

Research Article

Integration of Vermicompost and NPS Fertilizer Rates for Sesame (*Sesamum indicum* L.) Production at Gobu-Sayo District, Western Oromia, Ethiopia

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Abstract

Effect of vermicompost rate and NPS Fertilizer integrated on sesame yield and yield components at Gobu Sayo district was assessed for two years. Different rates of vermicompost and NPS fertilizer were integrated, no treated or control, recommended vermicompost alone, (4.64 tons ha⁻¹), and recommended NPS alone fertilizer were also included as checks, 25:25, 25:50, 25:75, 50:25, 50:50, 50:75, 75:25, 75:50, 75:75 (%), vermicompost and NPS fertilizer respectively combined. Growth parameters such as plant height (116.67cm) and branch number (5.230) significantly ($P < 0.05$) affected by the use of integrated vermicompost and NPS fertilizer. Yield parameters biomass yield, (4.61 tons ha⁻¹), grain yield (0.45 tons ha⁻¹), and composite soil data before planting and postharvest soil data were taken and analyzed. Treatment (50% recommended vermicompost and 50% NPS fertilizer) gave 701kg ha⁻¹ with (17,814.1 Ethiopia birr ha⁻¹), the highest net benefit with an acceptable marginal rate of return (45.52). Soil parameters, soil pH (1:1.2.5), soil organic carbon (SOC), soil organic matter (SOM), and total nitrogen in the soil (TN) were significantly different. Therefore, the results of the study showed that the integration of vermicompost and NPS fertilizers in sesame crop production is recommended and can improve the selected soil chemical properties of the study area and similar ecology.

Keywords

Organic Carbon, Organic Matter, Sesame, Soil pH, Total Nitrogen, Vermicompost, Fertility

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the most ancient crops and oilseeds known and used by mankind, [1]. It was a major oilseed crop in the ancient world due to its easiness of extraction, great stability, and resistance to drought [2]. Sesame is considered to have both nutritional and medicinal values, [3]. In Ethiopia, oil seeds added about 846,493.53 hectares of the grain crop area and 2.79% (about 8,550,738.16 quintals) of the production to the national grain total. Sesame

covered 2.92% (about 370,141.06 hectares) of the grain crop area and 0.84% (about 2,559,034.30 quintals) of the grain production, [4]. Despite of this, a decline in soil fertility implies either decline in the levels of some important soil properties such as soil organic carbon, pH, cation exchange capacity, and plant nutrients or an increment of the other to the level of toxicity. In the broadest sense, soil fertility decline includes nutrient depletion (large removal addition of nutri-

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ents), nutrient mining (large removal of nutrients and no inputs), [5].

To maintain soil fertility through a natural nutrient cycle, compost of organic material and returning it back to the soil is a common activity in developed nations, [6]. Compost is a technology for recycling organic materials in order to achieve enhanced agricultural production, [7]. Biological and chemical processes accelerate the rate of decomposition, transforming organic matter into a more stable humus form to apply to the soil. In addition to changes in chemical and physical properties, composted materials have a significant effect on soil biological properties such as microbial biomass and activity, as well as changes in the activity of soil enzymes, [8]. Increased fertilizer use without organic recycling has aggravated multi nutrient shortages in soil-plant systems, as well as damaged soil health and caused pollution in the environment, [9].

Vermicompost is the use of mesophilic earthworms to produce organic fertilizer from organic waste, [10]. Earthworms restore and improve soil fertility and significantly boost crop productivity. Earthworm excreta (vermicast) is a nutritive 'organic fertilizer' rich in humus, micronutrients, beneficial soil microbes, nitrogen fixing, and phosphate solubilizing bacteria' (actinomycetes) and growth hormones ('auxins, gibberellins and cytokines). Vermicompost alters the soil fertility in different ways, such as better aeration, porosity, bulk density, water holding capacity, nitrogen, phosphorous and potassium content, [11]. Presence of live earth worms in soil also makes a significant difference in flower and fruit formation in vegetable crops, [12]. Compost works as a "slow-release fertilizer," whereas chemical fertilizers release nutrients into the soil fairly quickly, depleting them quickly. In comparison to using each component alone, the integrated use of chemical fertilizers with vermicompost has been proven to be quite promising not just in terms of maintaining soil health and productivity, but also in terms of stabilizing crop production, [13]. However, determining the optimal rate of inorganic and vermicompost fertilizers is crucial for better productivity of the crop.

According to in an experiment done on the characterization of different feed materials, combinations with manure from crop residue in Bako Agricultural Research center, 4.64 tons of vermicompost prepared from soybean straw and cattle manure can replace the recommended amount of urea (200 kg) in terms of nitrogen which in the same time supply 139 kg DAP that outmatched the dose of phosphorus for the crop, [14]. The present study assessed integration of vermicompost rate application with NPS fertilizers in two years of a field experiment for sesame crop.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was carried out at in the western part of

Ethiopia Bako Agricultural Research Center experimental field, at an altitude of 1650 masl. The area has a warm-humid climate with annual means two years cropping season and minimum and maximum temperatures of 13.85⁰c and 29.25⁰c respectively. The rainfall received during the 2018 and 2019 cropping seasons was 96.80 mm and 111.025 mm, respectively. The experimental site is described by reddish, reddish-brown and clay loam, nitisol which strongly acidic pH (4.98), organic carbon (2.89), organic matter, (5), TN, (0.25) with (7.14) pre-planting available phosphorus.

2.2. Fertilizer Materials

The organic fertilizer used in this study was vermicompost produced from the combination of soybean straw and cattle manure in the previous experiment, which out ranked the other types of vermicompost in its quality (nutrient content composition). According to the laboratory analytical results, the major plant nutrients contained in this compost are 1.98% total N, 1.39% total P, 3.94% total K, 7.91% total Ca, 8.7% total Mg and it had a CN ratio of 16.27. The inorganic fertilizer and rate used was 23 P₂O₅. Improved variety of the test crop (Walini) was sown according to the recommended agronomic practices for crops.

2.3. Treatment and Experimental Design

Twelve treatments consisting of three levels recommended vermicompost (25, 50, and 75%) and 25, 50, and 75%) levels of recommended NPS fertilizers were combined with a control, standard check or 100% NPS alone, and 100% recommended vermicompost. The experiment was laid out in a randomized complete block design (RCBD) with three replications.

2.4. Experimental Procedures and Field Managements

The plot measured 9.6m² (3 m by 3.2 m). Blocks and plots were separated by 1.5 and 1 meters, respectively. The two outer rows (one from each side of the plot) were kept as border rows. As a result, the central six rows (7.2 m²) were chosen as the net plot size and data collection point. To reduce nutrient and water movement from plot to plot, earth bunds were constructed around each plot and the entire experimental area. In early June, seeds were manually drilled at a rate of 5 kg per hectare in rows 40 cm apart. The total NPS and vermicompost fertilizer was administered during sowing based on the treatment.

2.5. Soil Sampling and Analysis

Before the field trial, soil samples were obtained at random depths ranging from 0 to 20 cm and combined to generate a composite soil sample. This composite sample was used to

perform certain soil physicochemical evaluations. The same was done with post-harvest soil samples, which were collected plot-by-plot from each replication between 0 and 20 cm deep and bulked by treatment to produce a representative sample for each treatment for a specific soil physico-chemical investigation. Soil samples were air-dried, placed in plastic bags with labels, and sieved through a 2 mm sieve [15]. At the Bako Agricultural Research Center soil laboratory, all samples were evaluated using standard laboratory techniques. According to the usual operating procedure for soil pH measurement, the pH of the soil was measured potentiometrically using a digital pH meter with a glass electrode in a supplementary suspension of 1:2.5 soils to water ratio [16]. Organic carbon (OC) was assessed using the Walkley and Black method, which followed the standard operating procedure for OC [17]. The method outlined by Bremner (2019) was used to determine total nitrogen (TN%). The soil's available phosphorus was recovered using the Bray II technique [18]. The cation exchange capacity (CEC) of the soil was evaluated by measuring NH_4^+ in 1M ammonium acetate (NH_4OAc , pH 7.0) saturated soil samples [19].

2.6. Data Collection and Measurements

Days to Physiological Maturity: Number of days to 75% of plants reaches physiological maturity from date of planting.

Plant height (cm): The height of the main stem from ground level to the tip of the plant.

Number of branches/plant: was determined by counting the number of primary reproductive branches.

Pod number /plant: It was counted from five randomly selected pre-tagged plants from each treatment.

Biomass yield (tons ha^{-1}): It was cut off and weighed using sensitive balance at harvest and average weight was computed.

Grain Yield (tons ha^{-1}): It was measured using electronic balance and then adjusted to 11% moisture and convert to hectare basis.

2.7. Data Analysis

All collected parameters were subjected to analysis of variance using SAS version 9.3. Whenever a treatment effect is significant, the means was separated using the least significant difference (LSD) procedures test at 5% level of significance.

2.8. Economic Analysis

A partial budget analysis was performed to investigate the economic feasibility of the treatments. To compare the economic feasibility of the treatments used, the economic analyses were carried out using the procedures described by, [20]. The average yield was down warded by 10% to get what farmers would get. Costs that vary were considered to perform a partial budget analysis.

3. Results and Discussion

The average change in soil chemical properties as a result of applying integrated, vermicompost and NPS fertilizer for soil pH, (1:2.5) H_2O from, 5.28 to 5.91, organic carbon from 2.89 to 4%, organic matter from, 5 to 9.03%, total nitrogen from, 0.25 to 0.45. Accessible for two years, the amount of phosphate before planting and at harvest is compared. Treatments with the highest available phosphate are noted. The highest available phosphate is recorded in treatments 50:50%, integrated of vermicompost and NPS fertilizer, due to the ability of, vermicompost to access soluble phosphorus in soils. While the lowest available Phosphate is recorded in treatment, 100% recommended NPS and absolute control.

Integrated vermicompost and NPS fertilizer had a, significantly, ($P < 0.05$) affected on Sesame plant height, [Table 1]. The highest (111.67 cm) at plant height of Sesame was recorded from application of, 75:50%, which is statistically at par with, all treatment except 25:50%, and vermicompost alone. The application of vermicompost positively influenced the height of Sesame at growth stages. The branch numbers of Sesame was significantly ($P < 0.05$) affected by the use of integrated vermicompost, and NPS fertilizer, [Table 1]. The highest branch number (5.23), was recorded from application of 75:50%, vermicompost and NPS fertilizers which at per with all treatment, except 75:75%, 75:25%, 50:25%, 50:75% and vermicompost alone. While the lowest, (3.75), branch number of Sesame was recorded from 75:75% and vermicompost alone, (Table 1).

The biomass yield of Sesame significantly ($P < 0.05$) affected by the use of integrated vermicompost and NPS fertilizer, (Table 1). The highest ($4.61 \text{ tons ha}^{-1}$), biomass yield was recorded from application of, 50: 50% recommended vermicompost, and NPS fertilizer, which was statistically at par with all integrated treatments except at absolute control, vermicompost alone, and 25: 25%, (Table 1). The mean grain yield of Sesame was significantly ($P < 0.05$) affected by the use of integrated vermicompost, and NPS fertilizer, (Table 1). The highest ($0.44 \text{ tons ha}^{-1}$), grain yields of Sesame were observed from application of, 50: 50%, vermicompost and NPS fertilizer; which were statistically at par with all treatment except vermicompost alone, 25:50%, 50:25%, and 75:75%. From each observation, higher grain yield was obtained from treatment that received 50% (2.32 tons per hectare) of recommend vermicompost and 50% (50 kg ha^{-1}) of NPS fertilizers. Yield obtained from Sesame mean of the years ($0.44 \text{ tons ha}^{-1}$) (Table 1 and figure 1).

The grain yield and soil fertility parameters showed significant differences. The modification of acidity was possible due to balancing inorganic chemical fertilizers by incorporating nitrogen waste in the process which increases the soil moisture, neutralizing the pH of soil from strongly acidic to moderately acidic rated by [21], considering organic carbon, CN ratio, organic matter and increase availability of phosphorus, improvement in the fertility status of the soil due to

integrated vermicompost nutrient and NPS fertilizers, similar trend was obtained by [22]. The highest organic carbon distinctly indicated that leads to deposits of organic matter. Organic matter content influence ability of soil retaining moisture. TN was similar to the others, total nitrogen of the soil was increased from pre-planting to post-harvest soil samples, recorded after crop harvesting regardless of treatment and seasonal variations. The mean changes in soil chemical properties for soil pH (1:2.5) H₂O ranges from 5.28 to 5.91, % OC from 2.89 to 4% OM from 5 to 9.03, % TN from 0.25 to 0.45, agree with reported by [22].

The application of vermicompost integrated with NPS fertilizers was significantly influenced total biomass, grain yield,

and soil fertility status [23], reported similar result where the application of vermicompost positively influenced the height and stock of sesame at growth stages. From observation, higher grain yield was obtained from treatments that received 50:50% (2.32 tons and 50 kg per hectare) of recommended vermicompost and NPS fertilizers, agree with reported by [24], significant difference was observed in most parameters measured such as branch number, plant height, biomass and grain yield. Means rain fall (mm), Maximum and Minimum Temperature (0°), the total amount of rainfall (mm) in 2018 and 2019 during the cropping season vary the amount of rainfall influence on mean grain yield (Figure 1).

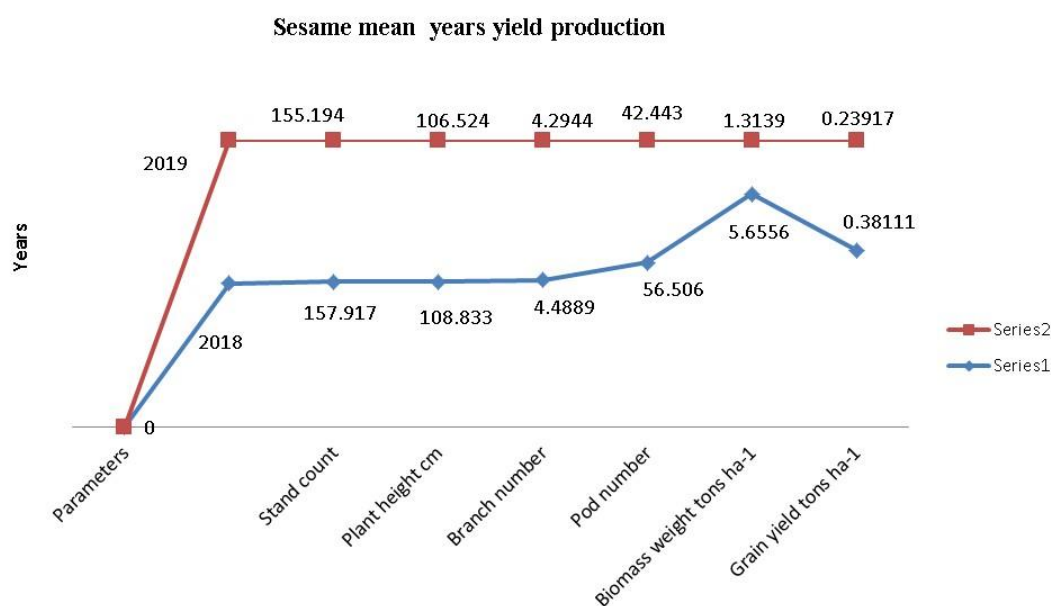


Figure 1. Sesame mean years, yield production parameters influenced by integrated vermicompost and NPS fertilizers.

Table 1. Sesame means of Yield production parameters influenced by integrated vermicompost and NPS fertilizers.

| Treatments | Stand count | Plant height cm | Branch number | Pod number | Biomass weight tons ha ⁻¹ | Gran yield tons ha ⁻¹ |
|-------------------|-------------|-----------------------|---------------------|------------|--------------------------------------|----------------------------------|
| Control | 157.83 | 109.06 ^{bac} | 4.73 ^{ba} | 44.72 | 2.98 ^b | 0.283 ^{bac} |
| 25:25% Ver &NPS | 158.00 | 109.18 ^{bac} | 4.36 ^{bac} | 45.84 | 2.48 ^b | 0.325 ^{bac} |
| 25:50% Ver &NPS | 155.33 | 102.31 ^c | 4.26 ^{bac} | 44.12 | 3.31 ^{ba} | 0.255 ^{bc} |
| 25:75% Ver & NPS | 156.83 | 107.83 ^{bac} | 4.46 ^{bac} | 52.99 | 3.30 ^{ba} | 0.248 ^{bc} |
| 50:25% Ver &NPS | 157.50 | 111.12 ^{ba} | 4.23 ^{bc} | 45.87 | 3.90 ^{ba} | 0.213 ^c |
| 50: 50% Ver & NPS | 154.50 | 106.69 ^{bac} | 4.76 ^{ba} | 54.97 | 4.61 ^a | 0.448 ^a |
| 50:75% Ver &NPS | 152.66 | 106.57 ^{bac} | 4.23 ^{bc} | 52.70 | 3.61 ^{ba} | 0.36 ^{bac} |
| 75:25% Ver & NPS | 157.50 | 109.56 ^{bac} | 4.03 ^{bc} | 45.66 | 3.83 ^{ba} | 0.30 ^{bac} |
| 75:50% Ver & NPS | 159.16 | 111.67 ^a | 5.23 ^a | 52.08 | 4.01 ^{ba} | 0.410 ^{ba} |
| 75:75% Ver &NPS | 157.00 | 104.36 ^{bac} | 4.10 ^{bc} | 49.10 | 3.58 ^{ba} | 0.250 ^{bc} |

| Treatments | Stand count | Plant height cm | Branch number | Pod number | Biomass weight tons ha ⁻¹ | Gran yield tons ha ⁻¹ |
|-----------------|----------------------|----------------------|---------------------|----------------------|--------------------------------------|----------------------------------|
| 100% Ver. Alone | 156.83 | 103.75 ^{bc} | 3.73 ^c | 46.99 | 2.88 ^b | 0.253 ^{bc} |
| 100% NPS alone | 155.50 | 109.99 ^{ac} | 4.53 ^{bac} | 58.60 | 3.28 ^{ba} | 0.365 ^{bac} |
| Cv (%) | 3.44 | 6.25 | 19.35 | 25.26 | 38.78 | 47.11 |
| LSD (0.05%) | 6.2315 ^{ns} | 7.7861 | 0.9822 | 14.614 ^{ns} | 1.5612 | 0.1688 |

Economic Analysis

The dominance analysis indicated that all treatments were dominated by treatments 25:50, 25:75, 50:25, 50:75, 75:25, 75:50, 75:75 (%) recommended vermicompost alone and recommended NPS fertilizer alone were dominated; treatments 25:25% and 50:50% were lower variable cost with higher net benefit (Table 2). Based on the dominance analysis, treatments 25:50% and 50:50% were potential options (Table 2), depending on the partial budget analysis, treatment 50:50%, vermicompost and NPS fertilizer application, (17, 814.1 ETB ha⁻¹) Showed the highest net benefit [20].

Table 2. Economics (partial budget and dominance Analysis) integrate vermicompost and NPS fertilizer rates on Sesame production.

| Treatments | Av.yield kg ha ⁻¹ | Adj.yield kg ha ⁻¹ | GB (Eth.Birr) | TCTV (Eth.birr) | NB (Eth.birr) | MR (%) |
|-------------------|------------------------------|-------------------------------|---------------|-----------------|---------------|--------|
| Control | 442.70 | 398.43 | 11952.98 | 0 | 11952.98 | |
| 25:25% Ver & NPS | 507.81 | 457.03 | 13710.94 | 549.89 | 13161.05 | 45.52 |
| 25:50% Ver & NPS | 333.32 | 300.00 | 8999.86 | 719.14 | 8280.72D | |
| 25:75% Ver & NPS | 471.35 | 424.22 | 12726.70 | 888.39 | 11838.31D | |
| 50:25% Ver & NPS | 398.43 | 358.59 | 10757.81 | 930.53 | 9827.28D | |
| 50: 50% Ver & NPS | 700.51 | 630.46 | 18913.92 | 1099.78 | 17814.14 | 11.82 |
| 50:75% Ver & NPS | 640.63 | 576.56 | 17296.88 | 1269.03 | 16027.85D | |
| 75:25% Ver & NPS | 388.02 | 349.21 | 10476.42 | 1311.17 | 9165.25D | |
| 75:50% Ver & NPS | 575.52 | 517.96 | 15538.92 | 1480.42 | 14058.50D | |
| 75:75% Ver & NPS | 390.63 | 351.56 | 10546.88 | 1649.67 | 8897.21D | |
| 100% Ver alone | 570.31 | 513.28 | 15398.44 | 2199.56 | 13198.88D | |
| 100% NPS alone | 395.83 | 356.25 | 10687.36 | 2300 | 8387.36D | |

Ver =vermicompost, Av. Yield=Average yield kilograms per hectare, Adj. yield=Adjusted yield 10% field Kilo grams per hectare' GB=Gross Benefit, TCTV=total cost that varies, NB=Net benefit, MRR=marginal rate of return

4. Conclusion and Recommendation

A decline in the levels of soil properties such as soil organic carbon, pH, cation exchange capacity (CEC), and plant nutrients or increment of the level of toxicity are causing significant productivity decline in crop productivity. Despite the potential of land productivity and could decrease due to sustainable cultivation of repeated application of inorganic fertilizer. This study declared to maintain soil fertility through vermicompost rates of organic materials integrated with inorganic fertilizers (NPS) indicated in the soil fertility of the area, and similar

ecology. The highest net benefit (17814.1ETB per hectare) was obtained from treatment with 50:50%, and higher grain yield was obtained from treatment that received 50% (2.32 tons per hectare) of recommend vermicompost and 50% (50 kg ha⁻¹) of NPS fertilizer application, with an acceptable marginal rate of return. Therefore, integration vermicompost with inorganic fertilizers is an unselected option for sesame producers and maintains the sustainability and fertility of soil.

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Author Contributions

Mamo Mekonnen Feyanbule: Conceptualization, Formal Analysis, Investigation, Methodology, Software, Supervision, Visualization, Writing – original draft, Writing – review & editing

Shiferaw Tadesse: Supervision, Writing – review & editing

Data Availability Statement

The corresponding author can provide data used to support the study's conclusions upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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