice husk on fresh weight and dry weight of okra at Gombe during 2017 and 2018 wet cropping season

Treatment	Fresh marketable weight (g)		Dry weight (g)	
	2017	2018	2017	2018
Goat manure (t ha^{-1})				
0.00	189.37	183.18^{b}	28.84	32.39
5.00	191.22	200.28^{a}	30.47	36.02
7.50	185.27	204.37^{a}	30.19	37.11
10.0	174.43	206.28^{a}	25.39	56.22
LS	NS	*	NS	NS
SE±	6.87	7.23	1.71	9.23
Rice Husk Ash (t ha^{-1})				
0.00	176.36	181.36^{d}	26.30	33.48
5.00	193.99	208.99^{a}	31.56	56.77
7.50	193.06	201.88^{ab}	30.40	38.56
10.0	177.28	198.28^{bc}	26.48	33.48
LS	NS	*	NS	NS
SE	6.87	7.23	1.71	9.23
Interaction				
Gm x Rh Ash	NS	NS	NS	NS

Means followed by common letters in a column are not significantly different at 5% probability level, DMRT. NS – Not significant; LS – Level of significance; SE – standard error; * – significant at 5%.

Conclusion and recommendation

The results of the experiments show that the application of GM and RHA up to 10.0 t ha^{-1} greatly improved the growth and yield indices of okra in the research area. Thus, GM can be exploited as a crucial part of organic manure, and when strengthened with RHA, its effectiveness can be enhanced towards the production of okra and other horticultural crops, lowering greenhouse gas emissions from the usage of synthetic agrochemicals in soils and the environment.

Conflict of interest

The authors declare no conflict of interest.

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