Original Research Article

Integrated Effect of Vermicompost and Inorganic Fertilizer Rates on Yield and Yield Components of Finger Millet [*Eleusine coracana* (L.) *Gaertn*.] in Gobu-Sayo District, Ethiopia.

ABSTRACT

Finger millet is an important food and beverage crop in the highlands and mid lands of Ethiopia, however marginal cultivation and suboptimal fertilizer application have caused soil nutrient depletion and yield decline of the crop. With this in view, an experiment was conducted to evaluate the integrated effect of vermicompost and inorganic fertilizer blended NPSB with urea on yield and yield components of finger millet. The treatments consisted of combination of four levels of vermicompost (25, 50, 75, and 100 %) and three levels of recommended NPSB and urea (25, 50 and 75 %) rates; control (non-treated), recommended vermicompost alone (4.64 t ha^{-1}), and inorganic fertilizer alone (100 kg NPSB ha^{-1} and 90 kg urea ha^{-1}). The experiment was laid out in Randomized Complete Block Design in fifteen treatments with three replications. Significantly ($P<0.05$) higher value in number of days to 50 % flowering (99.6 days) and days to 90 % to maturity (149.33 days) of finger millet were obtained with the application of 50:75 % vermicompost and recommended NPSB with urea, the longest (70 cm) plant height was obtained with the application of inorganic fertilizer alone. Moreover, the highest number of tillers per plant (6.4) and productive tillers per head (3.96) was obtained with the application of 100:75 % vermicompost and recommended NPSB with urea, while the maximum (10730.4 kg ha^{-1}) dry biomass weight and straw yield (88235 kg ha^{-1}) was obtained with the application of 100 : 25 % vermicompost and recommended NPSB with urea. The highest net benefit ETB 56475.9 ha^{-1} with a marginal rate of return of 93.63 % was recorded from application of 25:50 % vermicompost (1.16 tons ha^{-1}) and blended NPSB with urea, (50 kg NPSB ha^{-1} and 45 kg urea ha^{-1}), fertilizer. Therefore, farmers in the study area are advised to use 25:50 % vermicompost (1.16 tons ha^{-1}), and blended NPSB with urea, (50 kg NPSB ha^{-1} and 45 kg urea ha^{-1}), fertilizer to increase finger millet productivity. However, the experiment has to be repeated across locations and seasons to provide a reliable recommendation for sustainable finger millet production for similar agroecology.

Keywords*: Finger millet, NPSB, Urea, Vermicompost*

1. INTRODUCTION

"In most parts of the world, Finger millet [*Eleusine coracana* (L.) *Gaertn.*] is grown as a subsistence crop for local consumption" (Mundia *et al.*, 2019). "Finger millet is extensively cultivated in the tropical and sub-tropical regions of Africa and India and is known to save the lives of small-income farmers from starvation at times of extreme drought" (Kotschi, 2010). "It adapts to a wide range of environments and is grown mainly by subsistence farmers and serves as farmers and serves as a crop which ensures food security because of its high nutritional value and excellent storage qualities and its importance as a low input crop" (Dida, 2007). "Ethiopia is one of the major producer of finger millets; it is also native to the highlands of the country" (Ayalew, 2015). Major constraints for crop productivity in Ethiopia particularly in Oromia regions include, low soil organic matter content, and poor soil nutrients availability due to intensive land cultivation coupled with poor soil management techniques.

"The vermicompost alters the soil fertility in different ways, such as it enhances aeration, porosity, bulk density, water holding capacity, pH, nitrogen, phosphorous and potassium content. The application of the vermicompost is enriches the soil microorganism, plant growth and nutrient content in the economical yield" (Mahanta *et al*., 2012). Application of vermicompost integrated with inorganic fertilizers has significantly influenced total biomass, grain yield and soil fertility status (Shiferaw *et al*., 2019). "In comparison to each nutrient source alone, integrated application 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" (Yadav *et al*., 2020). However, determining the optimal rate of inorganic and vermicompost is crucial for better productivity of the crop.

Therefore, this field experiment was carried out to evaluate the integrated effect of vermicompost and blended NPSB with urea fertilizers and to determine economically optimal integrated vermicompost and blended NPSB with urea fertilizer rate for finger millet production in Toke Kutaye district.

2. MATERIALS AND METHODS

The study was conducted at Bako Agriculture Research Centre which is located in Gobu-Sayo District, East Wollega Zone, and Oromia National Regional State. Bako Agriculture Research Centre is situated in the western part of Ethiopia between 37^o 1' 00" E to 37^o 3' 40" E and 9^o 4' 20'' N to 9^o 7' 20" N with an altitude of 1650 m.a.s.l., covering a total land area of 1440 hectares. It is characterized by hot and humid weather. The annual mean minimum temperature is 13.3^0C and the mean maximum temperature is 28^0 C. The experimental site is described by reddish-brown and clay, Nitisol which is strongly acidic in reaction with 5.32 pH (Table 1).

"Bako 09, an improved variety of finger millet was used as a test variety. The variety was released by Bako Agricultural Research Centre in the year 2017 for its high grain yield potential and moderately resistant against *Magnapor* the *oryzea* disease. The average grain yield of the variety under the research and farmer fields were 2.99 and 2.426 t ha^{-1}, respectively. The variety is adapted to an altitude of 1400 to 2200 meters above sea level, rainfall 1200-1300 mm (MoA, 2017). Blended NPSB fertilizer containing (18.9 % N, 37.7 % P_2O_5, 6.9 % S, and 0.1 % B) and Urea (46 % N) were used for the study. Vermicompost prepared from soybean straw and cattle manure was used for the study. The vermicompost had a composition of 8.2 pH, 32.22 %, OC, 1.98 % total N, 1.39 % total P, 3.94 % total K, 7.91 % total Ca, 8.7 % total Mg and it had a C: N ratio of 16.27" (Kifle *et al*., 2017).

The treatment consists of a combination of vermicompost and inorganic fertilizer (NPSB with urea). These integrations were four levels of vermicompost (25, 50, 75, and 100 %) and three levels of recommended NPSB and urea (25, 50 and 75 %) rates; Control (untreated), vermicompost alone (4.64 tons ha^{-1}) as recommended by Kifle *et al*. (2017), and inorganic fertilizer alone (90 kg urea ha^{-1} and 100 kg NPSB ha^{-1}) as described by Fufa *et al*. (2017) for the crop. The experiment was laid out in a Randomized Complete Block Design with fifteen treatments with three replications.

The land was ploughed, disked and harrowed by a tractor. The area of the plot comprised (9.6 m2) (3.2 m x 3 m). The spacing between the blocks and plots was 1.5 m and 0.5 m respectively. The two outer rows (one row from both sides of the plot), were left as a border row. Thus, the central six rows (7.2 m^2) were used for data collection and as net plot size. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient and water movement from plot to plot. Sowing of seeds was done on June 23, 2021 by hand drilling at a seed rate of 15 kg ha^{-1} in rows spaced 40 cm apart. Nitrogen is applied in two equal splits. The first 50 % of Urea was applied basal at planting and the remaining half was side-dressed to the side of plant rows at 5-10 cm depth at the maximum tilling stage (40 days after emergence). Unlike N, the total dose of NPSB fertilizer was applied during sowing based on treatment. All agronomic practices were given as per the recommendation for the crop.

"Before planting, soil samples were collected randomly from the experimental field at the depth of 0-20 cm to prepare a one kg composite soil sample. This composite sample was used for selected soil physicochemical analysis. In addition, soil samples were collected after harvesting from each treatment in the plots replicated three times at the depth of 0-20 cm and the sub-samples from the same treatment were combined and thoroughly mixed together and the desired quantity of the soil samples were collected into the new plastic bags and labelled with the necessary information and transported to the laboratory. After that, the soil samples were air-dried, sieved to pass through a 2 mm sieve and prepared for soil chemical analysis following the standard lab procedures at Bako agricultural research centre soil laboratory and Jije laboglass Addis Ababa" (Dick *et al.*, 1997).

"Soil texture was determined using the Bouyoucos hydrometer method. Soil pH was measured potentiometric using a digital pH meter with a glass electrode in the supplemental suspension of 1:2.5 soils to water ratio following the standard operating procedure for soil pH determination" (Amazirh *et al.*, 2021). "Organic carbon (OC) was determined by Walkley and black method following the standard operating procedure for OC. Total nitrogen (TN %) was analyzed according to the procedure described by" (Bremner, 1960). "Soil available phosphorus was extracted by using Bray II procedure.

Cation exchange capacity (CEC) of the soil was determined by ammonium acetate (NH4OAc, pH 7.0) saturated soil samples. Available Sulfur (Ava.S) was measured using turbid metric method" (Kilmer and Near pass, 1960). Available Boron (Ava. B mg kg $^{-1}$) was determined using the hot water method.

Data Collected and Measurements

Days to 50% emergence: It was recorded as a number of days from the date of sowing to the time when 50 % of the seedlings emerged in each plot from the ground.

Days to 50% flowering: Number of days from sowing to the date on which 50 % of plants on the net plot produce at their first flower was recorded.

Plant height: It was measured starting from the base of the ground to the tip of the plant using measuring tape for ten randomly selected plants for each plot at maturity.

Green leaf number: It was counted from ten randomly selected plants for all plots at the stage flag-leaf appear.

Green leaf area: "A green leaf area (GLA) was calculated using the formula below, correction factor which became 0.79, based on the formula below green leaf area (GLA) was calculated can be as described" by Assefa (2013). Leaf length (L) and Leaf width (W) were measured by leaf area meter, Am100 Bio Scientific Ltd, UK.

Days to 90% physiological maturity: The number of days from sowing to the stage when 90 % of the plants in a plot have reached physiological maturity was determined based on visual observation. i.e. the stage at which the leaf loses their pigmentation and begins to dry.

Total tillers per plant: It was recorded from ten randomly selected pre-tagged plants of each plot at physiological maturity.

Number of Productive tillers per plant: The numbers of tillers with fertile heads from ten randomly selected pre-tagged individual plants were recorded for each treatment, excluding the mother plant.

Panicle number per head: It was counted from ten randomly selected pre-tagged plants from each treatment.

Panicle Length: It was measured from the base of the panicle to the tip of the panicle from randomly selected pre-tagged ten plants for each treatment.

Biomass Yield : It was cut off and weighed using sensitive balance at harvest and average weight was computed and used for further analysis after sun drying until attain constant weight.

Straw yield: It was calculated by subtracting the grain yield from the total above-ground biomass output after threshing and measuring the grain yield.

Grain yield: It was measured using electronic balance and then adjusted to 12.5% moisture and convert to hectare basis.

Thousand seed weight: It was determined from 1000 randomly taken from each plot and weighed using electronic grain counter and then adjusted to 12.5 % moisture level.

Harvest Index: It was estimated from the proportion of grain yield to the above-ground biomass yield per plot.

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.

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 CIMMYT (1988). 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. The finger millet grain yield and straw yield were valued at an average open market price of ETB 3200.00 and ETB 30.00, 100kg^{-1} respectively. The cost of blended NPSB, urea, vermicompost fertilizer and cost of vermicompost transportation and cost of inorganic fertilizers transportation were 2017.68 ETB, 2946.89ETB, 800 ETB, 20 ETB and 60 ETB) per 100kg respectively, were used for economic analysis. Cost of land preparation, seed, field management, harvest and storage was not included in the analysis, as they were not variable.

3. RESULTS AND DISCUSSION

3.1. Soils Physicochemical Properties before Sowing

"The initial soil physicochemical properties showed that the soil texture at the trial site was clay, with 27 % sand, 9 % silt and 64 % percent clay" (USDA Textural Tringle Soil Survey Staff, 2011). "The soil pH was 5.32, which is considered as strongly acidic" (Hazelton and Murphy, 2007). "Organic carbon content of the soil was 1.89, which is in the medium range" (Hazelton and Murphy, 2007). "The total nitrogen content was 0.16 %, which is in the medium range' (Hazelton and Murphy, 2007). "The available phosphorus level was determined to be 7.33 mg $kg^{-1,}$ which is low range" (Hazelton and Murphy, 2007). "Similarly, the available sulfur of (1.09) mg kg^{-1}, which was in a very low range" (Horneck *et al.*, 2011). "While the available boron amount was not detected. The Cation Exchange Capacity of the soil was 32 cmol kg^{-1}, which was found in high range" (Hazelton and Murphy 2007).

Table 1.Initial selected soil physico-chemical properties of the experimental field of finger millet at Gobu-Sayo district

A. Soil physical properties	Percentage	References
Sand (%)	27	(USDA Textural Tringle, Soil Survey Staff, 2011)
Silt (%)	9	
Clay (%)	64	
Textural class	Clay	

B. Soil chemical properties	**Values**	**Rating**	**References**
pH(1:2.5)H_2O	5.32	Strongly acid	(Hazelton and Murphy, 2007)
Organic carbon (%)	1.89	Medium	(Hazelton and Murphy, 2007)
Total Nitrogen (%)	0.16	Medium	(Hazelton and Murphy, 2007)
Available phosphorus (ppm)	7.33	Low	
Available Sulfur	1.09	Very low	(Horneck *et al.*, 2011)
Available Born	ND	ND	
CEC (cmol/ 100g soil)	32	High	(Hazelton and Murphy 2007)

Note: - CEC: Cation exchange capacity, ND=Indicates not detected

3.2. Post-harvest Soil Chemical Properties

The post-harvest soil analysis indicated that the pH value was in the range of 5.09 to 5.56, (strongly acidic to moderately acidic in reaction). The highest pH value of 5.56 was recorded that received 50:50 % vermicompost and blended NPSB with urea (5.56) which is in the range of moderately acidic. The lowest pH value (5.09) was obtained from application of 25: 25 % vermicompost and blended NPSB with urea (Table 2). The carbon % was ranged from 1.17-2.16 %. The highest soil organic carbon value was recorded from application of 50: 50 % vermicompost and blended NPSB with urea and inorganic fertilizers alone, which is in the high range. Whereas the lowest (1.17 %), organic carbon was observed from application of 25: 50 % vermicompost and blended NPSB with urea, which is categorized in medium range.

The total nitrogen and available phosphorus of the soil after harvest ranged from 0.10-0.19 % and 4.96 - 9.3 ppm, respectively (Table 2). The highest (0.19 % and 9.3 ppm) total nitrogen and available Phosphorus were recorded from application of 50: 50 % vermicompost and blended NPSB with urea, and inorganic fertilizers alone (for total N % only); which is in the high range (Table 2). The lowest total nitrogen (0.10 %) was recorded at 25:50 % vermicompost and blended NPSB with urea, while available P the lowest (4.96 ppm) was obtained at 25: 25 % vermicompost and blended NPSB with urea treatment.

The Cation Exchange Capacity, available sulfur and available boron of post-harvest soils ranged from 17-41cmol/100 g soil, (0.09-2.99 mg $kg-^{1}$) and (indicates not detected) respectively (Table 2). The highest (41cmol/100 g soil) and lowest (17 cmol/100 g soil) CEC values were recorded on 50:50 % vermicompost and blended NPSB with urea, and 25: 25 % vermicompost and blended NPSB with urea treatments, respectively (Table 2). This inconsistent nutritional change could be due to the residual nutrient available from the previous cropping system, and high availability of nutrient from vermicompost which contribute for maximum nutrient up take by the plant in the experimental plots. Moreover. Similarly, Ali *et al.* (2018) reported changes in the chemical properties of post-harvested soils as a result of vermicompost with inorganic fertilizers and nutrient uptake by the crop plants.

Table 2. Post-harvest selected soil chemical properties of the experimental field of finger millet at Gobu-Sayo district.

Treatments	pH (1:2.5) H_2O	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Available P (ppm)	CEC (cmol/ 100g soil)	Available Sulfur	Available Boron
Control (non-treated)	5.17	1.44	2.49	0.12	6.14	19	0.26	ND
Vermicompost alone	5.18	1.37	2.35	0.12	6.42	18	0.38	ND
Inorganic fertilizers alone	5.24	2.16	3.73	0.19	6.94	30	1.52	ND
25:25 % VC and NPSB, urea	5.09	1.64	2.82	0.14	4.96	17	1.08	ND
25:50 % VC and NPSB, urea	5.11	1.17	2.02	0.10	6.35	18	2.85	ND
25: 75 % VC and NPSB, urea	5.16	1.33	2.29	0.11	5.95	19	0.70	ND
50: 25 % VC and NPSB, urea	5.25	1.76	3.03	0.15	6.17	31	1.03	ND
50:50 % VC and NPSB, urea	5.56	2.16	3.73	0.19	9.3	41	2.99	ND
50:75 % VC and NPSB, urea	5.28	1.93	3.33	0.17	6.2	29	0.75	ND
75: 25 % VC and NPSB, urea	5.23	1.91	3.29	0.16	8.76	21	0.54	ND
75: 50 % VC and NPSB, urea	5.37	2.07	3.56	0.18	8.15	33	0.27	ND
75: 75 % VC and NPSB, urea	5.22	1.45	2.50	0.13	5.97	23	1.8	ND
100 : 25 % VC and NPSB, urea	5.19	1.23	2.12	0.11	6.79	33	ND	ND
100 : 50 % VC and NPSB, urea	5.38	1.37	2.35	0.12	7.14	35	0.09	ND
100: 75 % VC and NPSB, urea	5.36	1.81	3.13	0.16	6.67	32	0.58	ND

ND=Not detected

3.3. Number of Days to 50 % emergence

The number of days to 50 % emergence of finger millet was significantly ($P < 0.05$) affected by integrated use of vermicompost and blended NPSB with urea fertilizer (Table 3). Application of integrated 50: 75 % vermicompost and blended NPSB with urea, 25: 25 % vermicompost and NPSB with urea and inorganic fertilizer alone resulted in shorter days (7 days) to emergence for finger millet, which was at par to all treatments except absolute control, 100: 75 % vermicompost and blended NPSB with urea that have the longest (9 days) number of days to emergence (Table 3). The finding was in agreement with Sumalata (2020) who stated that the maximum combined application of vermicompost with inorganic fertilizers prolonged days to emergence as compared to applied integrated level of optimum fertilized on proso-millet.

3.4. Number of Days to 50 % flowering

The mean number of days to reach 50 % of flowering of finger millet was significantly ($P<0.05$) affected by the integrated use of vermicompost and blended NPSB with urea fertilizer (Table 3). The shortest number of days (99.6 days) to 50% flowering was recorded from application of 50:50 % vermicompost and blended NPSB with urea, which was statistically at par with 100 % NPSB with urea alone, 25:50 % vermicompost and NPSB with urea, and 25:75% vermicompost and NPSB with urea treatments (Table 3). While the longest (108 days) number of days to 50 % flowering of finger millet was recorded on absolute control treatment, which was statistically similar with the rest of the treatments except inorganic fertilizers alone, vermicompost 25:50 and 75 % NPSB with urea, 50: 75 % vermicompost and NPSB with urea treatments. Early flowerings of finger millet were perhaps due to optimum rate of vermicompost and NPSB with urea fertilizers which encouraged the crop in early establishment, rapid growth and development. Similarly, Tekulu *et al*. (2019) reported that “the interaction of vermicompost and NPS fertilizers, as well as the NPS, had a significant effect on days to 50 % flowering tef crops that received optimal vermicompost and NPS heading earlier than others”, Sumalata *et al*. (2020) also reported that, “the combined use of organic and inorganic sources of nutrients and inorganic sources readily provides nutrients to the growing plants”.

3.4. Number of Days to 90 % physiological maturity

The number of days to 90 % physiological maturity was significantly ($P < 0.05$) affected by integrated use of vermicompost and blended NPSB with urea fertilizer (Table 3). The shortest (149.33) number days to 90 % physiological maturity was recorded from application of 50: 75 % on treatment of vermicompost and NPSB with urea, which was statistically at par with NPSB with urea alone, and 75: 25 % vermicompost and NPSB with urea (Table 3). Whereas the longest (157.00 days) number of days to 90 %

physiological maturity was recorded on absolute control, 75: 75 % vermicompost and blended NPSB with urea, 50 : 25 and 50 % vermicompost and blended NPSB with urea (Table 3). The prolonged days to maturity might happen due to the nutrition difference between treatments, which increases vegetative growth of crops when it is applied at different rates of optimum integrated fertilizer application. These findings matched with Jadhav *et al*. (2015). Maturity in finger millet it's a potential can be achieved under adequate crop management.

Table 3. Integrated effects of vermicompost and inorganic fertilizers on number of days to 50 % emergence, number of days to 50 % flowering and number of days to 90 % physiological maturity dates of finger millet.

Treatment combination	Number of Days to 50% emergence	Number of Days to 50% flowering	Number of Days to 90 % physiological maturity
Control (non-treated)	9.0^{a}	108^{a}	157.00^{a}
Vermicompost alone	8.3^{ab}	106^{ab}	156.167^{ab}
Inorganic Fertilizers alone	7.0^{b}	100.3^{cd}	152.66^{bc}
25:25 % VC and NPSB, urea	7.0^{b}	104.6^{abc}	154.33^{ab}
25:50 % VC and NPSB, urea	8.3^{ab}	102.0^{bcd}	155.00^{ab}
25: 75 % VC and NPSB, urea	7.7^{ab}	102.3^{bcd}	154.167^{ab}
50: 25 % VC and NPSB, urea	7.7^{ab}	105.3^{ab}	157.00^{a}
50:50 % VC and NPSB, urea	7.7^{ab}	105.0^{ab}	157.00^{a}
50 :75 % VC and NPSB, urea	7.0^{b}	99.6^{d}	149.33^{c}
75:25 % VC and NPSB, urea	7.7^{ab}	103.6^{abcd}	153.33^{abc}
75:50 % VC and NPSB, urea	8.3^{ab}	104.0^{abcd}	155.00^{ab}
75:75 % VC and NPSB, urea	8.3^{ab}	105.3^{ab}	157.00^{a}
100 : 25 % VC and NPSB, urea	7.7^{ab}	104.3^{abc}	156.33^{ab}
100 : 50 % VC and NPSB, urea	8.3^{ab}	105.3^{ab}	154.50^{ab}
100: 75 % VC and NPSB, urea	9.0^{a}	104.6^{abc}	156.167^{ab}
LSD (5 %)	1.56	4.46	4.31
CV (%)	11.79	2.56	1.67

Means followed by the same letter within a column are not significantly different at P<0.05 probability level

3.5. Plant height

The plant height of finger millet was significantly (P < 0.05) affected by integrated vermicompost and blended NPSB with urea fertilizer (Table 4). The highest (70.8cm) at plant height of finger millet was recorded from application of inorganic fertilizer alone, which is statistically at par with all treatments except control which the shortest (55.4cm) plant height of finger millet (Table 4). The reason for better growth and development under inorganic fertilizer alone might be the increased availability of nutrients from the inorganic fertilizers. The result was in harmony with Aparna *et al*. (2019) observed that plant height of finger millet was significantly affected by the application of 75 % recommended dose of nutrients + 25 % N through cotton stubbles vermi compost + 2% rock phosphate significantly increased plant height (107.1 cm).

3.6. Number of leaf per plant and leaf area

The integrated use of vermicompost and inorganic fertilizers did not significantly ($P<0.05$) affect the number of leaves per plant and leaf area of finger millet crop (Table 4). However, numerical difference observed between control and the rest of the treatments in the case of Number of Leaf per plant. This could be due to the ability of plants to switch from using most of its energy from vegetative development to reproductive organs development. The result agreed with Wafula *et al*. (2016) who reported that inorganic fertilizer rates did not influence the number of leaves per plant of finger millet.

Table 4. Integrated effects of vermicompost and inorganic fertilizers on plant height, number of leaf and leaf area of finger millet

Treatment combination	Plant height(cm)	Number of Leaf per plant	Leaf area (cm^2)
Control (non-treated)	55.40^{b}	8.90	33.56
vermicompost alone	62.06^{ab}	8.93	29.13
Inorganic Fertilizers alone	70.80^{a}	9.66	34.69
25:25 % VC and NPSB, urea	63.23^{ab}	9.63	29.76
25:50 % VC and NPSB, urea	64.76^{ab}	9.33	30.64
25:75 % VC and NPSB, urea	69.13^{a}	9.63	32.62
50: 25 % VC and NPSB, urea	62.33^{ab}	9.20	31.84
50:50 % VC and NPSB, urea	65.27^{a}	9.60	28.05
50:75 % VC and NPSB, urea	68.07^{a}	9.73	32.69
75: 25 % VC and NPSB, urea	67.00^{a}	9.33	27.55
75: 50 % VC and NPSB, urea	63.23^{ab}	9.40	30.96
75: 75 % VC and NPSB, urea	61.90^{ab}	9.33	33.63
100 : 25 % VC and NPSB,urea	66.36^{a}	9.80	30.49
100 : 50 % VC and NPSB,urea	62.86^{ab}	9.40	33.89

100: 75 % VC and NPSB,urea	67.16[a]	9.23	32.49
LSD (5 %)	9.85	NS	NS
CV (%)	9.11	8.68	14.35

Means followed by the same letter within a column are not significantly different at P<0.05. NS= non-significant

3.7. Number of total tillers per plant

The number of total tillers per plant significantly (P<0.05) affected using integrated vermicompost and blended NPSB with urea fertilizer (Table 5). The highest (6.4) number of Total tillers per plant of finger millet was recorded on recommended vermicompost with 75 % blended NPSB with urea treatment, which was statistically at par with all treatments except 75: 50 % vermicompost and blended NPSB with urea treatment (Table 5). While the lowest (3.27) number of total tillers per plant was recorded from application of 75:50% vermicompost and blended NPSB with urea, which was statistically similar with the rest of the treatments, except for recommended vermicompost with 75% blended NPSB with urea. This might be due to the availability of nutrients from integrated of organics and inorganics fertilizers produced under favourable condition in terms of nutrients uptake by the crop. The result was in agreement with Aparna *et al.* (2019), who reported highest number of tillers under 75% recommended dose of nutrients + 25 % N through cotton stubbles vermi compost + 2 % phosphate over other treatments.

3.8. Number of productive tillers per plant

The number of productive tillers per plant was significantly (P<0.05) affected by the use of integrated vermicompost and blended NPSB with urea fertilizer (Table 5). The highest (3.96) productive tiller was recorded from application of 100:75% recommended vermicompost and blended NPSB with urea, which was statistically at par with all integrated treatments except at 25: 50 and 75 % vermicompost integrated with 75: 75 and 50 % blended NPSB with urea, respectively (Table 5).While the smallest (2.03) productive tiller was recorded from application of 50: 75 % vermicompost and NPSB with urea fertilizer treatments, which was statistically par with the rest of the treatments except 100 % vermicompost with 50 and 75 % blended NPSB with urea and control. The reason for high productive tillers at full dose of vermicompost with 75 % inorganic fertilizer could be due to the readily available nutrients from inorganic source of fertilizer and the enhancement of high vermicompost mineralization which provides better nutrition for the crop and better soil environment. Likewise, Maitra *et al.* (2020) reported that 75 % recommended dose of fertilizer + 2 t FYM + *Azospirillum* @ 5 kg ha^{-1} gave maximum number of productive tillers on finger millet.

Table 5. Integrated effects of vermicompost and inorganic fertilizers rates on number of total tillers per plant and number of productive tillers per plant of finger millet

Treatment combination	Number of total tillers per plant	Number of productive tillers per plant
Control (non-treated)	5.97^{ab}	3.46^{ab}
Vermicompost alone	5.00^{ab}	2.90^{abc}
Inorganic Fertilizers alone	4.17^{ab}	2.90^{abc}
25:25 % VC and NPSB, urea	5.03^{ab}	2.96^{abc}
25:50 % VC and NPSB, urea	5.17^{ab}	3.00^{abc}
25: 75 % VC and NPSB, urea	3.93^{ab}	2.46^{bc}
50: 25 % VC and NPSB, urea	5.83^{ab}	3.10^{abc}
50:50 % VC and NPSB, urea	4.20^{ab}	2.76^{abc}
50 :75 % VC and NPSB, urea	3.93^{ab}	2.03^{c}
75 :25 % VC and NPSB, urea	3.90^{ab}	2.70^{abc}
75: 50 % VC and NPSB, urea	3.27^{b}	2.30^{bc}
75: 75 % VC and NPSB, urea	5.77^{ab}	2.96^{abc}
100: 25 % VC and NPSB, urea	4.17^{ab}	2.70^{abc}
100 : 50 % VC and NPSB, urea	6.03^{ab}	3.50^{ab}
100: 75 % VC and NPSB, urea	6.40^{a}	3.96^{a}
LSD (5 %)	3.03	1.2032
CV (%)	16.42	22.38

Means followed by the same letter within a column are not significant (P < 0.05) probability level

3.9. Biomass yield

The biomass yield of finger millet was significantly ($P<0.05$) affected by the use of integrated vermicompost and blended NPSB with urea fertilizer (Table 6). The highest (10730 kg ha^{-1}) biomass yield was recorded from application of 100:25 % vermicompost with NPSB with urea. While the lowest (5632 kg ha^{-1}) biomass yields finger millet was recorded from absolute control (Table 6). The possible reason for the increase in biomass yield compared to the control treatment might be due to readily available nitrogen to the crop from inorganic source of fertilizer and the mineralization of vermicompost which provides better nutrition and soil environment for the finger millet crop. It is also possible that due to sufficient amounts and balanced proportions of plant nutrients in vermicompost were given to the crop as needed during the growth phase, resulting in a beneficial enhancement in yield. The result was similar with Dass *et al*. (2013) who observed that biomass weight was significantly affected by integrated nutrient management on finger millet. Similarly, Tekulu *et al*. (2019) reported that as biomass yield was considerably increased under balanced fertilization with vermicompost and blended NPS fertilizer.

3.10. Grain yield

The mean grain yield of finger millet was significantly ($P<0.05$) affected using integrated vermicompost and blended NPSB with urea fertilizer (Table 6). The highest (2201.6, 2030.2 and 1948.4 kg ha^{-1}) grain yields of finger millet were recorded from application of 25: 50 and 50: 75 % vermicompost and NPSB with urea, and inorganic fertilizer alone; which were statistically at par with 100: 25 % vermicompost and NPSB with urea , and 100: 75 % vermicompost with NPSB with urea (Table 6). While the lowest (1058 kg ha^{-1}) grain yields finger millet were recorded on absolute control treatment.

The significant relationship between the increasing integrated vermicompost and inorganic fertilizer on the yield and growth components could also be attributed to the optimum photosynthetic activities in addition to the availability of the nutrients and the presence of adequate moisture in the soil. Also, Selim (2021) suggested that “finger millet responds well to integrated vermicompost and inorganic fertilizer treatment. These indicated that optimal blended NPSB levels of vermicompost and inorganic fertilizer have a good effect on the yield components of finger millet in the study area". Pallavi *et al*. (2017) found "comparable results in a study on the performance of finger millet as influenced by nutrient sources as well as integrating organic vermicompost and inorganic fertilizer".

3.11. Straw yield

The mean straw yield of finger millet was significantly ($P<0.05$) affected by the use of integrated vermicompost and inorganic fertilizer rate (Table 6). The highest (8823 and 8399 kg ha^{-1}), straw yield of finger millet were recorded from the application of 100: 25 and 25:75 % vermicompost and blended NPSB with urea, respectively (Table 6), while the lowest (4574 kg ha^{-1}), the straw yield was recorded on absolute control treatments.

The higher straw yield could be due to higher photosynthetic rate which is due to adequate supply of nitrogen, vermicompost along with inorganic fertilizer increase the photosynthetic activity and production of biomass, which ultimately resulted in high straw yield. Similarly, Ejigu *et al*. (2022) found that using organic vermicompost fertilizers in conjunction with inorganic NPSB with urea fertilizers greatly boosted straw yield. Maitra *et al*. (2020) also discovered that the use of 100 percent NPK in combination with 10 tons of FYM per hectare resulted in significantly improved grain and straw yields, as well as an increase in soil organic matter.

The combined use of organic fertilizers and microorganisms that promote plant growth are two strategies that contribute to soil biodiversity (Olivares et al. 2020a; Olivares, 2016). There are works in which microorganisms with properties to promote plant growth have been incorporated into the substrates used as fertilizers with satisfactory results. Similarly, Chirinos and Olivares (2013) mention outstanding effects on growth and productivity in crops (Olivares et al. 2022c), when using biofertilizers, significantly reducing the use of chemical fertilizers (Olivares et al. 2022a, 2022b; Montenegro et al. 2021). State-of-the-art technologies must focus on the sustainable maintenance of a system, in such a way that the use and application of resources must be conceived to conserve the environment (Olivares, 2022; Olivares and Hernández, 2020; Olivares et al. 2020b).

Table 6. Integrated effects of vermicompost and inorganic fertilizers on biomass weight, grain and straw yields of finger millet

Treatments	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Control (non-treated)	5631.7^{i}	1057.7^{gf}	4574^{ef}
Vermicompost alone	7962.7^{f}	1457.0^{ef}	6505.7^{abcd}
Inorganic Fertilizers alone	10026.7^{b}	1948.4^{a}	8078.3^{ab}
25:25 % VC and NPSB, urea	6867.2^{gh}	1447.5^{ef}	5419.7^{bcde}
25:50 % VC and NPSB, urea	7983.6^{ef}	2201.6^{a}	6082^{abcd}
25: 75 % VC and NPSB, urea	9996.2^{b}	1597.1^{bcde}	8399.1^{a}
50: 25 % VC and NPSB, urea	8009.3^{ef}	1374.0^{ef}	6635.3^{abcd}
50:50 % VC and NPSB, urea	7344.5^{g}	1467.1^{de}	5877.4^{bcde}
50 :75 % VC and NPSB, urea	8497.8^{de}	2030.2^{a}	6467.6^{abcd}
75: 25 % VC and NPSB, urea	9106.8^{c}	1486.7^{de}	7620.1^{abc}
75: 50 % VC and NPSB, urea	7989.0^{ef}	1408.2^{ef}	6580.8^{abcd}
75 :75 % VC and NPSB, urea	7371.9^{g}	1505.6^{cde}	5866.3^{bcde}
100 :25 % VC and NPSB, urea	10730.4^{a}	1907.9^{abc}	8822.5^{a}
100:50 % VC and NPSB, urea	6867.2^{gh}	1457.1^{ef}	5410.1^{bcde}
100:75 % VC and NPSB, urea	8698.0^{dc}	1642.4^{abcde}	7055.6^{abc}
LSD (5 %)	3006.4	416.95	1601.1
CV (%)	3.81	16.34	11.75

Means followed by the same letter within a column are not significant (P < 0.05) probability level

4. CONCLUSION

The current research on the effects of integrated vermicompost and blended NPSB fertilizer with urea rates was critical for developing long-term finger millet cultivation. The pre-sowing soil analysis indicated that the study region has strongly acidic soil with poor soil fertility, which requires an amendment to boost crop output in the study area. The post-harvest soil analysis also revealed that the application of integrated vermicompost along with blended NPSB with urea fertilizers had a positive effect on crop growth and yield, and maintained good soil health. However, inconsistent soil nutrient change was observed on the treated experimental plots.

The highest (99.6 days and 149.33 days) number of days to 50 % flowering and number of days 90 % physiological maturity of finger millet were obtained with the application of

50: 75 % vermicompost and recommended NPSB with urea. The tallest (70 cm) plant height was obtained with the application of inorganic fertilizer alone. Moreover, the highest (6.4 and 3.96) number of tillers per plant and number of productive tillers per plant were obtained with the application of 100: 75 % vermicompost and recommended NPSB with urea; and the maximum (10730 and 8823 kg ha^{-1}) dry biomass and straw yield (was obtained with the application of 100: 25 % vermicompost and recommended NPSB with urea. Similarly, the highest (33.8 7% and 2202 kg ha^{-1}) harvest index, and grain yield of finger millet were obtained with the application of 25: 50 % vermicompost and recommended NPSB with urea. The highest net benefit of ETB 56475.9 ha^{-1} with a marginal rate of return 93.63 % was recorded from the treatment that received 25: 50 % vermicompost and inorganic NPSB with urea application in the study area.

Based on some of the soil lab analysis result, the soil of the study area is medium in fertility, but strongly acidic in reaction. Therefore, the use of integrated soil fertility management practices such as liming and the addition of organic and inorganic fertilizers are recommended to improve yields of finger millet, and soil fertility in the study area. Application of integrated 25: 50 % vermicompost and blended NPSB with urea resulted in better grain yield (2202 kg ha^{-1}) with a net benefit of ETB 56475.9 ha^{-1} and a marginal rate of return 93.63 %. Hence, farmers in the study area and similar agro ecologies can be advised to use integrated**,** 25:50 % vermicompost (1.16 tons ha^{-1}) and blended NPSB with urea, (50 kg NPSB ha^{-1} and 45 kg urea ha^{-1}**)** to boost finger millet production and productivity. However, experiment was conducted in one location and season; hence it should be repeated in different locations and seasons to provide a credible suggestion for long-term finger millet production and productivity.

REFERENCES

Ali, S., Kashem, M. A., and Sarker, M. (2018). Effect of vermicompost on the growth and yield of cauliflower in acid soil of Bangladesh. *Journal of Sylhet Agricultural University*, 5(1), 37-43.

Amazirh, A., Merlin, O., Er-Raki, S., Bouras, E., and Chehbouni, A. (2021).Implementing a new texture-based soil evaporation reduction coefficient in the FAO dual crop coefficient method. *Agricultural Water Management*, 250 (106827), 2-3.

Aparna K, Rekha KB, Vani KP, and Prakash R. (2019). Growth and yield of finger millet as influenced by crop residue composting. *Journal of Pharmacognosy and Photochemistry*, 8(4), 110.

Ayalew, B. (2015).Trends, growth and instability of finger millet production in Ethiopia. *Research Journal of Agriculture and Environmental Management*, 4(2), 078-081.

Bremner, J.M. (1960). Determination of nitrogen in soil by the Kjeldahl method. *The Journal of Agricultural Science*, 55(1), 11-33.

Chirinos, J. and Olivares, B. (2013). Biological Effectiveness of Plant Extracts in the in vitro Control of the Phytopathogenic Bacteria Xanthomona. *Revista Multiciencias* 13(2):115-121.

CIMMYT Economics Program, International Maize and Wheat Improvement Center. (1988). from agronomic data to farmer recommendations: *An economics training manual*, *CIMMY*T, 27(47), 777-780.

Dass, A., Sudhishri, S., and Lenka, N. (2013).Integrated nutrient management to improve finger millet productivity and soil conditions in hilly region of Eastern India. *Journal of crop improvement*, 27(5), 528-546.

Dick, R.P., Thomas, D. and Halvorson, J. (1997). Standardized methods, sampling, and sample pretreatment. *Methods for assessing soil quality*, 49(1), 107-121.

Dida M. (2007).The genetic map of finger millet, *Eleusine coracana*. *The or Appl Genet*, 114(2), 321–332.

Ejigu, W., G. Selassie, Y., Elias, E., and Smaling, E. (2022). Effect of integrated fertilizer application on soil properties and tef (*Eragrostis tef [Zucc] Trotter*) yield on Vertisols of Northwestern Ethiopia. *Journal of Plant Nutrition*, *45*(5), 761-774.

Fufa Anbessa, Dagnachew Lule, Magarsa Kebede,.Zarihun Ababe,.Magarsa Dabala, Gudeta Badada, Kebede Desalagn Girma Chemeda, Chamada B. and Hailu F. (2017).Yield Improvement of Finger Millet due to Blended Fertilizers at Bako and Gute 2017 Oromia Agricultural Research Institute (1000). *Crop research Proceeding Oromia*, 176-178.

Hazelton, P., and Murphy, B. (2007). *Interpreting soil test results: What do all the numbers mean.* CSIRO publishing.

Horneck, D. A., Sullivan, D. M., Owen, J. S., & Hart, J. M. (2011). Soil test interpretation guide.

Jadhav, R., Babu, D. R., and Rao, L. (2015). Character association and path coefficient analysis for grain yield and yield components in finger millet (*Eleusine coracana (L.*) Gaertn.). *Electronic Journal of Plant Breeding*, *6* (2), 535-539.

Kifle, D., Shumi, G. and Degefa, A. (2017). Characterization of Vermicompost for Major Plant Nutrient Contents and Manuring Value. *Journal of Science and Sustainable Development*, 5(2), 97-108.

Kotschi, J. (2010). Reconciling agriculture with biodiversity and innovations in plant breeding. *GAIA-Ecological Perspectives for Science and Society*, 19(1), 20-24.

Mahanta, K., Jha, D. K., Rajkhowa, D. J., and Kumar, M. (2012). Microbial enrichment of vermicompost prepared from different plant biomasses and their effect on rice (Oryza sativa L.) growth and soil fertility. *Biological Agriculture & Horticulture*, *28*(4), 241-250.

Maitra, S., Reddy, M.D. and Nanda, S. (2020). Nutrient Management in Finger Millet (*Eleusine coracana L. Gaertn*) in India. *International Journal of Agriculture, Environment and Biotechnology*, 13(1), 13-21.

Mundia, C. W., Secchi, S., Akamani, K., and Wang, G. (2019). A regional comparison of factors affecting global sorghum production: *The case of North America, Asia and Africa's Sahel. Sustainability*, 11(7), 2135.

Olivares, B.O., Araya-Alman, M., Acevedo-Opazo, C. (2020a). Relationship Between Soil Properties and Banana Productivity in the Two Main Cultivation Areas in Venezuela. *J Soil Sci Plant Nutr*, 20 (3): 2512-2524. https://doi.org/10.1007/s42729-020-00317-8.

Olivares, B. (2016). Description of soil management in agricultural production systems of sector hammock in Anzoátegui, Venezuela. *La Granja: Revista de Ciencias de la Vida*. 23(1): 14–24. https://doi.org/10.17163/lgr.n23.2016.02.

Olivares, B.O., Calero, J., Rey, J.C., Lobo, D., Landa, B.B., Gómez, J.A. (2022a). Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. *Catena*, 208, 105718. https://doi.org/10.1016/j.catena.2021.105718,

Olivares, B., Hernández, R. (2020). Application of multivariate techniques in the agricultural land's aptitude in Carabobo, Venezuela. *Tropical and Subtropical Agroecosystems*, 23(2):1-12.

Olivares, B. (2022). Determination of the potential influence of soil in the differentiation of productivity and in the classification of susceptible areas to banana wilt in

Venezuela. UCOPress: Spain, pp. 89-111, https://helvia.uco.es/handle/10396/22355.

Olivares, B., Pitti, J., Montenegro, E. (2020b). Socioeconomic characterization of Bocas del Toro in Panama: an application of multivariate techniques. *Revista Brasileira de Gestao e Desenvolvimento Regional*, 16(3):59-71.

Olivares, B.O., Rey, J.C., Perichi, G., Lobo, D. (2022b). Relationship of Microbial Activity with Soil Properties in Banana Plantations in Venezuela. *Sustainability* 14, 13531. https://doi.org/10.3390/su142013531.

Olivares, B., Vega, A., Calderón, M.A.R., Rey, J.C., Lobo, D., Gómez, J.A., Landa, B.B. (2022c). Identification of Soil Properties Associated with the Incidence of Banana Wilt Using Supervised Methods. *Plants*, 11(15):2070. https://doi.org/10.3390/plants11152070.

Pallavi, C. H., Joseph, B., Khan, M. A., and Hemalatha, S. (2017). Effect of organic fertilizers and bio fertilizers on yield and yield attributing traits of direct sown rainfed finger millet, *Eleusine coracana* (L) Gaertn. *International Journal of Farm Sciences*, 11(1), 101-105.

Selim, M. M. (2021). Introduction to the Integrated Nutrient Management Strategies, and Contribution on Yield and Soil Properties. *Journal of Plant Sciences*, *9*(4), 139-150.

Sumalata, B., Sahana, N., and Siddaraju, R. (2020). Influence of integrated nutrient sources and seed priming on growth seed yield and quality in Nutri-cereal Proso-millet. *Journal of Pharmacognosy and Phytochemistry*, *9*(2), 1074-1078.

Shiferaw, D. and Rut, G. (2019). Effects of Blended Fertilizer Rates on Bread Wheat (*Triticum Aestivum* L.) Varieties on Growth and Yield Attributes. *J Ecol & Nat Resour*, 3(3), 170.

Tekulu, K., Tadele, T., Berhe, T., Gebrehiwot, W., Kahsu, G., Mebrahtom, S., and Tasew, G. (2019). Effect of vermicompost and blended fertilizers rates on yield and yield components of Tef (*Eragrostis tef* (Zucc.) Trotter). *Journal of Soil Science and Environmental Management*, 10(6), 130-141.

Wafula, W.N., Korir, K.N., Ojulong, H.F., Siambi, M. and Gweyi-Onyango, J. (2016). Finger millet (*Eleusine coracana L.*) grain yield and yield components as influenced by phosphorus application and variety in Western Kenya. *Tropical Plant Research*, 3(3), 673-680.

Yadav, B., Sharma, S. and Meena, S. (2020). Effect of different fertility levels and organic manures on biological properties of soil in Pearl millet. *Journal of Pharmacognosy and Photochemistry*, 9(1), 210-213.