Original Research Article

Improving Growth and Yield Performance of Sesame (*Sesamum Indicum* L.) Under the Effects of Soil Amendments and Planting Geometry

ABSTRACT

The agronomy of sesame and production barriers in Ghana, such as nutrient management and planting geometry, are largely unexplored. This poses a significant obstacle to its commercial cultivation. As a result, this study was carried out to investigate the effects of organic and inorganic fertilizers, as well as planting geometry, on sesame growth and yield. The experiment was carried out at the University for Development Studies' research field. It was a split plot laid out in a Randomized Complete Block (RCB) design with three replications. The main plot treatments were three planting geometries (G_1 = 45 x 15, G_2 = 60 x 10, and G_3 = 75 x 15 cm), and the sub-plot treatments were four soil amendments with a control [F_0 = 0 t $ha^{-1,}$ F_1 = 16 t ha^{-1} compost, F_2 = 16 t ha^{-1} biochar, F_3 = 16 t ha^{-1} (compost + biochar), and F_4 = N− P_2O_5 −K_2O (16−60−60 kg ha^{-1})]. The results showed that the treatments significantly (*P<.05*) affected growth and yield parameters. The increase in percentage for each treatment over the control is shown in the following order: **number of branches** (B 22% < NPK 24%< B+C 27%< C32%); **number of seeds per capsule** (B+C 4% < B 5 % < NPK 7% < C 8%); and **seed yield** (B+C 75% < B 80%< NPK 137% < C157%). Moreover, the optimum seed yield of 1,115 kg ha^{-1} was obtained with the application of compost at 16 t ha^{-1}. In addition, compared to 45 x 15 and 75 x 15 cm planting geometry, sesame at the intermediate planting geometry of 60 x 10 cm increased seed yield by 10 and 57%, respectively. Therefore, compost application at 16 t ha^{-1} and planting geometry of 60 x 10 cm is recommended for sesame production in similar savannah environments.

Key words: sesame, soil amendments; planting geometry, yield components, seed yield.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is cultivated in tropical and sub-tropical Africa for its significant nutritive value and edible seeds [14]. However, the deterioration in soil fertility is one of the main limitations to agricultural production in sub-Saharan Africa [1]. Farmers apply fertilizer below the recommended rates in Africa [39]. This coupled with poor agricultural practices has led to soil nutrient reduction [38]. A result of this trend is an intensely unbalanced soil nutrient composition that eventually leads to a decrease in crop yield potential [40]. In Northern Ghana, the continuous application of sole inorganic fertilizer (NPK) has been a widely and common practiced, which has resulted in worsening of soil health in terms of soil physiochemical and biological properties, and decrease in the amount of soil organic matter [1].

Organic materials are a major source of plant nutrients, and integrating organic materials into soil enhances soil structure, water holding capacity, aggregate stability, soil drainage, soil aeration and root penetration. Studies have revealed that organic fertilizer have beneficial effects in improving microbial activity, increasing the amount of soil nutrients availability and electrical conductivity [2, 8, 24,27]. Seed yield and quality of sesame could be improved with the application of organic manures from variety of composting materials including crop residues and animal manure [3,4]

Biochar is the product of the thermal decomposition of organic material under limited supply of oxygen (O_2) and at relatively low temperature (< 700 ^{0}C). The rationale behind the application of biochar to soil is to promote its biochemical and agronomic characteristics, and to facilitate carbon sequestration. Sustainable agriculture in the long term can be achieved by the utilization of biochar as a significant tool for enhancing soil fertility, increasing yield, soil carbon sequestration, and lessening the impact of greenhouse gas emissions [17,18, 30].

The combination of organic and inorganic fertilizers for restoring depleted nutrient stock to support continuous crop production is of significant importance [10,11]. According to several research results, sustainable crop productivity may not be attained with the sole application of either inorganic or organic fertilizers [20, 24]. Soil fertility management in an integrated way will promote judicious use, and proper combinations of organic and inorganic resources as a practicable technique to overcome soil fertility problems and to ensure high crop productivity [12, 41].

In addition, the agronomic performance of any crop is partly attributed to plant population density on the field. Plant population affects the capture of sunlight by plant canopy [21, 33]. Plant densities vary much in sesame cultivation, and reliant on the growing environment, cultivar, and system of production. Population density is an integral factor of yield, and a uniform plants distribution per unit area is a requirement for yield stability [25]. The finding of [23] revealed that Sesame with closest spacing was better in terms of seed yield per land area while widest spacing produced the maximum individual yield attributes. Commercial production of sesame in Ghana is new and is limited to few farmers in northern Ghana. Information on plant spacing is lacking and farmers adopt spacing based on other crops they cultivate. There are variations among the genotypes cultivated in Ghana and this requires that information on plant densities be established. Therefore, this study was conducted to: (i) examine the main effects of organic and inorganic nutrients, and planting geometry; (ii) determine the interaction effects between organic and inorganic fertilizers, and similarly soil amendments and planting geometry.

2. MATERIAL AND METHODS

2.1 Location

The experiment was carried out at the University for Development Studies Experimental Field at Nyankpala Campus. This area lies within the Guinea savannah zone of Ghana with an altitude of about 183 m above sea level and located on longitude 0 ° 58 °W and 9 ° 25 °N. It has a unimodal rainfall pattern with mean annual rainfall of 1000 – 1100 mm fairly distributed from April to November with the peak in August and September. Temperature distribution is uniform with mean monthly minimum of 23.4°c and with relative humidity varying greatly from 46.9 % minimum and 76.8 % maximum. [29].

2.2 Experimental design and treatments

The experiment was a split plot laid out in a Randomized Complete Block Design (RCBD) with three replications. The main plot treatments were three planting geometry (G_1 = 45 x 15, G_2 = 60 x 10, and G_3 = 75 x 15 cm) and the sub-plot treatments were four soil amendments with a control [F_0 = 0 t ha^{-1}, F_1 = 16 t ha^{-1} compost, F_2 = 16 t ha^{-1} biochar, F_3 = 16 t ha^{-1} (compost + biochar); and F_4= N− P_2O_5 −K_2O (16−60−60) kg ha^{-1}]. Plot size measured 10 x 10 m with 1m between plots and 2m between blocks. The field was ploughed and harrowed to a depth of about 15-20 cm and ridges were created to facilitate good condition for planting. Designated plots received compost and biochar two weeks before planting. Moreover, half dose of NPK was applied at sowing time and the remaining half was applied at flowering stage. Five seeds of "Namsubani" variety were planted in shallow furrows.

2.3 Agronomic Data Collection and Analysis

2.3.1 <u>Growth characteristics</u>

Data were collected three weeks after planting, and at three weeks interval till harvesting. Nine plants were randomly tagged in each plot for; plant height, and number of branches per plant.

2.3.2 <u>Yield characteristics</u>

Number of seeds per capsule, capsule weight, and 1000-seed weight were determined. Seed yield was computed as:

$$= \times 10{,}000$$

2.3.3 <u>Statistical Data Analysis</u>

Data were subjected to analysis of variance (ANOVA) using the GenStat statistical package. Means were separated using the Least Significant Difference (LSD) at 5% level of probability. Duncan's Multiple Range Test (DMRT) was used to determine the significant differences among the treatments. Results were represented in Tables and Figures.

3. RESULTS

3.1 Soil analysis

The physical and chemical properties of the soil before the experiment are presented in Table 1. The results indicated the soil to be sandy loam with a pH of 5.6. The soil organic carbon was 1.02%; nitrogen and available phosphorus were 0.09% and 5.40 mg kg^{-1}, respectively. The K^{+}, Ca^{2+} and Mg^{2+} were 28.00, 1.25 and 0.76 cmol kg^{-1} respectively. The study area was evidently low in essential nutrient concentrations and therefore required better nutrient management strategy, for efficient and sustainable crop production.

3.2 Number of branches

The main effect of soil amendments as well as the interaction effects between planting geometry and soil amendments at 6 WAP significantly (*P*=.05; *P=.05*) influenced the number of branches per plant, respectively. Sole compost application at 16 t ha^{-1} induced the highest branches of 4.50 per plant whilst the control produced 3.70 minimum number of branches (Figure 1). Moreover, compost treated plants at 16 t ha^{-1} in combination with the widest planting geometry of 75×15 cm produced the maximum branches of 4.9 per plant (Table 2). However, this result was not different significantly from the values (4.5, 4.6, and 4.7) of plants that received only biochar at 16 t ha^{-1}, NPK at 16− 60− 60 kg ha^{-1}, and biochar + compost at 16 t ha^{-1} under the same planting geometry, respectively. The percentage increase in the number of branches for the various treatments are B 22% < NPK 24%< B+C 27% < C32% with respect to the control.

3.3 Plant height

Plant height at 6 WAP was significantly (*P*= .05*;* *P*=.05) affected by the main effects of soil amendments, and planting geometry, respectively. The application of compost at 16 t ha^{-1} recorded the highest height of 56.31 cm, with the control supporting the least height of 41.89 cm (Figure 2a). Moreover, the optimum height of 54.30 cm was attained under 45×15 cm planting geometry, whilst 41.78 cm minimum height was observed in the widest planting geometry of 75×15 cm (Figure 2b).

3.4 Number of seeds per capsule

There was a significant difference (*P* =.05) among the various soil amendments. Compost treated plants gave the optimal number of 64 seeds per capsule (Figure 3). The control plots produced the lowest number of 59 seeds per capsule. The percentage increase of the various soil amendments is in the order of B+C 4% < B 5 % < NPK 7% < C 8% when juxtaposed with the control.

3.5 Seed yield

The main effects of soil amendments, and planting geometry were significant (*P*<.001; *P*=.05) for seed yield. Compost application at 16 t ha^{-1} produced the highest seed yield of 1,115 kg ha^{-1} whilst the control gave the least value of 435 t ha^{-1} (Figure 4a). The Percentage increase of grain yield with respect to control for the various treatments are in the order B+C 75% < B 80%< NPK 137% < C157%. Likewise, the intermediate planting geometry of 60×10 cm produced the best yield of 978 kg ha^{-1} whereas the minimum seed yield of 619 kg ha^{-1} was recorded for the widest planting geometry of 75×15 cm (Figure 4b). This implies that, sesame at the intermediate planting geometry of 60 x 10 cm increased seed yield by 10 and 57% as compared to 45 x 15 and 75 x 15 cm planting geometry, respectively.

3.6 Capsule and 1000-seed weights

There was significant (*P*=.05; *P*=.05) main effects of soil amendments on capsule and 1000-seed weights, respectively. Compost application at 16 t ha^{-1} recorded the highest capsule weight of 1,719 kg ha^{-1} (Table 3). Similarly, the optimum seed weight of 3.46 g was obtained at the same rate whilst the control gave the minimum weight of 1.32 g (Figure 5).

Table 1: Physical and chemical properties of the soil before planting at the depth of 0-20 cm.

Table 2: Number of branches per plant as influenced by the interaction between soil amendments and planting geometry.

Treatments	Rate of application	Plant Spacings (cm)		
		45×15	10×60	75×15
Biochar	16 t ha^{-1}	3.6 ^{bc}	3.7^{bc}	4.5 ^{ab}
Compost	16 t ha^{-1}	4.0 ^{abc}	4.4 ^{ab}	4.9^{a}
Compost +biochar	16 t ha^{-1}	4.0 ^{abc}	4.3 ^{ab}	4.7^{ab}
NPK	16− 60− 60 kg ha^{-1}	4.2 ^{ab}	4.4^{ab}	4.6 ^{ab}
Control		3.0 ^{c}	3.6 ^{bc}	3.7^{bc}
LSD (.05): 1.10	Grand Mean =	**4.10**		

LSD = Least significance difference. Means followed by the same letter (s) are not statistically different according to Duncan Multiple Range Test (DMRT) at 5% level of probability.

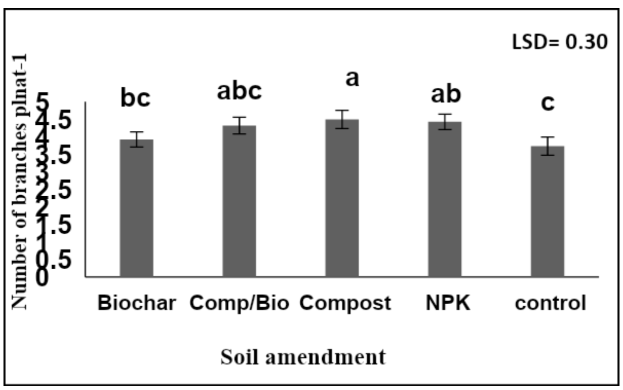

Fig. 1: Number of branches as influenced by soil amendments, Bars represent S.E.M

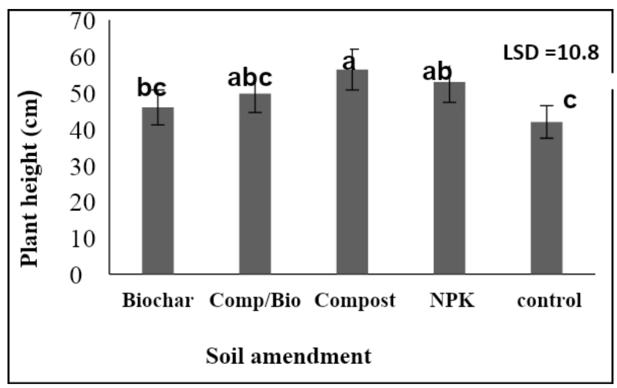

Fig. 2a: Plant height as influenced by soil amendments. Bars represent S.E.M.

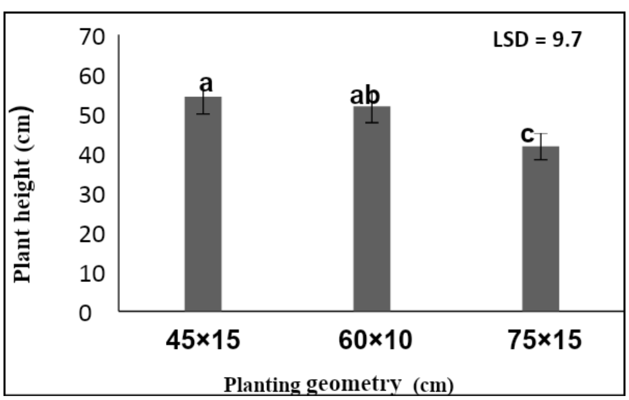

Fig. 2b: Plant height as influenced by planting geometry. Bars represents S.E.M

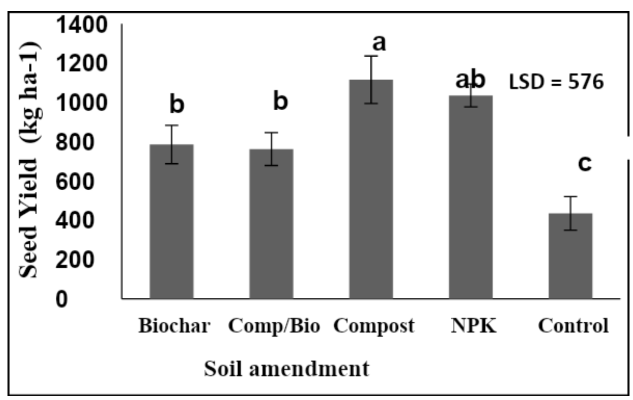

Fig. 4a: Seed yield as influenced by soil amendments. Bars represent S.E.M

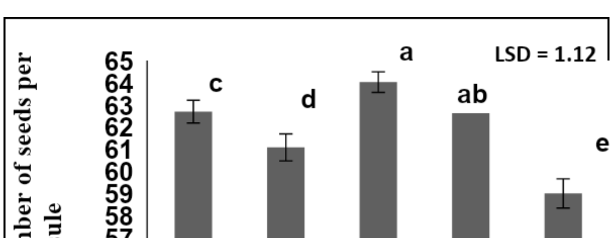

Fig. 4b: Seed yield as influenced by planting geometry. Bars represent S.E.M

Table 3: Total capsule weight as influenced by soil amendments

LSD = Least significance difference. Means followed by the same letter (s) are not statistically different according to Duncan Multiple Range Test (DMRT) at 5% level of probability

4. DISCUSSION

The best growth trait result was observed in the number of branches for plants treated with sole compost application at 16 t ha^{-1}, and the interaction effects between compost application at 16 t ha^{-1} and a planting geometry of 75×15 cm. This finding could be attributed to the adequate nutrient provision, complemented with optimum light interception enhanced photosynthesis, plant growth, and the number of branches per plant. The widest spacing between the rows led to less competition between plants for available nutrients and other growth resources (19, 21]. The possible soil physical characteristics modifications (structure, increased in permeability and active surface sites) triggered by organic matter addition largely boosted the capacity of the soil to store water and nutrient retention [9,20,24, 28]. Additionally, the highest plant height recorded with 45×15 cm planting geometry could be due to the increase in the number of plants per unit area coupled with apical meristem competition for growth resources. Responses to spacing in crops enhanced inter-plant competition for water and light, which resulted in taller plants expression as a phenotypic trait [7, 25, 26]

Moreover, soil amendments with sole compost, NPK, and biochar, as well as compost and biochar combination increased yield parameters such as number of seeds per capsule, seed yield, capsule weight, and 1000-seed weight over the control. This performance could be ascribed to the capacity of the various soil amendments to supply plants with regular available N in a sustained manner throughout the whole vegetative period. This is an important feature in soils characterized by required N availability, as it lowers the possibility to have N plant deficiencies during important vegetative stages, and decreases the risk of N leaching and N_2O gas emissions [23, 31]. Similarly, improved nutrient availability positively affected cell physiology that translated into optimum yield through the translocation of photosynthates to the sink (seed), which promoted seed weight. Likewise, several authors have indicated that plants grown under co-composted biochar environment produced good results of growth and yield attributes as a result of its potential in nitrate-capture of some redox-active moieties, and meso-porosity enhanced biochar water which promotes nutrient retention [13, 16, 28, 34]. In addition, the plant population produced under the intermediate planting geometry of 60×10 cm resulted in more seed yield than the plant populations under the planting geometries of 45×15 and 75×15 cm. This result suggests that plant populations below or above certain thresholds could result in unproductivity in sesame cultivation since sparsely populated fields with widest spacing could lead to uneconomic use of space, prolific growth of weeds and pests, and lessening of sesame yield per unit area [15, 23]. Moreover, the yield effect of higher plant population density from this study may be due to the higher number of plants per area in closer rows spacing had compensated for imminent reduction in the yield components such as the weight of 1000 –seeds, and number of capsules per plant [25].

CONCLUSION

The results indicated that sesame with the planting geometry of 45 x 15 and 75 x 15 cm outperformed in growth parameters such as plant height and number of branches, whilst 60 x 10 cm intermediate spacing performed better in terms of yield parameters. The maximum seed yield of sesame was achieved with compost application at 16 t ha^{-1}. For effective and economic use of land, planting geometry of 60 x 10 cm could be adopted in the production of sesame. Therefore, compost application at 16 t ha^{-1} and planting geometry of 60 x 10 cm is recommended for sesame production in the study area and similar savannah environments.

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