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**Research Article**

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# Effect of Combined Application of Vermicompost and NPS Fertilizer Rates on Growth, Yield and Yield Components of Maize (*Zea mays* L.) at Toke Kutaye District, Ethiopia

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**ABSTRACT**
Maize is one of the major and important cereal crops in Western Shewa Zone, particularly, in the Toke Kutaye district. However, the yield of the crop is low mainly due to the low fertility status of the soils. Integrated use of vermicompost and NPS fertilizers is indispensable to improve this condition of the soil. In this context, a study was conducted in 2019/2020 to assess the effect of the combined use of vermicompost and NPS fertilizer on yield and yield components of maize. To achieve this objective field experiment was laid out in a randomized complete block design and replicated three times. The results of this study revealed that the current scenarios of maize production in Toke Kutaye district call for appropriate ways of adding nutrients to the soil to obtain optimum maize productivity. In response to this, the combined application of different rates of vermicompost and NPS fertilizer to soil significantly affected most parameters used for this investigation such as plant height, leaf number, leaf length, leaf area, stand count, ear length, and a number of ears per plant, thousand-grain weight, total above-ground dry biomass and grain yield of maize. Moreover, the combined form of NPS blended fertilizer and vermicompost was applied and the result revealed that the sole application of recommended NPS fertilizer and vermicompost increased maize yield by 52.27 and 55.72% over control treatments, respectively. Besides this, the combined use of vermicompost and NPS fertilizer by the rating of half of the recommended rate of both fertilizers increased maize yield by 60.05% over the control treatment. This indicates that the best option for soil fertility management is integrated soil fertility management that involves the combined use of vermicompost and NPS fertilizers as nutrient sources than the strategy of using organic or inorganic amendments alone. Then, it could be concluded that the use of blended NPS fertilizer at 50 kg ha$^{-1}$with supplemental vermicompost at 5 t ha$^{-1}$ to Jibat variety is the realistic approach to address the problem of low productivity of maize in the study area and other similar agroecology. Based on the findings and conclusions of this study it can be recommended that farmers in the study area should, therefore, be advised to use this variety and combined use of vermicompost and NPS fertilizer at a rate of 5 t ha$^{-1}$ VC +50 kg ha$^{-1}$ NPS for sustainable maize crop production tentatively. Nevertheless, further studies are needed to recommend agronomical optimum and to measure the long-term effects of the integrated soil fertility management techniques in more seasons, soil types and crop varieties before giving a conclusive recommendation.
**Keywords:** Grain yield; NPS fertilizer; Soil fertility; Vermicompost.

## INTRODUCTION
Maize is an important staple food crop and the most useful cereal crop next to tef in western Ethiopia (Abera *et al.*, 2013). Maize is one of the most important cereal crops in the world which is ranked as the third major cereal crop after wheat and rice. The USA, China and Brazil contribute 63% to the global maize production and topped the list of maize-producer countries which includes Ukraine, Argentina, India, Mexico, South Africa and Canada with an amount of about 351 million metric tons (FAO, 2011). Its centre of origin also is located in America, particularly, Mexico, and spread throughout North and South America (Vigouroux *et al.*, 2011). In Africa, it is a popular and widely cultivated food crop since its introduction to the continent around 1500 A.D. (Zamir, 2013). The main maize producers in Africa include Kenya, Tanzania, Zambia, Zimbabwe and Ethiopia (Kidist *et al.*, 2013; Mitiku and Asnakech, 2016). Likewise, in Ethiopia maize is the second most widely cultivated crop next to tef and it is grown as a subsistence crop in the mid-altitudes (1500–2000 m above sea level) in southern, south-central, and southwestern parts of Ethiopia (Tsedeke *et al.*, 2015). It accounts for the largest share in total production and the total number of farm holdings involved among cultivated cereals in Ethiopia. In the 2011 cropping season, maize accounted for 28 per cent of the total cereal production, and approximately 9.3 million smallholder farmers in

Ethiopia grow maize, mainly for human consumption (Demeke, 2012; Tsedeke *et al*., 2017).

Maize covers nearly 197, 204, 250 million hectares of the world's arable land (FAO STAT, 2017). It is also the most widely grown staple food crop in eastern Africa occupying more than 15.7 million ha (FAO, 2019). According to a report by the Central Statistical Agency (CSA, 2020), around 17.68% of Ethiopian cultivated land is covered by maize. The average yield of maize on research field in Toke Kutaye District, in particular, is 7.59 t ha$^{-1}$ (Tolera and Tesfaye, 2021) and that in the country is 4.2 t ha$^{-1}$ (CSA, 2019), which is lower than the world's average yield of 5.8 t ha$^{-1}$ (Kumar and Kumar, 2017) as the result of the inadequate soil fertility of the country.

The most limiting factors for sustainable maize production in smallholder farming systems of Ethiopia are low soil fertility (Okoko and Makworo, 2012). In line with these most Ethiopian soils are deficient in nutrients especially nitrogen and phosphorus due to continuous and intensive mono-cropping of maize production, removal of crop residue, insufficient inputs of replacement nutrients, accelerated soil erosion caused by inappropriate land uses and poor soil management practices, as well as unbalanced fertilization, also aggravate soil organic matter and nutrient depletion (IFPRI, 2010; Sanchez, 2015).

However, organic farming or chemical fertilizers are used as a solution for such situations, there are some problems related to chemical fertilizers such as inadequate supply or even unavailability of fertilizer at the time of need and becoming very costly for farmers to apply the full recommended rates. Further, the continuous use of chemical fertilizer creates a potential polluting effect on the environment. On the other hand, the sole application of organic matter is constrained by access to sufficient organic inputs, low nutrient content, high labor demand for preparation and transporting. It has been reported that application of integration of organic sources with synthetic sources of nutrients not only supply essential nutrients but also improves soil physical properties, sustainable maize production and reduces environmental hazards. In this regard, study conducted in southern Ethiopia, by using integrated use of coffee by products and N fertilizer increased N uptake and grain yield of maize (Fanuel and Gifole, 2013). Similarly, the combined use of vermicompost and NPS fertilizers affect some of maize growth parameters such as height, yield and yield components more than chemical fertilizer or vermicompost alone (Alam, 2014).

Integrated use of organic and chemical fertilizers is beneficial in improving soil fertility and sustainable productivity better than the application of either organic or inorganic NPS fertilizer alone (Endris and Dawid, 2015). Tilahun and Tamada *(*2019) also stated that neither inorganic nor organic fertilizers alone can result in the sustainable productivity of maize crops. In this line, the integration of organic and inorganic sources such as vermicompost and NPS fertilizer can improve soil properties and sustain crop yields without degrading soil fertility status. Besides this, the recommended rate of blended NPS with vermicompost has not been described and the combined effect of blended NPS and vermicompost on maize production particularly in Toke Kutaye district has not been well studied so far. It is pertinent to study the response of maize crop to the combined application of vermicompost and NPS fertilizer. Hence, this calls for a need for research on the improvement of soil fertility status and the response of maize crops to the combined use of vermicompost and NPS chemical fertilizers. Therefore, this study was conducted to assess the effect of blended NPS fertilizer supplemented with vermicompost on growth, yield components and yield of maize in the Toke Kutaye district.

## MATERIALS AND METHODS

### Description of the Study Area

Location and area coverage

The field experiment was conducted at Ambo University Guder Mamo Mezemir Campus, which is found in Toke Kutaye district of Western Shewa Zone, Oromia Regional State at a distance of approximately 138 and 12 km, respectively, from Addis Ababa and Ambo town. Toke Kutaye district is located at a latitude of 8° 49'0"-9° 5'30"N and a longitude of 37° 26'0''-37° 57'30"E. The district is bounded by Liban Jawi district in the west, Midakegn district in the north, Ambo and Amaya district in the east and Dire Inchini district in the south. Toke Kutaye district has a total area of 51,313.19 hectares (Tolera *et al*., 2020).

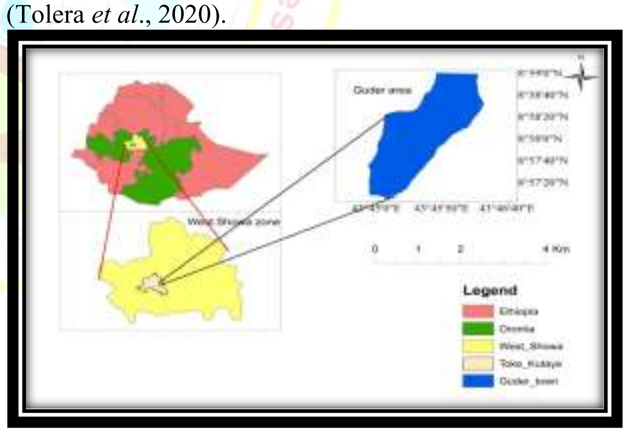


**Figure 1.** Area map of Toke Kutaye Woreda in Ethiopia

**Climate and topography of the study area**

The study area consists of three agro-climatic zones: lowland (desert/beraha), middle (subtropical/woina dega), and highland (temperate/dega) (Tolera *et al*., 2016). These agro climatic divisions covered 18%, 57% and 25%, respectively. The annual rainfall ranges from 800-1100 mm. The district has a unimodal rainfall pattern in which rain is received from April to September, but the highest rains are received from June to August. The minimum and maximum temperatures of the district are 10 and 29$^{o}$C, respectively. The altitude of the area ranges from 1,880-3,194m above sea level (MAARC, 2019).

**Geological parent materials and soil types**

The soils of the study area are developed from different parent materials such as schist, granite, gneiss and basalt through weathering (Adane *et al*.,2020). According to Abera and Belachew (2011) the dominant soil type of a study area is vertisol. Furthermore, soils of the study area are strong to moderately acidic in reaction (pH of 5-5.5), with loose and friable consistence, deep and well drained and clay in texture.

**Population, land uses and farming system**

The total population of the district was about 125,658 where 62,860 (50.2%) were male and 62,798 (49.8) female of which about 98,856 (78.6%) of the population live in a rural area and 49,456 (39.35) male and 49,409 (39.32%) female and 26,793 (23.3%) live in urban. The total number of household farmers in the district was 25,166 of which 21,855 (86.8%) were male and 3,311 (13.2%) female (Aman, 2018). Religious activity which practised in the study area included Christianity with different denomination like protestant, orthodox, catholic, Adventist, Muslim and Wakefata being dominant. Toke Kutaye district has 35, 209 ha of cultivated land, 8,017 ha of grazing land, 2,846 ha of forest land, and 5,241 ha occupied by construction. A mixed crop-livestock system that involves crop production and animal husbandry is the predominant farming system in the study area. The main crops grown in the study area are maize, barley, wheat, tef, bean and oil seeds such as nug (Tariku *et al*., 2018). The major livestock reared are cattle, poultry, mule, horse, sheep, and goats. Intercrop, grazing and livestock production land use and traditional farming system are used in the district. Oxen power is the main power source for ploughing and threshing activities.

**Methods of Study**

Compost materials and vermicompost preparation procedures

Vermicompost was prepared as a head of field experiment by using earthworm and organic materials such as green plants, animals dung, pulse straw and inputs like cattle manure was used as bedding materials for Vermicomposting and bulking in the composting process. For vermicompost preparation, vermicompost bin with 2m length, 1m width and 1m deep was used. The bin has a lid to keep out ants, birds, flies and rodents and holes in the bottom a quarter inch or smaller for ventilation and drainage. Since worms like moderate temperature, the bin was placed in a shady location where it was not overheated (Lazcano *et al*., 2008).

At the bottom of the bin vermicompost material such as green plants, animal's dung, pulse's straw was added as bedding material. Then, compost materials were placed in stacks according to the following sequences of a layer of crop residues/green plants (20 cm) or 60%, a layer of manure (animal dung, sheep manure) (5-10 cm) or 30%, and a layer of topsoil (2-4 cm) or 10% (Suparno, 2013). Some layer of soil spread over it again and worms are introduced to the bin. The materials in the bin were turned every 3 days and regular watering was done to keep moisture and make the materials soft for the worms. After composting was completed new stack of compost materials was prepared for one side of the bin and the worms were gradually moved to the new stack by leaving the finished vermicompost. Then, the finished vermicompost was harvested and it is dark in colour light and free from any unpleasant odor (Ahmadabodi *et al*., 2011).

**Experimental treatments and design**

The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments and three replications. The treatment consists of a combination of vermicompost and chemical NPS fertilizer. The recommended rate of Vermicompost 10 t $ha^{-1}$was used depending on recommendations given by different researchers (e.g.Fekadu *et al*., 2014). While, the rate of NPS fertilizers was determined from the local blanket recommendation that is in use by the local farmers. The recommended rate of NPS fertilizer is 100kg $ha^{-1}$ in place of DAP (Di-ammonium phosphate) as per suggestion by ATA (2014). The treatments consist of control (no fertilizer), 100% of recommended NPS, 100% recommended vermicompost, 5 t $ha^{-1}$ VC +50 kg $ha^{-1}$NPS, 5 t $ha^{-1}$ VC+100 kg $ha^{-1}$ NPS, 10 t $ha^{-1}$ VC +50 kg $ha^{-1}$NPS, 10 t $ha^{-1}$ VC+100 kg $ha^{-1}$ NPS, 15 t $ha^{-1}$ VC+50 kg $ha^{-1}$NPS and 15 t $ha^{-1}$ VC+100 kg $ha^{-1}$NPS were laid out in a randomized complete block design and a total of nine treatments with three replication.

**Experimental procedures and field management**

The field experiment was conducted to evaluate different rates of NPS fertilizers integrated with vermicompost using maize crop of FS53xFS67xKit23 Jibat variety which was released from Ambo Plant Protection Research Centre and its yield potential on the research field is 6.5-7.8 t $ha^{-1}$and on farmers' fields is 4.5-5.5 t $ha^{-1}$ (MoARD, 2009). The total land area selected for the experiment was 352.35 $m^2$ (26.1 m x 13.5 m). It was divided into three blocks and each block was divided into nine sub-plots. The spacing between blocks, plots, rows and plants were 1, 0.5, 0.7, and 0.3 m, respectively. Land preparation (seed bed preparation) of the experimental test field was done by ploughing three times with traditional oxen-driven practices. Ploughing was done twice per week intervals to destroy the emerging weeds. Harrowing was done after ploughing to further pulverize larger soil aggregates.

Vermicompost was applied by hand in the row and thoroughly mixed with the top surface layer soils of each plot one month before planting because immediate sowing of the crop after vermicompost application sometimes sufficient time must be permitted for more decomposition before sowing of crops. Inorganic fertilizers were placed in a hole 5 cm from the seeds in the furrow covered with a thin layer of soil then followed by the sowing of seeds and then covered again with soil to have close contact between the seed and the soil, thus, would facilitate uniform germination. Maize crop was hand drilled at a recommended seeding rate of 20-25 kg ha$^{-1}$(Okoko and Makworo, 2012). Sowing was conducted in the first week of April 2019. All management aspects were done by adopting the recommended agronomic practices of maize production and local practices.

**Soil sampling and analysis**

To determine soil physicochemical properties, composite and core soil samples were drawn from the top layer of each experimental unit before and after planting. Soil samples from 0-30 cm depth were collected before maize planting for analysis of selected soil physicochemical properties planting. A total of three composite samples were collected from the three blocks. Soil samples were collected by auger from nine plots and thoroughly mixed to make one composite sample per block. At the same time, undisturbed core samples from 0-30 cm depth layers were also collected randomly by taking one sample per block using the core method to determine soil bulk density before planting.

For soil sampling, after harvesting from each plot an auger was used to sample five randomly selected spots per plot. These five subsample soils were combined into one composite soil sample per plot for investigating the soil properties of each treatment. Similarly, undisturbed core samples from 0-30 cm depth layers were also collected to determine the soil bulk density of each plot. The collected soil samples were bagged, labelled and transported to the laboratory for preparation and analysis of soil properties. A sufficient amount of composite soil samples was air-dried and ground to pass through a 2 mm sieve in preparation for the analyses of the selected physicochemical properties following standard laboratory procedures (Sahlemedin and Taye, 2000). A portion of the disturbed soil samples was taken and sieved using a 0.5 mm diameter for the determination of the organic matter and total nitrogen. Soil sample preparation and analysis were done at Holeta agricultural research centre. The samples were analyzed for particle size distribution, soil texture, bulk density, particle density, porosity, moisture content, pH, available phosphorus, available potassium, available sulfur, total nitrogen, organic carbon, and cation exchange capacity.

**Laboratory analysis of soil:**

**Soil physical properties**

Particle size distribution was determined by the hydrometer method (Day, 1965). Then, the soil was assigned to a textural class using the USDA soil textural triangle (Soil Survey Staff, 1999). Bulk density was determined using the core method as described by Jamison (1950). Particle density was described using the pycnometer method following procedures described by Rao *et al*. (2005). Total porosity was calculated from the values of bulk density and particle density using the method described by Rowell (1994). Soil moisture content was determined using the gravimetric method as described by Reynolds (1970).

**Soil chemical properties**

Soil pH was measured in a soil-water suspension by the glass electrode pH meter (Peech, 1965) at 1:2.5 soil-to-water ratios. Soil organic carbon was determined using the Walkley - Black wet oxidation procedure (Walkley and Black, 1934) and the soil organic matter content was determined from the organic carbon as suggested by Nelson and Sommers (1996). Total nitrogen content in the soils was determined using the Kjeldahl procedure (Jackson, 1958). Available P in the soil samples was extracted by using the Bray II method (Bray and Kurtz, 1945). The Phosphorus extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley (1962). Available sulfur was extracted with ammonium acetate (1N $NH_4OAc$) and determined using the gravimetric determination method as described by Warman and Sampson (1992). Exchangeable potassium was extracted with neutral normal ammonium acetate and the content of potassium in the extract was estimated by a flame photometer (Jackson, 1973). Cation exchange capacity (CEC) was determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7 using the methods described by Chapman (1965). The result of the analysis is presented in Table 1 below.

**Table 1.** Selected soil physicochemical properties of an experimental site before planting

| Physical properties | BD (g.cm$^{-3}$) | PD (g.cm$^{-3}$) | Total porosity (%) | Soil moisture (%) | soil texture | PSD (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Sand | Silt | Clay |
| Mean values | 1.28 | 2.65 | 51.6 | 36.9 | Clay | 15.1 | 35.3 | 49.6 |

| Chemical properties | pH | OC (%) | TN (%) | C: N (%) | av. P (ppm) | av. S (ppm) | ex. K (cmol/kg) | CEC (cmol/kg) |
|---|---|---|---|---|---|---|---|---|
| Mean values | 5.24 | 1.61 | 0.14 | 11.5 | 9.01 | 2.97 | 0.42 | 21.14 |

**Table 2.** Chemical composition of vermicompost used for this study

| Physicochemical parameters | Moisture (%) | pH | OC (%) | Nt (%) | C: N | P (%) | K(cmol/kg) |
|---|---|---|---|---|---|---|---|
| Mean values | 43.2 | 6.85 | 11.76 | 1.64 | 7.17 | 2.26 | 1.14 |

**Chemical Composition of vermicompost**

To determine the composition of the vermicompost, samples of 100 g were collected for chemical analysis. Compost samples were analyzed for chemical parameters such as pH, total organic carbon, total Nitrogen, potassium and Phosphorus. The pH of vermicompost was determined by the method described by Ndegwa and Thompson (2001). Total organic carbon is described by Okalebo *et al*. (2002) method. The total Nitrogen content of vermicompost was determined using Kjeldahl procedure (Bremner and Mulvancy, 1982). The total phosphorus content was determined by the method described by Olsen (1954) and the total potassium content was determined as described by Hesse (1971). The result of the analysis is presented in Table 2.

**Agronomic Data Collection**

Agronomic data that were collected during the field experiment include plant height, leaf area, leaf length, leaf number, stand counts, number of ears per plant, number of ears per hectare, ear length, 1000 grain weight, biomass yield and grain yield. For this purpose, six maize plants were pre-tagged and randomly selected from each plot for sampling.

**Growth parameters**

Plant height was measured as the height from the soil surface to the base of the tassel of six randomly taken plants from the net plot area at 75% physiological maturity. Leaf numbers were counted per plant for all available leaves from six maize plants. Leaf length was measured from the base of the leaf to the tip of the leaf of that plant. The leaf area of all available leaves of six plants per net plot was collected at 50% milking stage and leaf length and width were measured: Leaf Area (LA) = Length (cm) x Maximum width of leaf (cm) and was adjusted by a correction factor 0.75 (0.75 x LL x maximum leaf width) (Mihiretu,2014; Uzun and Celik,1999). Leaf area index was calculated as the ratio of total leaf area per six plants ($cm^2$) per area of land occupied by the plants (Radford, 1967).

**Yield and yield components**

Stand count was recorded per plot after thinning and at harvest from the net plot area. Several ears per plant was recorded from the count of six randomly taken plants in the central net plot area at crop harvest. A number of ears per hectare was recorded by counting the number of ear per plot and converting to hectare. Ear length was recorded from the measure of six randomly taken ears per net plot at harvest. 1000-grain weight was measured by weighing air-dried hundred maize grains. Grain yield, cobs of each plot were shelled and weighted to have grain yield per plot, then yield were converted from Kg/plot into hectare by adjusting to 12.5% moisture content. Biomass yield was recorded from each plot after harvesting and air drying the samples to constant weight.

**Data analysis and Interpretation**

Analytically determined soil physicochemical and agronomic data were subjected to analysis of variance using GLM procedures of the Statistical Analysis System Software (version 9.0) (SAS, 2004). Whenever the ANOVA detects significant differences ($P<0.05$) between treatments, mean separation was conducted using Fisher's Least Significant Difference (LSD) test (Gomez and Gomez, 1984). A simple correlation analysis was also conducted to identify useful associations among key soil and agronomic variables.

**RESULTS AND DISCUSSION**

Effect of vermicompost and NPS fertilizer on growth, yield components and yield of maize crop

**Growth parameters**

There were significant variations ($p<0.05$) among the combined rate of vermicompost and NPS fertilizers on plant height, leaf number, leaf length and leaf area of maize crop after the field was incorporated with different doses of vermicompost and NPS fertilizers (Tables 3-5).

**Plant Height**

Average maize plant height was significantly influenced by the application of vermicompost and NPS fertilizers. The highest value of plant height (263.70 cm) was observed from 10 t $ha^{-1}$ VC + 100 kg $ha^{-1}$ NPS fertilizer whereas the lowest value (188.67 cm) was found from the control plot (Table 3). This showed that increasing a combined dose of vermicompost and NPS fertilizer application to soil, increased plant height than that of control treatment, sole use of vermicompost and NPS fertilizer, and low rate of application. The variation in plant height due to different doses of amendments might be due to variations in the availability of major nutrients. Moreover, the increase in plant height concerning increased vermicompost and NPS fertilizer application rate indicates high availability of major plant nutrients and maximum vegetative growth of maize plants under a higher combination of vermicompost and NPS fertilizer. Further, chemical fertilizer offers nutrients which are readily soluble in soil solution and thereby instantaneously available to plants. Nutrient availability from organic sources might be due to microbial action and improved physical condition of the soil. In line with this result, Priya *et al*. (2014) reported that plant height was significantly affected by the complementary application of 100% NPK (120: 60:30 kg ha) fertilizers with 10 t $ha^{-1}$ FYM. This finding was also supported by Manish *et al.* (2017) who demonstrated that the relatively highest values of plant height were recorded for plots fertilized with the highest doses of cow dung and NPK fertilizers.

**Leaf Number**

Combined application of vermicompost and NPS fertilizer increased leaf number of maize crop over control or sole application of each fertilizer. Accordingly, the highest value of leaf number (14.98) was recorded from 10 t $ha^{-1}$ VC + 100 kg $ha^{-1}$ NPS fertilizer while the lowest value (12.68) was recorded from the control treatment (Table 3). The highest value was recorded due to the availability of a sufficient amount of nutrients to plant growth through vermicompost and NPS fertilizer. Jeet (2012) also reported a significantly higher number of green leaves per plant with the application of increasing levels of organic and inorganic fertilizers. Moreover, this finding was supported by Singh and Singh (2016) who reported increases in leaf number with increasing doses of organic and inorganic fertilizers applied.

**Leaf Length**

Combined use of vermicompost and NPS fertilizer rate increase leaf length of the maize plant. The highest value of leaf length (86.08 cm) was recorded from 10 t ha$^{-1}$ VC+100 kg ha$^{-1}$NPS fertilizer while the lowest value (73.73 cm) was also recorded from the control treatment (Table 3). This might be attributed to the more vegetative growth of maize crops due to improved nutrient availability. In the same manner improvements in the growth and yield of maize crops due to vermicompost and NPS fertilizer application was also reported by Tolera *et al* (2016).

**Leaf Area**

The results presented in Table 3 showed that as the vermicompost and NPS fertilizer combination rate increased leaf area of maize also increased. The highest value of leaf area (830.58 cm$^2$) was recorded from 10 t ha$^{-1}$ VC + 100 kg ha$^{-1}$ NPS fertilizer while the lowest value (73.73 cm) was also recorded from the control treatment. This might be due to the more vegetative growth of maize crops and the development of vermicompost and blended fertilizer which increased the utilization of applied nutrients by the crop. In agreement with this result, Dagn (2016) stated that vermicompost produced significant improvements in leaf area.

**Table 3.** Effect of vermicompost and NPS fertilizer on plant height, leaf number, leaf length and leaf area of maize crop

| **Treatments** | **Plant height (cm)** | **Leaf Number** | **Leaf length (cm)** | **LA (cm$^2$)** |
|---|---|---|---|---|
| $T_1$ | 188.67$^e$ | 12.68$^f$ | 73.73$^g$ | 594.58$^c$ |
| $T_2$ | 242.50$^d$ | 13.82$^d$ | 79.55$^f$ | 745.84$^b$ |
| $T_3$ | 243.83$^{cd}$ | 13.73$^e$ | 81.61$^e$ | 747.30$^b$ |
| $T_4$ | 247.00$^{bcd}$ | 14.11$^{cd}$ | 81.66$^e$ | 788.31$^{ab}$ |
| $T_5$ | 249.17$^{bc}$ | 14.18$^{cd}$ | 82.71$^{de}$ | 775.46$^{ab}$ |
| $T_6$ | 251.28$^b$ | 14.28$^{bcd}$ | 83.36$^{cd}$ | 792.01$^{ab}$ |
| $T_7$ | 263.70$^a$ | 14.98$^a$ | 86.08$^a$ | 830.58$^a$ |
| $T_8$ | 258.33$^{ab}$ | 14.48$^{bc}$ | 84.38$^{bc}$ | 795.22$^{ab}$ |
| $T_9$ | 261.08$^a$ | 14.73$^{ab}$ | 85.06$^{ab}$ | 827.43$^a$ |
| LSD (0.05) | 5.53 | 0.17 | 1.39 | 49.66 |
| CV (%) | 1.3 | 0.69 | 0.97 | 3.74 |

The results of means in columns with the same letter(s) are not significantly different at 5% level of significance; CV= coefficient of variation; LSD= least significant difference; LA=leaf area

**Yield components of maize crop+**

The effect of vermicompost and NPS fertilizer rates significantly ($p<0.05$) affected stand count, ear length, ear number per plant and ear number per hectare of maize crop (Table 4).

**Stand count**

The stand count of maize plants was determined from the final number of emerging plants from each treatment and expressed in percentage. The highest value of stand count (96.23%) was recorded from 5 t ha$^{-1}$ VC+50 kg ha$^{-1}$NPS fertilizer, whereas the lowest value (82.8%) was recorded from the control treatment (Table 4). The reasons for, the increase of stand count with the application of vermicompost and NPS were attributed to the improving action of the amendments on the soil's physical properties as well as nutrient status in the soil, which enhances plant growth. Similarly, Shiferaw (2019) reported an increase in stand count with increasing amendment doses. Moreover, the combined use of vermicompost and NPS fertilizer in half of the recommended rate of both fertilizers maximize the emergency of plant population over control or sole and low application rate.

**Table 4.** Effect of combined vermicompost and NPS fertilizer on stand count, Ear number per plant, ear number per hectare and ear length of maize crops

| | Stand Count (%) | EN/plant | EL(cm) | EN/ha |
|---|---|---|---|---|
| $T_1$ | 82.8$^d$ | 1.72$^d$ | 21.83$^e$ | 80775$^f$ |
| $T_2$ | 92.16$^c$ | 2.40$^{bc}$ | 29.3$^{cd}$ | 125037$^{de}$ |
| $T_3$ | 91.83$^c$ | 2.28$^c$ | 29.42$^d$ | 118963$^e$ |
| $T_4$ | 96.23$^a$ | 2.80a | 32.12$^a$ | 154096$^a$ |
| $T_5$ | 92.70$^{bc}$ | 2.43$^{bc}$ | 30.36$^c$ | 127767$^{de}$ |
| $T_6$ | 92.53$^{bc}$ | 2.57$^{ab}$ | 30.61$^{bc}$ | 140309$^{bc}$ |
| $T_7$ | 95.50$^{ab}$ | 2.76a | 31.41$^{ab}$ | 151069$^{ab}$ |
| $T_8$ | 94.76$^{abc}$ | 2.63$^{ab}$ | 31.06$^{bc}$ | 141566$^{bc}$ |
| $T_9$ | 93.70$^{abc}$ | 2.50bc | 29.16$^d$ | 132339$^{dc}$ |
| LSD (0.05) | 2.93 | 0.17 | 0.76 | 10910 |
| CV (%) | 1.85 | 4.01 | 1.50 | 4.61 |

The results of means in columns with the same letters are not significantly different at 5% level of significance; CV= Coefficient of Variation; LSD= Least Significant Difference; EN/P=ear number per plant; EN/H=ear number per hectare; EL=ear length

**Ear Length**

Ear length substantially contributes to the grain yield of maize by influencing both numbers of grains cob and grain size. The highest value of ear length (32.12 cm) was recorded from 5 t ha$^{-1}$ VC+50kg ha$^{-1}$ NPS fertilizer whereas the lowest value (21.83 cm) was recorded from the control treatment (Table 4). This showed that combined use of vermicompost and NPS fertilizer with half of the recommended rate of both fertilizers created the longest length of maize ear over control and sole use of it. The highest value of ear length at 50% vermicompost and NPS fertilizer might be due to enough nutrients that allow the plants to accumulate more biomass with a higher capacity to convert more photosynthesis into sink resulting in longer ear per plant and attributed to good photo assimilate supply. From the report of El-Gawad and Morsy (2017), ear length was significantly affected with an application of 10 t of compost and 50 Kg Urea ha$^{-1}$. Raman and Suganya (2018), also in harmony with the above studies and conclude that the application of 100% RDF (135 N + 62.5 $P_2O_5$+50 K kg ha$^{-1}$) with Press mud compost at a rate of 5 t ha$^{-1}$ resulted in the highest cob length.

**Ear Number per Plant**

The highest value of ear number per plant (2.8) was recorded from 5 t ha$^{-1}$ VC+50 kg ha$^{-1}$ NPS fertilizer, whereas the lowest value (1.72) was recorded from the control treatment (Table 4). The increased number of ears per plant at 5 t ha$^{-1}$ VC+50 kg ha$^{-1}$ NPS fertilizer might be due to increased uptakes of major crop nutrients. Similarly, Tolera *et al*., (2017) reported that the number of cobs was significantly higher with the application of recommended NPK (225:50:50 kg ha$^{-1}$) with 5t FYM ha$^{-1}$.

**Ear Number per hectare**

The highest value of ear number per hectare (154,095) was recorded from 5 t ha$^{-1}$ VC+50 kg ha$^{-1}$NPS fertilizer. Whereas, the lowest values (80,775) were recorded from the control treatment (Table 4). The increase in the number of ears per hectare as vermicompost and NPS fertilizer levels increased might be attributed to better uptake of nutrients and increased translocation of photosynthetic products from source to sink.

**Thousand-grain weight, grain yield and biomass yield**

**Thousand-grain weight**

Combined application of vermicompost and NPS fertilizers significantly ($p<0.05$) affected thousand-grain weight. The thousand-grain weight is a parameter contributing to the economic yield of maize and directly relates to the yield of the crop. The highest value of thousand-grain weight (331.16 g) was recorded from the plot treated with 5 t ha$^{-1}$ VC+ 50 kg ha$^{-1}$ NPS fertilizer while the lowest weight (290.75 g) was recorded from the control plot (Table 5). The increase in thousand-grain weight might be due to the synergistic effects of combined fertilizers for better growth, grain filling of maize crop and positive interaction of nutrients in the vermicompost and NPS fertilizers. Admas *et al*. (2015) also reported that the combined application of compost, Nitrogen and Sulfur fertilizers affected thousand-grain weights significantly.

**Grain yield**

The effect of vermicompost and NPS fertilizer rates significantly ($p<0.05$) affected the grain yield of maize crops. Accordingly, the highest grain yield (7.36 t ha$^{-1}$) was recorded from 5 t ha$^{-1}$ VC +50 kg ha$^{-1}$NPS fertilizer and followed by that (7.31 t ha$^{-1}$) was recorded from 10 t ha$^{-1}$ VC+100 kg ha$^{-1}$ NPS fertilizer, while the lowest grain yield (2.94 t ha$^{-1}$) was recorded from control plot or treatment (Table 5). The sole application of recommended NPS fertilizer increased maize yield by 52.27% over the control treatment whereas the sole application of a full dose of vermicompost increased maize yield by 55.72% over the control treatment. This showed that organic fertilizer might have been more advantageous than inorganic fertilizer in maximizing productivity if properly used. Furthermore, the combined use of vermicompost and NPS fertilizer by the rating of half of the recommended rate of both fertilizers increased maize yield by 60.05% over the control treatment. This indicated that the combined use of organic and inorganic fertilizers is more valuable than the sole use of fertilizers. The highest grain yield with the combined application of vermicompost and NPS fertilizer might be attributed to the improving action of amendments on the soil's physicochemical properties and nutrient status in the soil, which enhances plant growth. Moreover, an increase in essential nutrients and organic matter due to the combined application of vermicompost and NPS fertilizer promotes microbial population, which ultimately enhances plant growth and production on a sustainable basis. This could be confirmed by significant and positive correlation (r = 0.92**, 0.91**, 0.82**, 0.74**, 0.88**) of grain yield of wheat with pht, TN, OC and Available P, respectively (Table 6). This finding was supported by Sanjiv (2014) who reported that the maximum grain yield of maize was recorded when 100% of NPK was applied with farmyard manure of 10 t ha$^{-1}$.

**Table 5.** The effect of vermicompost and NPS fertilizer on 1000-grain weight, grain Yield and biomass yield of maize crop

| | 1000-grain weight(g) | Grain yield (t ha$^{-1}$) | Biomass yield(t ha$^{-1}$) |
|---|---|---|---|
| $T_1$ | $290.75^{f}$ | $2.94^{d}$ | $4.83^{f}$ |
| $T_2$ | $312.16^{d}$ | $6.16^{c}$ | $11.54^{e}$ |
| $T_3$ | $314.4^{cd}$ | $6.64^{bc}$ | $12.41^{d}$ |
| $T_4$ | $331.16^{a}$ | $7.36^{a}$ | $14.51^{a}$ |
| $T_5$ | $316.5^{c}$ | $6.26^{c}$ | $12.71^{cd}$ |
| $T_6$ | $303.16^{e}$ | $6.94^{ab}$ | $13.20^{c}$ |
| $T_7$ | $322.0^{b}$ | $7.31^{a}$ | $13.77^{b}$ |
| $T_8$ | $313.9^{cd}$ | $7.11^{ab}$ | $13.81^{b}$ |
| $T_9$ | $302.86^{e}$ | $6.79^{abc}$ | $12.49^{d}$ |
| LSD (0.05) | 0.89 | 0.71 | 0.55 |
| CV (%) | 0.52 | 5.08 | 2.5 |

The results of means in columns with the same letters are not significantly different at a 5% level of significance; CV= Coefficient of Variation; LSD= Least Significant Difference, g=gram, t ha$^{-1}$=ton per hectare

**Biomass Yield**

The biomass yield of maize represents the total amount of above-ground biomass accumulated by the plant. Combined application of vermicompost and NPS fertilizer is highly significant ($p<0.05$) on biomass yield. The highest value (14.51 t ha$^{-1}$) was recorded from the plot treated by 5 t ha$^{-1}$ VC+50 kg ha$^{-1}$ NPS fertilizer while the lowest (4.83 t ha$^{-1}$) in the control plot (Table 5). This highest value in total above-ground dry biomass over the control and organic or inorganic fertilizer alone might be due to the good response of maize crops to synergistic effects of vermicompost and NPS fertilizers which are well-recognized for the vegetative growth of plants. In agreement with this finding Kibunja *et al.* (2010) reported that the total dry matter of maize was highest from treatment combinations of inorganic and organic fertilizers than control, organic and chemical fertilizers alone.

**Table 6.** Simple correlation among the selected parameters

| Variables | TN | OC | pH | av. P | BD | CEC | Pht | Y |
|---|---|---|---|---|---|---|---|---|
| TN | 1.000 | 0.95** | 0.84** | 0.92** | -0.67** | 0.96** | 0.88** | 0.82** |
| OC | | 1.00 | 0.93** | 0.92** | -0.67** | 0.91** | 0.79** | 0.74** |
| pH | | | 1.00 | 0.88** | -0.70** | 0.78** | 0.77** | 0.69** |
| av. P | | | | 1.00 | -0.78** | 0.89** | 0.87** | 0.83** |
| BD | | | | | 1.00** | -0.57** | -0.69** | -0.53** |
| CEC | | | | | | 1.00 | 0.80** | 0.79** |
| Pht | | | | | | | 1.00 | 0.92** |
| Y | | | | | | | | 1.00 |

***= significant at 0.01, TN= total nitrogen; OC= organic carbon; av. P= available phosphorus, BD=bulk density; CEC= cation exchange capacity; Pht= Plant height; Y= yield*

**CONCLUSION**

The results of this study revealed that the current scenarios of maize production in Toke Kutaye district call for appropriate ways of adding nutrients to the soil to obtain optimum maize productivity. In response to this, the combined application of different rates of vermicompost and NPS fertilizer to soil significantly affected most parameters used for this investigation such as plant height, leaf number, leaf length, leaf area, stand count, ear length, and several ears per plant, thousand-grain weight, total above-ground dry biomass and grain yield of maize. Moreover, the combined form of NPS blended fertilizer and vermicompost was applied and the result revealed that the sole application of recommended NPS fertilizer and vermicompost increased maize yield by 52.27 and 55.72% over control treatments, respectively. Besides this, the combined use of vermicompost and NPS fertilizer by the rating of half of the recommended rate of both fertilizers increased maize yield by 60.05% over the control treatment. This indicates that the best option for soil fertility management is integrated soil fertility management that involves the combined use of vermicompost and NPS fertilizers as nutrient sources than the strategy of using organic or inorganic amendments alone.

Then, it could be concluded that the use of blended NPS fertilizer at 50 kg ha$^{-1}$with supplemental vermicompost at 5 t ha$^{-1}$ to Jibat variety is the realistic approach to address the problem of low productivity of maize in the study area and other similar agroecology. Based on the findings and conclusions of this study it can be recommended that farmers in the study area should, therefore, be advised to use this variety and combined use of vermicompost and NPS fertilizer at a rate of 5 t ha$^{-1}$ VC +50 kg ha$^{-1}$ NPS for sustainable maize crop production tentatively. Nevertheless, further studies are needed to recommend agronomical optimum and to measure the long-term effects of the integrated soil fertility management techniques in more seasons, soil types and crop varieties before giving a conclusive recommendation.

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