A Comparative Analysis on the effects of three Organic Fertilizer Types on the Yield of Dual-Purpose Legume Forages and Soil Physiochemical Properties in the Coastal Rainforest of Akwa Ibom State

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DOI: 10.56201/ijaes.vol.11.no2.2025.pg12.26

Abstract
The surge of the global population on the food sustainability of the world is a major burden for agriculture in recent times. To sustain the growing population, agricultural best practices are constantly being improved to ensure food sustainability. This study investigated the effects of three organic fertilizers on the soil, forage and grain yield of cowpea, groundnut and soya bean. The study was conducted in Obio Akpa ,Akwa Ibom State, Nigeria ,and utilized a randomized complete block design (RCBD), including a control group,to assess the impact of goat, poultry droppings, and pig dung as organic fertilizers on the soil and yield of the legume crops. The findings showed Significant changes in soil physiochemical properties were observed including a reduction in the proportion of sand content, increased pH and total nitrogen when compared to the control. Cowpea with pig dung made the most significant effect on soil having 46.54mgkg^{-1}available phosphorus followed by soybean planted with pig dung with 44.94mgkg^{-1}. Soybean and groundnut planted with Goat manure made the highest contribution in terms of soil organic matter with 3.99% and 3.79% respectively. For yield potential, groundnut and soybean produced the highest grain yield with 3731.80t/ha and 3765.60t/ha respectively, while groundnut and cowpea performed better in terms of dry matter yield with total dry matter of 7716.40t/ha and 4694.40t/h respectively. Total grain yield values indicated significant support from pig dung for groundnut, whereas poultry manure was significant for soybean. Based on the findings, the use of pig dung and poultry manure was recommended as preferred organic fertilizer options for enhancing legume yields, particularly cowpea, groundnut, and soybean due to the significant positive effects on legume performance. Particularly, in terms of pod number, seed weight, shelling percentage, and total grain yield.

Keywords: *Legume, cowpea, soybean, groundnut, organic fertilizers, pig dung, poultry droppings, goat droppings, soil, forage and grain yield*

Introduction

Nigeria is a developing nation faced with food security issues as one of the major challenges due to the rapid rise of the population and as such, there is the need to continually find sustainable agricultural practices. To ensure food security, food production must increase exponentially in response to the growing population and their food demand. This has led to the study on this crucial aspect of agriculture which farmers are used to; that is the application of organic fertilizers (manure). Most farmers have no knowledge of the best fit or how they interact with improving the fertility of the soil, crop yield and with little impact on the environment. Organic fertilizers (manure) may be gotten from plant or animals and have been said to provide essential plant nutrients, improve the structure of the soil, its water-holding capacity, and the actions of microbes in the soil (Ukojeand Yusuf, 2013; Enemali*et al*., 2023). One major limitation of its usage in Nigeria despite the knowledge of organic fertilizers (manure) is its availability and lack of awareness about its benefits over synthetic fertilizers (Ukoje& Yusuf, 2013).

This study is aimed at providing a comparative evaluation of the effect of different manure types on forage and grain yields of three selected dual-purpose legume forages and as well how they affect the soil physical and chemical properties. Forage legumes such as cowpea (*Vignaunguiculata*) and groundnut (*Arachishypogaea*) have gained attention because of the development of dual-purpose varieties and to some extent because of their usage in soil fertility improvement(Dube&Fanadzo, 2013). Promoting the cultivation of forage legumes not only addresses nutritional deficiencies by providing sources of animal protein but also offers economic benefits for farmers through additional income streams. By evaluating the yield of forage legumes and the soil physiochemical properties under different organic manure types in the humid forest zone of Nigeria, the research aims to contribute to sustainable agriculture practices that enhance food production while mitigating the adverse effects of climate change. Also studying the physiochemical properties in soil characteristics such as nutrient content, pH levels, and organic matter due to the use of specific organic fertilizers is essential for assessing the sustainability and long-term impact of these fertilizers on soil health.

Materials and Methods

Description of the Study Area

The research was carried out at the Pasture Research Farm of the Department of Animal Science, AkwaIbom State University ObioAkpa, located inOrukAnam Local Government Area of AkwaIbom State, Nigeria, a natural humid rainforest biome of Nigeria.The area lies at coordinates 4°49′N, 7°39′E(Wikipedia, 2024).Its rich and diverse vegetation, which represents the climate of the coastal rainforest that mostly prevails in this area, is the reason for the area's uniqueness which favours this research. The study area is a perfect place for agricultural research because of its distinct geographical features, soil composition, and a climate marked by high annual rainfall and warm temperature.

Experimental Design

The experimental design used for this study was a 3 x 4 factorial experiment in a randomized complete block design (RCBD) consisting of twelve (12) treatments combination. The study was divided into four different treatment groups, with three replications of each group to guarantee the reliability and accuracy of the data gathering and analysis.

Legume Selection and Preparation

Three legumes species were selected for this study, groundnut (*A. hypogaea*), soya bean (*G. max*) and cowpea (*V. unguiculata*). The prostrate groundnut variety (SAM 23), and the variety of soybean (SAMSOY 1) used in this research were obtained from International Agricultural Research, Samaru Zaria, Nigeria and were subjected to pre-germinationpreparations similar toEkette*et al*., (2024). Following germination, the seedlings were transplanted to the experimental plot.

Selection and Treatmentof Organic Fertilizers used for the Experiments

Organic fertilizers used for the experiments were poultry droppings, pig dung, and goat droppings. They were all treated independently including a control treatment without any manure for proper monitoring of results.

Soil Analysis

The soil samples were collected from different depths, encompassing the topsoil (0 – 15 cm) and subsoil (15 – 30 cm), using standard soil sampling equipment such as soil augers and soil corers. Upon collection, the soil samples underwent air-drying to ensure uniform moisture levels and maintain consistency. The samples were then dispatched to the Physical Chemistry Laboratory of AkwaIbom State University for in-depth analysisto determine the physical and chemical properties of the soil in the study area. Standard protocols were used to determine the physical and chemical parameters of the soil including soil pH (FAO, 2021), organic matter content, nutrient available (N, P, K) (Edmeades and Clinton, 1981; Sahrawat and Burford, 1982;GutiérrezBoem*et al*., 2011; Shamrikova et al., 2022), and soil textureusing a hydrometer (Beretta *et al*., 2014). The soil was analysed before and after harvesting.

Legume Yield

Herbage yield were measured in terms number of pods (NO OF PODS), dry pod weight (DPOWT), seed weight (SEEDWT), shelling percentage (SHELLING %), and total grain yield (TOTGRYLD).

Harvest Parameters

Seed weight of 100 seeds of groundnut, soybean and cowpea seeds were measured by weighing them using a digital weighing balance in grams (g). To find the shelling percentage, pods were collected. The pods from the net plots of groundnut were each air-dried thoroughly. Harvest from fifteen tagged groundnut, soybean and cowpea plants was weighed before and after shelling, the shelled nuts were weighed and recorded. The shelling percentage was determined as SP = Weight of groundnut seed x 100% Weight of pods. The weights of seeds harvested from each net plot were recorded before shelling using a weighing balance. The total weight of groundnut, soybean and cowpea from the respective net plots were then extrapolated to give the total pod yield per hectare.

Statistical Analysis

Data obtained from the experiments were analyzed as factorial design using the PROC ANOVA procedure of SAS 2009. Where significant differences occurred, the means were separated using Duncan New Multiple Range Test at (P<0.05).

Results

The findings of the physical and chemical characteristics of the soil sample at the test location prior to planting and after application of treatment with organic fertilizers are shown in Table 1.Table 2 indicates the interactive effects of species with manure types, showing the performance of the various legumes with the different manure treatment, in terms number of pods (NO OF PODS), dry pod weight (DPOWT), seed weight (SEEDWT), shelling percentage (SHELLING %), and total grain yield (TOTGRYLD).In table 3, the main effects of the different manure treatments are recordedin terms of number of pods, DPODWT, SEEDWT, SHELLING %, TOTGRYLD, DPODYLD, 100GWT, dry forage yield (DFYLD), dry matter yield per hectare (DMYLDHA). Table 4 shows the effects of the cultivars in terms of number of pods, DPODWT, SEEDWT, SHELLING %, TOTGRYLD, DPODYLD, 100GWT, dry forage yield (DFYLD), dry matter yield per hectare (DMYLDHA).

Table 1: Physicochemical analysis of soil before and after harvest of legumes

S/N	Sample ID	Sand Kg^{-1}	Silt Kg^{-1}	Clay Kg^{-1}	pH (H_2O)	OC	OM (%)	TN (%)	Av.P	Mg $Cmolkg^{-1}$	Ca $Cmolkg^{-1}$	K $Cmolkg^{-1}$	Na $Cmolkg^{-1}$
1	Control (before)	938	32	30	4.17	1.23	2.13	0.140	31.90	1.40	3.20	0.144	0.049
2	G/N + PM	928	42	30	4.21	1.53	2.65	0.210	36.50	2.40	4.40	0.188	0.095
3	G/N + GM	888	48	64	5.26	2.19	3.79	0.165	34.03	1.60	3.60	0.195	0.092
4	G/N + PD	888	48	64	4.00	2.10	3.63	0.168	34.03	3.20	4.80	0.220	0.130
5	SB + PD	930	34	36	3.86	1.62	2.80	0.224	44.94	2.00	2.80	0.168	0.063
6	SB + GM	894	50	56	3.99	2.31	3.99	0.182	33.48	1.60	3.20	0.202	0.107
7	SB + PM	920	12	68	3.80	1.50	2.59	0.204	41.33	1.20	3.20	0.170	0.077
8	CP + GM	890	44	66	4.19	1.35	2.33	0.174	39.02	2.80	3.60	0.169	0.066
9s	CP + PD	930	22	48	4.93	1.25	2.16	0.284	46.54	2.80	5.20	0.181	0.084
10	CP + PM	844	86	70	4.70	1.32	2.28	0.254	43.44	2.00	5.20	0.170	0.073

The control soil, with sand (938), silt (32), clay (30), and baseline nutrient levels, provides a starting point for evaluating the impact of manure types on dual-purpose legume forages. The initial conditions are crucial in understanding the improvements achieved through various treatments.

Table 2: Interaction Effects of Species with Manure Type Add the Duncan superscripts and the units Kg/ha or t/ha

	MANURE TYPE	NO OF PODS	DPOWT(Kg/ha)	SEEDWT(Kg/ha)	SHELLING%	TOTGRYLD (Kg/ha)
Cowpea	Control	0.00	0.00	0.00	0.00	0.00
	GM	0.67	0.20	0.13	0.42	39.58
	PD	7.00	1.70	1.30	0.76	812.50
	PM	5.00	0.67	0.52	0.77	325.00
	SEM	1.69	0.37	0.29	0.18	187.29
Groundnut	CONTROL	59.33	3.20	3.05	0.95	1906.25
	GM	88.33	5.30	5.10	0.96	3187.50
	PD	156.33	9.40	8.73	0.93	5458.33
	PM	102.67	8.00	7.00	0.87	4375.00
	SEM	20.32	1.38	1.22	0.02	765.04
Soybean	CONTROL	120.00	4.60	4.10	0.89	2562.50
	GM	49.00	4.73	4.00	0.86	2500.00
	PD	120.00	7.90	7.30	0.92	4562.50
	PM	105.00	9.10	8.70	0.96	5437.50
	SEM	16.87	1.13	1.17	0.02	734.81

Manure	No of Pods	DPOWT	SEEDWT	SHELLING%	TOTGRYLD	DPODYLD	100GWT	DFYLD	DMYLDHA
Control	59[c]	2.60[d]	2.38[d]	0.61	1489.60[b]	1625.00[c]	13.56[d]	9.41[a]	5879.6[a]
GM	46[d]	3.41[c]	3.08[c]	0.75	1909.00[b]	2131.90[b]	20.00[c]	6.75[c]	4215.7[c]
PD	94[a]	6.33[a]	5.78[a]	0.87	3611.10[a]	3819.40[a]	36.67[a]	7.58[bc]	4739.00[bc]
PM	70[b]	5.92[b]	5.41[b]	0.87	3379.20[a]	3702.10[a]	32.67[b]	8.59[ab]	5370.90[ab]
SEM	1.55	0.107	0.039	0.082	24.81	553.65	5.39	0.58	363.31

Table 3: Main Effects for Manure

Table 4: Main Effects for Cultivar/ Species

Manure	No of Pods	DPOWT	SEEDWT	SHELLING%	TOTGRYLD	DPODYLD	100GWT	DFYLD	DMYLDHA
Groundnuts	101.67	6.48	5.97	0.93	3731.80	4046.90	43.17	12.35	7716.40
Soybean	98.50	6.58	6.03	0.91	3765.60	4114.60	21.75	4.39	2743.10
Cowpea	3.16	0.64	0.50	0.49	294.30	297.40	12.25	7.51	4694.40
Sem	32.32	1.96	1.83	0.14	1151.50	1261.26	9.14	8.59	5370.90

Discussions

Table 1 presents the findings of the physical and chemical characteristics of the soil sample at the test location prior to planting. The finding shows that the soil was mostly textured sandy loam corresponding with the results reported by Ekong & Uduak, (2015). The present analysis also reveal that the soil has a pH value of 4.17, the soil was mildly acidic, and agrees with the report of Ekong & Uduak, (2015), who reported that the soil is acidic with a pH range of 5.2 – 5.4. The exchangeable cations were low in particular in K, Ca, Mg and Na. Therefore, the soil was in low nutritional condition. This condition which have been articulated by Sheng *et al*., (2020) and Angst *et al*., (2021), be due to the certain factors such as the sandy loamy texture of the soil (Renzaho Ntakyo *et al*., 2020), organic matter content (Uwah & Eyo, 2014), as well as climatic factors (Chahal *et al*., 2022).The values of the total Nitrogen (N) content (0.14 – 0.28%) and available Phosphorus (P) (3.19 – 4.65 mg/kg) were low, as with Ekong & Uduak, (2015), who also reported low values of total Nitrogen (0.10 - 0.12 %) and available P (4.70 - 5.18 mg/kg) respectively. Furthermore, the exchangeable Ca, Na and K were low, the values ranged from 3.20 –5.20 cmol/kg, 0.049 – 0.130 cmol/kg and 0.144 – 0.220 cmol/kg respectively. Similarly, the exchangeable Mg ranged from 1.20 - 3.20 cmol/kg, which was at a low level compared to the standard exchangeable Mg as above 3 percent. The findings have this present study agrees with those of Ekong & Uduak, (2015), and therefore can be relied on. As reported by Ekong & Uduak, (2015), the soils were low in fertility and would require the use of fertilizers (organic and inorganic), cover crops to protect the soil surface against soil erosion and adequate use of lime to achieve the benefits of fertilizer application for sustainable crop production.The effect of the manure on the pH appears inconsistent because there was no uniform increase observed in the pH values. Therefore, it is difficult to conclude that the organic manure is responsible for the alkaline status of the soil in this instant case. Four treatments led to a drop in soil pH which was lower than the starting value of 4.17. The treatments are Groundnut and Pig dung (GN + PD), Soybean and Pig dung (SB + PD), Soybean and Goat manure (SB + GM), and Soybean and Poultry manure (SB + PM), corresponding to 4.00, 3.86, 3.99 and 3.80 respectively. The soya bean plots showed high acidity level of 3.86, 3.99 and3.99 this may have adversely affected the yield of the soya bean. Soya bean performs well in soils with pH level of 6 and 7, with an optimal range of 6.3-6.5(Bakari *et al*., 2020). Other treatments such as the G/N + PM (Groundnut + Poultry Manure) treatment, with a slight decrease in sand and an increase in silt and clay, exhibits enhanced soil fertility (organic carbon: 1.53, total nitrogen: 0.210). Soil organic carbon tends to be concentrated in the topsoil. Topsoil ranges from 0.5% to 3.0% organic carbon for most upland soils. Soils with less than 0.5% organic C is mostly limited to desert areas. Soils containing greater than 12–18% organic carbon is generally classified as organic soils. According to Witzgall *et al*., (2021), soil organic carbon (SOC) affects the chemical and physical properties of the soil, such as water infiltration ability, moisture holding capacity, nutrient availability, and the biological activity of microorganisms (Beillouin *et al*., 2022).The available phosphorous (36.50) is notably higher, and may lead to improvements in nutrient levels which can positively influence yield and nutritive value. Also, in the G/N + GM (Groundnut + Goat Manure) treatment, there is an increase in the alkaline pH with a value of (5.26) and significant increases in organic carbon (2.19) and total nitrogen (0.165). Despite a decrease in available phosphorous compared to G/N + PM, these changes suggest potential benefits for legume forages, possibly impacting yield and nutritive value(Tahir *et al*., 2022).The G/N + PD (Groundnut + Pig Dung) treatment, with decreased sand and increased silt and clay, shows a lower pH and substantial increases in organic carbon (2.10), total nitrogen (0.168), and various essential nutrients (Mg: 3.20, Ca: 4.80, K: 0.220, Na: 0.130). These soil improvements according to Lashari, (2023), are likely to contribute positively to forage yield and nutritive value.Also, the SB + PD (Soybeans + Pig Dung) treatment showed a lower pH and significant increase in organic carbon (1.62), total nitrogen (0.224), and available phosphorous (44.94) suggesting a favourable condition for dual-purpose legume forages(Bebeley *et al*., 2024). These changes may positively impact forage yield and nutritive value. Similarly, the SB + GD (Soybeans + Goat Droppings) treatment shows improvements in soil fertility, with increased organic carbon (2.31), total nitrogen (0.182), and available phosphorous (33.48). These enhancements may contribute to improved yield and nutritive value of legume forages, although the yield may have been affected significantly by the crop variety used.

In Table 2, the comparative analysis of organic fertilizers on all three crops reveals that in terms of number of pods, pig dung showed a significant increase as shown on the table 2; cowpea (7.00), groundnut (156.33) and soybean (120.00).For the DPOWT, cowpea and groundnut were significant for pig dung with values of 1.70 and 9.40 respectively. However, for soybean, poultry manure was outstanding with a value of 9.10. This distinction noticed for soybean with the poultry manure treatment is mainly due to the nitrogen, phosphorus and potassium contents in the poultry manure treatment. Soybean has been identified as having a high demand for nitrogen especially during the vegetative and reproductive stages (Du *et al*., 2020).

Similarly, for the SEEDWT, pig dung was significant for cowpea (1.30), and groundnut (8.73), while soybean was significant for the poultry manure treatment (8.70).For the SHELLING%, poultry manure was significant for soybean (96%), and cowpea (77%), while goat manure was significant for groundnut (96%) mainly due to the pH adjustment ability of goat manure which makes sure the pH remains optimal for groundnut cultivation (Effa *et al*., 2022).

The TOTGRYLD values indicates that pig dung is significant for cowpea (812.50), and groundnut (5458.33), while poultry manure is significant for soybean (5437.50). These findings show consistently that poultry manure supports the yield of soybean, and is consistent with the findings of Chiezey & Odunze, (2009) and Umoh *et al*., (2023).From the results in Table 3, pig dung treatment resulted in the highest number of pods, with an average of 94 pods per plant. This indicates that the use of pig dung as a fertilizer significantly promoted pod formation in the legume crop. Conversely, goat manure treatment recorded the least number of pods, with an average of 46 pods per plant. This suggests that the application of goat manure was less effective in stimulating pod production compared to pig dung and other manure treatments.Pig dung treatment also led to the highest dry pod weight, with an average DPOWT of 6.33. This indicates that pods produced under pig dung treatment had the highest weight after drying, reflecting better pod development and filling. Following pig dung, poultry manure treatment recorded a DPOWT of 5.92, indicating relatively heavy pods compared to other manure treatments. This results are significant due to certain factors such as crop variety and specific manure contents (Umoh *et al*., 2023).Seeds from pig dung treatment weighed the highest with 5.78, followed by poultry manure with 5.41. Furthermore, both pig dung and poultry manure showed SHELLING% of 87%, followed by goat manure with 75%. As for the TOTGRYLD, pig dung shows the largest value of 3611.10, followed by poultry with 3379.20. The same thing goes for the DPODYLD with pig dung indicating a value of 3819.40, and poultry manure showing 3702.10. The values for 100GWT also show pig dung having a value of 36.67, followed by poultry manure with 32.67. The DFYLD shows poultry manure with 8.59 and pig dung with 7.58. Finally, the DMYLDHA shows poultry manure with 5370.90 and pig dung with 4739.00.This substantial increase in herbage yield attributed to pig dung and poultry manure, indicates their potential as valuable organic manures, containing good nutrient sources for groundnut, cowpea and soybean. Pig dung (PD) demonstrates a positive impact on herbage yield, resulting in a 31% increase compared to the control group, in agreement with the findings of Raza *et al*., (2020), on the yield effects of pig dung as compared to other organic manure types. The overall finding disagrees with certain studies (Ayoola & Makinde, 2008; Jones *et al*., 2007; Law-Ogbomo & Ajayi, 2009; Oke *et al*., 2020), who consistently indicate poultry manure as the most effective organic fertilizer, showcasing its significant role in enhancing herbage yield across all three legumes, and making it a valuable resource for sustainable agricultural practices(Oke *et al*., 2020). This variation from other studies can be attributed to the plant varieties and the composition of the soils used for this study (Allito *et al*., 2015).

In Table 4, groundnut exhibits the highest pod production, with an average of 101.67 pods. This suggests that groundnut plants are better in pod formation, which is beneficial for yield. On the other hand, cowpea has the lowest pod production, with an average of only 3.16 pods per plant. This difference in pod production may be attributed to genetic factors, environmental conditions, and management practices(Fan *et al.*, 2021).Similarly, for the SEEDWT, soybean has the highest (6.03), followed by groundnuts with (5.97) and cowpea has the least with (0.50). Groundnut has the highest SHELLING% of 93%, followed by soybean with 91% and cowpea with 49%.Soybean has the highest TOTGRYLD of 3765.60, followed by groundnut with 3731.80 and cowpea with 294.30. Also, the DPODYLD values indicate that groundnut has the largest value of 4046.90, followed by soybean with 4114.60, and cowpea with 297.40.In terms of the 100GWT, groundnut has the highest value of 43.17, soybean 21.75 and cowpea has the least value of 12.25.For the DFYLD, groundnut has 12.35, cowpea 7.51 and soybean 4.39. The DMYLDHA shows groundnut with 7716.40, cowpea with 4694.40 and soybean with 2743.10.According to this result, groundnuts and soybeans outperformed cowpea irrespective of the manure treatment. This findings are in line those reported by Anyanwu *et al.*, (2021).

Conclusion

This study has been able to reveal the effects of the manure types on the soil physical and chemical properties, and as well the effects on the yield of the different legume types. The study provides insights into the main effects of different manure treatments, revealing notable variations in legume performance. Pig dung emerges as highly effective, yielding the highest number of pods (94), heaviest dry pod weight (6.33), and heaviest seeds (5.78), alongside poultry manure. Both pig dung and poultry manure exhibit a shelling percentage of 87%, while goat manure trails with 75%. Pig dung demonstrates superior total grain yield (3611.10) and dry pod yield (3819.40), followed closely by poultry manure. This significant increase in herbage yield attributed to pig dung and poultry manure underscores their potential as valuable organic fertilizers for groundnut, cowpea, and soybean cultivation. Pig dung notably showcases a 31% increase in herbage yield compared to the control group, aligning with prior research by Raza *et al*. (2020), while contradicting findings from studies by Ayoola&Makinde (2008), Jones *et al*. (2007), Law-Ogbomo&Ajayi (2009), and Oke*et al*. (2020), which consistently highlight poultry manure as the most effective organic fertilizer. These findings indicate the significant role of poultry manure in enhancing herbage yield across various legumes, advocating for its utilization in sustainable agricultural practices.Therefore, in choosing organic fertilizers, we recommend the use of pig dung and poultry manure as preferred organic fertilizer options for enhancing legume yields, particularly cowpea, groundnut, and soybean due to the significant positive effects on legume performance, particularly in terms of pod number, seed weight, shelling percentage, and total grain yield. However, it is essential to carefully manage application rates and timing to optimize their benefits while minimizing environmental impacts. By incorporating these organic fertilizers into agricultural practices, farmers can improve the overall health and yield potential of their legume crops.

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