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Influence of Manures on Some Soil Fertility Properties, Yield and Agronomic Efficiencies of Soybean (*Glycine max*) on Degraded Acid Soil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

Aluminum toxicity is a major limitation to leguminous crop production in acidic soils but mineral and organic fertilizer applications could ameliorate the condition. Thus, the focus of this study was to evaluate the influence of manures on post-harvest soil fertility quality, yield and agronomic efficiencies of soybean (*Glycine max*). The study had six fertilizer treatments: poultry manures, rabbit manures, pig manures, sheep manures, cattle manures, single super phosphate and the control (no soil additive) laid in a Completely Randomized Design (CRD), with four replicates. The experiment was conducted at the greenhouse of the Wesley University, Ondo, Nigeria. The treatments were applied at the rate of 40 kg $P_20_5ha^{-1}$ and the effects of treatments on yield

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parameters (biomass, grain yield and total dry weight), relative agronomic efficiencies, as well as soil fertility status were observed. Data analysis using ANOVA at 5% level of probability showed the application of poultry manure to have enhanced soybean grain yield and yield component. Poultry manure treatment had the highest mean total dry weight of 11.5 g while SSP resulted in the lowest yield (4.7g). The efficiency of available P released from the applied poultry manure was 2 times higher than the referenced single super phosphate fertilizer in Ondo. Poultry manure application again had higher RAE_{DSW} than to chemical fertilizer. Thus, applications of poultry or pig manures at 40 kg $P_20_5ha^{-1}$ could be excellent materials as alternatives to mineral fertilizer (single super phosphate) for improving soil fertility, yield of soybean and its agronomic efficiencies.

Keywords: Glycine max; manures; relative agronomic efficiencies; soil fertility; acid soil.

1. INTRODUCTION

Acidification of soil is a major constraint for plant growth [1]. As soils become acidic, crop production becomes increasingly difficult. It is a factor limiting the sustainability of agricultural production systems in the world [2] especially on highly weathered (Harter, 2002), low-activity clay soils in the humid and sub humid zones of West Africa (Sahrawat et al. 2000). Acid soils are widespread and are distributed over extensive areas of the humid tropics and subtropics.

Soil acidification is caused by natural processes and/ or man-made processes. Tropical soils are prone to acidification processes due to the prevalence of high annual precipitation of above 1600 mm [3] and the opening up of the soil that had been under tree cover for decades for crop production as a result of overpopulation (Lerner, 2000). Acid soil condition gives top soil pH value of less than 6.0 which decreases with depth. This results in a substantial reduction in plant macronutrients (P, K, Ca and Mg) supply (Sharawat et al. 2000).

“Several practices have been recommended to reclaim and upgrade the productivity of acid soils and such include the cultivation of acid tolerant plants” (Abate et al*.,* 2013), “covering the soil surface with non-acid soil” [4], fertilizer application (Budiante et al. 2010), use of conventional limes [4] and use of organic fertilizers (Shamsuddin et al. 2011). Among these practices, liming and the use of organic materials are considered the best measures because of the persistency of their effects on the amended soils. Among these practices, liming and use of organic materials are considered the best measures because of persistency of their effects on the amended soils. Organic fertilizers are sourced from organic wastes which have several advantages compared to mineral fertilizers. Examples of organic fertilizers are compost, green manure, animal manure, other agricultural wastes, human wastes, etc. Thus, there was a need to evaluate the effects of manures on soybean in acidic soil [5].

“Soybean (*Glycine max*) is one of the world’s most valued oil seed crops and most important grain legume in Nigeria. Soybean is among the major food crops grown on virtually every continent. The crop can be grown in many states in Nigeria using low agricultural inputs. Soybean cultivation in Nigeria has expanded as a result of its nutritive and economic importance and domestic usage. It is also a prime source of vegetable oil in the international market” (IITA, 2009). Animal manures have been found useful as sources of fertilizers, thus the main objective of this work was to evaluate the influence of manures on postharvest soil fertility quality, yield and agronomic efficiencies of soybean grown on acid soil.

2. MATERIALS AND METHODS

The study was carried out at the screen house, Department of Agriculture, Wesley University, Ondo, Nigeria. The soil was sandy loam based on USDA definition, strongly acidic and low in nitrogen, phosphorus, organic carbon and potassium. The materials for the study included: soybean seeds (TGM-674), single super phosphate (SSP) mineral fertilizer, cattle manure, poultry manure, sheep manure, pig manure and rabbit manure. The experiment was laid out as a Completely Randomized Design (CRD) with four replicates.

2.1 Agronomic Study

Soil used for the experiment was collected at the depth of 0-15cm from the Teaching and Research Farm, Wesley University, Ondo, Nigeria. Soil collected was air-dried and sieved (2 mm and 0.5 mm), some portion of the sampled soil was processed in the laboratory to determine the chemical and particle size distribution using the methods described by Udo and Ogunwale [6].

Composite soil samples were collected with a soil auger at 0-15 cm depths for chemical and physical soil analysis. The soil samples were air-dried and sieved with 2 mm mesh for routine analysis. Particle size distribution was determined by the hydrometer method, as cited by Tel and Hargarty, [7], using sodium hexametaphosphate (calgon) as the dispersing agent. Soil pH was determined using pH meter in water (1:1) Peech M. [8]. Organic carbon was determined using dichromate wet oxidation method Walkey A, Black C. A [9] and value of organic matter was obtained by multiplying the Organic carbon value by a factor of 1.724. Total nitrogen was determined by macro Kjeldahl procedure Jackson M. L. [10]. Available phosphorus was determined by the method of Bray and Kurtz [11] and determined colourimetrically using Molybdenum blue method, while K, Ca, and Mg was first extracted using neutral normal (NH_4OAC), thereafter K was determined by flame photometry, and Ca by spectrophotometry, using the atomic absorption spectrophotometer. Micronutrients (Mn, Fe and Cu) were extracted with Mehlich extractant and determined with Buck Scientific Atomic Absorption Spectrophotometer (AAS) model 210/211VGP.

The planting was done between May to July, 2022. Soybean variety (TGM-674) obtained from International Institute of Tropical Agriculture (IITA), Ibadan and single super phosphate (SSP) mineral fertilizer, cattle manure, poultry manure, sheep manure, pig manure, rabbit manure applied at the rate of 40 kg $P_20_5ha^{-1}$ (P requirement of the test crop) and control (no soil additive). The experiment was laid out as a Completely Randomized Design (CRD) with four replicates. Each treatment was applied to twenty eight (28) pots. Each pot was filled with 5 kg sieved soil and watered to 60% field capacity followed by the application of corresponding treatments which was allowed to mineralise for two weeks before the seeds were sowed at three (3) per pot and later thinned to two (2) plant per pot at two weeks after planting. Weeding was done manually as required while 8 ml of Lambda-cyalothrin (karate) in 2 litres of water was sprayed after sowing and 3 more times during flowering and podding stages for pest and disease control.

Data were taken on plant height (cm), number of leaves/ plant and yield components which include: Dry weight of stem (g), leaves (g) and root (g), grain yield/plant, total dry weight/plant (g), harvest index which was determined using:

$$\text{Harvest index} = \frac{\text{Grain weight}}{\text{Total top weight}} \times 100$$

Where:

Total top weight = Grain weight + Dry shoot weight.

Relative agronomic efficiency (RAE) of the manures was estimated following the formula adopted by Hellal et al. [12].

RAE of Manures = Dry matter from manures- Dry matter from control / Dry matter from SSP – Dry matter from control × 100

This formula was modified (using soil available phosphorus data) as

RAE of Manures = Avail. P from manures- Avail. P from control / Avail. P from SSP – Avail. P from control × 100

Data collected were subjected to statistical analysis using GENSTAT and the treatments means were separated using Least Significant Difference (LSD) at 5% significance of probability.

3. RESULTS

3.1 Pre-planting Chemical Properties and the Effects of Applied Treatments on Post-planting Soil Nutrients

The pre-planting chemical properties of the soil revealed that at that the pH of the soil was strongly acidic (4.4). At the end of the first planting, all the pots had their pH increased respectively (Tables 1, 2). The organic carbon-build up was significantly improved by various manure treatments with the poultry manure having the highest value (1.6 g kg^{-1}), closely followed by rabbit manure (1.1 g kg^{-1}) and the lowest value (0.7 g kg^{-1}) was obtained from the control pots. All the treated plots were high in organic carbon except the control (no soil additive). At the end of the first planting, all the plots had their total nitrogen increased respectively. Of all treatments, only poultry manure supported increases in total nitrogen above 0.1 g/kg prior before cropping, having the highest total nitrogen value (0.4 g kg^{-1}) and the lowest values in control pots (0.1 g kg^{-1}) (Table 1). The various treatments applied differ in the available P released into the soil solution in the order of poultry manure > SSP > pig manure > cattle manure > sheep manure > rabbit manure>control. All the treated pots had high exchangeable K values. Poultry and pig manures treated pots had high exchangeable K value (0.7 cmol kg^{-1}) which was followed closely by cattle and sheep manures (0.6 cmol kg-1) while SSP, rabbit manure and control (0.5 cmol kg^{-1}) pots had medium exchangeable K. All the various manure treatments applied (except SSP) significantly increased calcium percentage above the control. Poultry manure had statistically similar calcium with other manures. In term of magnesium saturation, also, poultry manure (2.6 cmol/kg) treated soil had the highest significant mean followed by rabbit manure (2.5 cmol/kg), then pig manure (2.3 cmol/kg), sheep manure (2.0 cmol/kg), cattle manure (1.9 cmol/kg), SSP (1.9 cmol/kg) while the control gave the lowest mean value of 1.8 cmol/kg.

3.2 Response of Soybean to Various Manures

The result of the yield parameters revealed that the plants performed better with manures than the SSP mineral fertilizer. The poultry manure treatment produced significantly higher ($p<0.05$) total dry weight (14.9 g/pot) than SSP mineral fertilizer (5.1 g/pot) as well as the control treatment, the least total dry weight (0.3 g/pot) was recorded in the control treatment.

However, the pig manure treatment resulted in a significantly higher ($p<0.05$) mean grain weight (1.9 g/pot) than other treatments, while the least (0.7 g/pot), was recorded in the control plots (no soil additive applied) Table 3. Although not significantly better than the rabbit manure, the pig manure treated pots had the highest mean harvest index (38.4 %). The harvest index (25 kg ha-1) was recorded from SSP mineral fertilizer pot (Fig. 2).

Poultry manure treatment gave higher relative agronomic efficiencies. In terms of relative agronomic efficiencies using soil available P data RAE_P, poultry manure treatment was the most efficient treatment which was significantly higher than all other manures. The least agronomic efficiencies were recorded in sheep manure pot. However, higher relative agronomic efficiencies using dry shoot weight (RAE_{DSW}) was still observed in poultry manure-treated pot compared to the other manures.

4. DISCUSSION

Generally, the manures fertilizer treatments showed better soil fertility status compared to other treatments based on the soil chemical status analysed in this investigation. This better fertility status could be due to the gradual decomposing effect of the compost and its ability to improve soil fertility over a period of time, as is the general case with organic matter [13]. The result is also an indication that compost could serve as a storehouse for essential nutrients for crops. The addition of organic amendments had been reported to increase soil pH [14,15]. The generally high soil reaction shows that all treatments tested released the highest concentration of basic cations in them. The post-soil chemical properties showed poultry manure as having more influence in improving soil pH compared relative to other treatments. The high pH value from poultry manure treated soils shows high proportions of soluble alkalinity in the poultry manure. The alkalinity in organic amendments is referred to as cations content [16]. The soil analysis result also showed that poultry manure improved soil nitrogen, phosphorus, organic carbon, calcium, magnesium and potassium compared to the mineral fertilizer (SSP). This could be attributed to organic matter having negatively charged sites that attract and hold positively charged particles [17]. It is also in accordance with the finding of Ayeni et al. [18] that manures improved the soil chemical properties after the main cropping. Manures significantly improved soybean grain yield with the highest mean recorded from pig manure, compared to control and mineral fertilizer. This shows the ability of the soybean sown to manures treated pots to utilize the nutrients from treated pots easily and transform them into better grain and biomass yields. This may be due to the higher nutrient uptake of manures which facilities more photosynthetic activity and more partitioning on dry matter into pods and seeds [19,20].

The relative agronomic efficiencies were very high in poultry manure treated soil compared to chemical fertilizer. Poultry manure gave RAE_P of 363 % and RAE_{DSW} of 925 % respectively. The results from the present work suggests poultry manure to be a more efficient P source in the soil studied compared to other manures and chemical fertilizer (SSP) tested. Ajayi et al., (2012) also attributed “the ability of organic fertilizer to easily supplement readily available phosphate ions in the soil solution to the generally higher relative agronomic efficiencies in soils treated by organic fertilizer”.

Chart 1. Primary macronutrient composition of fertilizer treatments

Nutrient elements	Rabbit manure	Sheep manure	Cattle manure	Pig manure	Poultry manure
Primary macronutrient (g/kg)					
Nitrogen	18.8	20.8	19	23.3	7.3
Phosphorus	1.1	0.9	0.7	1.1	1.5
Potassium	15	15	21	6.4	23

Table 1. Some physical and chemical properties of soil used for the experiment

Parameters	Soil
pH (H_2O) 1:1	4.4
Org C (g/kg)	3.6
Total N (g/kg)	0.1
Available P (mg/kg)	3.5
Exchangeable cations (cmolkg^{-1})	
K+	0.2
Ca2+	2.2
Mg2+	1.7
Na+	0.2
Extractable micronutrients (mgkg^{-1})	
Mn	31
Fe	20
Zn	0.7
Cu	0.4
Particle size distribution (g/kg)	
Sand	620
Silt	226
Clay	154
Textural class (USDA)	Sandy loam

Table 2. Effects of fertilizer treatment on soybean yield at 9 WAS

Treatment	Stem (g/pot)	Leaves (g/pot)	Root (g/pot)	Shaft (g/pot)	Grain (g/pot)
Control	0.7b	0.2b	0.7b	0.7c	0.7c
SSP	1.1b	0.6b	1.0b	1.0ab	1.0bc
Rabbit manure	2.1a	1.6ab	2.2a	1.4a	1.4ab
Poultry manure	2.9a	2.6a	3.3a	1.7a	1.1bc
Sheep manure	1.9a	1.8ab	2.3a	1.3ab	1.2bc
Cattle dung	1.9a	1.6ab	1.9a	1.2ab	1.1bc
Pig manure	2.0a	1.4ab	2.3a	1.7a	1.9a

Means with the same letter (s) in the column are not significantly ($p<0.05$) different using Duncan's Multiple Range Test.
SSP., single super phosphate

Table 3. Post-planting chemical properties of the soil during

Treatments	pH (H_2O) 1:1	Organic C (g/kg)	Total N (g/kg)	Avail. P (mg/kg)	Cacmol/kg	Mg	K
Control	5.0b	0.7ab	0.1b	5.5b	2.4b	1.8c	0.5
SSP	5.2ab	0.9ab	0.2b	7.6a	3.0ab	1.9c	0.5
Rabbit manure	5.3ab	1.1ab	0.2b	6.0ab	3.1a	2.5ab	0.5
Poultry manure	6.0a	1.6a	0.4a	9.8a	4.0a	2.6a	0.7
Sheep manure	5.4a	0.8ab	0.2b	6.1ab	3.3a	2.0bc	0.6
Cattle dung	5.3ab	1.0ab	0.1b	6.7ab	3.4a	1.9c	0.6
Pig manure	5.4a	1.0ab	0.2b	6.7ab	3.3a	2.3abc	0.7
							ns

Means with the same letter (s) in the column are not significantly ($p<0.05$) different using Duncan's Multiple Range Test.
ns., non-significant
SSP., single super phosphate

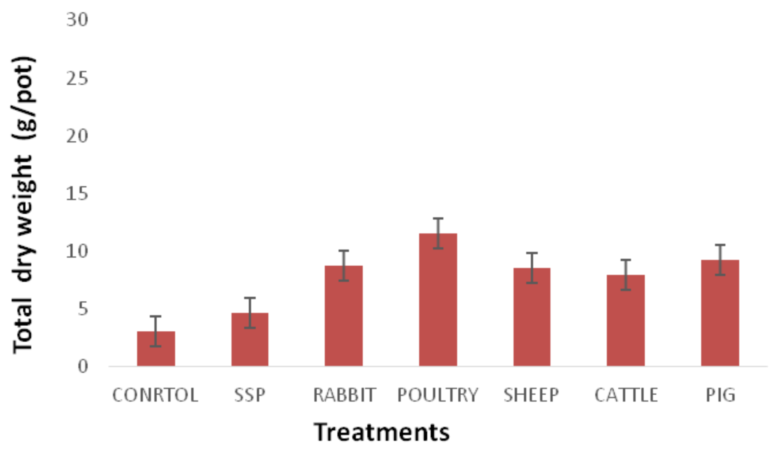

Fig. 1. Effect of treatments on total dry weight of soybean SSP; Sin gle super phosphate bar is standard error of mean

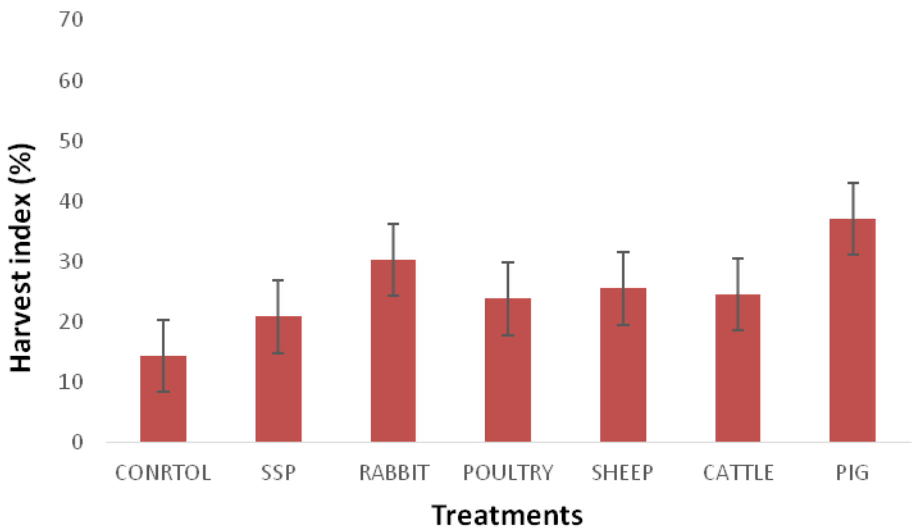

Fig. 2. Effect of treatments on harvest index soybean SSP; Single super phosphate bar is standard error of mean

Table 4. Relative agronomic efficiencies using available P (RAE_P) and soybean dry shoot weight (RAE_{DSW})

Treatments	Relative agronomic Efficiency ($_P$) (%)	Relative agronomic Efficiency ($_{DSW}$) (%)
Control	0	0
Rabbit manure	41	883
Poultry manure	363	925
Sheep manure	30	712
Cattle manure	128	901
Pig manure	37	749
SSP	100	100

5. CONCLUSION

In summary, the results of this research revealed that poultry or pig manures at 40 kg P_2O_5/ha could be excellent materials for improving soil fertility, yield of soybean and its agronomic efficiencies on degraded acid soil in Ondo.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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