Teff [Eragrostis teff (Zucc.) Trotter] Response to Integrated Organic and Inorganic Fertilizers

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ABSTRACT

Teff is one of the most important cereal crops and predominant staple food in Ethiopia. However, its productivity is constrained by a number of problems like lack of appropriate management practices, low soil fertility, lack of combined application of organic and inorganic fertilizer and lack of improved varieties in Ethiopia in general, and in the study area in particular. The flied experiment was conducted during main season of 2023 at Melkassa agricultural Research site to evaluate the response of teff yield and yield components to different fertilizers rates and types. The treatments consisted of seventeen treatments with different combinations and laid out by randomized complete block design in three replications. Analysis of data revealed that all growth and phonological, yield and yield components of teff had showed significant variations due to different fertilizer rates and types. The earliest to 50% days to panicle emergence (29.33 days) was recorded from recommended vermicompost and 25% VC + 25% EG + 75% NPSZnB application. The lowest days to physiological maturity (62.00 days) was obtained from 25%AM + 25% VC + 75% NPSZnB. The highest plant height (100.20 cm) was recorded from the treatment that received 25%AM +25% VC +25%EG + 75% NPSZnB combination. The highest total tiller and productive tiller (5.66 per plant), thousand seed weight (0.31 g), aboveground biomass (11416.70kgha^{-1}), grain yield (2281.00kgha^{-1}) and straw yield (9135.70 kgha^{-1}) were obtained from 25%AM +25% VC +25%EG + 75% NPSZnB application. The highest loading index (75.00%) and highest harvest index (25.83%) where recorded from the treatment that received 50%AM + 50% EG + 50% NPSZnB and recommended Eco- green, respectively. The result of partial budget analysis showed that the highest net benefit was obtained from the treatment that got 25%AM +25% VC +25%EG + 75% NPSZnB with marginal rate of return (3481.10). Therefore, the farmers of study area and similar agroecology can use combination of 25%AM +25% VC +25%EG + 75% NPSZnB for better teff production. However, this experiment was only conducted for one season at one location which needs further study for sound able recommendation.

Keywords: *Teff, Blended NPSZnB fertilizer, Vermicompost, Eco green, animal manure*

INTRODUCTION

Background and Justification of the study

Teff [*Eragrostis teff (Zucc.)* Trotter] is a cereal crop that belongs to the grass family Poaceae, which is endemic to Ethiopia and has been widely cultivated in the country for centuries (Teklu and Teffera, 2005). Teff (*Eragrostis tef*), also known as tef and t’ef, is an ancient grain of Ethiopia and Eritrea, where it is highly valued for its climate resilience and culinary uses. It is an annual, self-pollinated C4 member of the grass family (Poaceae), an allotetraploid with 20 chromosome pairs (Girma *et al*., 2018). Seed color ranges from white to dark brown, with white being the preferred color (Woldeyohannes *et al*., 2022). It is warm season cereal crop that have been domesticated and used throughout the world due to its excellent nutritional value as grains for human consumption and as forage for adaptation for the diverse agro-climatic and soil livestock (Baye, 2018). Teff is an economically superior commodity in Ethiopia. It often commands a market price two to three times higher than maize, the commodity with the largest production volume in the country (Fantu *et al*., 2015), thus making teff an important cash crop for producers (Abraham, 2015). Teff has got both cultural and economic value for Ethiopian farmers with more than six million households' lives depending on the production of teff (Tareke *et al*., 2011).

Despite being a staple food for many people in Ethiopia and Eritrea for centuries, teff has only gained prominence as a food crop in other parts of the world very recently. This interest is mainly associated with its gluten-free property and its nutrient composition, that comparable with other common cereals (Cheng, 2017; Hailu *et al.*, 2000; Hailu, 2011; Spaenij-Dekking *et al.*, 2005). Besides being gluten-free, teff contributes nutritionally through its 9% protein content, high proportions of fiber and lipids, and relatively high concentrations of phosphorus, magnesium, manganese, and copper (Gebru *et al*., 2020). However, it is also grown as a pasture crop in several countries (Kebebew *et al*., 2011). The straw from teff is a valuable source of livestock feed because of more palatable and nutritious than that from wheat and barley (Alemu, 2013). It grows well under a wide range of conditions at altitudes of 1700 to 2800 meters and has relatively few pests and diseases (Beyene *et al*., 2022). In addition to the Horn of Africa, teff is produced in Europe, India, Australia, and the U.S. (in California, Texas, Idaho, and Nevada) (Wikipedia, 2023). It is a staple food for the majority of the population in Ethiopia. Out of the total grain crop area, 81.97% (9,997,511.08 hectares) was under cereals. Teff, maize, sorghum and wheat took up 24.05% (about 2,932,670.03 hectares), 21.02% (about 2,563,201.21 hectares), 11.07% (about 1,350,509.37 hectares) and 15.31% (about 1,867,047.71 hectares) of the grain crop area, respectively. As to production, Cereals contributed 88.69% (about 290,808,263.25 quintals) of the grain production (CSA, 2022).

Maize, teff, wheat and sorghum made up 32.79% (about 107,513,689.44 quintals), 17.12% (about 56,143,388.01 quintals), 17.71% (about 58,078,220.52 quintals) and 10.84% (about 35,536,707.10 quintals) of the grain production, in the same order (CSA, 2022).

Teff is used to make injera, traditional flat bread. Hence it is a day-to-day food item in every household. Additionally, teff plant residues can be used as animal fodder. According to Wato (2021), teff is also an important food item for those who are on gluten-restricted diets and therefore is a superior economical commodity in the country.

Statement of the Problem

Teff (*Eragrostis teff* (Zucc.) Trotter] is one of the most important cereal crops and predominant staple food in Ethiopia and is ranks prior to maize, sorghum and wheat in area coverage, while it stands second in total production after maize in Ethiopia (CSA, 2022). Despite covering the largest agricultural area of the country than any other types of grain and its importance, teff production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies and susceptibility of the crop to lodging (Teklay and Girmay, 2016). These is due to low in productivity compared to the potential yield due to lack of adequate synthetic-fertilizer input, limited return of organic residues and manure, and high biomass removal, erosion, and leaching rates, low soil fertility and suboptimal use of mineral fertilizers. Although organic inputs, such as animal manure, Eco green and vermicompost, are potential sources of plant nutrients and have beneficial effects on soil fertility.

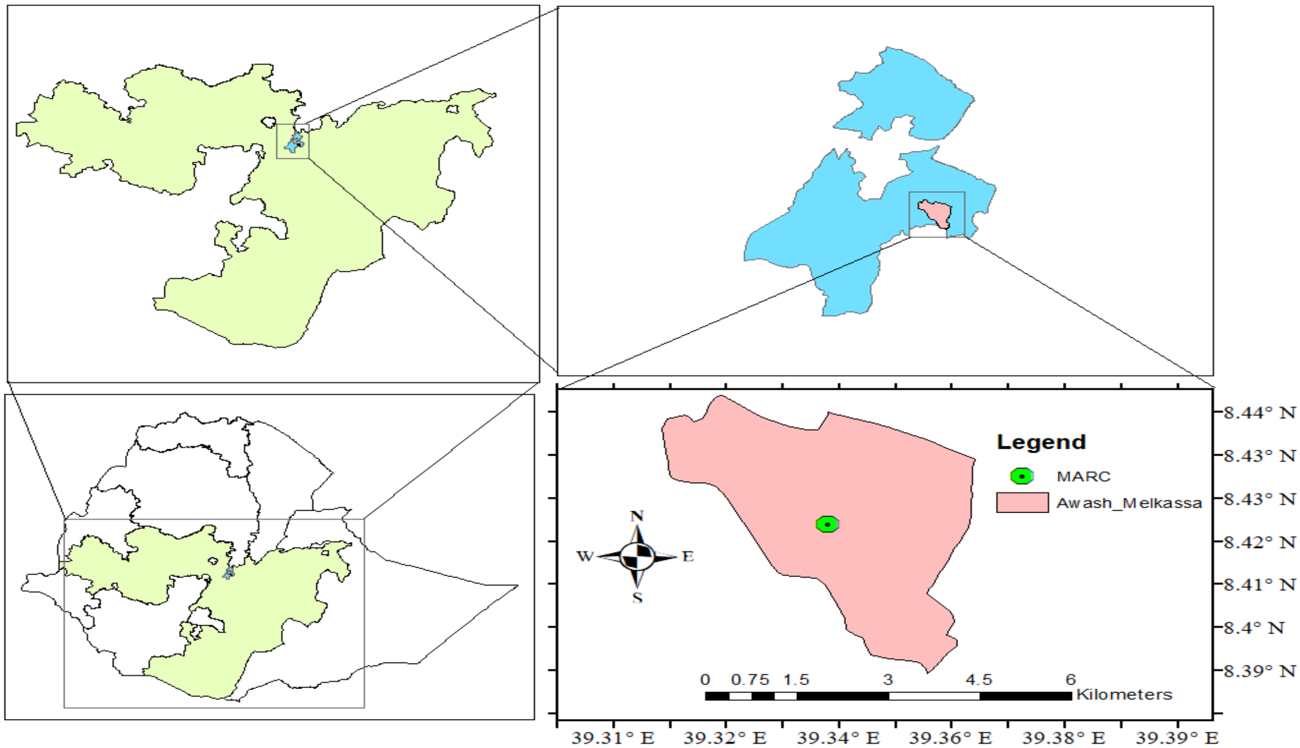
Teff productivity is constrained by a number of problems, lack of site-specific fertilizer recommendation, organic fertilizer and high yielding varieties are crucial in the study area. Soil fertility problem is one of the major causes of temporal and spatial yield variability (Brhan, 2012). Lack of appropriate blended fertilizer and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity. It is vital to increase the productivity along with desirable attributes through production management practices and application of other sources of nutrients beyond the blanket recommendation of DAP and urea alone for Teff production in Vertisols (EIAR, 2004). The most important short coming in teff production is its inherent low productivities of local cultivars and low soil fertility status (Abayu, 2012). Lack of appropriate blended fertilizers and lack of micronutrients in fertilizer blends are the major constraints to higher teff productivity. Following soil fertility map made over 150 districts EthioSIS (EthioSIS, 2013) reported that Ethiopian soil lacks about seven nutrients; N, P, K, S, Cu, Zn and B. Of which, the study area particularly lacks NPSZnB, which are among the major teff yield limiting soil nutrients.

The national average grain yield of teff in Ethiopia is relatively low amounting to about 2.07 t ha^{-1} (CSA, 2022). This, amongst others, is due to the widespread use of low yielding variety coupled with unimproved traditional practices and nutrient deficiencies that ultimately contribute to the low national average yield of major cereal crops in the country. However, using improved cultivars, combination of blended NPSZnB fertilizer with organic fertilizer and under good management practices yields up till 2.5 t ha^{-1} while the yield potential under optimal management and when lodging is prevented as high as 4.5 t ha^{-1} and the national average yield is 2.07 tha^{-1} (CSA, 2022). However, chemical fertilizers in effect, “kill” soil properties while organic fertilizers improve and sustain the soil (Goel and Duhan, 2014). Low soil fertility problem has been repeatedly reported as one of the major factors affecting teff production in the central rift valley of Ethiopia. To overcome this problem the study had used combinations of organic fertilizer (Animal manure, Eco-green and Vermicomost and mineral fertilizer NPSZnB for teff production. thus, the objective of the study was to evaluate the response of Teff to different fertilizers rates and types.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Melkassa Agricultural Research Center (MARC) in Oromia National Regional State near the town of Awash-Melkassa, Adama District, East Shewa Zone, 117 km East of Addis Ababa and 17 km South-east of Adama city during the main cropping season of 2023. The site was located of 8°24’N and 39°21’ E altitude of 1,550 m.a.s.l. Agro-ecological zones (AEZs) of the area was categorized to arid to semi-arid. The mean long-term annual rainfall of the station was 763 mm, which 70% received during June to September. The average annual minimum and maximum sandy loam. Available soil water lies between 34.04% at field capacity and 16.74% at permanent wilting point on weight basis. The average bulk density of the soil was 1.13 g cm^3. The soil was slightly alkaline ranging from 7.0 to 7.8 pH (MARC profile and meteorology, 2023).



Map of study area

Source :(MARC profile2023)

Experimental Materials

Teff variety namely: Boni (BZ2) which was high yielding and currently released variety(Table 1) that was obtained from Deberzeit agricultural research center; and fertilizer materials: animal manure; eco-green and vermicompost organic fertilizers where used for the experiment. NPSZnB Blended inorganic fertilizer which contains (17.8% N, 35.7% P_2O_5, 7.7% S, 2.2% Zn and 0.1% B) was used for the study along other organic fertilizers (MoA, 2017).

Description of Teff Variety used for the Study

The currently released new teff variety named Boni (DZ-Cr-498 RIL 37) .This variety had distinctive characteristics such as high yielding and the lemmas are yellowish green when immature and yellowish white when mature. In the current finding, Dtt2 x Dtt13 (DZ-Cr-498 RIL 37) belongs to the early maturity group, which almost equally divided between the days taken to head and the grain filling period (Worku *et al*., 2022).

Table 1. Description of variety of Teff Boni

Characteristics	**Description**
Basal stalk color	Yellowish green
Panicle form	Very Loose
Lemma color	Yellowish green when immature and yellowish white when mature
Anther color	Yellowish white
Seed color	Very white
Days to panicle emergence (days)	27 -49
Days to maturity (days)	62 -88
Grain filling period (days)	27- 46
Plant height (cm)	57 -109
Culm length (cm)	18-67
Panicle length (cm)	33-44
Biomass yield (t/ha)	6.5-20
Grain yield (t/ha)	1.7 -3.5

Treatments and Experimental Design

The field experiment was contained a total of seventeen (17) treatments. The treatments where recommended rate of Vermicompost, recommended rate of animal manure, recommended rate of Eco-green and recommended rate of blended fertilizer (NPSZnB) and their combinations by reducing the rates of applications of each fertilizer type. The treatments where arranged in RCBD in three replications.

Table 2. Treatment combination

S.no	Treatments
1	Control (Without external fertilizer application)
2	Eco green recommend level (40 $litha^{-1}$)
3	Animal Manure (Recommended level) (10tha^{-1})
4	Vermicompost (Recommended level)(4 tha^{-1})
5	NPSZnB (Recommended level)(150 $kgha^{-1}$)
6	50% Animal Manure + 50% NPSZnB
7	50% Eco-green + 50% NPSZnB
8	50% Vermicompost + 50% NPSZnB
9	50% Animal Manure + 50% Eco-green + 50% NPSZnB
10	50% Animal Manure + 50% Vermicompost + 50% NPSZnB
11	50% Vermicompost + 50% Eco-green + 50% NPSZnB
12	25% Animal Manure + 25% Eco-green + 75% NPSZnB
13	25% Animal Manure + 25% Vermicompost + 75% NPSZnB
14	25% Vermicompost + 25% Eco-green + 75% NPSZnB
15	25% Animal manure +25% Vermicompost +25%Eco-green + 25% NPSZnB
16	25% Animal manure +25% Vermicompost +25%Eco-green + 50% NPSZnB
17	25% Animal manure +25% Vermicompost +25%Eco-green + 75% NPSZnB

Experimental Procedures and Management

A plot size of $4m^2$ (2mx2m) with 20cm row spacing was used. On each plot area there was 10 planting rows. To avoid possible border effects the net harvestable area where adjust to $1.2m^2$ (1mx1.2m) and adjacent plots and blocks space 1m and 1.5m apart, respectively. The total area of experimental field was 636 m^2 (12m x 53m), including footpath and border. Field layout of the experiment was adjust according to treatments and assigned randomly to each plot. Number of plot in each block and total of plot in gross land area was 17 and 51 plot, respectively.

Soil Sampling and Chemical Analysis

Soil samples were taken in a zigzag pattern from the experimental plots at the depth of 0-30 cm using an auger before planting and fertilizer application. Samples from each replication where bulked together to form composite sample. Then the collected samples where air dried to a constant weight, grinded and mixed thoroughly and passed through 2mm sieve for laboratory analysis. The composite soil samples was done for selected physico-chemical analysis mainly textural analysis, PH, CEC, total Nitrogen (N), total Phosphorus (P), total Sulphur, total boron, total Zink and soil organic matter (OM) at soil laboratory.

Soil textural class was determined by Bouyoucos Hydrometer Method (Day, 1965). Soil pH was determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital pH meter (Walkley and Balck, 1934). Organic carbon (%) where determined by wet digestion method (Walkley and Black, 1934); then the organic matter (%) where calculated by multiplying the OC% by factor 1.724. Cation Exchange Capacity (Cmol kg-1 soil), of the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium where replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Total nitrogen (%) was determined using the Kjeldhal method (Jackson, 1973). Available phosphorus (mg L^{-1}) was determined by Olsen method (Olsen *et al*., 1954). Available sulfur (meq/l SO_4^{-2}) was determined turbidimetrically using a spectrophotometer method (Singh *et al*., 1999). Exchangeable bases (potassium, magnesium, sodium, and calcium) will be as determined by Melich-3 methods (Mehlich, 1984). Diethylenetriaminepentaacetic acid (DTPA) was used for the simultaneous extraction of elements such as Zn, Cu, Fe and Mn (Lindsay and Norvell, 1978). Available B was extracted by hot water extraction method (Berger and Truog, 1939).

Data Collection and Measurements

Growth, yield and yield components were collected from the net plot area of each plot and the data were analyzed using the standard procedures as described below;

Crop phenology and growth parameters

Days to 50% panicle emergence: was determined as the number of days from sowing to the time when 50% of the plants become emerged the tip of panicles through visual observation.

Days to 90% physiological maturity: was determined as the number of days from sowing to the time when the plants reached maturity based on visual observation and it was recorded when 90% of the plants in plots reached to their respective phenological stage. It was estimated when the leaves started to senescence as well as the grains came out free from the glumes upon when pressed between the forefinger and thumb.

Plant height (cm): was measured at maturity from the base of the stem of the main tiller to the tip of the main shoot panicle by using a ruler from average of six plants per plot and was recorded

Panicle length (cm): was measured from the node where the first panicle branch emerges to the tip of the panicle and it was determined from an average of six fertile tillers of selected plants per plot.

Yield and yield components

Total tillers: The number of total tillers was determined by counting the tillers from six plants of the two middle rows per plot at maturity.

Number of fertile tillers: The number of fertile tillers was determined by counting the tillers bearing panicle from six plants of the two middle rows per plot at maturity.

Lodging index (%): was assessed just before the time of harvest by visual observation based on the scale of 1-5 where 1 (0 to 15°) indicates no lodging, 2 (15 to 30°) indicate 25% lodging, 3 (30 to 45°) indicate 50% lodging, 4 (45 to 60°) indicate 75% lodging and 5 (60 to 90°) indicate 100% lodging (Donald, 2004).

Thousand kernels weight (g): was determined based on the weight of 1000 kernels sampled from the grain yields used to determine of each treatment, using an electric seed counter, weighing with an electronic balance and adjusted to 12.5% moisture level.

Total Biomass yield (kgha^{-1}): was measured by weighing the sun-dried total above ground plant biomass of the net plot at physiological maturity. Grain yield (kgha^{-1}): was weighted after harvesting and threshing the crop by taking the weight of the grains from the net plot area by adjusting the moisture of the grain at 12.5% and was converted to kg ha^{-1}.

Straw yield (kgha^{-1}): was determined by subtracting grain yield from total above ground biomass.

Harvest index (%): was calculated on a plot basis as the ratio of grain yield to the aboveground biomass yield and expressed as a percentage.

Statistical Data Analysis

Data on growth, yield and yield components were subjected to ANOVA using SAS software version 2002 (SAS, 2002). Parameters were ANOVA tested significant with respect to 17 treatments. Further means separation was done using least significant difference method (LSD) at 0.05 probability levels using the same software.

Partial Economic Analysis

The economic analysis was performed whenever significant difference was observed for mean grain yields with respect to the applied blended, Eco green, animal manure and vermicompost as per the procedures of (CIMMYT, 1988). Accordingly, those factors with significant effect were considered for partial budget analysis, dominance and marginal analysis. All costs and benefits were calculated on hectare basis in Ethiopian birr. The average yield obtained from experimental plot was reduced by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. The variable costs considered in the economic analysis included the cost of blended NPSZnB (Birr 50 kg^{-1}), cost of Eco green (60 $birrlit^{-1}$) cost of animal manure (Birr 10 kg^{-1}), and cost of vermicompost (Birr 17 kg^{-1}). The time price of grain and straw yield of teff were 120 birr kg^{-1} and 3.2 birr kg-^{1} respectively at an average open market price of local town.

The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that varied. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as “D”). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The net returns (benefits) and other economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Unadjusted grain and straw yields (UGY and USY) (kg ha^{-1}): the average grain and straw yield of each treatment.

Adjusted grain and straw yield (AGY and ASY) (kg ha^{-1}): the average grain and straw yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB = AGY (ASY) × field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}): was calculated by summing up the costs that vary, including the cost of NPSZnB ,Eco green, animal manure and vermicompost at planting (July, 2021), and labor cost for application of fertilizers. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing was considered the same for all treatments or plots.

Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as NB = GFB – TVC

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) as × 100.

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using the technique were referred to as dominated and non-dominated treatments, respectively. Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net return and a marginal rate of return greater than the minimum acceptable to farmers (100%) was considered for the recommendation.

RESULTS AND DISCUSSION

Pre-Planting Soil Physio-Chemical Properties

The results of the composite soil sample before sowing laboratory analyses indicated that the soil textural class of experimental site was 65.31% sand, 11.56% clay and 23.13% silt (Table 3). Thus, the texture of the soil was sandy loam according to Bouyoucos (1962) classification. The texture properties of the soil influence water holding capacity, water intake rates, aeration, root penetration and soil fertility which is suitable for teff production as it is well adapted to a wide range of soil types and ability to perform well in black soil (ATA, 2013). The pH of the soil was 7.4 (Table 3) which is basic (Tekalign, 1991). This value is optimum pH range (6.0-7.5) of teff production (Seyfu, 1993). The CEC of the site was 33.29 meq/100g soil (Table 3). According to Landon (1991), top soils having CEC greater than 40 cmol (+)/kg are rated as very high. Thus, the soil of the study area is high in CEC, which is an indication of good agricultural soil. Usually, soil cation exchange capacity describes the potential fertility of soils and indicates the soil texture, organic matter content and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile (Tegbaru, 2014). The organic carbon content (OC) of the experimental field was 0.96% (Table 3) which is low according to the rating of Tekalign (1991), who rated soils having OC value in the range of 0.5-1.5% is low. This indicated the low potential of the soil to supply nitrogen to plants through mineralization of organic carbon. The low amount of soil organic carbon might be due to complete removal of crop residues, and less aeration due to soil compaction of subsoils. Most cultivated soil of Ethiopia is poor in organic matter content due to low number of organic materials applied to the soil and complete removal of biomass from the field. The total nitrogen was 0.07% (Table 3) which was low according to the classification of Tekalign (1991). The low nitrogen content might be due to the loss of nitrogen from the soil system easily through leaching, denitrification, volatilization, crop removal, soil erosion and runoff as the land is continuously cultivated. According to Olsen et al. (1954), classified soil P availability of 20 ppm 23 very high. Therefore, the experimental soil has very low P content of 3.28 ppm. The analysis for available Sulfur, Boron and Zinc indicated that the experimental soil had value 2.13 ppm of available S which is rated very low, 0.33 ppm of available B which is rated as very low and 0.40 ppm of available Zn which is rated as low according to EthioSIS (2014).

Table 3.Soil physical and chemical properties of the experimental site before sowing

Soil properties	Values	Rating	Reference
Physical properties			
Sand	65.31%		
Silt	23.13%		
Clay	11.56%		
Textural class	Clay Loam		Bouyoucos (1962)
Chemical properties			
pH (1:2.5 H2O)	7.4	Basic	Tekalign (1991)
Organic Carbon (%)	0.96	Low	Tekalign (1991)
Total Nitrogen (%)	0.07	Low	Tekalign (1991)
Available P (ppm)	3.28	Very low	Olsen (1954)
CEC (meq/100 g soil)	33.29	High	Landon *et al*. (1991)
Available Sulfur (ppm)	2.13	Very low	Ethio-SIS (2014)

Available Boron (ppm	0.33	Very low	Ethio-SIS (2014)
Available Zinc(ppm	0.40	Very low	Ethio-SIS (2014)

Source :(MARC laboratory report)

Table. 4. Chemical properties of vermicompost, Eco-green and animal manure

Chemical properties vermicompost	Values
pH	7.40
EC (µS/cm)	1.30
Total N (%)	1.37
Available P(ppm)	46.5
OC (%)	12.1
C:N	8.83
Chemical properties of Eco green	Values
pH	7.28
EC (µS/cm)	2.13
Total N (%)	3.98
P(ppm)	215.49
S(ppm)	106.84
Zn(ppm)	2.21
B	1.99
Chemical properties Animal manure	Values
pH	6.8
EC (µS/cm)	1.40
Total N (%)	2.15
Available P (ppm)	45
OC (%)	25
C:N	8.12

Source: (Debreziet agricultural research center laboratory report, MARC laboratory report and Eco green Manual)

Effect Different Fertilizers Types and Rates on Crop Phenology and Growth Parameters of Teff

Days to panicle emergence

Analysis of variance of combined application of different fertilizers types and rates on days to panicle emergence showed highly significant ($p<0.05$) effect (Appendix Table 1 and Table 5). The earliest days to 50% panicle emergence (29.33 days) was recorded from recommended vermicompost and 25% VC + 25% EG + 75% NPSZnB; while the latest days to 50 % panicle emergence (39.67) was recorded from the control plot. This may indicate the increased rate of chemical fertilizers increased 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 teff were perhaps due to highest rate of organic and NPSZnB fertilizers encourage the crop in early establishment, rapid growth and development.

This result agreement with Seifu *et al*. (2018), who stated that the highest (73 days) days to 50% panicle emergence, was recorded from the control plot, while the lowest (50 days) was recorded from the combined application of 138 kg N and 200 kg NPSZnB ha^{-1} blended fertilizer. This result is consistent with the result of Getahun *et al*. (2018) and Tadele *et al*. (2019) who reported that the heading of teff plants was accelerated as NP rate increased from zero to 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} and from 0-69 kg N ha^{-1} fertilizer applications. It is also supported by Adera (2016) who reported that the fertilizer blended in different proportions of N, P, K, S, Zn, and B contributed to the enhanced days of emergence of teff.

Days to physiological maturity

As the result of analysis of variance showed that the application of different types and rates of fertilizers had highly significant ($p<0.05$) effect on days to physiological maturity (Appendix Table 1 and Table 5). Improved Boni teff variety fertilized with 25%AM + 25% VC + 75% NPSZnB gave shortest (62.00 days) physiological maturity, while the longest days (71.33) to reach 90% physiological maturity was recorded from the recommended animal manure treated. The early maturity of improved variety might be due to application of blended NPSZnB fertilizer rate and combination of organic fertilizer that enhance maturity could be due to the presence of balanced fertilizer in the blended fertilizer and treated with organic fertilizer show better vegetative growth and that treated with P fertilizer exhibit good root development to reach physiological maturity in time. Phosphorus application could possibly shorten maturity date since it promotes rapid cell division. However, the delay of physiological maturity on recommended animal manure plots may be due to insufficient number of essential elements. Onasanya *et al*. (2009) also reported that phosphorus plays an important role in many physiological processes that occur within a developing and maturing plants. To some extent the presence of Zn and B in blended fertilizer might have also helped in enhancing the days to attain early physiological maturity due to fact that Zn and B played an important role in protein synthesis, formulation of some growth hormones and promoted flowering and seed maturation.

In line with this result, Seifu *et al.* (2018) reported that the shortest (95) days to physiological maturity of Teff were obtained from the application of 150 kg NPSB ha^{-1} and 69 kg N ha^{-1} and the longest (106) days from the control. The result of the present study is in contrast with the result of Fenta (2018) which reported that as the rate of N increased from 0 to 69 kg N ha^{-1}, days to maturity of teff was significantly delayed. The result also in line with Chala (2020) who articulated that the shortest (137.4) days to physiological maturity of Teff were obtained from the application of 25% compost with 75% recommended N and P, while the longest (146.8) was recorded from recommended rate of FYM.

Panicle length

The analysis of variance showed that integrated application of different fertilizer type and rates had highly significant effect ($p<0.01$) on panicle length of teff (Appendix Table 1 and Table 5). The longest panicle length (40.16 cm) was recorded from the plot received 25%AM +25% VC +25%EG + 75% NPSZnB: while the shortest (28.30) was recorded from the control plot. This highest panicle length is due to efficient utilization of blended NPSZnB fertilizer with organic fertilizer combination which plays critical role in the structure of chlorophyll and other proteins which favor vegetative growth of teff and results in taller teff plants having relatively greater panicle length. Panicle length is an indicator of sink capacity which differed significantly with the variety. The result is in line with the report of Fayera *et al*. (2014) reported that the longest (45.60 cm) panicle length was recorded from the application of 150 kg NPKSZnB ha^{-1} blended with 23 kg N ha^{-1} while the shortest (30.17 cm) was recorded from the control. Also the result is agreement with Chala (2020) who revealed that The highest

(37.9cm) panicle length of teff was recorded from application of 25% FYM + 75% Rec NP, whereas the lowest (29.0cm) panicle length was obtained from negative control treatments

Plant height

The analysis of variance showed that different types and rates of fertilizers had highly significant effect ($p<0.01$) on the plant height of teff (Appendix 1 and Table 5). The highest teff height (100.20 cm) was recorded from the treatment that received 25%AM +25% VC +25%EG + 75% NPSZnB, while the shortest plant height (89.93 cm) from control plot and Eco- green recommended. The increase in plant height might be due to the adequate amount of nitrogen in the high rate of blended NPSZnB fertilizer; animal manure and vermicompost which promoted the vegetative growth of teff with resulted in better cell division, cell expansion and enlargement. The result in line with, Yonas *et al*. (2016) reported application of nutrient either in the form of inorganic or organic forms resulted in enhanced plant height ranged from 77 to 82 cm in comparison with unfertilized crop (62cm) elucidating better vegetative growth.

This result is in agreement with Feyera *et al*. (2014) who reported that highest (119.97cm) plant height was recorded from NPS applied at a rate of 120 kg ha^{-1}; while, the lowest plant height (82.03cm) was observed from the null rate of NPS fertilizer application. Similarly, Fissehaye *et al*. 2009 stating that Teff plant height could be higher due to increased amount of N fertilizer (92 kg N ha^{-1}).The result also in line with Chala (2020) who articulated that the highest (101.7 cm) plant height was recorded from 25% compost +75% recommended rate of nitrogen and phosphorus, while the lowest teff height (81.1cm) was recorded from recommended rate of compost.

Table 5. Mean values of 50% panicle emergency (PE), 90% physiological maturity (PM), panicle length (PL) and plant height (PH) of teff as affected by different fertilizers type's and rates

Treatments	PE(Days)	PM(Days)	PL(cm)	PH(cm)
Control (No fertilizer)	39.67^{a}	64.66^{def}	28.30^{g}	89.93^{edf}
EG (Recommended:,40 litha^{-1})	31.67^{bc}	64.33^{def}	36.13^{cdef}	89.93^{edf}
Animal Manure (Recommended level;10tha^{-1})	34.66^{b}	71.33^{a}	37.93^{abcd}	99.73^{ab}
VC (Recommended level; 4 tha^{-1})	29.33^{c}	66.00^{bcde}	37.43^{abcde}	88.40^{ef}
NPSZnB (Recommended level; 150 kgha^{-1})	32.67^{bc}	63.66^{ef}	36.93^{bcdef}	95.2^{abcde}
50%AM + 50% NPSZnB	30.33^{bc}	67.66^{bc}	37.70^{abcd}	97.76^{abc}
50% EG + 50% NPSZnB	34.00^{b}	66.33^{bcde}	34.0.03^{f}	91.13^{cdef}
50% VC + 50% NPSZnB	31.33^{bc}	66.33^{bcde}	37.96^{abcd}	97.76^{bcde}
50%AM + 50% EG + 50% NPSZnB	30.66^{bc}	66.33^{bcde}	35.93^{cdef}	84.46^{f}
50%AM + 50% VC + 50% NPSZnB	31.00^{bc}	66.66^{bcd}	35.16^{edf}	94.3^{abcde}
50% VC + 50% EG + 50% NPSZnB	30.66^{bc}	64.33^{def}	37.50^{abcde}	97.73^{abc}
25%AM + 25% EG + 75% NPSZnB	33.33^{bc}	65.66b^{cde}	38.86^{abc}	95.56^{abcd}
25%AM + 25% VC + 75% NPSZnB	34.66^{b}	62.00^{f}	40.03^{ab}	91.76^{cde}
25% VC + 25% EG + 75% NPSZnB	29.33^{c}	68.00^{b}	38.53^{abc}	97.53^{abc}
25%AM +25% VC +25%EG + 25% NPSZnB	31.67^{bc}	66.66^{bcd}	34.33^{ef}	97.96^{abc}
25%AM +25% VC +25%EG + 50% NPSZnB	30.66^{bc}	65.00^{cde}	38.40^{abc}	90.26^{edf}
25%AM +25% VC +25%EG + 75% NPSZnB	30.33^{bc}	65.00^{cde}	40.16^{a}	100.20^{a}
LSD(0.05)	4.58	2.81	2.82	7.10
CV (%)	8.61	2.57	5.22	4.55

Effect of Different Fertilizers Types and Rates on Yield Components and Yield of Teff

Number of total tiller and fertile tiller

The analysis of variance of this experiment showed that different types and rates of fertilizer had highly significant ($p<0.01$) effect on total tiller and fertile tiller (Appendix Table 2 and Table 6). The highest number of total and fertile tillers (5.66 and 5.66 per plant) were obtained with an application 25%AM +25% VC +25%EG + 75% NPSZnB; while the lowest number of total and fertile tillers (1.66 and 1.33 per plant) were obtained from 50% EG + 50% NPSZnB and 50% EG + 50% NPSZnB as well as on NPSZnB (Recommended level), respectively. The possible reason for increment in number of total tillers and fertile tiller might be due to the effect of balanced fertilizer rate in which readily soluble minerals help to the vegetative growth and branching of this crop. The total number of tillers formed is a major factor that affects grain yield in Teff.

This result is in agreement with that of Tekulu *et al*. (2019), who reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) brought significant increase in total tillers (15 tillers per plant) of teff as compared to 5 tillers per plant of unfertilized plot. In agreement with this result, Fayera *et al*. (2014) reported that tillering capacity of the variety determines number of tillers produced per plant, the highest (10.10) total number of tillers was recorded with application of 150 kg NPSZnB ha^{-1} blended fertilizer rate and the lowest (2.43) total number of tillers was recorded from plots without application of fertilizer. Similarly, this result is in agreement with that of Fenta (2017) who reported that application of blended fertilizer (69 kg N ha-1+ 46 kg P_2O_5+ 22 kg S ha-1+ 0.3 kg Zn ha^{-1}) brought significant increase in total tillers (15) of Teff as compared to (5) tillers per plant of unfertilized.

Thousand Seed weight

The analysis of variance of this experiment showed that different types and rates of fertilizer had highly significant ($p<0.01$) effect on thousand seed weight (Appendix Table 2 and Table 6). The highest thousand seed weight of teff (0.31g) was obtained from the treatment that received from 25%AM +25% VC +25%EG + 75% NPSZnB and 25%AM + 25% EG + 75% NPSZnB ; while the lowest thousand seed weight (0.216g) of teff was obtained on unfertilized treatment. This is because integration of nutrition increases head diameter and 1000-seed weight (Renukadevi *et al*., 2003). Generally, the increase of thousand grain weight with applied of S+Zn+B blended fertilizer might be due to the positive effects of Zn and B on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth (Kohnaward *et al*., 2012).

Table 6. Number of total tiller, fertile tiller and thousand seed weight of teff as affected by different types and rates fertilizers

Treatments	TT(Number)	FT(Number)	TSW(gram)
Control (No fertilizer)	2.00gh	2.00fg	0.216i
EG (Recommended:,40 litha^{-1})	3.00efg	2.66def	0.266fhg
Animal Manure (Recommended level;10tha^{-1})	4.00bcde	3.33cde	0.286bcdef
VC (Recommended level; 4 tha^{-1})	3.66cde	3.66bcd	0.280cdefg
NPSZnB (Recommended level; 150 kgha^{-1})	2.00gh	1.33g	0.253h
50%AM + 50% NPSZnB	3.66cde	3.33cde	0.270efhg
50% EG + 50% NPSZnB	1.66h	1.33g	0.300abc
50% VC + 50% NPSZnB	3.33def	3.33cde	0.260gh
50%AM + 50% EG + 50% NPSZnB	3.00efg	2.33efg	0.250h
50%AM + 50% VC + 50% NPSZnB	3.00efg	3.00cdef	0.263gh
50% VC + 50% EG + 50% NPSZnB	2.33fgh	2.33efg	0.290abcd
25%AM + 25% EG + 75% NPSZnB	5.00ab	4.00bc	0.310a
25%AM + 25% VC + 75% NPSZnB	4.00bcde	3.66bcd	0.290abcd
25% VC + 25% EG + 75% NPSZnB	4.00bcde	4.00bc	0.270defg
25%AM +25% VC +25%EG + 25% NPSZnB	4.33bcd	3.66bcd	0.306ab
25%AM +25% VC +25%EG + 50% NPSZnB	4.66abc	4.66ab	0.300abc
25%AM +25% VC +25%EG + 75% NPSZnB	5.66a	5.66a	0.310a
LSD(0.05)	1.11	1.23	0.022
CV (%)	19.24	23.18	4.77

Above ground biomass yield

The analysis of variance showed that different type and rate of fertilizer had highly significant effect ($p<0.01$) on above ground biomass yield (Appendix Table 3 and Table 7). The highest above ground biomass yield teff (11416.70 kg ha^{-1}) was recorded from 25%AM +25% VC +25%EG + 75% NPSZnB applied plot; while the lowest above ground biomass yield of teff (4556.5 kg ha^{-1}) was recorded from unfertilized treatment. The increased in aboveground dry biomass at combination of fertilizer might have resulted from improved root growth and increased uptake of nutrients favoring better growth of the crop due to the synergetic effect of the different type and rates. 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. Similarly, Teshome *et al*. (2019) and Wakjira (2018) suggested that aboveground dry biomass yield was significantly increased by enhancing the application of blended fertilizer because of better crop nutrition via applied blended micronutrients with macronutrients, which is result in nicely enhancing crop's vegetative growth. In conformity with Chala (2020) who reported that the highest above ground mass (8535 kg ha^{-1}) was recorded from full dose of recommended rate of nitrogen and phosphorus, while the lowest (2505 kg ha^{-1})) was obtained from negative control treatments.

Grain yield

The analysis of the variance indicated that different types and rates of fertilizers had highly significant effect ($p<0.01$) on grain yield of teff (Appendix Table 3 and Table 7). Therefore, the highest grain yield (2281.00kgha^{-1}) was obtained from the plot treated with 25%AM +25% VC +25%EG + 75% NPSZnB; while, the lowest (354.00 kgha^{-1}) grain yield was obtained from unfertilized plot. The higher Teff yield obtained might be due to the synergic effect of optimum level of nutrient and improved variety of Teff. These might have increased nutrients availability, photosynthesis, and greater mobilization of photosynthesis towards reproductive structures of improved variety, which contributed to respond and produce higher yields than unfertilized plots. The increase in grain yield due to interaction effects at this rate could be attributed to the positive effects of different types and rates of fertilizer in increasing the efficiency of synthetic fertilizer by preventing losses of nutrients and releasing of the nutrients within the growing period.

In conformity with Kinfe (2019) reported that the highest grain yield of teff (2269.80 kg ha^{-1}) was obtained from plots treated with 150 kg NPS ha^{-1} plus basal application of Zinc and Boron which increased over the control by 321.42% and lowest (538.60 kg ha^{-1}) was found from control plot. Likewise, Teshome (2018) reported that application of 100 kg NPSZnB ha^{-1} fertilizer produced the highest (1386.5 kg ha^{-1}) grain yield of Teff, while the lowest (1085.8 kg ha^{-1}) grain yield was obtained under the control treatment. The result also in line with Chala (2020) who reported that the highest grain yield (2042.6 kg ha^{-1}) was recorded from

25% compost +75% recommended rate of nitrogen and phosphorus, while the lowest grain yield (746.77 kg ha^{-1})) was recorded from recommended rate of compost.

Straw yield

The analysis of the variance indicated that different types and rates of fertilizer had highly significant effect ($p<0.01$) on straw yield of teff (Appendix Table 3 and Table 7). The highest straw yield (9135.7 $kgha^{-1}$) was obtained from the plot that received 25%AM +25% VC +25%EG + 75% NPSZnB; while, the lowest straw yield (3738.00$kgha^{-1}$) was obtained from recommended rate of NPSZnB plot. The increment of straw yield could be due to the vegetative growth as the result of high N-level from combination of blended inorganic fertilizer and organic fertilizer and the synergic effect with improved variety. The highest plant height and tillers also have great contribution to higher straw yield. Low straw yield plots might have been due to reduced leaf area development resulting in reduced radiation interception and, consequently, low efficiency in the conversion of solar radiation. This implies that integration of different fertilizer type and rates supply good sources of essential nutrient of N and P which leads better straw growth of teff. Tewolde *et al*. (2020) also indicated that application of S enhanced the photosynthetic assimilation of N in crops. Likewise, Fayera *et al*. (2014), who reported that the highest (5852.8 kg ha^{-1}) straw yield of Teff was obtained in response to the application of higher rates 200 kg NPSZnB $ha^{-1}$of blended fertilizer application. Straw yield of Teff has to be considered while evaluation of any agronomic practice as its importance has become as equal as its grain yield as it is preferred as animal feed during dry period and also sold at reasonable price.

Table 7. Mean of total biomass yield (TBY), grain yield (GY) and straw yield (SY) of teff as affected by the different types and rates of fertilizer

Treatments	TBY($kgha^{-1}$)	GY ($kgha^{-1}$)	SY ($kgha^{-1}$)
Control (No fertilizer)	4556.5^{i}	354.00^{i}	4202.50^{fgh}
EG (Recommended:,40 $litha^{-1}$)	6000.00^{gh}	1661.70^{de}	4481.00^{efgh}
Animal Manure (Recommended level;10tha^{-1})	7662.40^{de}	1594.30^{def}	6068.10^{cd}
VC (Recommended level; 4 tha^{-1})	6917.30efg	1414.70ef	5502.70^{de}
NPSZnB (Recommended level; 150 $kgha^{-1}$)	4498.10^{i}	760.00^{h}	3738.1^{h}
50%AM + 50% NPSZnB	6689.10^{efg}	1793.00^{cde}	4896.1^{efg}
50% EG + 50% NPSZnB	5057.80^{hi}	922.30^{gh}	4135.5^{fgh}
50% VC + 50% NPSZnB	6010.30^{gh}	1250.00^{fg}	4760.3^{efgh}
50%AM + 50% EG + 50% NPSZnB	4864.30^{i}	960.00^{gh}	3904.3^{gh}
50%AM + 50% VC + 50% NPSZnB	7148.30^{ef}	1950.00^{bcd}	5198.3^{def}
50% VC + 50% EG + 50% NPSZnB	6130.30^{fgh}	1215.00^{fg}	4915.3^{efg}
25%AM + 25% EG + 75% NPSZnB	9457.00^{b}	2443.00^{a}	7014.0^{bc}
25%AM + 25% VC + 75% NPSZnB	8785.00^{bc}	2148.70^{abc}	6636.3^{bc}
25% VC + 25% EG + 75% NPSZnB	9542.30^{b}	2202.00^{ab}	7340.3^{b}
25%AM +25% VC +25%EG + 25% NPSZnB	8278.60^{cd}	1661.70^{de}	6616.9^{bc}
25%AM +25% VC +25%EG + 50% NPSZnB	9245.70^{bc}	2214.00^{ab}	7031.7^{bc}
25%AM +25% VC +25%EG + 75% NPSZnB	11416.70^{a}	2281.00^{ab}	9135.7^{a}
LSD(0.05)	1079.70	393.49	1076.6
CV (%)	9.05	15.10	11.54

Lodging index

The analysis of the variance indicated that different types and rates of fertilizers had highly significant effect ($p<0.01$) on lodging index of teff (Appendix Table 4 and Table 8). The highest lodging (75.00%) was recorded from the treatment that received 50%AM + 50% EG + 50% NPSZnB; while the lowest lodging (0.00%) from unfertilized and 50% EG + 50% NPSZnB. This could be due to the profound effect of high N supply on increasing vegetative growth thereby leading to bending of the weak stem of the plant due to the sheer load of the canopy. These results therefore, revealed that increasing the rate of N within the blended fertilizer leads to the detrimental effect of crop losses due to lodging. . This result is consistent with the suggestion of Kinfe (2019) who reported that excess N application causes high vegetative growth, and enlargement of stem cells that consequently leads to weak stem and lodging. Likewise, Teshome, who reported highest lodging of Teff (38.92%) at 150 kg ha^{-1} of blended fertilizer rates. Similarly, Fayera *et al*. (2014) reported that the highest (79.74%) lodging percentage of Teff was recorded in the highest rate of NPK application though the rate reported earlier is much higher (138 kg N/ha+55 kg Pha^{-1}) than the present result.

Harvest index

The analysis of variance showed that different types and rates of fertilizer had highly significant effect ($p<0.01$) on harvest index (Appendix Table 3 and Table 8). The highest harvest index (25.83%) was recorded from treatment that got recommended Eco-green; while the lowest (8.71%) was recorded from unfertilized treatment. The increase in harvest index with increasing rates of both organic and inorganic fertilizer could be due to the fact that organic and inorganic 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, by Tekle and Wassie (2018) who reported that harvest index of Teff was found to be highest in blended fertilizer treatments. Also in agreement with the result by, reported by Lawrence *et al*. (2008) that harvest index in maize increased when N rate increased. The result also in line with Chala (2020) who reported that the highest (32.6%) and lowest (23.3%) harvest index was obtained from control treatments and recommended nitrogen and phosphorus respectively.

Table 8. Mean of total loading index (LI) and harvest index (HI) of teff as affected by the different types and rates of fertilizer

Treatments	LI (%)	HI (%)
Control (No fertilizer)	0.00^{e}	8.707^{g}
EG (Recommended:,40 litha^{-1})	25.00^{cd}	25.83^{ab}
Animal Manure (Recommended level;10tha^{-1})	41.667^{bc}	24.02^{abcd}
VC (Recommended level; 4 tha^{-1})	41.667^{bc}	21.01^{bcdef}
NPSZnB (Recommended level; 150 kgha^{-1})	16.667^{de}	16.42^{f}
50%AM + 50% NPSZnB	41.667^{bc}	25.99^{ab}
50% EG + 50% NPSZnB	0.00^{e}	18.24^{ef}
50% VC + 50% NPSZnB	25.00^{cd}	20.19^{cdef}
50%AM + 50% EG + 50% NPSZnB	75.00^{a}	19.05^{def}
50%AM + 50% VC + 50% NPSZnB	50.00^{b}	26.89^{a}
50% VC + 50% EG + 50% NPSZnB	25.00^{cd}	20.66^{bcdef}
25%AM + 25% EG + 75% NPSZnB	41.66^{bc}	27.72^{a}
25%AM + 25% VC + 75% NPSZnB	50.00^{b}	24.17^{abcd}
25% VC + 25% EG + 75% NPSZnB	50.00^{b}	23.04^{abcde}
25%AM +25% VC +25%EG + 25% NPSZnB	41.667^{bc}	20.06^{cdef}
25%AM +25% VC +25%EG + 50% NPSZnB	25.00^{cd}	25.08^{abc}
25%AM +25% VC +25%EG + 75% NPSZnB	25.00^{cd}	20.37^{cdef}
LSD(0.05)	17.43	5.3312
CV (%)	31.04	14.86

Partial Budget Analysis

As indicated in table 9, the highest net benefit (245683.82 Birr ha^{-1}) with better marginal rate of return (3481.10%) was obtained from the treatment that received 25%AM +25% VC +25%EG + 75% NPSZnB. However, the lowest net benefit was obtained from the control (47785.20). Thus, 25%AM+25% VC+25%EG+75% NPSZnB combination where economical beneficial as compared to other treatment in study area due to highest net benefit with marginal rate of return was above the minimum above level (100%).

Table 9. Summary of partial budget analysis of teff production due to application to different types and rates of fertilizers

Treatments	Adjusted grain yield (Kg ha^{-1})	Adjusted straw yield (Kg ha^{-1})	Total revenue (ETBha^{-1})	Total variable cost (ETBha^{-1})	Net benefit (ETB ha^{-1})	Marginal rate of return (%)
Control	318.60	3782.25	50335.20	2550.00	47785.20	0.00
EG (Recommended)	1495.53	4032.90	192368.88	4950.00	187418.88	5818.10
50% EG + 50% NPSZnB	830.07	3721.95	111518.64	7500.00	104018.64	D
NPSZnB (Recommended level)	684.00	3364.29	92845.73	10050.00	82795.73	D
25%AM + 25% EG + 75% NPSZnB	1954.40	5611.20	252483.84	12575.00	239908.84	6222.30
50%AM + 50% NPSZnB	1613.70	4406.49	207744.77	13300.00	194444.77	D
50%AM + 50% EG + 50% NPSZnB	864.00	3513.87	114924.38	14500.00	100424.38	D
AM (Recommended level)	1434.87	5461.29	189660.53	16550.00	173110.53	3545.70
25%AM +25% VC +25%EG + 25% NPSZnB	1495.53	5955.21	198520.27	23225.00	175295.27	32.73
25% VC + 25% EG + 75% NPSZnB	1981.80	6606.27	258956.06	23475.00	235481.06	24074
25%AM +25% VC +25%EG + 50% NPSZnB	1992.60	6328.53	259363.30	25100.00	234263.30	D
25%AM + 25% VC + 75% NPSZnB	1933.83	5972.67	251172.14	26375.00	224797.14	D
25%AM +25% VC +25%EG + 75% NPSZnB	2052.90	8222.13	272658.82	26975.00	245683.82	3481.10
50% VC + 50% NPSZnB	1125.00	4284.27	148709.66	36300.00	112409.66	D
50% VC + 50% EG + 50% NPSZnB	1093.50	4423.77	145376.06	37450.00	107926.06	D
50%AM + 50% VC + 50% NPSZnB	1755.00	4678.47	225571.10	43300.00	182271.10	1270.9
VC (Recommended level)	1273.23	4952.43	168635.38	62550.00	106085.38	D

Where, D = Dominated treatments; ETB ha^{-1} = Ethiopian Birr per hectare; Market price of teff = 120 ETB kg^{-1}; Market price of straw = 3.2 ETB kg^{-1}; Cost of blended NPSZnB fertilizer =50 birr per 1 kg; cost of Animal manure 10 birr per 1kg; Cost of vermicomost 17 birr per kg Eco green price 60 birr per liter; Cost of labor=150 per kg.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary and Conclusion

Teff is one of the most important cereal crops and predominant staple food in Ethiopia. However, its productivity is constrained by a number of problems like lack of appropriate management practices, low soil fertility, lack of combined application of fertilizer and lack of improved varieties are crucial in Ethiopia in general, and in the study area in particular. The field experiment was conducted during main rainy season of 2023 at Melkassa Agricultural Research site with the objective of evaluating the response of teff to different fertilizers rates and types. The experiment was consisted of seventeen treatments with different combinations of organic and inorganic fertilizers and laid out by randomized complete design in three replications.

Analysis of variance revealed that all parameters of phonological and yield and yield components of teff significantly affected by the applied fertilizers combinations. The earliest days to 50 % panicle emergence (29.33 days) was recorded from the plot applied with the recommended vermicompost and the shortest days to physiological maturity (62.00 days) recorded from the plot received 25%AM + 25% VC + 75% NPSZnB. The highest plant height (100.20 cm) and the longest panicle length (40.16 cm) was recorded from the plot received 25%AM +25% VC +25%EG + 75% NPSZnB combination of fertilizers. The highest total tiller (5.66), fertile tiller (5.66) as well as thousand grain weight (0.31g) was recorded from the plot received 25%AM +25% VC +25%EG + 75% NPSZnB combination. The highest above ground biomass (11416.70kg), grain yield (2281.00 kg) as well as straw yield (9135.70 kg) was obtained from the plot received 25%AM +25% VC +25%EG + 75% NPSZnB. The highest loading index (75%) and harvest index (25.99) was obtained the plot received 50%AM + 50% EG + 50% NPSZnB and 50%AM + 50% EG + 50% NPSZnB, respectively.

Among the treatment combinations 25%AM +25% VC +25%EG + 75% NPSZnB is the best treatment for teff production in the study area. The partial budget analysis also revealed that the combination of 25%AM +25% VC +25%EG + 75% NPSZnB has produced better economic benefit (226,809.00Birr ha^{-1}) with better marginal rate of return (3481.10%). So, it can be concluded that the combination of 25%AM +25% VC +25%EG + 75% NPSZnB is the better way of combination for teff production. Hence, combined or multiple use of chemical fertilizer and locally available organic fertilizer application is the best approach for, maximum yield and economic return of input than the sole application of either of the input types.

Recommendations

For teff production in Ethiopia, increasing teff yield with acceptable grain yield from different fertilizer types and rates for future. Among different combination of fertilizer rates and types, 25%AM +25% VC +25%EG + 75% NPSZnB is recommended for Boni teff variety for study area. This types and rates also can be used as a point of reference for additional study. Moreover emphasis is should be given to such combinations since the experiment has been done only for one season and one location. Repeating the experiment at different sites and seasons would be the most crucial for sound able recommendation.

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