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Effect of Organic and Inorganic Fertilizers on Growth and Yield of Tef (*Eragrostis tef*) in the Central Highlands of Ethiopia

Girma Chala[1] and Gebreyes Gurmu[2]
[1]*Ethiopian Institute of Agricultural Research, Holetta Research Center chalagirma4@gmail.com*
[2]*Ethiopian Institute of Agricultural Research, Addis Abeba gebreyes2004@yahoo.com*

አህፅርኦት

ይህ የመስክ ላይ ሙከራ በኦሮሚያ ክልል ደንዲ ወረዳ በአርሶ አደር ማሳዎች ላይ ለሁለት ተከታታይ ዓመታት (ከ2006 – 2007 ዓ.ም) የተከናወነ ሲሆን ዋና አላማዉም የተፈጥሮ እና ሰዉ ሰራሽ ማዳበሪያዎችን በጤፍ ዕድገትና ምርት እንዲሁም የአፈር ኬሚካላዊ ባህሪ ላይ ያላቸዉን ተጽዕኖ መገምገም ነበር፡፡ ይህንንም ለማጥናት የፍግ፣ ቨርሚኮምፖስት፣ ኮምፖስት፣ ዩሪያ፣ ዳፕና የነሱን ቅልቅሎች በRCBD ዲዛይንና በሦስት ድግግሞሽ ተሞክሯል፡፡ ዉጤቱ እንደሚያሳየዉ የጤፍ ምርት እና የአፈር ኬሚካላዊ ባህርይ በተፈጥሮና ሰዉ ሰራሽ ማዳበሪያ መጠቀም አመርቂ ለዉጥ አሳይቷል፡፡ በመሆኑም 4.8 ቶን ቨርሚኮምፖስት እና 34.5 ኪ.ግ ናይትሮጅን እንዲሁም 30 ኪ.ግ ፎስፌት በሄ/ር በመጠቀም 3144.8 ኪ.ግ የጤፍ ምርት እና 12562.5 ኪ.ግ ገላባ በሄ/ር ተገኝቷል፡፡ በመቀጠልም 69 ኪ.ግ ናይትሮጅን እና 60 ኪ.ግ ፎስፌት በመጠቀም 2846 ኪ.ግ የጤፍ ምርት እና 11833.3 ኪ.ግ የገላባ ምርት በሄክታር ተገኝቷል፡፡ በሌላ በኩል የተፈጥሮ ማዳበሪያዎችን በመጠቀም የአፈር ካርቦናዊ ቁስ ይዘት፣ የጠቅላላ የናይትሮጅን ይዘት፣ የፎስፈረስ እንዲሁም የአፈር pH ይዘቱ የተወሰነ ለውጥ ሊያሳይ ችሏል፡፡ ይህ በእንዲህ እንዳለ 3.2 ቶን በሄ/ር ቨርሚኮምፖስት፣ 2.37 ቶን በሄክታር ኮምፖስት እና 1.37 ቶን በሄ/ር ፍግ አደባልቆ መጠቀም ከፍተኛ የሆነ ትርፍ ያለዉና አዋጭ የማዳበሪያ አጠቃቀም መሆኑ ተረጋግጧል፡፡

Abstract

A field experiment was conducted for two consecutive cropping seasons (2013-2014) on farmers' fields in Dendi district of Oromiya Regional State. The objective of this study was to evaluate the effect of organic and inorganic fertilizers on growth and yield of tef and soil chemical properties. The treatments included eleven selected combinations of organic and inorganic nutrient sources (Farm yard manure, vermicompost, Compost, Nitrogen and Phosphorus). The design was randomized complete block with three replications. Results showed that tef yield, some yield components and soil chemical properties are significantly affected by the application of organic and inorganic fertilizer sources. The highest tef grain yield (3144.8kg ha^{-1}) and biomass yield (12562.5kg ha^{-1}) were obtained from the applications of half doses of vermicompost (4.8t ha^{-1}) which is based on recommended N equivalent and half doses of the recommended nitrogen and phosphorus fertilizers (34.5kg ha^{-1}N and 30kg ha^{-1}P that half dose contains) followed by 2846 kg $ha^{-1}$and 11833.3 kg $ha^{-1}$for grain yield and biomass yield, respectively, due to the application of the full recommended N and Prates (69kgN $ha^{-1}$and 60kg P ha^{-1}). Application of the different organic fertilizers improves the organic matter, Total N, available P and pH of the soil in the study area. The result also showed that the highest marginal rate of return was obtained from application of 3.2t ha^{-1}vermicompost + 2.37t ha^{-1} conventional compost + 1.37t ha^{-1} farmyard manure (based on equivalent N rate, which is economically the most feasible alternative on vertisols of central Ethiopian highlands.

Introduction

In Ethiopia, century-long, low-input agricultural production systems and poor agronomic management practices, limited awareness of communities and absence of proper land-use policies have aggravated soil fertility degradation. This has also led to farming marginal lands, including steep landscapes and range lands. In sustainable agricultural system, integrated soil fertility management is an approach that attempts to make the best use of inherent soil nutrient stocks, locally available soil amendments and mineral fertilizers to increase land productivity while, maintaining or enhancing soil fertility. Integrated soil fertility management strategies include the combined use of soil amendments, organic materials and mineral fertilizers to replenish soil nutrient pools and improve the efficiency of external inputs (Lee, 2005).

Rong *et al*., (2001) reported that combined application of organic and inorganic fertilizers decreased soil bulk density, increased soil moisture, soil fertility, and improved maize grain quality. It is also a fact that organic fertilizers increase yields of crops significantly over inorganic fertilizers mainly because these materials decompose, and hence release nutrients gradually over the crop growth period and they also build up organic carbon content essential for maintaining soil structure and the water holding capacity of the soil.

The use of organic matter such as animal manures, human waste, food wastes, backyard wastes, sewage sludge and composts has long been recognized in agriculture as beneficial source for plant nutrients and thereby improving, yield of crops. Traditional composting of organic wastes has been known for many years but new methods of thermophilic composting have become much more popular since it eliminates some detrimental effects of organic wastes in the soil and it is also cost effective and environmentally sound process for treatment of many organic wastes (Hoitink and Keener, 1993). When the composting process is assisted by the presence of the earthworms in the compost heap, it is named vermicomposting. It is a non-thermophilic process by which organic materials are converted by earthworms and micro-organisms into rich soil amendments with greatly increased microbial activity and nutrient availability.

According to Arancon and Edwards (2005), the use of vermicomposts in different locations in Tigray region doubled the yield of several crops as compared to the unfertilized check. The use of vermicompost also gave higher yields than the yields obtained from conventional compost and from chemical fertilizer application. In contrast, Bationo *et al.,* (1993) found that the use of mineral fertilizers without recycling of organic materials resulted in higher yields, but this increase was not sustainable without the inclusion of organic soil amendments. This indicates that the use of organic soil inputs in any form (FYM, conventional compost and vermicompost) is very important. However, our small-scale farmers lack the information on the rate, quality, and of course alternate sources of these fertilizers.

Then again, the most common chemical fertilizers used in Ethiopia are diammonium phosphate (DAP) and urea. Chemical fertilizers are also becoming very costly for farmers to apply the full recommended rates. On the other hand, sole application of organic matter is constrained by access to sufficient organic inputs, low nutrient content, high labor demand for preparation and transporting. Thus, the integration of organic and inorganic sources can improve and sustain crop yields without degrading soil fertility status. In this regard, integrated use of N and P and FYM are better than application of either N and P or FYM alone for maize production (Wakene et al., 2004). Similarly, Tolessa (1999a) indicated that application of FYM every three years at the rate of 16 t ha^{-1} supplemented by N and P fertilizer annually at the rate of 20-46 kg N-P_2O_5 ha^{-1} was recommended for sustainable maize production around Bako area. The integrated use of 4.53 t ha^{-1} FYM and 37 kg N ha^{-1} were recommended for tef production on Vertisols of central highlands (Teklu and Hailemariam, 2009). The integrated use of 5 t ha^{-1} of compost either with 55/10 or 25/11 kg of N/P ha^{-1} is economical for maize production in Bako Tibe district. In another study conducted at Hawassa, Southern Ethiopia, the integrated use of coffee byproducts and N fertilizer increased N uptake and grain yield of haricot bean and maize. Coffee residue along with N fertilizer positively influenced soil moisture, soil nitrogen and organic matter, grain and water use efficiency of maize (Tenaw, 2006). Integrated use of 23/20 kg N/P ha-1 with 20 t FYM ha^{-1} or 46/40 kg N /P ha^{-1} with 10 t FYM ha^{-1} are recommended for wheat around Hagerselam, and barley and potato producers around Chencha. The integrated use of 5 tons ha-1 of compost either with 55/10 or 25/11 kg of N/P ha^{-1} is economical for maize production in Bako Tibe districts. Applications of the full-recommended doses of NP fertilizers integrated with five ton per hectare crop residue are advised to improve the fertility of these soils for sustainable maize production in Haramaya area. According to Balesh *et al.* (2007), tef was most responsive to FYM and compost on Vertisols and Nitisols. This experiment was therefore, carried out with objective of determining the effect of farmyard manure, compost, vermicompost, and N and P fertilizers and their combinations on the yield and yield components of tef.

Materials and Method

Experimental Site

The trial was conducted at Ginchi, West Shewa Zone of Oromiya Regional State for two consecutive cropping seasons (2013 and 2014). Geographically, the experimental site is located at 09^0 02'N and 38^0 12'E and an altitude of 2200 masl at a road distance of about 74 km West of Addis Ababa. The area is characterized by a unimodal rainfall pattern and receives an average annual rainfall of 1080 mm, about 85% of which is received from June to September (Figure 1). The annual average minimum and maximum air temperatures are 9 and 24°C, respectively (Getachew and Amare, 2004). Vertisols, which are known for their high water-logging problem, are the dominant soil type at Ginchi area. The crops widely grown in the study area include wheat and tef, whereas chickpea, grasspea and others have low area coverage and mostly grow on residual soil moisture at the end of the rainy season. Tef variety (Kuncho) was used as test crop in the experiment. The rates of organic fertilizers applied were based on the recommended N equivalent rate for the test crop.

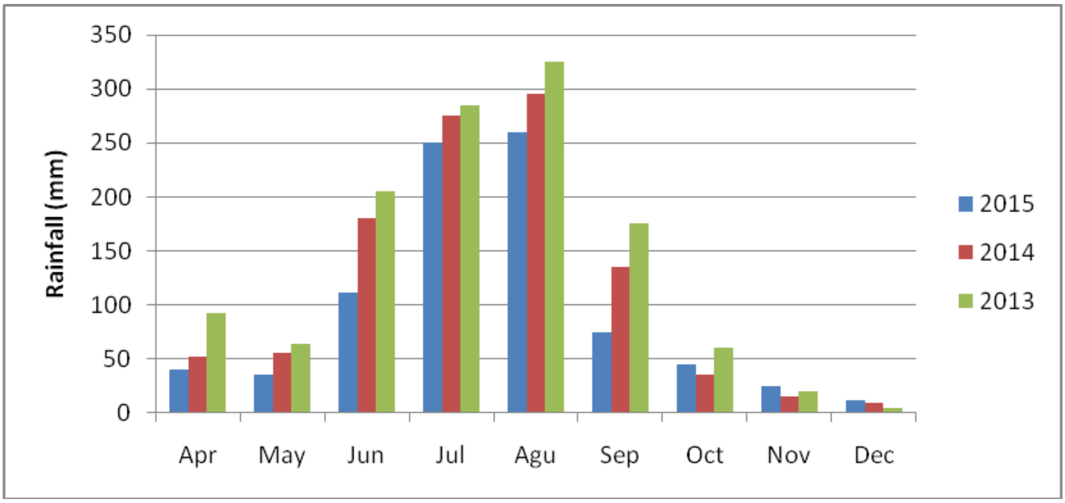

Figure 1: Monthly total rainfall for 2013, 2014 and 2015 cropping season at Holeta and around the trial sites.

Treatments

1. Control-without fertilizer
2. Recommended rate of NP (69 N kg/ha and 60 P kg/ha)
3. Compost (7.1t/ha)
4. Farmyard manure (FYM) 4.1t/ha
5. Vermicompost (9.6 t/ha)
6. Vermicompost (50% of treatment 5) + Compost (50% of treatment 3)
7. Vermicompost (50% of treatment 5) + FYM (50% of treatment 4)
8. Vermicompost (33% of treatment 5) + Compost (33% of treatment 3) + FYM (33% of treatment 4)
9. Vermicompost (50% of treatment 5) + Recommended N and P (50% of treatment 2)
10. Compost (50% of treatment 3) + Recommended N and P (50% of treatment 2)
11. FYM (50% of treatment 4) + Recommended NP (50% of treatment 2)

The above mentioned treatment combinations were laid down in randomized complete block design with three replications. Compost was prepared following the standard procedure for compost preparation (Getachew et al., 2012). Similarly, vermicompost were produced by using earth worms and the same inputs i.e cattle manure and straw as bedding for the vermicomposting and bulking in the composting process. Samples were collected from well decomposed farmyard manure, compost and vermicompost before they are applied to the field. Then their N and P contents were analyzed in the laboratory using standard procedure to determine the rate of application of each treatment, which was based on recommended N equivalent rate for the test crop. The contents of N and P before application in the analyzed samples were 0.86% N and 1.72% P for vermicompost, 0.97% N and 0.43% P for conventional compost both on 55% dry weight basis and 1.67% N and 0.67% P for farm yard manure on 50% dry weight basis. Manure and compost were applied to the field three weeks before sowing and thoroughly mixed in the upper 15 to 20 cm soil depth. Nitrogen and P fertilizers were applied in the form of Urea and DAP respectively. To minimize the loss and increase its efficiency34.5 kg ha^{-1}half rate of N was applied as split at planting and the remaining half 34.5 kg ha^{-1}at tillering stage of the crop whereas all Prate was applied as basal application during planting time. The seed was drilled at the recommended seed rate of 12 kg ha^{-1}in row on 18th and 21st July of 2013 and 2014 respectively. All recommended agronomic management practices were carried out during the crop growth period as per needed.

Data collection and analysis

Composite surface soil samples were collected from experimental fields (0-20 cm depth) before treatment application. Similarly, samples were collected after harvest from each plot and then composited by replication to obtain one representative sample per treatment. Samples collected during both times were then analyzed for the determinations of soil pH, total organic carbon (OC), total N, available P. Soil pH was measured in H_2O with 1:2.5 soil: water ratio. Organic carbon was determined according to Walkley and Black method and total nitrogen using Kjeldahl method. Available P was determined using the Bray- II method. Exchangeable cations and CEC were also analyzed using ammonium acetate method.

Plant parameters collected were grain yield, above ground total biomass, plant height and panicle length (average of 5 plants). Mature plan height was measured from the ground level to the tip of panicle at physiological maturity. Grain yield was adjusted to a moisture content of 12.5% before proceeding to statistical analysis. The agronomic data were subjected to analysis of variance (GLM procedure) using SAS statistical computer package (SAS, 2002). The total variability for each trait was quantified using separate and pooled analysis of variance over years using the following model (Gomez and Gomez, 1984).

$$Pijk = \mu + Yi + Rj(i) + Tk + Ty(ik) + eijk$$

Where pijk is total observation, μ = grand mean, yi= effect of the i^{th} year, Rj(i) is effect of the j^{th} replication (with in the i^{th} year), Tk is effect of the K^{th} treatment with i^{th} year TY(ik) is the interaction of k^{th} treatment with i^{th} year and eijk is the random error. Duncan multiples range test (DMRT) test at 5% probability level was used to detect differences among means and linear regression was performed between grain yield and some relevant component parameters.

Results and Discussion

Effects of fertilization on soil chemical properties

Soil chemical properties such as pH, organic carbon (OC), N and P measured for samples taken after harvesting were significantly ($P<0.05$) affected by the application of different rate of organic and inorganic fertilizers The result indicated relatively higher pH levels, OM and nutrient concentrations for plots treated with manure, conventional compost and vermicompost (Table 1). The highest pH value 6.54 and 6.53 were recorded from full doses of farm yard manure and conventional compost respectively .The average soil pH of the experimental field after harvest was found to be 6.40, which is nearest to neutral. The lowest soil pH (6.3) was recorded from the plot which received recommended N and

P. Similarly, Ano and Ubochi (2007) reported that application of animal manure and compost increased soil pH.

Though the values of OC were generally rated as medium(Jones, 2003), the highest OC, 3.42% and 3.39% were recorded from plots treated with full doses of farm yard manure and compost respectively and the least (2.83%) was from the plot which received recommended N and P (Table 1). Likewise, the total N and available P determined after harvesting is rated high (Tekalign, 1991). As mentioned above for OC, the highest soil total N (0.32% and 0.30%) were recorded from plots treated with full doses of farm yard manure and compost respectively. The lowest soil N content 0.22% was obtained from the plot which received recommended N and P as usual. Similarly, the highest soil available P (29.44 mg kg^{-1}) was recorded from plots treated with one-third of each nutrient source (manure + conventional compost + vermicompost). But, all plots which received fertilizer, either alone or in combination did not significantly differ one from the other.

The above findings are in line with the reports of Eghball *et al*. (2004) that the residual effects of manure and compost applications significantly increased electrical conductivity, pH levels and plant available P and NO_3-N concentrations where the lowest pH and nutrient content were observed on plots not treated with organic fertilizer. Sharma *et al*. (1990) also indicated that the use of organic fertilizer might have made the soil more porous and pulverized, to allow better root growth and development, thereby resulting in higher root cation exchange capacity (CEC). According to Vanlauwe *et al.* (2001) the direct interactions between chemical fertilizer and organic matter can improve soil fertility by restocking nutrients lost through leaching and by modifying the pH of the rhizosphere and making unavailable nutrients available. Generally, the above results indicate that integrated use of nutrient sources have significant improvement in the overall condition of the soil as well as agricultural productivity if best alternative option is adopted in the area.

Table 1: The effect of organic and inorganic fertilizer application on soil chemical properties analyzed for samples after harvest of the crops (2013 and 2014)

Treatments	pH(H_2O)	Nitrogen (%)	Phosphorous (mg kg^{-1})	OC (%)
Recom.NP(69/60)	6.3^{b}	0.23^{c}	26.48	2.83^{e}
Conventional Compost (CC)	6.53^{a}	0.30^{ab}	28.41	3.39^{ab}
Farmyard manure (FYM)	6.54^{a}	0.32^{a}	28.19	3.42^{a}
Vermi Compost (VC)	6.45^{ab}	0.28^{ab}	28.57	3.12^{bcd}
50% VC + 50% CC	6.4^{ab}	0.27^{b}	27.11	2.99^{cde}
50% VC + 50% FYM	6.42^{ab}	0.267^{bc}	28.75	3.02^{cde}
33% VC + 33% CC + 33% FYM	6.52^{a}	0.267^{bc}	29.44	3.06^{cde}
50% VC + 50% NP	6.41^{ab}	0.273^{b}	28.12	3.26^{abc}
50% CC + 50% NP	6.32^{b}	0.267^{bc}	24.44	2.9^{de}
50% FYM + 50% NP	6.48^{a}	0.267^{bc}	23.70	3.05^{cde}
Overall mean	6.40	0.245	26.14	3.03
DMRT(0.05)	0.147	0.043	NS	0.287
CV (%)	1.35	8.9	18.3	5.3

Means in a column with different letters are significantly different at $P<0.05$, NS= Not significant.

Effects of integrated nutrient application on tef yield and yield components

The combined analysis of variance over two years revealed that the effect of cropping season was highly significant (p<0.01) on panicle length and biomass yield of tef and significant (p<0.05) on grain yield. The highest mean grain yield, panicle length and biomass yield of tef were recorded during 2014 cropping season (Table 2) due to the fact that the plots were fixed during the study period and there was carry over effect of the application of the organic fertilizers in the previous year (2013). This study clearly indicated that productivity of tef was significantly affected by different treatment applied. Thus, applications of inorganic and organic nutrient sources either alone or in combination had a significant (p<0.05) effect on grain yield, biomass yield and panicle length of tef, but not on its plant height.

The highest tef grain and biomass yield (3144.8 kg ha^{-1} and 12562 kg ha^{-1} respectively) were obtained from the application of 50% VC and half the recommended rate of N and P followed by full dose of recommended rate of N and P from inorganic fertilizer resulting in 2846 kg ha^{-1} grain and 11833 kg ha^{-1} biomass yields respectively, where there is no significance differences between the two treatment effects. The application of 50% CC with 50% N and P has also given comparable grain and biomass yield as compared to application of full dose of N and P from inorganic fertilizer. The rest set of treatments had given inferior yields under all tested parameters where the lowest biomass yield was recorded from conventional compost and the lowest grain yield was from plot treated with vermicompost alone (Table 2).

Table 2: Effects of organic and inorganic fertilizers application on tef yield and yield components

Year	PHT(cm)	PL(cm)	BY($kgha^{-1}$)	GY($kgha^{-1}$)
2013	100.9	38.1^{b}	10780.3^{b}	1964.1^{b}
2014	101.1	40.55^{a}	17564.4^{a}	2435.9^{a}
F-Probability	NS	**	**	*
DMRT $_{0.05}$	2.86	1.09	758	152.29
Treatments				
Recommended NP	114.17	42^{a}	11833.3^{ab}	2846^{ab}
Conventional Compost (CC)	98.3	39.7^{abc}	7979.2^{d}	1941de
Farmyard manure (FYM)	92.67	38.3^{c}	8250^{d}	1920^{e}
Vermi-Compost (VC)	102.17	39.17^{bc}	9020^{cd}	1904.7^{e}
50% VC + 50% CC	101.5	40^{abc}	8500^{cd}	2027.3^{de}
50% VC + 50% FYM	103.17	40.5^{abc}	8750^{cd}	1933.5^{de}
33% VC + 33% CC + 33% FYM	100.83	39.17^{bc}	9145.8^{cd}	2293^{cd}
50% VC + 50% NP	111.5	41.17^{ab}	12562.5^{a}	3144.8^{a}
50% CC + 50% NP	108	41^{ab}	10208.3^{bc}	2516.7^{bc}
50% FYM + 50% NP	103.5	38.17^{c}	9687.5^{cd}	2420^{c}
DMRT $_{0.05}$	6.7	2.33**	1940.2**	368.02
Y x T	NS	**	**	*
CV (%)	5.12	5.6	16.6	13.9

**, **= significant at P< 0.05 and P< 0.001, respectively; NS= Not significant. Means in a column with the same letter are not significantly different (P<0.05).PHT= plant height; PL= panicle length; BY= biomass yield; GY= grain yield*

Therefore, the result of this study has clearly indicated that it is possible to fairly produce tef through integrated nutrient application approach, rather than applying nutrient from one source. In line with the current result, research findings of Tekalign *et al.* (2001), Ayalew (2011) and Getachew *et al.* (2012) indicated that tef has showed significance response to the integrated soil fertility management treatments containing both organic and inorganic forms under farmers' field condition that they could be considered as alternative options for sustainable soil and crop productivity in the degraded highlands of Ethiopia. Moreover, the crop has responded differently to application of N and P on different soil types. The observed simple linear correlation analysis indicated that grain yield was positively and highly significantly correlated with biomass yield (R^2 = 0.948***) (Figure 2).

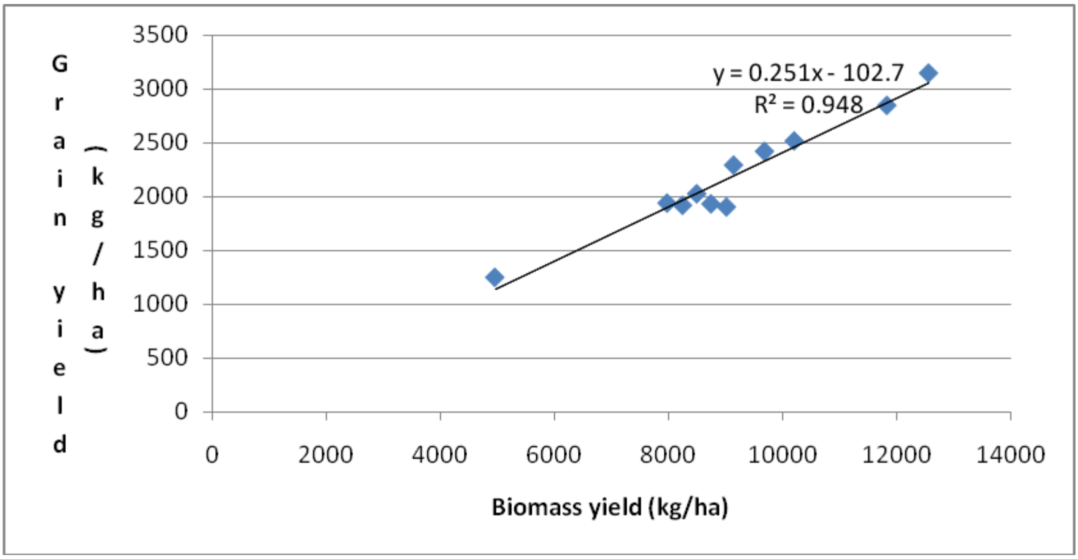

Figure 2: Correlation of tef grain yield with biomass yield

Economic analysis

As farmers attempt to evaluate the economic benefits of shift in practice, partial budget analysis was done to identify the rewarding treatments. Yield from on-farm experimental plots was adjusted downward by 15% i.e., 10% for management difference and 5% for plot size difference, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment (Getachew and Taye, 2005).

Three years average market grain price of tef (ETB 13.5kg^{-1}), farm-gate price of N and P fertilizers (ETB 12kg^{-1} and 15kg^{-1}) respectively and labour valued at ETB 40 per person-day were used. Labour for tef field management was 30 person- days per hectare. The result of the partial budget analysis is given in (Table 3). The economic analysis revealed that the highest net benefit of (birr 28588.9 ha^{-1}) was obtained from the application of 50% vermicompost plus 50% N and P fertilizers, where as the control treatment (no application of input) gave the lowest net benefit (birr 10778.9 ha^{-1}).

Table 3: Partial budget and dominance analyses of organic and inorganic fertilizers trial on tef

Treatments	Average yield (kg/ha)	Adjusted yield-15% (kg/ha)	Gross benefits (birr/ha)	Costs that vary (ETB ha^{-1}) Fertilizer	Labour	Total cost	Net benefit (birr/ha)	Dominated
Control	1253	1065.1	14378.9		3600	3600	10778.9	
Recom. N & P (69/60)	2846	2419.1	32657.9	4750	1850	6600	26057.9	
Conventional Compost (CC)	1941	1649.85	22272.9	-	4500	4500	17772.9	D
Farmyard manure (FYM)	1920	1632.00	22032	-	5100	5100	12832	D
Vermicompost (VC)	1905	1619.25	21859.9	-	4800	4800	17059.9	D
50% VC + 50% CC	2027	1722.95	23259.8	-	4650	4650	18609.8	
50% VC + 50% FYM	1934	1643.9	22192.7	-	4300	4300	17892.7	D
33% VC + 33% CC + 33% FYM	2293	1949.05	26312.2	-	5250	5250	21062.2	
50% VC + 50% NP	3145	2673.25	36088.9	3250	4250	7500	28588.9	
50% CC + 50% NP	2517	2139.45	28882.6	3250	4000	7250	21632.6	D
50% FYM + 50% NP	2420	2057	27769.5	3250	3500	6750	21019.5	D

Three years average price of tef is ETB 13.5/kg, Urea birr 12/kg and DAP birr 15/kg (1USD = 20.40 Ethiopia birr); D= Dominated

The economic analysis further revealed that the application of 33% of each of the nutrient sources used i.e. 3.2t ha^{-1} vermicompost + 2.37t ha^{-1} conventional compost and 1.37t ha^{-1} farmyard manure (based on recommended N equivalent rate) provided the highest marginal rate of the return (MRR) of 408.7% (Table 4) suggesting for each birr invested in tef production, the producer would collect birr 4.087 after recovering his cost. Since the MRR assumed in this study was 100%, the treatment with application of 33% of VC, CC and FYM gave an acceptable MRR. Therefore, the combined application each of these organic fertilizers (based on N equivalent rate) would be economical to be recommended on Vertisols of central highlands of Ethiopia.

Table 4: Marginal analysis of organic and inorganic fertilizer effects on tef at Ginchi, 2013 and 2014

Particulars	Control	Rec.NP	1/2VC+1/2 CC	1/3VC + 1/3 CC+ 1/3FYM	1/2 VC + 1/2 NP
Average yield(Kg ha^{-1})	1253	2846	2027	2293	3145
Adjusted yield-15%(Kg ha^{-1})	1065.1	2419.1	17222.95	1949.1	2673.25
Gross benefit(ETB ha^{-1})	14378.9	32657.9	23259.8	26312.2	36088.9
Cost of fertilizer(ETB ha^{-1})	0.00	4750	0.00	0.00	3250
Cost of labour(ETB ha^{-1})	3600	1850	4650	5250	4250
TCV (ETB ha^{-1})	3600	6600	4650	5250	7500
NB (ETB ha^{-1})	10778.9	26057.9	18609.8	21062.2	28588.9
MC (ETB ha^{-1})		550	550	600	900
MB(ETB ha^{-1})		4995.7	677.8	2452.4	2531
MRR (%)		370.1%	123.2%	408.7%	281.2%

Conclusion

The result of this experiment has showed that the two years result were significantly different from each other most probably attributed to season differences and the carry over effect of the previous year fertilizer application as the plots were fixed during the experimental period. Thus, the combined analysis indicated that integrated application of organic and inorganic fertilizer mix 50% VC (4.8 t ha^{-1}) and 50% recommended N and P rate (34.5 kg ha^{-1} N and 30 kg ha^{-1} P) have given the maximum grain and biomass yield of tef (3144 kg ha^{-1} and 12562 kg ha^{-1} respectively) followed by the full recommended N and P rate (2846 kg ha^{-1} and 11833 kg ha^{-1}). But, considering the economical feasibility of input use, the application of 33% of each of the organic fertilizers i.e. vermicompost, conventional compost and farmyard manure (based on N equivalent rate), has been found to be economical to be recommended on Vertisols of the study area and similar agro-ecologies. Moreover, the status of soil fertility has been improved where the OM is increased from 2.83% to 3.03%, TN from 0.23% to 0.25%, while P showing no significant difference. Therefore, integrated use of chemical fertilizer and locally available soil amendments is the best approach for achieving higher crop yields and economic feasibility. In order to address soil fertility problems, potential synergies can be gained by combining technical options with farmers' knowledge as well as training of farmers and development agents on integrated soil fertility management approaches.

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