Hindawi
International Journal of Agronomy
Volume 2023, Article ID 7123826, 11 pages
https://doi.org/10.1155/2023/7123826

Research Article

Vermicompost and NPSZnB Fertilizer Levels on Maize (*Zea mays* L.) Growth, Yield Component, and Yield at Guto Gida, Western Ethiopia

Abdela Tufa

Department of Plant Sciences, Wollega University, P.O. Box 38, Shambu, Ethiopia

Correspondence should be addressed to Abdela Tufa; abdelatufa2014@gmail.com

Received 17 August 2022; Revised 7 February 2023; Accepted 3 March 2023; Published 9 March 2023

Academic Editor: David Clay

The application of organic and inorganic fertilizers together increases crop productivity and soil fertility. However, it is crucial to identify the combined application level. A field experiment was carried out in the Guto Gida district in 2021 to determine the effect of vermicompost levels and chemically mixed NPSZnB fertilizer rates on the growth and yield of maize. Four vermicompost levels (0, 2.5, 5, and 7.5 $t \cdot ha^{-1}$) combined with four artificial NPSZnB fertilizer rates (0, 50, 100, and 150 $kg \cdot ha^{-1}$) were used for the study in a randomized complete block design (RCBD) with 3 replicates. Crop phenology and biomass yield were both significantly influenced by the main effects of vermicompost level and NPSZnB rate. Vermicompost and NPSZnB fertilizer applied together had a large effect on plant height, leaf area index, ear weight, thousand kernel weight, and grain yield. The largest grain yield (8.03 $t \cdot ha^{-1}$) was produced by the interaction of vermicompost at 7.5 $t \cdot ha^{-1}$ with 150 $kg \cdot ha^{-1}$ NPSZnB, followed by all levels of vermicompost at and above 5 $t \cdot ha^{-1}$ with 100 and 150 $kg \cdot ha^{-1}$ NPSZnB. Additionally, plots treated with a combined application of vermicompost and NPSZnB fertilizer at rates of 5 $t \cdot ha^{-1} \times 100\, kg \cdot ha^{-1}$ and 5 $t \cdot ha^{-1} \times 150\, kg \cdot ha^{-1}$, respectively, recorded the greatest values of ear weight (276.1 g) and thousand kernel weight (49.79 g). However, the lower yield was obtained from plots that were untreated with both vermicompost and NPSZnB, and the plot treated only with 50–150 $kg \cdot ha^{-1}$ of NPSZnB. In conclusion, integrated applications of vermicompost at 5 $t \cdot ha^{-1}$ and NPSZnB fertilizer at 100 $kg \cdot ha^{-1}$ increased maize yield by about 10.36%, with a net benefit of 140486.00 $ETB \cdot ha^{-1}$ and a marginal rate of return of 797.98%. As a result, vermicompost application at 5 $t \cdot ha^{-1}$ rate with synthetic NPSZnB fertilizer at 100 $kg \cdot ha^{-1}$ is found suitable for the study area.

1. Introduction

Maize (*Zea mays* L.) is a monocotyledonous annual plant and the most widely cultivated crop in tropical areas of the world, and it is farmed for both human and animal consumption [1]. The most important major food crop in Ethiopia ranks second in terms of area coverage with an average total grain production of 4.24 $t \cdot ha^{-1}$ [2], and it is grown on more than two million hectares [3]. According to data from the Central Statistical Agency [3], maize is planted in an area of around 2.5 million hectares, or roughly 23.97 percent of the total area used for cereal crops.

Today, food security is one of the major challenges to the rapidly growing worldwide population. Millions of people now live below the poverty line and are hungry as a result of declining agricultural output brought on by the shrinking area of arable land and climate change [4]. Additionally, overuse of agrochemicals and deep tillage caused soil acidity, soil infertility, and soil quality contamination, which decreased soil organic matter content, biodiversity, and productivity. In underdeveloped nations, these unsustainable farming techniques threaten food security and produce significant economic limitations [4, 5].

Fertilizing crops using organic fertilizer made from organic matter, which has enormous potential to improve soil biodiversity and health, is an alternate strategy for sustainable and commercially viable agricultural production with little environmental contamination. Vermicompost is one of many alternatives and technologies that are frequently employed in sustainable agriculture and one of the stabilized organic fertilizers with a low C : N ratio that contains a variety of nutrients that are available to plants right away [6, 7]. It is produced by feeding earthworms with chopped plant biomass materials mixed with cow dung and water under the shade of trees, especially horticultural trees.

In conjunction with other resources that limit crop growth, organic matter releases several plant nutrients into the soil solution that have a major impact on crop growth rate and yield [8]. Vermicomposting is a method for decomposing organic waste that is both affordable and environmentally friendly [9]. Based on the source of the vermiworm feed, it is made from various organic material sources and contains various vital plant nutrients [10]. It is more advantageous to use organic matter in combination with other organic or inorganic fertilizers than to apply it alone [11], and their inclusion in crop production systems reduces the negative impacts of salt and drought [12]. It also increases soil organic matter [13], decreases exchangeable soil acidity [14], improves the availability of soil nutrients [15], increases micronutrient levels in the soil [16], and increases crop yield [17, 18]. Vermicompost-based fertilizer boosts soil fertility, the physicochemical properties of soil, and the cation exchange capacity (CEC) [19]. In addition, vermicompost significantly improves soil structure, porosity, soil temperature, aeration, and water retention [20, 21]. In the highlands of western Ethiopia, the utilization of organic matter to address the issue of soil infertility, enhance the physicochemical qualities of soil, and establish ideal soil conditions to increase crop yield in acidic soil has been growing [22]. The rate of vermicompost and NPSZnB in the research area, however, was not further investigated. Hence, the current study was carried out to determine the effects of vermicompost and mineral NPSZnB fertilizers on the growth, yield, and yield-related variables of maize.

2. Materials and Methods

2.1. Experimental Site. The study was carried out during the 2021 growing season (May–November) in the Guto Gida district in western Ethiopia's East Welega Zone. The experimental site is situated between (09° 11′N and 37° 09′E), between 1450 and 1700 meters above sea level. The region has a monomodal (1200–1450 mm) rainfall distribution, a long rainy season that lasts from late April to mid-October, and an average annual temperature range of 14.6–31.5°C (Figure 1). The mixed farming system used in the research area is notable for producing crops like maize, millet, sorghum, peanuts, soybean, and sesame as well as raising livestock.

The soil in the research region is nitisol, an acidic soil with a red tint that predominates in the western parts of Ethiopia (Guto Gida Agricultural Office, 2021, unpublished data). The experimental site's topsoil (0–30 cm) was classified as a clay loam with total nitrogen (0.16%), organic carbon (1.78%), and a pH of 5.02 (Table 1).

2.2. Experimental Material. For the experimental study, the low-land hybrid maize variety "BH-546," released by the

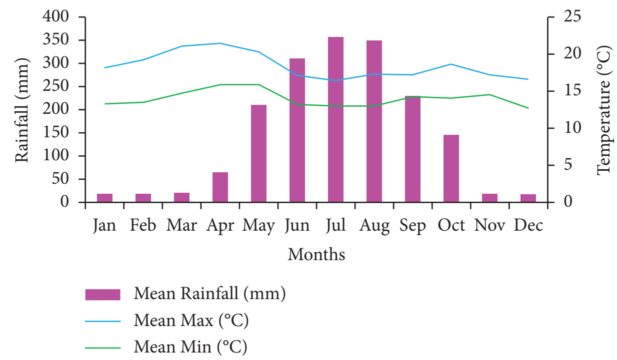

Figure 1: Mean monthly rainfall and temperature recorded for last five years (2016–2021).

Bako Agricultural Research Center, was used. The maize hybrid BH-540 is a single cross created from two genetically separate parents; it thrives in environments with rainfall ranging from 1000 to 1200 mm and altitudes between 1000 and 2000 meters above sea level. Depending on the surrounding environment, it can reach a height of 200–240 cm. On research stations' and farmers' fields, harvestable grain yields range from 7 to 8 $t{\cdot}ha^{-1}$ and 4.5 to 6.0 $t{\cdot}ha^{-1}$, respectively.

2.3. Treatments and Experimental Design. The experiment was carried out in a randomized complete block design (RCBD) with 16 treatments (4×4) and three replications, with each factorial combination consisting of four vermicompost levels (0, 2.5, 5, and 7.5 $t{\cdot}ha^{-1}$) and four inorganic NPSZnB fertilizer rates (0, 50, 100, and 150 $kg{\cdot}ha^{-1}$). The compound fertilizer NPSZnB has a ratio of 17.8% N, 35.7% P_2O_5, 7% S, 2.2% Zn, and 0.1% B and contains highly homogeneous granules of essential plant nutrients. In the highlands of western Ethiopia, 100 $kg{\cdot}ha^{-1}$ of NPSZnB and 200 $kg{\cdot}ha^{-1}$ of urea ($CO(NH_2)_2$) are the recommended fertilizer rates for maize. Because of this, the amounts of nitrogen needed at 0, 50, 100, and 150 $kg{\cdot}ha^{-1}$ of NPSZnB fertilizer rate with urea were 0, 8.9, 17.8, and 26.7 $kg{\cdot}ha^{-1} + 92$ $kg{\cdot}ha^{-1}$ of urea, yielding 92, 100.9, 109.8, and 118.7 $kg{\cdot}ha^{-1}$ of nitrogen, respectively. The full description of the treatment is provided in Table 2. Each plot was 5.1 m by 4.5 m in length and width (22.95 m^2).

2.4. Experimental Procedure. Before planting, the experimental field was physically leveled and plowed by oxen to create a fine soil tilth. Within each row and between each row, maize seed was sown at intervals of 0.30 m and 0.75 m, respectively. To maintain the recommended population (44,444 plants ha^{-1}), two seeds $hill^{-1}$ were planted, and one week following emergence, it was thinned down to one plant $hill^{-1}$. In each plot, 102 plants were planted in 6 rows, with 17 plants in each row. Urea ($CO(NH_2)_2$) was applied in a split application, i.e., half of the recommended dose (100 $kg{\cdot}ha^{-1}$) was applied during the time of planting, and the remaining half (100 $kg{\cdot}ha^{-1}$) was applied 40 days later. According to the treatment levels, vermicompost was put in the soil two weeks

Table 1: Vermicompost nutrient composition and the physicochemical features of the study site soil in Guto Gida, Western Ethiopia.

Parameters	Presowing soil properties	Nutrient composition of vermicompost
Particle distribution (%)		—
Clay	39	—
Silt	29	—
Sand	32	—
Textural class	Clay loam	—
Chemical properties	—	—
pH (H_2O) 1: 2.5 (w/v)	5.02	7.18
Organic carbon (%)	1.78	13.4
Organic matter (%)	3.06	23.10
Total nitrogen (%)	0.16	1.79
Available phosphorus (mg kg^{-1})	4.26	43.7
Exchangeable Ca (cmol/kg)	3.11	25.9
Exchangeable Mg (cmol/kg)	1.29	17.1
Exchangeable K (cmol/kg)	0.24	21.5
CEC (cmol/kg)	14.81	142

CEC stands for cation exchange capacity.

Table 2: The treatment used for the experiment.

Treatments (T)	Treatments combination
T1	0 t·ha^{-1} vermicompost + 0 kg·ha^{-1} NPSZnB
T2	0 t·ha^{-1} vermicompost + 50 kg·ha^{-1} NPSZnB
T3	0 t·ha^{-1} vermicompost + 100 kg·ha^{-1} NPSZnB
T4	0 t·ha^{-1} vermicompost + 150 kg·ha^{-1} NPSZnB
T5	2.5 t·ha^{-1} vermicompost + 0 kg·ha^{-1} NPSZnB
T6	2.5 t·ha^{-1} vermicompost + 50 kg·ha^{-1} NPSZnB
T7	2.5 t·ha^{-1} vermicompost + 100 kg·ha^{-1} NPSZnB
T8	2.5 t·ha^{-1} vermicompost + 150 kg·ha^{-1} NPSZnB
T9	5 t·ha^{-1} vermicompost + 0 kg·ha^{-1} NPSZnB
T10	5 t·ha^{-1} vermicompost + 50 kg·ha^{-1} NPSZnB
T11	5 t·ha^{-1} vermicompost + 100 kg·ha^{-1} NPSZnB
T12	5 t·ha^{-1} vermicompost + 150 kg·ha^{-1} NPSZnB
T13	7.5 t·ha^{-1} vermicompost + 0 kg·ha^{-1} NPSZnB
T14	7.5 t·ha^{-1} vermicompost + 50 kg·ha^{-1} NPSZnB
T15	7.5 t·ha^{-1} vermicompost + 100 kg·ha^{-1} NPSZnB
T16	7.5 t·ha^{-1} vermicompost + 150 kg·ha^{-1} NPSZnB

The acronym NPSZnB represents the fertilizers containing 17.8% nitrogen, 35.7% P_2O_5, 7% sulfur, 2.2% zinc, and 0.1 boron.

before planting and mixed well with the soil to lessen loss from rain and wind uptake. The remaining required cultural and agronomic practices were applied uniformly for all treatments following the local recommendations, and the full dose of inorganic NPSZnB fertilizer was applied at the rates (0, 114.75, 229.5, and 344.25 g $plot^{-1}$) as per the treatment at the time of planting.

2.5. Vermicompost Preparation and Application. Vermicompost was prepared from chopped and dried maize stock and cow dung. The maize stock was reduced in size to maximize the surface area available to vermiworms. It was then combined in a 3 : 1 ratio with cow dung solution and allowed to partially decompose for three weeks before being ready in 60 days. At the bottom of the 182.88 cm × 60.96 cm × 60.96 cm bed, a layer of 15 to 20 cm of chopped maize stock was kept as bedding material. Partially decomposed vermicompost was then moved from one bedding material (box) to another within a month interval for proper decomposition and to maintain aeration until the compost matured at 60 days (23). An adult red earthworm *(Eisenia fetida)*, which is 3 to 5 months old, 8 to 10 cm long, 0.5 to 0.6 g heavy, and 500 to 1000 in number, was released on the top layer of the bed with 10 earthworms to break down mixed cow manure and corn stock. After the worms were placed on the bed, water was immediately sprayed on the surface of the chopped material to enhance material decomposition. Water was sprinkled daily and covered with polythene to keep the material moist (60 to 70% moisture content) and prevent evapotranspiration from the bedding material (23). Vermicompost, which was put into the soil two weeks before the planting of maize, was a mature and well-decomposed product with a pH of 7.18, organic carbon of 13.4%, and total nitrogen of 1.79% (Table 1).

2.6. Soil Sampling, Analysis, and Vermicompost Chemical Composition. Before planting, random soil samples were taken in a zigzag pattern at a depth of 0 to 30 cm. Composite samples were air-dried, prepared, and homogenized to make an analysis and identify the soil's physicochemical characteristics, such as texture, pH, organic carbon, total nitrogen, exchangeable calcium, magnesium, potassium, cation exchange capacity (CEC), and available phosphorus. The soil samples were mashed up, passed through a 2 mm sieve, and then examined at the Holota Soil Laboratory to determine their physicochemical makeup. The distribution of soil particle size was determined by the hydrometer method, and the pH of the soil was determined by using a pH meter at 1 : 2.5 soils-to-water ratio [23, 24]. The amounts of soil organic carbon, total nitrogen, and available phosphorus were measured using the techniques created by Walkley Black Oxidation [25], Kjeldahl [26], and Bray-I [27], respectively. Similar to this, vermicompost's physical and chemical characteristics were examined before being applied to the soil at the Holota Soil Laboratory Test, Holota, Ethiopia.

2.7. Data Collection and Analysis

2.7.1. Phenology and Growth Parameter. Days to 50% tassel and silk, days to 90% maturity, and other phenological parameters of maize were calculated as the number of days from the day of planting to the time at which 50% of each plot produced tassels, began to produce pollen, and formed a black layer at the point where the kernel attached to the corn cob, respectively. Plant height was assessed as the distance from the ground level to the location where the tassel appeared and started to branch out at the physiological maturity stage from randomly selected 10 plants per net plot. The leaf area index (LAI) was calculated as the ratio of total leaf area obtained from 10 plants per net plot ($L \times W \times K$) to the land area occupied by the plant ($0.75\,\mathrm{m} \times 0.30\,\mathrm{m} = 0.225\,\mathrm{m}^2$), where L = leaf length, W = leaf width, and K = correction factor (0.75) [28].

2.7.2. Yield Components and Yield of Maize. Data from 10 pretagged plants per net plot area were used to calculate the number of ears plant^{-1}, ear weight (g), and the number of kernels ear^{-1}. Using an electronic grain counter and a sensitive balance, thousand-grain weights (g) were counted from a bulk of shelled grain and measured at the standard moisture level (12.5%). Additionally, the total biomass harvested from each experimental plot at the time of harvest and the weight of the bulk of grain harvested from the net plot were used to determine the biological yield (t·ha^{-1}) and grain yield (t·ha^{-1}) correspondingly. The harvest index (%) was calculated by dividing grain yield (t·ha^{-1}) by aboveground biomass yield (t·ha^{-1}).

2.8. Economic Analysis. According to the CIMMYT procedure, a partial budget analysis of grain yields was conducted to choose a level of vermicompost application that would be economically viable and lucrative when combined with the rate of NPSZnB fertilizer [29]. After deducting 10% from the grain output to estimate the true yield under farmers' conditions, the prices for NPSZnB fertilizer (17.50 ETB kg^{-1}) and the cost of applying vermicompost and NPSZnB fertilizers (0.30 ETB kg^{-1}) were utilized for a partial budget analysis. At the local market of the research area, the yield of maize was appraised at an average open market price of 20 ETB kg^{-1} in December 2021.

2.9. Data Analysis. The various collected data were examined using Genstat Software 18 [30], following the statistical techniques given by Gomez and Gomez [31]. An analysis of variance (ANOVA) for a randomized complete block design was used for the statistical test, and Fisher's protected least significant difference was used to identify parameters with significant differences between treatments at a $p = 0.05$ level of probability.

3. Result and Discussion

3.1. Experimental Site Physicochemical Characteristics of Soil and Vermicompost. The physicochemical makeup of the soil at the study location before planting and that of the vermicompost used are shown in Table 1. The experimental soil pH of the study site was moderately acidic as rated by Tekalign [32], available phosphorus (4.26 mg·kg^{-1}) was at a low level, total nitrogen (0.16%) was present in a low range, and a cation exchange capacity of 14.81 was found to be poor (Table 1). Vermicompost had values for pH, organic carbon, organic matter, total nitrogen, calcium, potassium, and cation exchange capacity that were relatively high when compared to presowing soil (Table 1). These findings suggest that adding more vermicompost to the soil has a tremendous potential to improve soil structure, soil pH, and soil porosity and decrease soil bulk density because organic fertilizers in nature have larger pore spaces and lower bulk densities than soil. According to [6], increasing vermicompost levels enhance soil organic matter, total nitrogen, and pH, which is consistent with the current finding.

Table 3: Main effect of vermicompost levels and inorganic NPSZnB fertilizer rates on the number of days to 50% of the days to tassel, number of days to 50% silking, and the number of days to 90% physiological maturity of maize in Guto Gida, Western Ethiopia.

Treatments	50% days to tassel	50% days to silk	90% days to maturity
Vermicompost (t·ha^{-1})			
0	70.21^{b}	75.33^{b}	141.40^{b}
2.5	71.21^{a}	75.67^{ab}	142.20^{ab}
5.0	71.43^{a}	76.33^{a}	141.90^{ab}
7.5	71.55^{a}	76.44^{a}	142.70^{a}
p value	0.003	0.003	0.042
LSD (0.05)	0.95	0.91	1.20
NPSZnB (kg·ha^{-1})			
0	69.86^{cd}	74.79^{b}	141.10^{cd}
50	70.21^{bc}	75.00^{b}	141.60^{bc}
100	70.86^{b}	76.06^{a}	142.30^{ab}
150	72.06^{a}	76.39^{a}	142.80^{a}
p value	0.001	<0.001	0.015
LSD (0.05)	0.74	0.71	0.94
CV (%)	1.6	1.4	0.96

LSD = least significant difference; CV = coefficient of variation (%). Means in the same column followed by the same letter(s) are not statistically significantly different at a 5% probability level.

3.2. Phenology and Growth Parameters of Maize. Vermicompost concentrations and inorganic NPSZnB fertilizer rates significantly influenced days to 50% tasseling, days to 50% silking, and days to 90% physiological maturity, although their interactions were not significant for all phenological parameters of maize. However, the interaction effect of NPSZnB fertilizer rate and vermicompost levels had a significant impact on growth metrics such as plant height and leaf area index. The rate of vermicompost applied at 7.5 t·ha^{-1}, which was on par with rates applied at 5.0 t·ha^{-1} and 2.5 t·ha^{-1}, resulted in the longest days to tasseling (71.55), whereas the shortest days (70.21) to grow tassels were reported in plots not treated with vermicompost (Table 3). In comparison to the control treatment, which tasseled r quickly (69.86 days), maize cultivated with

Table 4: Interaction effect of vermicompost levels and inorganic NPSZnB fertilizer rates on plant height (cm) and leaf area index (LAI) of maize in Guto Gida, Western Ethiopia.

Vermicompost ($t{\cdot}ha^{-1}$)	NPSZnB ($kg{\cdot}ha^{-1}$)	Plant height (cm)	Leaf area index
0	0	252.50^{f}	3.937^{h}
0	50	260.80^{e}	4.398^{fg}
0	100	273.70^{b}	4.497^{efg}
0	150	282.80^{a}	$4.714^{b\text{-}f}$
2.5	0	267.40^{cd}	4.327^{g}
2.5	50	268.50^{c}	4.309^{g}
2.5	100	267.30^{cd}	$4.771^{b\text{-}e}$
2.5	150	266.30^{cd}	$4.791^{b\text{-}e}$
5.0	0	266.80^{cd}	4.493^{efg}
5.0	50	269.00^{c}	$4.541^{d\text{-}g}$
5.0	100	268.80^{c}	4.982^{b}
5.0	150	270.00^{bc}	$4.790^{b\text{-}e}$
7.5	0	267.40^{cd}	$4.574^{c\text{-}g}$
7.5	50	263.70^{de}	4.835^{bcd}
7.5	100	270.00^{bc}	4.889^{bc}
7.5	150	269.60^{c}	5.657^{a}
p value		0.001	0.048
LSD (0.05)		3.926	0.335
CV (%)		0.9	4.4

LSD = least significant difference; CV = coefficient of variation (%). Means in the same column followed by the same letter(s) are not statistically significantly different at a 5% probability level.

NPSZnB fertilizer applied at a rate of 150 $kg{\cdot}ha^{-1}$ took a maximum of 72.06 days to develop tassel (Table 3). In agreement with the findings of the current study, [33] reported a considerable influence of inorganic fertilizer on the number of days to 50% tasseling. In terms of days to 50% silking and days to 90% maturity, maize in the control plot silks and reaches maturity quickly, whereas the highest number of days to 50% silking (76.44 days) was found in the vermicompost-treated plot at 7.5 $t{\cdot}ha^{-1}$, which was on par with the results from 5.0 $t{\cdot}ha^{-1}$ and 2.5 $t{\cdot}ha^{-1}$. Vermicompost applied at 7.5 $t{\cdot}ha^{-1}$ was on par with all vermicompost levels, except for the control treatment, in terms of days to 90% maturity (142.7 days). Similar to this, the NPSZnB fertilizer rate at 150 $kg{\cdot}ha^{-1}$, which was on par with the value obtained from 100 $kg{\cdot}ha^{-1}$, produced the longest days to silking (76.39 days) and maturity (142.80 days) (Table 3).

Higher soil fertility and increased nutrient uptake for all basically needed plant nutrients may be the cause of the delayed phenological parameters of maize that responded to the longer vegetative development period of the plant. Increased maize vegetative growth, expanded leaves, and better nitrogen usage efficiency may be the causes of the prolonged days to tasseling, days to silking, and days to maturity in plots treated with increased amounts of NPSZnB fertilizer (0–150 $kg{\cdot}ha^{-1}$). In agreement with this finding, Lal [34] showed that elevated levels of organic and inorganic nitrogen sources result in a prolonged vegetative development period (crop phenology). As vermicompost levels rose from 5 to 20 $t{\cdot}ha^{-1}$, watermelon flowering was delayed [35].

The study also showed that the interaction between vermicompost levels and the rate of chemical NPSZnB fertilizer had a considerable impact on the growth parameters of maize, including plant height and leaf area index (LAI). The greatest plant height (282.80 cm) was achieved by the maize plant growing in a plot treated with 150 $kg{\cdot}ha^{-1}$ of NPSZnB fertilizer at zero level of vermicompost, whereas the least plant height (252.5 cm) was obtained in the control plot or plot untreated with vermicompost and NPSZnB fertilizers (Table 4). This finding may be the result of the inorganic nitrogen in NPSZnB fertilizer having a beneficial influence on rapid maize vegetative growth. Additionally, the addition of vermicompost improves soil pH and increases nutrient uptake by plants, resulting in enhanced production of vegetative growth and parts, specifically increased plant height and leaf blade size. According to a study by [36], plants grow taller when chemical fertilizer levels hold nitrogen fertilizer. However, [11] observed that the height of the maize plant treated with vermicompost plus NPK was greater than that of the vermicompost or minerally fertilized plot. Additionally, increasing the vermicompost level was found to boost pak choi height [37].

Similar to this, the greatest leaf area index (5.657) was calculated from a plot treated with vermicompost at 7.5 $t{\cdot}ha^{-1}$ associated with 150 $kg{\cdot}ha^{-1}$ NPSZnB fertilizer and was followed by a 4.982 leaf area index assessed from a combination of 5 $t{\cdot}ha^{-1}$ vermicompost and 100 $kg{\cdot}ha^{-1}$ of NSPZnB, while the lowest leaf area index (3.937) was registered from the control plot untreated with vermicompost and NPSZ (Table 4). The largest leaf area index (5.657) at greater vermicompost levels and NPSZnB may be connected to the direct role of vermicompost in enhancing the physical, biological, and chemical characteristics of the soil to produce favorable conditions for crop growth and development. When applied together, vermicompost and mineral fertilizer may release greater amounts of plant nutrients and more quickly make nitrogen from mineral fertilizer NPSZnB available, both of which may play a significant role in more vigorous plant development compared to other treatments.

Table 5: Interaction effect of vermicompost levels and inorganic NPSZnB fertilizer rates on-ear weight (g) and thousand kernel weight (g) of maize in Guto Gida, Western Ethiopia.

Vermicompost ($t \cdot ha^{-1}$)	NPSZnB ($kg \cdot ha^{-1}$)	Ear weight (g)	Thousand kernel weight (g)
0	0	237.10^{f}	42.14^{e}
0	50	239.60^{ef}	44.49^{d}
0	100	248.30^{de}	44.31^{de}
0	150	268.00^{bc}	44.82^{cd}
2.5	0	247.60^{de}	43.38^{de}
2.5	50	250.50^{d}	44.90^{cd}
2.5	100	274.60^{ab}	48.03^{ab}
2.5	150	268.00^{bc}	48.90^{ab}
5.0	0	250.20^{d}	43.59^{de}
5.0	50	260.30^{c}	45.27^{cd}
5.0	100	276.10^{ab}	49.79^{a}
5.0	150	277.80^{a}	48.75^{ab}
7.5	0	249.00^{d}	44.28^{de}
7.5	50	268.30^{bc}	46.98^{bc}
7.5	100	276.50^{ab}	48.75^{ab}
7.5	150	276.90^{ab}	48.87^{ab}
p value		0.004	0.045
LSD (0.05)		8.971	2.225
CV (%)		2.1	3.0

LSD = least significant difference; CV = coefficient of variation (%). Means in the same column followed by the same letter(s) are not statistically significantly different at a 5% probability level.

Khan et al. [38] found increased plant height with increasing application levels of nitrogen-containing fertilizer, which is consistent with the findings of the current investigation. Similar findings were made by [39], who noted higher plant height and leaf area with greater nitrogen fertilizer available over the course of a maize crop's life cycle.

3.3. Yield Components and Yield

3.3.1. Ear Weight (g). Vermicompost applied in combination with mixed NPSZnB fertilizer at various rates considerably altered the ear weight of maize. The maximum ear weight (277.80 g), which was at par in the application of vermicompost at all levels with 100 $kg \cdot ha^{-1}$, was obtained when vermicompost level at 5 $t \cdot ha^{-1}$ was combined with an inorganic NPSZnB fertilizer rate at 150 $kg \cdot ha^{-1}$, except plots not treated with vermicompost at the same rate of NPSZnB fertilizer. The lowest ear weight (237.10 g) was obtained from the plot not treated with both vermicompost and NPSZnB fertilizer, which was comparable to the outcome of the plot not treated with vermicompost and a 50 $kg \cdot ha^{-1}$ inorganic NPSZnB fertilizer rate (Table 5). Improved crop growth and greater dry matter output as a result of improved nutrient uptake, particularly nitrogen, from inorganic and vermicompost (organic) sources may be the cause of increased ear weight with increased NPSZnB fertilizer at levels of vermicompost. Additionally, greater ear weight with higher vermicompost levels may be caused by a change in the composition of the soil's organic matter as a result of the vermicompost's decomposition and mineralization, which would boost the early nutrient supply from commercial fertilizers (NPSZnB). Ear weight was increased with a higher level of both organic fertilizer (vermicompost) and inorganic fertilizer and was favorably affected when organic and inorganic sources of fertilizer were used together [40, 41]. In contrast, [42] reported the maximum bean pod weight when treated with 100% vermicompost.

3.3.2. Thousand Kernel Weight (g). The use of chemically blended NPSZnB fertilizer rates and vermicompost levels together had a significant effect on thousand kernels' weights. The highest grain weight (49.79 g) came from an integrated application of vermicompost and blended NPSZnB fertilizer at a rate of 5.0 $t \cdot ha^{-1}$ with 100 $kg \cdot ha^{-1}$, which was at par to 7.5 $t \cdot ha^{-1} \times 150$ $kg \cdot ha^{-1}$ (48.87 g), 7.5 $t \cdot ha^{-1} \times 100$ $kg \cdot ha^{-1}$ (48.75 g), 5 $t \cdot ha^{-1} \times 150$ $kg \cdot ha^{-1}$ (48.75 g), and 2.5 $t \cdot ha^{-1} \times 150$ $kg \cdot ha^{-1}$ (48.03 g). In comparison, the plot not treated with any of the two fertilizers had the lowest thousand kernel weight (42.14 g) (Table 5). Greater soil fertility, enhanced nutrient uptake, and an effective photosynthetic process may all contribute to a heavier thousand kernel weight at higher vermicompost levels and higher rates of NPSZnB, which may be assimilated to economic yield (grain). The fact that the control treatment resulted in lower weight could be a result of the decreased nutrient content of the soil, which would make fewer nutrients available for healthy and optimal plant growth. Similar to previous research, [11] reported enhanced thousand-grain weight when vermicompost and NPK were applied together as opposed to separately. The linear increase in thousand seed weight coincided with the amounts of mineral and organic fertilizers.

Table 6: Main effects of vermicompost levels and inorganic NPSZnB fertilizer rates on the number of kernel ear^{-1}, biological yield (t·ha^{-1}), and harvest index (%) of maize in Guto Gida, Western Ethiopia.

Treatments	Number of kernels ear^{-1}	Biological yield (t·ha^{-1})	Harvest index (%)
Vermicompost (t·ha^{-1})			
0	540.13	18.31^{c}	36.00
2.5	546.00	19.67^{ab}	35.79
5.0	562.30	20.33^{a}	34.82
7.5	569.66	20.52^{a}	35.14
p value	0.106	<0.001	0.103
LSD (0.05)	33.136	0.938	2.021
NPSZnB (kg·ha^{-1})			
0	522.40^{b}	18.76^{b}	35.20
50	522.54^{b}	18.95^{b}	35.24
100	555.20^{a}	19.81^{a}	35.04
150	566.80^{a}	20.34^{a}	35.95
p value	<0.001	<0.001	0.415
LSD (0.05)	25.667	0.727	1.565
CV (%)	6.30	5.60	5.60

LSD = least significant difference; CV = coefficient of variation (%). Means in the same column followed by the same letter(s) are not statistically significantly different at a 5% probability level.

Table 7: Interaction effect of vermicompost levels and inorganic NPSZnB fertilizer on grain yield (t·ha^{-1}) and grain yield increased (%) in Guto Gida, Western Ethiopia.

Vermicompost (t·ha^{-1})	NPSZnB (kg·ha^{-1})	Grain yield (t·ha^{-1})
0	0	6.96^{h}
0	50	7.03^{gh}
0	100	7.24^{ef}
0	150	7.47^{de}
2.5	0	7.22^{fg}
2.5	50	7.32^{def}
2.5	100	7.74^{cd}
2.5	150	7.78^{bc}
5.0	0	7.29^{ef}
5.0	50	7.54^{d}
5.0	100	7.99^{ab}
5.0	150	7.97^{ab}
7.5	0	7.30^{ef}
7.5	50	7.71^{cd}
7.5	100	7.97^{ab}
7.5	150	8.03^{a}
p value		0.005
LSD (0.05)		0.227
CV (%)		2.1

LSD = least significant difference; CV = coefficient of variation (%). Means in the same column followed by the same letter(s) are not statistically significantly different at a 5% probability level.

3.3.3. Number of Kernel Ear^{-1}. The main effect of the inorganic NPSZnB fertilizer rate had a significant influence on the number of kernels in ear^{-1}. The vermicompost ratios and their interactions with the rates of inorganic NPSZnB fertilizer, however, had not shown a significant effect. An increase in the number of kernels ear^{-1} was seen with increased incorporation of NPSZnB fertilizer rates from 0 to 150 kg·ha^{-1}. In comparison to the control plot and the plot treated with 50 kg·ha^{-1} of NPSZnB fertilizer, which produced the least amount of kernel ear^{-1}, the plot treated with 100 kg·ha^{-1} and 150 kg·ha^{-1} of chemically blended NPSZnB fertilizer produced a greater number of kernel ear^{-1} (Table 6). Increased numbers of kernel ear^{-1} with increased NPSZnB fertilizer rates may be associated with greater availability of nitrogen and phosphorus, as well as the micronutrients zinc and boron. Even though it was not statistically significant, the number of kernels ear^{-1} increased when vermicompost concentration rose from 0 to 7.5 t·ha^{-1}. This may be because vermicompost application increased the soil's biophysicochemical characteristics, such as its CEC and organic carbon, phosphorus, and nitrogen content. Vermicompost also increases soil moisture since it is an organic material with a large surface area, which improves nutrient uptake and utilization efficiency and may result in more kernels ear^{-1}. According to [43], vermicompost-treated plots of rice had 8.65% more grains per panicle than plots that had only received mineral fertilizer. Following the current study [36, 41], it was found that plots treated with a combined mineral and organic fertilizer application had longer cobs and more kernels per cob^{-1} than plots received with separate applications of the two fertilizers.

3.3.4. Above Ground Biomass (t·ha^{-1}). The biological yield of maize was significantly influenced by the main effects of vermicompost and chemically blended mineral NPSZnB fertilizer. The increased biomass weight of 19.67–20.52 t·ha^{-1} was obtained by applying vermicompost at a level of 2.5–7.5 t·ha^{-1}. In contrast, plots that were not given vermicompost had the least above-ground biomass of 18.31 t·ha^{-1} (Table 6). Concerning NPSZnB fertilizer rates, the highest and lowest values (18.76 t·ha^{-1} and 20.34 t·ha^{-1}) were obtained from the application of NPSZnB at 150 kg·ha^{-1} and were statistically similar to the values obtained from 100 kg·ha^{-1} of NPSZnB and control, respectively (Table 6). The enhanced nutrient content in the soil improved nutrient uptake, and the timely availability of nitrogen released quickly from NPSZnB fertilizer could all result in an increased biological yield of maize with an increased amount of vermicompost and NPSZnB. This could be because vermicompost has better soil properties that encourage root growth, which could lead to higher growth of above-ground plant parts. Increases in the growth components of maize, such as leaves, sheaths, stems, cobs, and grain, as well as water retention as a consequence of the high specific area properties of vermicompost fed to the soil, lead to an increase in the crop's above-ground biomass. Additionally, applying vermicompost to the crop during the growth phase may result in favorable conditions for yield-determining components and, consequently, biological yield. Vermicompost contains sufficient quantities of vital plant nutrients. Compared to maize that was not treated with vermicompost fertilizer, [33] reported an increased total dry weight of maize with a higher amount of

Table 8: Partial budget analysis of maize yield for determination of the economically profitable level of vermicompost and NPSZnB fertilizer rate.

Treatment	V/ compost ($t{\cdot}ha^{-1}$)	NPS ($kg{\cdot}ha^{-1}$)	Grain yield ($t{\cdot}ha^{-1}$)	Adjusted grain yield ($t{\cdot}ha^{-1}$)	Gross benefit ($ETB{\cdot}ha^{-1}$)	TVC ($ETB{\cdot}ha^{-1}$)	Net benefit ($ETB{\cdot}ha^{-1}$)	MRR %
T1	0	0	6.96	6.26	125226	0.00	125226.00	—
T2	0	50	7.03	6.33	126540	890.00	125650.00	47.64
T3	0	100	7.24	6.52	130320	1780.00	128540.00	324.72
T4	0	150	7.47	6.73	134514	2670.00	131844.00	371.24
T5	2.5	0	7.22	6.50	130014	750.00	129264.00	—
T6	2.5	50	7.32	6.59	131760	1640.00	130120.00	96.18
T7	2.5	100	7.75	6.98	139500	2530.00	136970.00	769.66
T8	2.5	150	7.78	7.00	140076	3420.00	136656.00	D
T9	5.0	0	7.29	6.56	131166	1500.00	129666.00	—
T10	5.0	50	7.54	6.79	135774	2390.00	133384.00	417.75
T11	5.0	100	7.99	7.19	143766	3280.00	140486.00	**797.98**
T12	5.0	150	7.97	7.18	143532	4170.00	139362.00	D
T13	7.5	0	7.30	6.57	131400	2250.00	129150.00	—
T14	7.5	50	7.71	6.94	138780	3140.00	135640.00	729.21
T15	7.5	100	7.97	7.18	143514	4030.00	139484.00	431.91
T16	7.5	150	8.03	7.23	144540	4920.00	139620.00	13.60

Application costs of vermicompost and mineral NPSZnB fertilizer = 30 ETB $quintal^{-1}$; unit cost of NPSZnB fertilizer = 17.5 $ETB{\cdot}kg^{-1}$; maize price 20 $ETB{\cdot}kg^{-1}$; ETB = Ethiopian birr; NPSZnB = fertilizer containing 17.8%N, 37.5%P_2O_5 7%S, 2.2%Zn, and 0.1%B; TVC = total variable cost; MRR = marginal rate of return; and D = dominated.

vermicompost and NPS fertilizer. Similar results were reported by Nasab et al. [44], who found that the biomass weight of maize increased by 13.58% when vermicompost application increased from 4 to 12 $t{\cdot}ha^{-1}$. Application of vermicompost at 10 $t{\cdot}ha^{-1}$ and mineral fertilizer together increased rice biomass compared to cow dung applied at the same level plus mineral fertilizer or only mineral fertilizer [43]. The study found that applying 50% vermicompost and 50% of the locally recommended NPS together increased biomass by 8.72% when compared to applying 100% of the locally recommended NPS alone [45]. Furthermore, increased vermicompost application alone or with other organic and inorganic fertilizers increased above-ground biomass [46].

3.3.5. Grain Yield ($t{\cdot}ha^{-1}$). Analysis of variance revealed that the combined application of organic fertilizer (vermicompost) and mineral fertilizer (NPSZnB) had a significant influence on the grain production of maize. The highest grain yield (8.03 $t{\cdot}ha^{-1}$) was recorded from the integrated application of vermicompost with blended NPSZnB fertilizer at a rate of 7.5 $t{\cdot}ha^{-1}$ and 150 $kg{\cdot}ha^{-1}$, which was statistically similar to the grain yield harvested from plots treated with 5 $t{\cdot}ha^{-1} \times 100\ kg{\cdot}ha^{-1}$, 5 $t{\cdot}ha^{-1} \times 150\ kg{\cdot}ha^{-1}$, and 7.5 $t{\cdot}ha^{-1} \times 100\ kg{\cdot}ha^{-1}$ (Table 7). The lowest grain yield, 6.96 $t{\cdot}ha^{-1}$, was produced from a treatment not treated with either vermicompost or inorganic NPSZnB fertilizer (Table 7). The effectiveness of vermicompost at higher rates, as well as the increased number of kernel ear^{-1} and enhanced thousand-grain weights at this level, may be related to the increased grain output at the higher level of vermicompost. Additionally, the potential for vermicompost to reduce soil bulk density, exchangeable aluminum, and iron, and restrict root growth and nutrient uptake may account for the higher grain yield with increased vermicompost application. Vermicompost and mineral fertilizer used together may result in better soil properties such as pH, porosity, aeration, temperature, moisture, permeability, soil biodiversity, and fertility for plant growth, which may promote more photosynthate allocation. Vermicompost boosts soil-plant nutrients, including potassium, calcium, and micronutrients like copper, zinc, and iron when combined with other minerals. These nutrients support many physiological processes in plants, which resulted in higher grain yields as a consequence of improved fertilizer usage efficiency and increased cation exchange capacity of the soil with organic matter.

Similar to the current study, several findings showed that maize grain production improved when organic and inorganic fertilizers were applied together [47]. According to Chimdessa and Sori [33], the addition of 3 $t{\cdot}ha^{-1}$ of vermicompost increased grain production by approximately 66.88% compared to the treatment using 100 $kg{\cdot}ha^{-1}$ of the locally advised NPS rate. Additionally, past research indicated that higher vermicompost quality and vermicompost levels boosted grain yield [11, 44, 48–50]. Similarly, [36, 45, 51–53] found that grain yield responded well when organic fertilizer and mineral fertilizer were applied together. Moreover, Hoque et al. [43] reported that rice yield increased by 5.68% when vermicompost at 10 $t{\cdot}ha^{-1}$ and mineral fertilizer were applied in combination, and compared with applying only the recommended rate of mineral fertilizer. In contrast to the present study, Abera et al. [54] in their three consecutive years study, reported a lower yield of maize in plots treated with only vermicompost from 4–12 $t \cdot ha^{-1}$or in plots treated with both vermicompost (25–75% of 4 $t \cdot ha^{-1}$) and 50–75% of recommended mineral NPS fertilizer compared with the plot treated with only NPS at the recommended rate (100%).

3.3.6. Harvest Index (%). Analysis of variance revealed that the main effects of blended NPSZnB fertilizer, vermicompost, and their interaction had no statistically significant effects on the harvest index of maize (Table 6). However, [55] reported a significantly higher harvest index when organic and inorganic fertilizer were used together compared to separate utilization. Similarly, [56] also found an increased harvest index of maize treated with a higher level of vermicompost, lime, and chemical fertilizer.

3.4. Economic Analysis. Analysis of variance showed that integrated application of vermicompost and mineral NPSZnB fertilizer at $5\,t \cdot ha^{-1} \times 100\,kg \cdot ha^{-1}$ yielded the highest net benefit (140486 $ETB \cdot ha^{-1}$) with a marginal rate of return of 797.98%, followed by a net benefit of 136970 $ETB \cdot ha^{-1}$, which was obtained at $2.5\,t \cdot ha^{-1} \times 100\,kg \cdot ha^{-1}$, with a marginal rate of return of 769.66% (Table 8). The combined application of vermicompost at a rate of 0 $t \cdot ha^{-1}$ with NPSZnB fertilizer at a rate of 50 $kg \cdot ha^{-1}$ produced a minimum net benefit of 125650 $ETB \cdot ha^{-1}$ with a marginal rate of return of 47.64% (Table 8). In contrast, the plots treated with 150 $kg \cdot ha^{-1}$ with NPSZnB fertilizer and 2.5 $t \cdot ha^{-1}$ and 5.0 $t \cdot ha^{-1}$ of vermicompost were dominated (Table 8). Therefore, it was found that applying vermicompost at a level of 5 $t \cdot ha^{-1}$ along with 100 $kg \cdot ha^{-1}$ of mineral NPSZnB fertilizer rate was economically viable for maize production in Guto Gida district, Western Ethiopia, according to this partial budget study.

4. Conclusion

Farmers are using vermicompost to amend the soil in highland parts of western Ethiopia. However, there is limited information regarding the ideal ratio of vermicompost with other types of mineral fertilizer. Therefore, the study was conducted to determine the effects of different vermicompost ratios and mineral NPSZnB fertilizer rates on the growth and productivity of maize in the Guto Gida district of western Ethiopia. The results of this study showed that the phenology, growth, and yield parameters of the maize crop were considerably influenced by the mixed use of vermicompost and inorganic NPSZnB fertilizer. The ear weight and thousand kernels weight improved by 11.19% and 12.37%, respectively, in the application of vermicompost and mineral NPSZnB fertilizer at $5\,t \cdot ha^{-1} + 100\,kg \cdot ha^{-1}$. Additionally, applying vermicompost at and above 5 $t \cdot ha^{-1}$ in conjunction with inorganic NPSZnB fertilizer at 100 $kg \cdot ha^{-1}$, and 150 $kg \cdot ha^{-1}$ resulted in higher grain yield. Moreover, combined applications at $5\,t \cdot ha^{-1} + 100\,kg \cdot ha^{-1}$ of vermicompost and NPSZnB fertilizer produced the maximum net benefit (140486 $ETB \cdot ha^{-1}$) and marginal rate of return (797.98%). In conclusion, integrated application of vermicompost and mineral NPSZnB fertilizer at $5\,t \cdot ha^{-1} \times 100\,kg \cdot ha^{-1}$ is advised for the study area, as a mixed-use of the two fertilizers improves the soil environment and increases production and productivity.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This research was funded by Wollega University. The authors (the authors) would like to appreciate and acknowledge Wollega University and Holota Research Center for supporting all materials required for the current study.

References

[1] S. W. Zaidun, M. B. Jalloh, A. Awang et al., "Biochar and clinoptilolite zeolite on selected chemical properties of soil cultivated with maize (Zea mays L.)," *Eurasian Journal of Soil Science*, vol. 8, no. 1, pp. 1–10, 2019.

[2] Fao Food and agricultural organization, *FAOSTAT Statistical Agricultural Production Data-Based*, Food and agricultural organization, Rome, Italy, 2020.

[3] Csa, "Agricultural Sample Survey, 2020/2021: report on area and production of major crops," Statistical Bulletin 590, vol. 1, Addis Ababa, Ethiopia.

[4] A. Pradhan, C. Chan, P. K. Roul, J. Halbrendt, and B. Sipes, "The potential of conservation agriculture for climate change adaptation and food security under rain fed uplands of India," A Trans disciplinary approach," *Agricultural Systems*, vol. 163, 2017.

[5] J. Pender, *The World Food Crisis, Land Degradation, and Sustainable Land Management: Linkages, Opportunities, and Constraints*, IFPRI, New York, NY, USA, 2009.

[6] A. Bekele, K. Kibret, B. Bedadi, M. Yli-Halla, and T. Balemi, "Effects of lime, vermicompost, and chemical phosphorus fertilizer on selected properties of acid soils of ebantu district, western highlands of Ethiopia," *Applied and Environmental Soil Science*, vol. 2018, Article ID 8178305, 13 pages, 2018.

[7] J. Dominguez and C. A. Edwards, "State of the art and new perspectives on vermicomposting research," in *Earthworm Ecology,* CRC Press, Boca Raton, FL, USA, 2004.

[8] A. Tufa, A. Hunduma, M. N. S. Hasan, F. Asefa, and B. C. Nandeshwar, "Levels of biochar and NPS fertilizer rates on growth, yield component, and yield of maize (*Zea mays* L.) at Guto Gida, western Ethiopia," *Advances in Agriculture*, vol. 2022, Article ID 5400431, 10 pages, 2022.

[9] G. S. Rekha, P. K. Kaleena, D. Elumalai, M. P. Srikumaran, and V. N. Maheswari, "Effects of vermicompost and plant growth enhancers on the exo-morphological features of *Capsicum annum* (Linn.) Hepper," *International Journal of Recycling of Organic Waste in Agriculture*, vol. 7, no. 1, pp. 83–88, 2018.

[10] W. Robe Elema, "Preparation and characterization of vermicompost made from different sources of materials," *Open Journal of Political Science*, vol. 6, no. 1, pp. 042–048, 2021.

[11] K. Dawar, A. Khan, I. A. Mian et al., "Maize productivity and soil nutrients variations by the application of vermicompost and biochar," *PLoS One*, vol. 17, no. 5, Article ID e0267483, 14 pages, 2022.

[12] A. Najarian and M. K. Souri, "Influence of sugar cane compost as potting media on vegetative growth, and some biochemical parameters of Pelargonium × hortorum," *Journal of Plant Nutrition*, vol. 43, no. 17, pp. 2680–2684, 2020.

[13] C. A. Edwards, J. Dominguez, and N. Q. Arancon, "The influence of vermicompost on plant growth and pest incidence," *Soil zoology for sustainable development in the 21st century Cairo, Egypt*, vol. 18, pp. 397–420, 2004.

[14] R. Abafita, "Evaluation of vermicompost on maize productivity and determine optimum rate for maize production," *World Journal of Biology and Medical Sciences*, vol. 3, no. 1, pp. 9–22, 2016.

[15] B. K. Singh, K. A. Pathak, A. K. Verma, V. K. Verma, and B. C. Deka, "Effects of vermicompost, fertilizer and mulch plant growth, nodulation and pod yield of French bean (*Phaseolus vulgaris*)," *Journal of Fruit and Ornamental Plant Research*, vol. 74, no. 1, pp. 153–165, 2011.

[16] S. Jaikishun, N. Hunte, A. A. Ansari, and S. Gomathinay, "Effect of vermiwash from different sources (Bagasse, Neem, Paddy Straw in different combinations) in controlling fungal diseases and growth of tomato (*Lycopersicon esculentum*) Fruits in Guyana," *Journal of Biological Sciences*, vol. 14, no. 8, pp. 501–507, 2014.

[17] M. Blouin, J. Barrere, N. Meyer, S. Lartigue, S. Barot, and J. Mathieu, "Vermicompost significantly affects plant growth: a meta-analysis," *Agronomy for Sustainable Development*, vol. 39, no. 4, pp. 34–15, 2019.

[18] J. W. van Groenigen, I. M. Lubbers, H. M. J. Vos, G. G. Brown, G. B. De Deyn, and K. J. van Groenigen, "Earthworms increase plant production: a meta-analysis," *Scientific Reports*, vol. 4, no. 1, p. 6365, 2014.

[19] H. Wu, C. Lai, G. Zeng et al., "The interactions of composting and biochar and their implications for soil amendment and pollution remediation: a review," *Critical Reviews in Biotechnology*, vol. 37, no. 6, pp. 754–764, 2017.

[20] E. T. Kayabasi and O. Yilmaz, "The importance of vermicompost in agricultural production and economy," *Eurasian Journal of Agricultural Research*, vol. 5, no. 2, pp. 146–159, 2021.

[21] J. Dominguez, M. Aira, A. R. Kolbe, M. Gomez-Brandon, and M. Perez-Losada, "Changes in the composition and function of bacterial communities during vermicomposting may explain beneficial properties of vermicompost," *Scientific Reports*, vol. 9, pp. 9657–9711, 2019.

[22] A. Getahun, D. Muleta, F. Assefa, S. Kiros, and M. Hungria, "Biochar and other organic amendments improve the physicochemical properties of soil in highly degraded habitat," *European Journal of Engineering Research and Science*, vol. 5, no. 3, pp. 331–338, 2020.

[23] G. W. Gee and D. Or, "Particle-size analysis," in *Methods of Soil Analysis. Part 4. Physical Methods*, J. H. Dane and G. C. Topp, Eds., pp. 255–294, SSSA Inc, Madison, WI, USA, 2002.

[24] S. Sahilemedhin and B. Taye, "Procedures for soil and plant analysis," National Soil Research Center Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia, Tech. Rep, 2000.

[25] M. Schnitzer, "Total carbon, organic matter and carbon," in *Methods of Soil Analysis. Part 2*, P. A. Kamara, A. Kamara, M. M. Mansaray, and P. A. Sawyerr, Eds., American Society of Agronomy, Madison, Wisconsin, 1982.

[26] J. M. Bremner and C. S. Mulvaney, "Nitrogen-total in methods of soil analysis. Part 2: chemical and microbiological properties," in *Agronomy Monograph*, A. L. Page, R. H. Miller, and D. R. Keeney, Eds., pp. 595–624, American Society of Agronomy, Madison, Wis, USA, 1982.

[27] D. L. Spark, A. L. Page, and P. A. Helmke, *Methods of Soil Analysis. Part 3. Chemical Methods*, Soil Science Society of America Inc, Madison, WI, USA, 1996.

[28] S. H. M. Aikins, J. J. Afuakwa, and O. Owusu-Akuoko, "Effect of four different tillage practices on maize performance under rainfed conditions," *Agriculture and Biology Journal of North America*, vol. 3, no. 1, pp. 25–30, 2012.

[29] Cimmyt, *Agronomic Data to Farmer Recommendations: An Economics Training Manual, Completely Revised Edition*, DF, Mexico, 1998.

[30] W. P. Goedhart and T. N. M. Jac Thissen, *Biometris GenStat Procedure Library Manual*, Biometris, Wageningen UR, Wageningen, The Netherlands, 2016.

[31] K. A. Gomez and A. A. Gomez, *Statistical Procedures for Agricultural Research*, John Wiley and Sons, Inc. Inter-Science Publications, New York, NY, USA, 1984.

[32] T. Tedese, "Soil, plant, fertilizer, animal manure and compost analysis manual," *International Livestock Center for Africa*, Addis Ababa, Ethiopia, 1991.

[33] D. Chimdessa and G. Sori, "Integrated effects of vermicompost and NPS fertilizer rates on soil chemical properties and maize production in bedele district, western oromia," *Plant*, vol. 8, no. 4, pp. 115–121, 2020.

[34] R. Lal, "Sequestering carbon and increasing productivity by conservation agriculture," *Journal of Soil and Water Conservation*, vol. 70, no. 3, pp. 55–62, 2015.

[35] T. L. Dalorima, A. J. Zakaria, A. Majrashi et al., "Impacts of vermicomposting rates on growth, yield and qualities of red seedless watermelon," *Australian Journal of Crop Science*, vol. 12, no. 11, pp. 1765–1773, 2018.

[36] M. H. Sigaye, A. Nigussei, B. Lulie, R. Mekuria, and K. Kebede, "Effects of organic and inorganic fertilizers on soil properties, yield and yield components of maize (Zea mays L.) grown on an andisols at hawassa zuria, Ethiopia," *Advances in Applied Science Research*, vol. 11, no. 4, pp. 1–8, 2020.

[37] K. M. Tripathi, D. D. Dhakal, S. C. Sah, D. R. Baral, and M. D. Sharma, "Evaluation of vermicompost and chemical fertilizers on performance of pak choi and soil biological process," *Journal of the Institute of Agriculture and Animal Science*, vol. 33, no. 34, pp. 243–250, 2015.

[38] H. Z. Khan, M. A. Malik, and M. F. Saleem, "Effect of rates and sources of organic material on the production potential of spring maize," *Pakistan Journal of Agricultural Sciences*, vol. 45, no. 1, pp. 40–43, 2008.

[39] G. Agegnehu, A. M. Bass, P. N. Nelson, and M. I. Bird, "Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil," *The Science of the Total Environment*, vol. 543, pp. 295–306, 2016.

[40] P. S. L. E. Silva, P. I. B. E. Silva, V. R. D. Oliveira, F. H. T. D. Oliveira, and L. R. D. Costa, "Vermicompost application improving semiarid-grown corn green ear and grain yields," *Revista Caatinga*, vol. 30, no. 3, pp. 551–558, 2017.

[41] H. Admas, H. Gebre Kidan, B. Bedadi, and E. Adgo, "Effects of organic and inorganic fertilizers on yield and yield components of maize at Wujiraba watershed, Northwestern highlands of Ethiopia," *American journal of plant nutrition and fertilization technology*, vol. 5, no. 1, pp. 1–15, 2014.

[42] S. O. Mahmoud and D. A. M. Gad, "Effect of vermicompost as fertilizer on growth, yield and quality of bean plants (*Phaseolus vulgaris* L.)," *Middle East Journal of Agriculture Research*, vol. 9, no. 1, pp. 220–226, 2020.

[43] T. S. Hoque, A. K. Hasan, Md. A. Hasan et al., "Nutrient Release from Vermicompost under Anaerobic Conditions in Two Contrasting Soils of Bangladesh and its Effect on Wetland Rice Crop," vol. 12, Agriculture, 2022.

[44] M. V. Nasab, H. R. Mobasser, and H. R. Ganjali, "Effect of different levels of vermicompost on yield and quality of maize varieties," *Biological Forum -An International Journal*, vol. 7, no. 1, pp. 856–860, 2015.

[45] M. H. Sigaye, "Effects of using different organic sources in combination with mineral nitrogen fertilizer on soil fertility, grain yield, and maize quality," *Advances in Life Science and Technology*, vol. 92, pp. 1–9, 2022.

[46] J. Shamshuddin, S. Muhrizal, I. Fauziah, and M. H. A. Husni, "Effects of adding organic materials to an acid sulfate soil on the growth of cocoa (Theobroma cacao L.) seedlings," *The Science of the Total Environment*, vol. 323, no. 1-3, pp. 33–45, 2004.

[47] T. Emamu and T. Wakgari, "The effect of application of vermicompost and NPS fertilizer on selected soil properties and yield of maize (*Zea may* L.) at toke kutaye, Ethiopia," *International Journal of Applied Agricultural Sciences*, vol. 7, no. 5, pp. 247–257, 2021.

[48] J. Theunissen, P. A. Ndakidemi, and C. P. Laubscher, "Potential of Vermicompost produced from plant waste on the growth and nutrient status in vegetable production," *International Journal of physiological science*, vol. 5, pp. 1964–1973, 2010.

[49] C. Lazcano and J. Dominguez, "Effects of vermicompost as a potting amendment of two commercially grown ornamental plant species," *Spanish Journal of Agricultural Research*, vol. 8, no. 4, pp. 1260–1270, 2010.

[50] M. Younas, H. Zou, T. Laraib et al., "The influence of vermicomposting on photosynthetic activity and productivity of maize (*Zea mays* L.) crop under semi-arid climate," *PLoS One*, vol. 16, no. 8, Article ID e0256450, 9 pages, 2021.

[51] Y. Geng, G. Cao, L. Wang, and S. Wang, "Effects of equal chemical fertilizer substitutions with organic manure on yield, dry matter, and nitrogen uptake of spring maize and soil nitrogen distribution," *PLoS One*, vol. 14, no. 7, Article ID e0219512, 16 pages, 2019.

[52] X. Wang, Y. Ren, S. Zhang, Y. Chen, and N. Wang, "Applications of organic manure increased maize (Zea mays L.) yieldand water productivity in a semi-arid region," *Agricultural Water Management*, vol. 187, pp. 88–98, 2017.

[53] M. Kmetova and P. Kovacik, "The impact of vermicompost application on the maize (Zea mays L.) phytomass creation at the growth stage 16 (BBCH-scale) and on the selected yield parameters of maize," in *Proceedings of the MendelNet 2014 – Proceedings of International PhD Students Conference*, pp. 53–58, Brno, Czech, November 2014.

[54] T. Abera, T. Tufa, B. Tola, and H. Kumbi, "Effects of vermicompost and NPS fertilizer rate on yield and yield components of highland maize in vertisol ambo," *Ethiopian Journal of Applied Science and Technology*, vol. 10, no. 1, pp. 1–15, 2019.

[55] L. Singh and P. Sukul, "Impact of vermicompost, farm yard manure, fly ash and inorganic fertilizers on growth and yield attributing characters of maize (*Zea mays* L.)," *Plant Archives*, vol. 19, no. 2, pp. 2193–2200, 2019.

[56] B. Abdissa, K. Kibebew, B. Bobe, B. Tesfaye, and Y. H. Markku, "Effects of lime, vermicompost and chemical P fertilizer on yield of maize in Ebantu District, Western highlands of Ethiopia," *African Journal of Agricultural Research*, vol. 13, no. 10, pp. 477–489, 2018.