Effect of vermicompost and blended fertilizers rates on yield and yield components of Tef (Eragrostis tef (Zucc.) Trotter)

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Tef is a stable crop in Ethiopia in which its yield is constrained by poor soil fertility management. Therefore, a field experiment was conducted for two consecutive years during 2016 and 2017 on clayey textural soil to assess the effect of vermicompost and inorganic fertilizer rates on yield and yield components of tef. Accordingly, field experiment with four levels of vermicompost (0, 2, 4 and 6 t ha⁻¹) and four levels of NPS (0, 100, 150 and 200 kg ha⁻¹) were arranged in randomized complete block design (RCBD) in a factorial combination with three replications. A tef variety, qunco was used as test crop. Analysis of the data revealed that highest grain yield (2269.80 kg ha⁻¹) was obtained from the treatment of 4 t vermicompost ha⁻¹ + 150 kg NPS ha⁻¹. Significantly highest straw yield (6480.60 kg ha⁻¹) was obtained from the treatment of 6 t vermicompost ha⁻¹ + 200 kg NPS ha⁻¹, but statistically similar with 4 t vermicompost ha⁻¹ + 150 kg NPS ha⁻¹. To evaluate the feasibility of the treatments with view of farmers’ practices, a partial budget analysis was conducted on straw and grain yield of tef and accordingly the highest marginal rate of return 4184% were obtained from combined fertilization of 4 t vermicompost ha⁻¹ and 150 kg NPS ha⁻¹. Therefore, based on the data obtained from this study application of 4 t vermicompost ha⁻¹ and 150 kg NPS ha⁻¹ will be recommended as profitable for the production of tef at Beles kebelle Tahtay Koraro district.

Key words: Integrated nutrient management, NPS fertilizer tef yield, vermicompost.

INTRODUCTION

Tef is one of the most stable food crop originated and diversified in Ethiopia. It is highly preferred by Ethiopian people for consumption as food, since it is nutritionally rich and free of protein gluten (Ketema, 1991; Merga, 2018). Tef performs well at an altitude of 1800 to 2100 m above sea level, annual rainfall of 750 to 850 mm, growing season’s rainfall of 450 to 550 mm and a temperature of 10 to 27°C although it can adapt wide range of agro-climatic conditions (Ketema, 1993). Moderately fertile clay and clay loam textural soils are ideal for tef growing. It can also withstand moderate water logged conditions (Anonymous, 1994).

According CSA (2017/2018) area coverage of tef crop in Ethiopia was around 23.85% (3,023,283.50 ha) first and in terms of grain yield production it was about 17.26% (5,283,401.2 t) second after maize. Report of

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CSA (2017/2018) an area coverage and grain yield production of tef in Tigray region was approximately to 21.79% (167,748.72 ha) and 15.10% (257,906.10 t), respectively which was second only to sorghum in both productions. The national tef average grain yield was 1.75 t ha⁻¹ which was higher than the regional tef yield (1.54 t ha⁻¹). Farming systems in Ethiopia lack sustainability due to nutrient losses by soil erosion, lack of soil fertility restoring inputs and unbalanced nutrient using (Ajayi et al., 2007; Hirpa et al., 2009). Estimated essential plant nutrients loss in Africa was approximately 50 kg ha⁻¹·year⁻¹ (Janssen et al., 1995). Inorganic fertilizers overcome soil fertility problems and responsible for increasing large part of world's food production (Sanchez and Leakey, 1997). Increment of crop yield from 30 to 50% has resulted from application of commercial fertilizers (Vlek, 1990; Stewart et al., 2005). However, chemical fertilizers in effect, “kill” soil properties while organic fertilizers improve and sustain the soil (Goel and Duhan, 2014). Excessive and inappropriate use of chemical fertilizers is the major cause of nutrient imbalance and degrading our soil (Singh et al., 2001; Meena et al., 2003; Mahajan et al., 2008; Mukhtar et al., 2011). There is no substitute for nutrients in providing high production (Ahmad, 1992). There is no absolute replacement of chemical fertilizers as the soils of Ethiopia are low in nutrients and organic matter. Nutrient recycling by use of organic manures is preferred to restore nutrient removed by crops (Jobe, 2003). Vermicompost is particularly good for farmers, consumers and ultimately for soil as it can be used as a resource for maximizing crop productivity on sustainable basis and with more financial safe in comparison to these chemical fertilizers (Singh and Chauhan, 2009). Vermicompost increase soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orózco et al., 1996). Vermicompost is the recently organic fertilizers in supplementing chemical fertilizers for sustainable development of agriculture (Gupta, 2003).

But, application of only organic manures inefficiently improves the yield per unit area (Satyanarayana et al., 2002; Jobe, 2003). Higher cost of chemical fertilizers joined with its scarcity and non availability at market during growing period of crops resulted in farmers fail to apply these fertilizers to their crop field in time. On the other hand, organic manure is readily available to the farmers and the price is also low (Alam et al., 2007). In addition to that, applications of manures reduce the environmental pollution but chemical fertilizers cause environmental pollution during manufacturing in the industry (Rathier and Frink, 1989) and caused water eutrophication which is resulted in increasing of unwanted species of aquatic plants and algae formation, degradation of water quality and water environment, bad water odor and dying of fish (Göksu et al., 2003; Sönmez et al., 2008).

Therefore, integrated management of plant nutrients can lessen this problem and can be suitable for any farming system and socio-economic conditions (Lamps, 2000). Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per unit area (Patra et al., 2000; Aulakh et al., 2008; Mahajan et al., 2008; Roberts, 2010). Organic matter is an imperative indicator of soil fertility Rahman et al. (2007) by improve soil structure, nutrient exchange and maintain soil physical conditions (Becker et al., 1995; Ayoub, 1999). Organic matter also reduces the level of carbon dioxide in the atmosphere that contributes positively to climate change (Anon et al., 2003). This trial was, therefore, conducted to study the effect of application rate of organic (vermicompost) and nitrogen, phosphorus and sulfur (NPS) on the growth and yield of tef.

MATERIALS AND METHODS

Area description

The field experiment was conducted for two consecutive years during 2016 and 2017 main cropping season under rain fed conditions at Shire Soil Research Center site in Beles kebelle Tahtay Koraro district, North Western zone of Tigray regional state (Figure 1). The altitude of the district varies between 1957 m above sea level. Vertisols are the dominant soil types in the area. The study area is found in a semi-arid climatic zone and has mixed crop-livestock farming system. It received mono-modal erratic distribution of rainfall, with annual rainfalls of 1088.7 and 919.5 mm during the growing seasons of 2016 and 2017, respectively (Figure 2a). The average monthly temperatures were 20.7, 20.77°C, respectively in the years of 2016 and 2017 (Figure 2b).

Experimental design and treatment

The experiments were conducted at site of Shire Soil Research Center at Tahtay Koraro district. Permanent site and plots were used for conducting the experiment. The field experiments contain a total of sixteen (16) treatments. The treatments were four levels of Vermicompost (0, 2, 4, 6 t ha⁻¹) and four levels of new blended fertilizer (NPS) (0, 100, 150 and 200 kg ha⁻¹). The treatments were arranged in factorial arrangement and were laid out in RCBD with three replications. The plot size was 3 × 4 m (12 m²) and the net harvested plot size area was 10.4 m². The spacing between rows, plots and replications was 0.2, 1 and 1.5 m, respectively. Zn (2 kg ha⁻¹) and B (1 kg ha⁻¹) fertilizers were applied foliarly for all treatments except control treatment as uniform before head initiation. A full dose of blended fertilizer (NPS) was applied at planting time close to seed drilling line. The recommended seed rate of 10 kg ha⁻¹ quencho variety was used and sown by drilling method at each row. All recommended cultural practices (plowing, weeding, pesticides, etc.) for tef crop was done as per the recommendation of the study area.

Soil and vermicompost samples analysis

Before planting surface composite soil sample was collected from experimental site for site characterization and the soil sample was taken at a depth of 0 to 20 cm, auger was used for collecting the
**Figure 1.** Location of the study area.

**Figure 2.** Ten years (2008 to 2017) annual rainfall (a), and monthly rainfall, maximum and minimum temperatures (b) measured in the study area during experimental years of 2016 and 2017.

The collected sample was properly labeled, packed and transported to the Shire Soil Research Center and
Table 1. Soil physiochemical properties pre-planting.

| Parameter          | Value | Rating | Reference                        |
|--------------------|-------|--------|----------------------------------|
| % Sand             | 19    |        |                                  |
| % Silt             | 22    |        |                                  |
| % Clay             | 59    |        |                                  |
| Textural class     | Clay  |        |                                  |
| OC (%)             | 0.550 | Very low | Emerson (1991); Charman and Roper (2007) |
| OM (%)             | 0.95  | Very low | Emerson (1991); Charman and Roper (2007) |
| Total N (%)        | 0.048 | Low    | Bruce and Rayment (1982)         |
| pH                 | 6.75  | Neutral | Bruce and Rayment (1982)         |
| ECe (dS/m)         | 2.32  | Slightly saline | Richards (1954). |
| Ava. P (ppm)       | 2.65  | Very low | Holford and Cullis (1985)       |
| CEC [cmol(+)/kg]   | 34.3  | High   | Metson (1961)                    |

Exchangeable base

| Na [cmol(+)/kg]   | 0.21  | Low    | Metson (1961)                    |
| K [cmol(+)/kg]    | 0.52  | Moderate | Metson (1961)                    |
| Mg [cmol(+)/kg]   | 14.91 | Very high | Metson (1961)                    |
| Ca [cmol(+)/kg]   | 17.49 | High   | Metson (1961)                    |

Table 2. Chemical properties of vermicompost.

| Chemical properties | Values |
|---------------------|--------|
| pH                  | 7.40   |
| EC (dS/m)           | 1.70   |
| OC (%)              | 23.00  |
| Total N (%)         | 1.7    |
| Total P (ppm)       | 8200   |
| Total K (ppm)       | 11000  |

prepared for analysis according to the standard procedures.

Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). And electrical conductivity (EC) 1:2.5 soil to water suspension was measured according to the method described by (Jakson, 1967). Organic carbon (%) was determined by method as described by (Walkely and Black, 1934). Available P (ppm) was analyzed by employing the Olsen method Olsen et al. (1954) using ascorbic acid as the reducing agent. Total nitrogen was measured using Kjedahl method as described by (Bremner and Mulvaney, 1982). Exchangeable cations (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, and K$^+$) and CEC in cmol (+) kg$^{-1}$ soil was determined by ammonium acetate method. The laboratory soil result was revealed in Table 1.

For conducting of the experiment organic fertilizer vermicompost was used as component of the treatments. Source of vermicompost was Lantana camara weed plant by the digestion of it by earth worms as worm cast. The organic carbon, N, P, K, pH and EC of vermicompost used in the experiment were determined used the standards applied for soil and the results are illustrated in Table 2.

Agronomic data collection and analysis

Data collected for the experiment were days to 50% heading, days to 90% maturity, plant height (cm), biomass yield (kg ha$^{-1}$), straw yield (kg ha$^{-1}$), grain yield (kg ha$^{-1}$) and harvest index (%). Data were collected for the experiment on yield and yield component related parameters on plot basis and converted to hectare. Harvest index was calculated by considering the ratio of grain yield to biomass yield.

The collected data were subjected to statistical two way analysis of variance (ANOVA) using SAS version of 9.0 (SAS, 2002). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

To evaluate the feasibility of different treatments partial budget analysis technique of CIMMYT (1988) was applied to straw and grain yield. The partial budget analysis was performed based on the field price of the crop with prices of 0.82 and 0.11 $ kg$^{-1}$ for grain and straw of tef, respectively. The partial budget analysis also included all the variable costs of fertilizers application, transportation, vermicompost production costs and prices of each fertilizer that vary for each treatment. Based on the CIMMYT manuscript it is expected that experimental yields are often higher than the yields that farmers could expect using the same treatments. Hence, in economic calculations, the straw and grain yield has been adjusted to 10% lower than the actual yield obtained from the experimental plots to make the representative yield at the farmers' fields, (CIMMYT, 1988).
RESULTS AND DISCUSSION

Effects of vermicompost and NPS fertilizer rates on phenological, growth, and yield and yield component parameters of tef crop

Phenological parameters

Days to 50% heading:
The interaction of vermicompost and NPS fertilizers and impact of NPS had brought significant effect (Table 3) on days to 50% heading. Tef crop that did receive high vermicompost and NPS headed earlier than these that receive no fertilizer or low fertilizer. Generally, all the treated plots excluding the unfertilized plot, 2 t vermicompost ha\(^{-1}\), 4 t vermicompost ha\(^{-1}\) and 6 t ha\(^{-1}\) plus basal application of Zn and B to all these mentioned vermicompost amounts had significantly lowest number of days to 50% heading. This may indicate the increased rate of chemical fertilizers increase the matrix potential of the soil and short period of moisture content in the study area speed up heading of the crop at that time. Early headings of tef were perhaps due to highest rate of vermicompost and NPS fertilizers encourage the crop in early establishment, rapid growth and development. In line with this result, Mitiku et al. (2014) had found that application of farmyard manure, vermicompost and nitrogen, phosphorus and potassium (NPK) fertilizers hastened days to heading and maturity as compared to unfertilized plots. This result is also in agreement with findings of Sewnet (2005) who reported of early flowering with an increased amount of N application in rice. In contrast, Abraha (2013) reported that heading was found significantly delayed at the highest N fertilizer rate when compared to the lowest dose of application on tef, wheat and barley crops.

However, at the plots fertilized with vermicompost only there were no significant variation. On the other hand, when plots were fertilized with single NPS fertilizer there were significant effects on headings of tef. The delayed days to headings of tef were recorded at the plots treated without NPS fertilizer. Early headings of tef were measured from application of high levels of NPS fertilizers.

Days to 90% maturity:

It was observed that 90% days of maturity of tef crop were significantly affected by single levels of NPS fertilizer plus basal application of Zn and B fertilizers, but not by the combined application of vermicompost and NPS plus basal application of Zn and B fertilizers and single levels of vermicompost plus basal application of Zn and B fertilizers (Table 3). When plots were fertilized with only levels of NPS fertilizer there were significant effects on headings of tef. The extended days to maturity of tef was measured at plots treated without NPS fertilizer. Early days to maturity of tef were recorded from application high levels of NPS fertilizers. This is probably due to the fact that chemical fertilizers enlarge the matrix potential of the soil and short period of moisture content in the soil of study area speed up heading of the crop at that growing period. Application of optimum (NPS) fertilizers encouraged early establishment, rapid growth and development. Similarly Mitiku et al. (2014) had articulated that fertilization of NPK fertilizers hastened days to maturity as compared to unfertilized plots.

Growth parameters

Panicle length

The combined application of vermicompost and NPS fertilizers and main effect of NPS fertilizer significantly (P<0.0001) affected the panicle height of tef crop but this was not so in case of sole application of vermicompost fertilizer (Table 4). Thus tallest panicle height (49.30 cm) was found from plots that received vermicompost at 6 t ha\(^{-1}\)+nil NPS plus basal applied Zn and B fertilizers but this was not significantly different from other using treatments of 2, 4 and 6 t vermicompost ha\(^{-1}\) in various combination of NPS fertilizers. However, there was no consistent augmentation of plant height in all increased doses of the treatments. While the shortest panicle height (35.27 cm) was obtained from control plot and from all plots those fertilized with interaction of nil vermicompost with the levels of NPS (100, 150 and 200 kg ha\(^{-1}\)). In line with this finding, Fayera et al. (2014) reported that the application of balanced fertilizer and efficient utilization of nutrients leads to high photosynthetic productivity and accumulation of high dry matter, which ultimately increases panicle length and grain yield.

While plots were treated with different amounts of NPS significant variation between the levels were shown. Plots received three levels of NPS (100, 150 and 200 kg ha\(^{-1}\)) did not show significant variation among them but had brought significant longest panicle height over the plot fertilized without NPS fertilizer.

Plant height

The effects of combined application of vermicompost and NPS fertilizers, and at their individual levels brought significance effect on plant height of tef crop (Table 4). Longest plant height (120.27 cm) was obtained from application of vermicompost at 4 t ha\(^{-1}\)+200 kg NPS ha\(^{-1}\) plus basal applied Zn and B fertilizers, and this was not significantly different from using (0, 2, 4, 6) t vermicompost ha\(^{-1}\) with various combination of positive NPS fertilizers. In some increased combined application of vermicompost and NPS fertilizers inconsistent plant heights were observed. The plant heights were shortest
Table 3. Heading and maturity of tef under the effect of vermicompost and NPS fertilizers.

| VC (t ha⁻¹) | NPS (kg ha⁻¹) | DH (days) Mean | PM (days) Mean |
|-------------|----------------|----------------|----------------|
|              | 0  100  150  200 |                |                |
| 0           |                | 70.67a  61.0Cd | 59.00d  59.33d | 62.50  113.50 | 111.67  111.00 | 110.83  110.00 |
| 2           |                | 73.33a  59.00d | 59.00d  58.33d | 62.42  109.50 | 109.67  109.33 | 109.33  109.79 |
| 4           |                | 73.33a  59.67d | 59.00d  58.67d | 62.67  108.50 | 109.00  108.17 | 108.00  109.42 |
| 6           |                | 69.67b  63.33c | 58.67d  58.67d | 62.58  108.50 | 108.83  108.17 | 107.67  109.08 |

Mean

|                | 71.75a  60.75b | 58.92c  58.75c | 111.75A  109.71B  110.57abc  117.63ab |

CV (%) 4.48  3.18

LSD (P=0.99) for VC NS
LSD (P<0.0001) for NPS 1.6
LSD (P<0.0001) for VC*NPS 3.23

Where, means followed by the same letters are not significantly different (P≤0.05), VC = vermicompost, NPS = (nitrogen, phosphorus, sulfur), DH = days to headings, PM = physiological maturity.

Table 4. Panicle length and plant height of tef under the effect of vermicompost and NPS fertilizers.

| VC (t ha⁻¹) | NPS (kg ha⁻¹) | PL (cm) Mean | PH (cm) Mean |
|-------------|----------------|---------------|--------------|
|              | 0  100  150  200 |                |              |
| 0           |                | 70.67a  61.0Cd | 59.00d  59.33d | 62.50  72.60  109.17  110.57  117.63ab  102.49 |
| 2           |                | 73.33a  59.00d | 59.00d  58.33d | 62.42  75.30  109.83  108.70  112.90ab  101.68 |
| 4           |                | 73.33a  59.67d | 59.00d  58.67d | 62.67  86.03de  98.00cd  113.10ab  120.27a  113.45 |
| 6           |                | 69.67b  63.33c | 58.67d  58.67d | 62.58  84.27de  104.33bc  109.77abc  120.03a  104.60 |

Mean

|                | 71.75a  60.75b | 58.92c  58.75c | 79.55c  105.33b  110.53ab  117.71a |

CV (%) 12.99  12.48

LSD (P=0.81) for VC NS
LSD (P=0.83) for VC NS
LSD (P<0.0001) for NPS 3.27
LSD (P<0.0001) for NPS 7.40
LSD (P<0.0001) for VC*NPS 6.54

Means followed by the same letters are not significantly different (P≤0.05), VC = vermicompost, NPS = (nitrogen, phosphorus, sulfur), PL = panicle length, PH = plant height.

for treatments having plots fertilized with interaction of all levels of vermicompost with zero NPS fertilizer. The increment of plant height is due to sufficient supply of balanced essential nutrients from vermicompost and NPS fertilizers. In agreement with this experiment, Kondappa et al. (2009) observed that integrated nutrient management treated plots showed improved growth and yield of chilli. Alike, Degwale (2016) also observed that interacted application of vermicompost and NP fertilizers had resulted on increased plant height of onion.
In the same way, Shrivastava et al. (2018) studied that application of farmyard manure and vermicompost with inorganic fertilizers resulted in better cell division, cell expansion and enlargement that led to higher plant height of W. somnifera at different crop development stages. Likewise, Getachew (2009) reported that the use of organic manures in combination with mineral fertilizers maximized the plant height of barley. Kannan et al. (2013) reported that integrated nutrient management had positive effect on maize height. The growth, flowering and yields of field strawberries increased after applications of food wastes and paper waste vermicompost experimental soils, at rates of 2.5 or 5 ton ha⁻¹, supplemented with inorganic fertilizers (Arancon et al., 2004). In contrast, Assefa et al. (2016) found that interaction of compost and NP fertilizer did not show significant effect on plant height of tef.

Inversely, plots treated with sole levels of vermicompost showed no significance effect on plant height of tef. The non-responsiveness of vermicompost might be due to slow release of nutrients. Similarly with the current finding, Assefa et al. (2016) found that treating of tef crop with compost did not reveal significance difference. Whereas plots were fertilized with levels of NPS only significant variation amongst levels of NPS were shown. Plot received NPS at the dose of 200 kg ha⁻¹ did show significant effect over plots treated with no fertilizer and plots received 100 kg NPS of NPS but not in cease of fertilizer of 150 kg NPS ha⁻¹.

**Yield and yield components**

**Biomass yield**

The combined application of vermicompost and NPS under balanced fertilizer significantly (P<0.0001) increased the biomass yield. Each single level of fertilizers of vermicompost and NPS had also significance effect on biomass yield of tef (Table 5). Therefore, the highest biomass yield (8150.40 kg ha⁻¹) was obtained from plots treated with 6 t vermicompost ha⁻¹+200 kg ha⁻¹ NPS plus basal application of Zn and B fertilizers. However, it was not significantly different from using of 6 t vermicompost ha⁻¹+150 kg NPS ha⁻¹, 4 t vermicompost ha⁻¹+150 kg NPS ha⁻¹, 4 t vermicompost ha⁻¹+200 kg NPS ha⁻¹, and 2 t vermicompost ha⁻¹ + 200 kg NPS ha⁻¹. All these treatments uniformly took basal application of Zn and B fertilizers. It was clearly observed that with increased levels of the combination of the fertilizers there were increasing of biomass yields consistently in almost of the treatments. Devi et al. (2011) reported that it might be due to adequate quantities and balanced proportions of plant nutrients in vermicompost supplied to the crop as per its need during the growth period resulting in favorable increase in yield attributing characters.

In the same way, biomass yield was significantly affected by the main effect of NPS fertilizer under

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**Table 5. Biomass and grain yield of tef under the effect of vermicompost and NPS fertilizers.**

| VC (t ha⁻¹) | NPS (kg ha⁻¹) | NPS (kg ha⁻¹) |
|------------|---------------|---------------|
|            | 0 100 150 200 | Mean 0 100 150 200 |
|            | BY (kg ha⁻¹) | Mean | GY (kg ha⁻¹) | Mean |
|------------|--------------|------|-------------|------|
| 0          | 2759.8 5141.0 | 6488.9 6451.7 | 5210.4 538.6 | 1301.7 1520.2 1660.2 1255.17 |
| 2          | 3401.7 5393.2 | 6145.3 7034.2 | 5493.6 779.4 | 1461.2 1651.5 1752.8 1411.2 |
| 4          | 4379.5 5427.4 | 7984.6 7140.2 | 6232.9 909.4 | 1400.7 2269.8 1641.3 1555.29 |
| 6          | 5940.6 6587.2 | 7254.7 8150.4 | 6983.2 1223.2 | 1571.5 1885.3 1669.9 1587.46 |
| Mean       | 4120.4 5637.2 | 6968.4 7194.10 | 862.62 1433.8 1831.69 1681.03 |
| CV (%)     | 19.6 | 17.41 |
| LSD (P<0.0001) for VC | 673.24 | LSD (P<0.0001) for VC | 145.27 |
| LSD (P<0.0001) for NPS | 673.24 | LSD (P<0.0001) for NPS | 145.27 |
| LSD (P<0.0001) for VC*NPS | 1346.5 | LSD (P<0.0001) for VC*NPS | 290.54 |

Means followed by the same letters are not significantly different (P≤0.05), VC = vermicompost, NPS = (nitrogen, phosphorus, sulfur), BY = biomass yield, GY = grain yield.
balanced fertilizer, and vermicompost levels. In general, at the level of 150 and 200 kg ha\(^{-1}\) NPS plus basal of Zn and B fertilizers significantly higher grain yield was found as compared to the nil and 100 kg ha\(^{-1}\) NPS fertilizer. The smallest biomass yield was measured from fertilization of nil NPS fertilizer. Similarly, highest biomass yield was also recorded from vermicompost application at the rate of 6 t vermicompost ha\(^{-1}\) as compared with the other three levels of vermicompost (0, 2, 4 t ha\(^{-1}\)). The least yield was obtained from nil level and 2 t vermicompost ha\(^{-1}\).

**Grain yield**

The analysis of the variance indicated that combined application of vermicompost and NPS and main effect vermicompost and NPS fertilizers significantly (P<0.0001) increased the grain yield (Table 5). Therefore, the highest grain yield (2269.80 kg ha\(^{-1}\)) was obtained from plots treated with 4 t vermicompost ha\(^{-1}\)+150 kg NPS ha\(^{-1}\) plus basal application of Zinc and Boron which increased over the control by 321.42%. The lowest (538.60 kg ha\(^{-1}\)) was found from control. The increase in grain yield due to interaction effects at this rate could be attributed to the positive effects of vermicompost in increasing the efficiency of synthetic fertilizer by preventing losses of nutrients and releasing of the nutrients within the growing period. In agreement with this result, Fayera et al. (2014) postulated that fertilization with balanced fertilizer leads to high photosynthetic efficiency and accumulation of high dry matter, which finally enhance grain yield of tef. Manivannan et al. (2009) stated that the increased growth and yield of the beans, may be due to the application of vermicompost which indirectly influences the physical conditions of the soil and support better aeration to the plant roots, absorption of water, induction of N, P and K exchange there by resulting better growth of the plants. This is in agreement with reports of Bayu et al. (2006) and Makinde and Ayoola (2010) who concluded that high and sustainable crop yields are only possible with integrated use of mineral fertilizers and organic matter. Tilahun et al. (2013) also verified that integrated fertilizers application gave the maximum grain yield compared to the control. Babbu et al. (2015) also reported that the highest maize grain yield was in treatment having NPK with farm yard manure (FYM), whereas the lowest was in non-treated plots. Likewise, Quansah (2010) also indicated that the use of organic (household waste and poultry manure compost) and inorganic fertilizers (NP) increased maize grain yield separately, but, the yields obtained by the combined treatments were significantly higher than their sole treatments. Assefa et al. (2016) found that interaction of compost (2.5, 5, and 7.5 t ha\(^{-1}\)) and NP (64:46 kg ha\(^{-1}\)) fertilizer had significant effect on grain yield of tef.

Grain yield was significantly affected by the main effect of NPS fertilizer under balanced fertilizer. Generally, at the level of 150 and 200 kg ha\(^{-1}\) NPS plus basal of Zn and B fertilizers significantly higher grain yield was found as compared to the nil and 100 kg ha\(^{-1}\) NPS fertilizer. From sole application of vermicompost highest yield was found from the rate of 6 t ha\(^{-1}\) as contrasted with nil and 2 t ha\(^{-1}\), but not statistically significance than 4 t ha\(^{-1}\).

**Straw yield**

The ANOVA showed that straw yield of tef was significantly affected by the interaction of vermicompost and NPS fertilizers, and also by both main effect of NPS and vermicompost fertilizers (Table 6). The highest straw yield (6480.60 kg ha\(^{-1}\)) was obtained from plots treated with combined application 6 t ha\(^{-1}\) of vermicompost and 200 kg NPS ha\(^{-1}\) plus basal application of Zn and B fertilizers whereas the lowest value (2221.20 kg ha\(^{-1}\)) was obtained from control. At the tef crop grown plot received integrated 6 t ha\(^{-1}\) of vermicompost and 200 kg NPS ha\(^{-1}\) increased the straw yield by 129% over the control. But, the highest straw yield obtained from 6 t vermicompost ha\(^{-1}\)+200 kg NPS ha\(^{-1}\) was not significantly different from using of 6 t vermicompost ha\(^{-1}\)+150 kg NPS ha\(^{-1}\), and 4 t vermicompost ha\(^{-1}\)+150 kg NPS ha\(^{-1}\). This implies that vermicompost supply good sources of essentail nutrient of N and P which leads better straw growth of tef. The increase in straw yield as result of the interaction of vermicompost and NPS fertilizers due to vermicompost may have enhanced the efficiency of chemical fertilizer. Similar with this result, Sarwar et al. (2008) who reported that straw yield was significantly increased by the application of organic fertilizers along with inorganic fertilizers. Furthermore, Devi et al. (2011) and Singh et al. (2011) found that addition of vermicompost with or without phosphate solubilizing bacteria produced significantly higher grain and biological yields of wheat than the application of chemical fertilizers alone.

On the other hand, main effects of vermicompost and NPS fertilizers have brought significance difference on straw yield of tef. Treatments of plots with only amount of vermicompost at the dose of 6 t ha\(^{-1}\) gave highest yields. The lowest straw yield was recorded from application nil and 2 t vermicompost ha\(^{-1}\). On the other hand when plots were treated with single NPS fertilizer largest yield was measured from application of 200 kg NPS ha\(^{-1}\), this was significantly not different from 150 kg NPS ha\(^{-1}\). The lowest yield was found from control treatment.

**Harvest index**

Harvest index was significantly (P<0.0001) affected by the interactive effect of compost and NPS chemical fertilizer rates, and by main effect of NPS and
vermicompost and NPS fertilizers. The highest harvest index was measured from integrated use of 4 t vermicompost ha⁻¹ + 150 kg NPS ha⁻¹ fertilizers as a result of higher conversion efficiency of dry matter to grain part of tef, but the smallest value was found from the control treatment. The highest harvest index was increased by 42.80% over the control treatment. The control treatment and highest combination of vermicompost and NPS fertilizers had smallest harvest index due to the vegetative growth of tef in control treatment remains sterile (unconverted the dry mass to the economic part), while in the highest combinations of vermicompost and NPS fertilizers vegetative part of tef continuously develop until the rainfall withdrew and not speed up to produce grain. Though the augmentation was not consistent, the harvest index showed increasing trend with increasing of interaction of vermicompost and NPS fertilizers. The increase in harvest index with increasing rates of both compost and NPS fertilizer could be due to the fact that compost and NP fertilizer encouraged more vegetative growth and grain in a proportional way since the harvest index is the ratio of grain yield to dry biomass yield. In line to this result, Agegnehu et al. (2014) reported that increased harvest index of rice with application of 15 t compost ha⁻¹, 83 kg N ha⁻¹ and 50 kg superphosphate ha⁻¹ over the control. In contrast to this result, Gebrekidan and Seyoum (2006) reported that harvest index constantly declined with increasing levels of applied N (150 kg ha⁻¹) though they found that harvest index increased with the application of P fertilizer at the rate of 26.4 kg ha⁻¹ while further input beyond this optimum range resulted in highly significant reduction in rice crop.

Partial budget analysis

As it was presented in Table 7 the net farm benefit was calculated taking all possible field variable costs and all benefits of straw and grain yields of tef. The maximum farm net benefits of $2037.39/ha⁻¹ were obtained from the interaction application of 4 t vermicompost ha⁻¹ and 150 kg NPS ha⁻¹ plus basal application of Zn and B fertilizers but this was not statistically different from 4 t vermicompost ha⁻¹ plus basal application of Zn and B fertilizers. The smallest harvest index was obtained from 6 t vermicompost ha⁻¹ plus basal application of Zn and B fertilizers.

Table 6. Straw yield and harvest index of tef under the effect of vermicompost and NPS fertilizers.

| VC (t ha⁻¹) | NPS (kg ha⁻¹) | Mean | NPS (kg ha⁻¹) | Mean | HI (%) |
|------------|---------------|------|---------------|------|--------|
|            | 0 100 150 200 |      | 0 100 150 200 |      |        |
| 0          | 2221.2         | 3839.3 | 4968.7        | 4791.5 | 3955.2 |
| 2          | 2622.4         | 3931.9 | 4493.8        | 5281.4 | 4082.4 |
| 4          | 3470.1         | 4026.6 | 5714.8        | 5498.9 | 4677.6 |
| 6          | 4717.4         | 5015.6 | 5369.4        | 6480.6 | 5395.8 |
| Mean       | 3257.8         | 4203.4 | 5136.7        | 5513.1 | 21.37  |
| CV (%)     | 21.77          |        | 12.35         |       |        |
| LSD (P<0.0001) for VC | 566.18 |      | LSD (P=0.02) for VC | 1.72 |        |
| LSD (P<0.0001) for NPS | 566.18 |      | LSD (P<0.0001) for NPS | 1.72 |        |
| LSD (P<0.0001) for VC*NPS | 1132.4 |      | LSD (P<0.0001) for VC*NPS | 3.45 |        |

Means followed by the same letters are not significantly different (P≤0.05), VC = vermicompost, NPS = (nitrogen, phosphorus, sulfur), SY = straw yield, HI = harvest index.
that combined application 4 t vermicompost ha$^{-1}$ and 150 kg NPS ha$^{-1}$, nil vermicompost and 100 kg NPS ha$^{-1}$, nil vermicompost and 150 kg NPS ha$^{-1}$, 2 t vermicompost ha$^{-1}$ and nil NPS, 2 t vermicompost ha$^{-1}$ and 200 kg NPS ha$^{-1}$, and nil vermicompost plus 200 kg NPS ha$^{-1}$ had highest marginal rate of return (MRR) over the minimum acceptable rate of return (100%). From the previously mentioned treatments highest MRR% with value of 4184 was obtained from the combined application of 4 t vermicompost ha$^{-1}$ and 150 kg NPS ha$^{-1}$ plus basal Zn and B fertilizers. This value implies that with 1 $ cost it was attained $41.84 profit. Therefore, in Tahtay Koraro district integrated 4 t vermicompost ha$^{-1}$ and 150 kg NPS ha$^{-1}$ can be used for the production of tef (quencho variety).

**CONCLUSION AND RECOMMENDATION**

Previously, conventional compost and farmyard manure have been used as sources of organic fertilizer in Tigray. Recently, vermicompost technology has been widely disseminated through extension and nongovernmental organization in the region in most of the districts and kebles on the assumption that vermicompost can be an alternative source of chemical fertilizers.

Based on this research was done on vermicompost along with NPS fertilizers and the results indicated that, combined application of vermicompost and NPS fertilizers significantly improved early heading and physiological maturity, panicle length, plant height, biomass yield, grain yield, straw yield and harvest index of tef crop. Increased rate of combined application of vermicompost and NPS fertilizers enhanced tef crop to initiate early heading and early maturity in

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**Table 7. Partial budget analysis of VC and NPS fertilizers effect on straw and grain yield of tef.**

| TRT | VC (t ha$^{-1}$) | NPS (kg ha$^{-1}$) | BA (kg ha$^{-1}$) | ASY (kg ha$^{-1}$) | ADSY (kg ha$^{-1}$) | AGY (kg ha$^{-1}$) | ADGY (kg ha$^{-1}$) | TVC ($ ha^{-1}$) | TR ($ ha^{-1}$) | NB ($ ha^{-1}$) | MRR |
|-----|-----------------|--------------------|------------------|-------------------|-------------------|-----------------|-----------------|----------------|---------------|----------------|-----|
| T1  | 0               | 0                  | 0                | 2221.20           | 1999.08           | 538.60          | 484.74          | 0.00           | 610.94        | 610.94         | 0   |
| T2  | 0               | 100                | 2                | 3839.30           | 3455.37           | 1301.70         | 1171.53         | 1875.25        | 1327.95       | 1262.63        | 407 |
| T3  | 0               | 150                | 2                | 4968.70           | 4471.83           | 1520.20         | 1368.18         | 2812.88        | 1597.98       | 1500.01        | 727 |
| T6  | 2               | 100                | 2                | 3931.90           | 3538.71           | 1461.20         | 1315.08         | 3095.25        | 1453.95       | 1346.14        | D   |
| T13 | 6               | 0                  | 2                | 4717.40           | 4245.66           | 1223.20         | 1100.88         | 3660.00        | 1355.70       | 1228.22        | D   |
| T4  | 0               | 200                | 2                | 4791.50           | 4312.35           | 1660.20         | 1494.18         | 3750.50        | 1683.46       | 1552.82        | 162 |
| T7  | 2               | 150                | 2                | 4493.80           | 4044.42           | 1651.50         | 1486.35         | 4032.88        | 1648.15       | 1507.68        | D   |
| T10 | 4               | 100                | 2                | 4026.60           | 3623.94           | 1400.70         | 1260.63         | 4315.25        | 1418.77       | 1268.47        | D   |
| T8  | 2               | 200                | 2                | 5281.40           | 4753.26           | 1752.80         | 1577.52         | 4970.50        | 1798.99       | 1625.86        | 172 |
| T11 | 4               | 150                | 2                | 5714.80           | 5143.32           | 2269.80         | 2042.82         | 5252.81        | 2220.35       | 2037.39        | 4184|
| T14 | 6               | 100                | 2                | 5015.60           | 4514.04           | 1571.50         | 1414.35         | 5535.25        | 1640.17       | 1447.37        | D   |
| T12 | 4               | 200                | 2                | 5498.90           | 4946.91           | 1641.30         | 1477.17         | 6190.50        | 1738.34       | 1522.72        | D   |
| T15 | 6               | 150                | 2                | 5369.40           | 4832.46           | 1885.30         | 1696.77         | 6472.88        | 1904.74       | 1679.28        | D   |
| T16 | 6               | 200                | 2                | 6480.60           | 5832.54           | 1669.90         | 1502.91         | 7410.50        | 1854.72       | 1596.60        | D   |

VC=vermicompost, TRT=treatment, BA=basal application, ASY=average straw yield, NPS= (nitrogen, phosphorus, sulfur), ADSY=adjusted straw yield, AGY=average grain yield, ADGY=adjusted grain yield, TVC=total variable cost, TR=total revenue, NB=net benefit, MRR=marginal rate of return, D=dominated treatment. Yield adjustment=10%, price of tef straw = $0.11/kg, price of tef grain = $0.82/kg, minimum acceptable rate of return (MARR) = 100%, fertilizer transportation cost= $1.74 100 kg$^{-1}$, fertilizer application cost=4man/day/200 kg; NPS Fertilizer cost=$0.57/kg$^{-1}$; Zn Fertilizer cost=$1.01/ kg$^{-1}$, B Fertilizer cost=$0.47/kg$^{-1}$, VC production cost=$1.43/100 kg$^{-1}$, VC application cost=6man/day/6tons.
lesser number of days. The vegetative parameters like panicle length and plant height of tef crop were also significantly better by the higher rates of integrated application of vermicompost and NPS plus basal application of Zn and B fertilizers. The yield attributes like biomass, straw and grain yield were as well significantly enhanced by the higher rates of combined application of vermicompost and NPS fertilizers, particularly, combined application of 4 t vermicompost ha\(^{-1}\) and 150 kg NPS ha\(^{-1}\) plus basal application of Zn and B fertilizers brought highest yield almost in all the yield attributes.

According to the partial budget analysis the highest marginal rate of return was attained from combined application of 4 t vermicompost ha\(^{-1}\) and 150 kg NPS ha\(^{-1}\) plus basal application of Zn and B fertilizers. Therefore, it can be concluded that 4 t vermicompost ha\(^{-1}\) and 150 kg NPS ha\(^{-1}\) plus basal application of Zn and B fertilizers could be recommended in terms of economic return and productivity of tef (quencho variety) in the study area. This rate also can be used as a point of reference for additional study at vermicompost and NPS fertilizer for different tef varieties.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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**REFERENCES**

Abraha A (2013). Effects of rates and time of nitrogen fertilizer application on yield and yield components of tef [Eragrostis tef (zucc.) trotter] in Habro district, Eastern Ethiopia. M.Sc. Thesis. Aşayi OC, Akinnifesi FK, Gudeta S, Chakeredza S (2007). Adaptation of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. Natural Resources Forum 31(4):306-317.

Alam MN, Jahan MS, Ali MK, Islam MS, Khandaker SMAT (2007). Effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth. Australian Journal of Basic and Applied Sciences 1:706-716.

Anon, USDA, NRCS (2003). Managing soil organic matter, the key to air and water quality. In: Soil Quality Technical Note 5(4):07.2011.

Anonymous (1994). Training materials on soils for use by development personnel. Watershed development and land use department MONRDEP, Addis Ababa, Ethiopia.

Arancon NO, Edwards CA, Bierman P, Welch C, Metzger JD (2004). The influence of vermicompost applications to strawberries: Part 1. Effects on growth and yield. Bioresource Technology 93:145-153.

Assefa A, Tana T, Abdulahi J (2016). Effects of compost and inorganic np rates on growth, yield and yield components of tef (Eragrostis tef (Zucc.) Trotter) in Girar Jarso district, Central Highland of Ethiopia. Journal of Fertilizer and Pesticides 7:174. doi:10.4172/2471-2728.1000174

Aulakh MS, Grant CA (2008). Integrated nutrient management for sustainable crop production. The Haworth Press, Taylor and Francis Group; New York.

Ayoub AT (1990). Fertilizer and environment. Nutrient Cycling in Agroecosystems 55:117-121.

Bayer SB, Jagtap S, Gurpreeet K (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. Agronomy 5:220-238.

Bayu W, Rethman NFG, Hammes PS, Alemu G (2006). Application of farmyard manure improved the chemical and physical properties of the soil in a semi-arid area in Ethiopia. Biological Agriculture and Horticulture 24(3):293-300.

Becker M, Ladha JK, Ali M (1995). Green manure technology: potential usage, limitations: a case study for low land rice. Plant Soil 174:181-194.

Bruce RC, Raymond GE (1982). Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Queensland Department of Primary Industries. Bulletin QB8 (2004), Indooroopilly, Queensland.

Central Statistical Agency (CSA) (2017/2018). Agricultural sample survey. Statistical Bulletin, Addis Ababa, Ethiopia.

Charman PEV, Roper MM (2007). Soil organic matter. In ‘Soils – their properties and management.’ 3rd edn. (Eds P. E. V. Charman and B. W. Murphy.) (Oxford University Press: Melbourne.). pp. 276-285.

CIMMYT (1988). From agronomic data to farmer recommendations: An economics training manual. Mexico, CIMMYT.

Degwale A, Dechassa N, Gedamu F (2016). Effects of vermicompost and inorganic NP fertilizers on growth, yield and quality of garlic (Allium sativum L.) in Enebse Sar Midir district, Northwestern Ethiopia. Journal of Biology, Agriculture and Healthcare 6(3):57-75.

Devi KN, Singh MS, Singh NG, Athokpam HS (2011). Effect of integrated nutrient management on growth and yield of wheat (Triticum aestivum L.). Journal of Crop and Weed 7(2):23-27.

Emerson WW (1991). Structural decline of soil, assessment and prevention. Australian Journal of Soil Research 29:905-922.

Fayera A, Adugna D, Muktar M (2014). Evaluation of tef [Eragrostis tef (Zucc.) Trotter] responses to different rates of NPK along with Zn and B in Dedessa district, Southwestern Ethiopia. World Applied Sciences Journal 32:2245-2249.

Fayera A, Muktar M, Adugna D (2014). Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of tef [Eragrostis tef (Zucc.) Trotter] in Dedessa district, Southwestern Ethiopia. Journal of Biology, Agriculture and Healthcare 4:254-258.

Getachew A (2009). Ameliorating effects of organic and inorganic fertilizers on crop productivity and soil properties on reddish- brown soils. In: Proceedings of 10th Conference of the Ethiopian Society of Soil Science. 127-150, EIAS, Addis Ababa, Ethiopia, March.

Gökşü ZL, Su Kirill, Ders KÖ (2003). Çukurova Üniversitesi Su Ürünleri Fakültesi YayYolular, No: 7, ISBN: 975-8561-24-3. BalcaİÖ. Adana.

Gomez KA, Gomez AA (1984). Statistical procedure for agricultural research 2nd ed. John Wiley and Sons, New York, pp. 146-184.

Gupta PK (2003). Vermicomposting for sustainable agriculture. Agrobios, p. 188.

Hira T, Gebrekidan H, Tesfaye K, Hailiemariam A (2009). Biomass and nutrient accumulation of green manuring legumes terminated at different growth stages. East African Journal of Sciences 3:18-28.

Holford ICR, Cullis BR (1985). Effects of phosphate buffer capacity on yield response curvature and fertilizer requirements of wheat in relation to soil phosphate tests. Australian Journal of Soil Research
23:417-427.
Janssen DM, Stoorvogel JJ, Shipper RA (1995). Using sustainability indicators in agricultural land Use analysis: An example from Costa Rica. Netherlands Journal of Agricultural Science 43:61-81.
Jabe (2003). Integrated nutrient management for increased rice production in the inland valleys of the Gambia. In: Samyang SA, Ajayi AA. See (Ends). Proc. 2nd Biennial Regional Rice Research Review. WARD Proceedings Series 2(1):35-41.
Kannan RL, Diva M, Anaya D, Krishna RL, Krishna KS (2013). Effect of integrated nutrient management on soil fertility and productivity in maize. Bulletin of Environment, Pharmacology and Life Sciences 2(8):61-67.
Ketema S (1991). Germplasm evaluation and breeding work on teff (Eragrostis teff) in Ethiopia. In: Plant Genetic Resources of Ethiopia 323-328. Cambridge University Press, Cambridge, New York Port Chester.
Ketema S (1993). Tef Breeding, agronomy, genetic resources, utilization and role in Ethiopian agriculture. Institute of Agricultural Research, Korendop, Rift Valley, Ethiopia (1993). (in Amharic).
Effect of integrated nutrient management on growth, yield and economics of chilli (Cv. Byadgi dabb) in a vertisol. Karnataka Journal of Agricultural Sciences 22:438-440.
Lamps S (2000). Principles of integrated plant nutrition management system. In: Proc. Symp. Integrated plant nutrition management (Nov 8-10, 1999), NFDC, Planning and Development Division, Govt. of Pakistan pp. 3-17.
Mahajan A, Bhagat RM, Gupta RD (2008). Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. SAARC Journal of Agricultural Science 6:29-32.
Makinde EA, Ayoola OT (2010). Growth, yield and NPK uptake by maize with complementary organic and inorganic fertilizers. African Journal of Food, Agriculture, Nutrition and Development 10(3).
Manivannan S, Balakrishnan, Pundasarathan, Ganesakumar, Ranganathan R (2009). Effect of vermicompost on soil fertility and crop productivity - beans (Phaseolus vulgaris) Journal of Environmental Biology 30:275-281.
Meena SL, Surendra S, Shivay VS, Singh S (2003). Response of hybrid rice (Oryza sativa) to nitrogen and potassium application in sandy clay loam soils. Indian Journal of Agricultural Research 73:8-11.
Metson AJ (1961). Methods of chemical analysis for soil survey samples. Soil Bureau, Bulletin No. 12. New Zealand Department of Scientific and Industrial Research, (Government Printer: Wellington, New Zealand.), pp. 168-175.
Merga M (2018). Progress, achievements and challenges of teff breeding in Ethiopia. Journal of Agricultural Science and Food Research 9(1):1-8.
Mitiku W, Tamado T, Singh TN, Teferi M (2014). Effect of integrated nutrient management on yield and yield components of food barley (Hordeum vulgare L.) in Kaffa zone, Southwestern Ethiopia. Science, Technology and Arts Research Journal 3(2):34-42.
Mukhtar T, Arif M, Hussain S, Tariq M, Mehmoond K (2011). Effect of different rates of nitrogen and phosphorus fertilizers on growth and yield of maize. Journal of Agricultural Research 52(2):197-206.
Orozco F, Gecarrar J, Trujillo L, Roig A (1996). Vermicomposting of coffee pulp using the earthworm Eisenia fetida: Effects on C and N contents and the availability of nutrients. Biology and Fertility of Soils 22:162-166. Doi: 10.1007/BF00384449
Patra AK, Nayak BC, Mishra MM (2000). Integrated nutrient management in rice (Oryza sativa)-wheat (Triticum aestivum) cropping System. Indian Journal of Agronomy 45:453-457.
Quansah GW (2010). Effect of organic and inorganic fertilizers and their combinations on the growth and yield of maize in the semi-deciduous forest zone of Ghana. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. (Doctoral dissertation).
Rahman S, Parkinson RJ (2007). Productivity and soil fertility relationships in rice production systems, Bangladesh. Agricultural Systems 92:318-333.
Rathier TM, Frink CR (1999). Nitrate in runoff water from container-grown Juniper and Alberta Spruce under different irrigation and N fertilization regimes. Journal of Environmental Horticulture 7:32-35.
Richards LA (Ed.) (1954). Diagnosis and improvement of saline and alkaline soils. USDA Handbook No. 60. Washington, DC.
Roberts TL (2010). Nutrient best management practices: Western perspectives on global nutrient stewardship, 19th World Congress of Soil Science, Soil Solutions for a Changing World, 172-175, Brisbane, Australia. August 1-6.
Sanchez AP, Leakey RB (1997). Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. Agronomy Journal 7:15-23.
Sarwar G, Hussian, N, Schmiesky H, Muhammad S, Ibrahim M, Safdar E (2008). Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pakistan Journal of Botany 40:275-282.
Satyanarayana V, Prasad PV, Murthy VRK, Boote KJ (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. Journal of Plant Nutrition 25(10):2081-2090.
Sewnet A (2005). Effects of nitrogen and seed rates on grain yield components and nitrogen uptake of rain-fed rice (Oryza sativa) in Fogera, South Goender,MSc Thesis, Alemary University, Alemary, Ethiopia.
Shrivastava AK, Upadhayay VB, Gautam DS, Sarvade S, Sahu RK (2018). Effect of integrated nutrient management on growth and productivity of Withania somnifera (L.)Dunal in Kymore Plateau and Satpura hills of Madhya Pradesh, India. Archives of Agriculture and Environmental Science 3(2):202-208. Doi:10.26832/24566632.2018.0302015
Singh J, Bisen S, Bora DK, Kumar R, Bera B (2011). Comparative study of organic, inorganic and integrated plant nutrient supply on the yield of Darjeeling tea and soil health. Field Crop Research 58:58-61.
Singh N, Chauhan JS (2009). Response of French bean (Phaseolus Vulgaris L.) to organic manures and inorganic fertilizer on growth and yield parameters under irrigated condition. Natural Science 7(5):1-3.
Singh R, Agarwal SK (2001). Growth and yield of wheat (Triticum aestivum L.) as influenced by levels of farmyard manure and nitrogen. Indian Journal of Agronomy 46:462-467.
Sönmez Ö, Kaplan M, Şönmez S (2008). Kimyasal Gübrelerin Çevre Indicatorleri ve Çözüm Önerileri, BatÖ Akdeniz Tarım OrMANI AraüOrma Enstitüsü Dergisi 25(2):24-34 ISSN 1300-3496.
Stewart WM, Dibb DW, Johnston AE, Smyth TJ (2005). The contribution of commercial fertilizer nutrients to food production. Agronomy Journal 97:1-6.
Tilahun T, Nugussie D, Wondimun B, Setegn G (2013). Effect of farmyard manure and inorganic fertilizers on the growth, yield and moisture stress tolerance of rain-fed lowland rice. American Journal of Research Communication 1(4):275-301.
Vlek PL (1990). The role of fertilizers in sustaining agriculture in sub-Saharan Africa. Fertility Research and Practice 25:327-339.