

Effects of Compost and Inorganic NP Rates on Growth, Yield and Yield Components of Teff (*Eragrotis teff* (Zucc.) Trotter) in Girar Jarso District, Central Highland of Ethiopia

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Abstract

Teff is the major crop produced in study area whose productivity is being affected by low soil fertility and organic matter depletion. Hence, an experiment, having factorial combination of 0, 2.5, 5 and 7.5 t ha⁻¹ of compost and 0/0, 16/11.5, 32/23 and 64/46 kg ha⁻¹ of N/P₂O₅, was conducted in 2014/15 main cropping season to assess the effect of rates of compost and NP fertilizers on growth, yield and yield components of teff and to determine their economical rates. Treatments were laid out in RCBD in three replications. The results indicated that the main effect of compost rate significantly increased dry biomass and straw yield and decreased harvest index. Except on number of productive tillers, the main effect of NP fertilizer was significant on all the parameters measured. The shortest days to heading, highest; lodging percentage, plant height, panicle length and dry biomass were recorded at 64/46 kg ha⁻¹ of N/P₂O₅, all showing increasing trend with increasing NP. The highest grain and straw yield and net farm benefit were recorded at interaction of 64/46 N/P₂O₅ kg ha⁻¹ and 7.5 tons ha⁻¹ of compost. Generally, the study suggested that, the use full dose of nationally blanket recommended NP rate (64/48 kg of N/P₂O₅) with 7.5 tons ha⁻¹ of compost is likely combination to attain the optimum grain yield and profit and can be alternative approach for integrated soil fertility management measure instead of the sole application of inorganic fertilizers.

Keywords: Grain yield; Interaction effect; Partial budget analysis; Straw yield

Introduction

Cereals are an important dietary protein and energy source throughout the world [1]. Teff is grown as important cereal in Ethiopia [2]. It is national obsession and is grown by an estimated 6.3 million farmers [3]. It has also recently been receiving global attention particularly as a 'health food' due to the absence of gluten and gluten-like proteins in its grains [4].

Teff has significantly highest share in Ethiopian in area of production. It was reported that teff covered 22.23% of the total area under cereal production followed by maize (16.39%) in 2013 [5]. According to the same report, teff is also the major crop grown in North shoa (study area) covering more than 28% of the total area under grain production.

Teff performs well at an altitude of 1800-2100 m a s l, annual rainfall of 750-850 mm, growing seasons rainfall of 450-550 mm, and a temperature of 10°C-27°C although it can adapt wide range of agro-climatic conditions [6]. Moderately fertile clay and clay loam soils are ideal for teff. It can also withstand moderate water logged conditions [7].

Regardless of its wider adaptation, productivity of teff is low in the country with the national average grain yield of 1.379 tons ha⁻¹ [5]. This is mainly because of low soil fertility [8] and severe organic matter depletion [9] aggravated by low rate of chemical fertilizer application. The rate of chemical fertilizer application is low in the country due to unaffordable price for resource-poor smallholder farmers [10]. The continued use of chemical fertilizers is also not recommendable as it causes for health and environmental hazards such as ground and surface water pollution by nitrate leaching [11].

One of the possible options to make use of low rate of chemical fertilizer application without nutrient deficiency of the soil could be recycling of organic wastes. But it is also difficult to attain sustainable

productivity neither by inorganic fertilizers nor organic sources alone [12,13]. The best remedy for soil fertility management is, therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil [13]. The combined application of inorganic and organic fertilizers is also widely recognized as a way of increasing yield and/or improving productivity of the soil sustainably [14]. Several researchers [15] have demonstrated the beneficial effect of integrated nutrient management in mitigating the deficiency of many secondary and micronutrients. There are also some research reports in Ethiopia that revealed the combined effect of organic (compost and manure) and chemical (NP) fertilizer enhanced the yield of teff and reduced the amount of recommended chemical fertilizer by half [16,17] Though there is a huge variation in crop response to different NP fertilizer rates, 64/46 N/P₂O₅ kg ha⁻¹ was given by Ministry of Agriculture and Rural Development as national blanket recommendation [18].

Farmers in Ethiopia have also awareness about compost and have been preparing and using huge amount especially in central highlands of Ethiopia. According to North Shoa zone agriculture department annual report (2014), about 5,056,260 m³ of compost has been prepared and

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Color	pH	OC%	Particle size distribution			Textural class	Available P in ppm	TN (%)
Black	6.4	1.3	Clay=45	Silt= 24	Sand=31	Clay	8	0.12

Table 1: Physico-chemical properties of experimental soil.

				Exchangeable bases (cmol/kg)					Available Micronutrients and Phosphorus (mg/kg)						
EC	pH	%OC	TN	Ca	Mg	Na	K	Ca	Mn	Fe	Cu	Zn	B	S	P
2.32	7.22	17.81	0.96	62.5	20.5	10	0.96	20.14	31.05	61.2	1.42	16.75	4.56	113.06	382

Table 2: Constituents of experimental compost determined during incorporation to the soil.

used in 2013/14 cropping season. However, there is little information about the rate of application of compost and chemical fertilizer in the study area either to apply in sole or in combination. Therefore this study was undertaken with the objectives: to assess the effect of rates of compost and inorganic NP fertilizers on growth, yield and yield components of teff; and to determine economically appropriate rate of compost and inorganic NP fertilizers for teff production.

Materials and Methods

Experimental site description

Field experiment was conducted on farmer's field in 2014/15 main cropping season in Girar Jarso District of North Shoa Zone of Oromia Regional State. The site is geographically located at 09°45.121'N latitude and 038°46.728'E longitude and at an altitude of 2677 meters above sea level. The area receives mean maximum and minimum temperature of 22.13°C and 10.26°C, respectively and average long term annual rainfall of 1000 mm. Some of soil physical and chemical properties of the trial field determined during planting are given in Table 1. Accordingly the initial status of the experimental soil is classified as slightly acidic in soil reaction [19] low in total N [20], medium in P content [21] and medium in organic matter content [22].

Experimental materials

Compost: The experimental compost was collected from five farmers pit and was thoroughly mixed to be representative of the compost currently prepared and being used by the farmers around the study area. One composite sample from the mixture was taken and submitted to JEJE analytical Testing Laboratory for chemical analysis. The weight of the compost was measured for each level at air dried (at 10.5% moisture) bases right before application (Table 2).

Crop/variety: The teff variety named Quncho (DZ-Cr-387), which was developed and released by Debrezeit Agricultural Research Centre in 2006 was used for the experiment. It is a high yielding white-seeded cultivar adapted to a wide range of altitudes. The certified seed was used for the trial collected from Ethiopian seed enterprise.

NP sources: Urea (46% N) and DAP (18% N and 46% P₂O₅) were used as a source of nitrogen and phosphorus.

Treatment and layout

A total of sixteen treatment combinations (0, 2.5, 5, and 7.5 tons ha⁻¹ of compost combined with 64/46, 32/23, 16/11.5 and 0/0 kg ha⁻¹ of NP) were used.

The experiment was laid out in randomized complete block design (RCBD) in factorial arrangement and treatments were replicated three times. The gross plot size was 2 m × 3 m (6 m²) and the net plot size was 2.5 × 1.5 m (3.75 m²). Compost was incorporated to the soil on prepared seedbeds twenty one days before planting and chemical fertilizers (NP) were applied during planting and seeds were broadcast at the rate of 25 kg ha⁻¹ (15 g/plot). All other cultural practices were uniformly applied as per the recommendations.

Data collection, measurements and analysis

Phenological, Growth, Yield and Yield Component data were collected according to the descriptor for teff.

Days to 50% panicle emergence: This parameter of the plant was determined by counting the number of days from sowing to the time when 50% of the plants started to emerge the tip of panicles through visual observation.

Days to 90% physiological maturity: Days to physiological maturity was determined as the number of days from sowing to the time when 90% of the plants in a plot reached maturity based on visual observation. It was indicated by senescence of the leaves as well as free threshing of grain from the glumes when pressed between the forefinger and thumb.

Plant height: Plant height was measured at physiological maturity from the ground level to the tip of panicle from ten randomly pre-tagged mother plants in each plot.

Panicle length: It is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle which was determined from an average of ten randomly pre-tagged mother plants per plot.

Number of productive tillers: The numbers of effective tillers was determined by counting the tillers from an area of 0.25 m × 0.25 m by throwing a quadrat into the middle portion of each plot.

Biomass yield: At maturity, the whole plant parts, including leaves, stems and kernels from the net plot area was harvested and after sun drying for five days the biomass was measured.

Thousand kernel weight: Thousand kernels from the bulk of threshed yield were counted from each net plot and weight was recorded using a sensitive balance.

Grain yield: Grain yield was measured by harvesting the crop from the net plot area of 2.5 × 1.5 m excluding border effects.

Straw yield: After threshing and measuring the grain yield, the straw yield was measured by subtracting the grain yield from the total above ground biomass yield.

Harvest index: Harvest index was calculated by dividing grain yield by the total above ground air dry biomass yield.

$$\text{Harvest Index (\%)} = \frac{\text{Seed Yield per plot}}{\text{Above Ground Biomass per plot}} \times 100$$

Lodging index: Lodging percentage was taken as the sum of the product of each scale of lodging (0-5 scale) and its respective percentage divided by five where 0 stands for upright stand, 1 for slightly slant, 2 for medium slant, 3 for very slant and 4 for extremely slant and 5 stands for 100% plants lodged.

Data analysis

The collected data was analyzed by general linear model (GLM) procedures using GenStat Release 15 software [23]. Means of significant treatment effects were separated using the Fishers' protected Least Significant Difference (LSD) test at 5% level of significance. Finally, economic analysis is made following CIMMYT methodology [24].

Results and Discussion

Days to Heading

Days to heading was highly significantly ($P < 0.01$) affected by the main effects of chemical fertilizer rates. But this parameter was not affected either by compost rates or interaction effects of compost with chemical fertilizer.

Generally, as the rate of NP increased, the number of days elapsed to heading was shortened. Hence, the longest days (78.4) to heading was recorded at a control plots while the shortest days to heading (67)

Treatment	Days to heading
Compost (t ha⁻¹)	
0.0	74.75
2.5	73.58
5	74.50
7.5	74.25
LSD (0.05)	NS
N/P₂O₅ (kg ha⁻¹) 0/0	78.42a
16/11.5	76.17b
32/23	73.58c
64/46	68.92d
LSD(0.05)	1.81
CV (%)	2.9

Table 3: Days to 50% heading of teff as affected by the main effect of NP and compost.

Compost Chemical Fertilizer (N/P ₂ O ₅) rates (kg ha ⁻¹)	Compost (t ha ⁻¹)			
	0/0	16/11.5	32/23	64/46
0.0	135.3e	144.3abc	143.7abc	138.3cde
2.5	139cde	138.7cde	139cde	143.7abc
5.0	145.7ab	147.3a	141.7a-d	136.3de
7.5	141.7a-d	147a	141.7a-d	140.0b-e
LSD (0.05)	6.260			
CV (%)	2.7			

Table 4: Days to maturity of teff as affected by the interaction of NP fertilizer and compost rates.

Treatments	Plant height (cm)	Panicle length (cm)	Lodging (%)
Compost (t ha⁻¹)			
0.0	70.37	28.18	25.00
2.5	70.82	28.45	27.08
5.0	68.58	27.29	33.33
7.5	69.12	27.48	33.33
LSD (0.05)	NS	NS	NS
N/P₂O₅ (kg ha⁻¹)			
0/0	55.59d	23.45c	8.33d
16/11.5	62.99c	24.96c	22.92c
32/23	72.18b	28.64b	37.5b
64/46	88.13a	34.34a	50.0a
LSD(0.05)	4.999	1.786	7.9
CV (%)	6.8	7.7	32.2

Table 5: Plant height, panicle length, and lodging index of teff as affected by the main effects of NP fertilizer rates.

was recorded at the highest (64/46 N/P₂O₅ kg ha⁻¹) rate of NP fertilizer (Table 3). The hastened heading as a result highest rate of NP could be due to the fact that plots receiving the highest rates of nutrients encouraged for early establishment, rapid growth and development promoted by nitrogen as explained by Ref. [25]. In contrary, delayed heading at lower rates of the nutrients (NP) could result due to longer time required to establish, grow and complete the vegetative growth. In line with this result, Ref. [26] found that N and P₂O₅ at the rates of 64/46 kg ha⁻¹ significantly shortened days to heading of teff than the control. Likewise Ref. [27] and Ref. [28] reported that as the rate of N fertilizer increased to 90 kg ha⁻¹, tasseling of maize was significantly hastened than the control and lower rates of N. In contrast to this result, Ref. [29] found increased days to heading of wheat at the rate of 80/60 of NP than the control and other lower rates. Similarly, Ref. [30] reported that the application of N at the rate of 46 kg ha⁻¹ delayed heading of teff than the control.

Days to Maturity of teff was significantly ($P = 0.023$) affected by the main effect of NP fertilizer rates while compost rate was not significant to affect this parameter. Interaction of compost and NP rates was also significantly ($P = 0.014$) affected maturity days of teff. Regardless of significant effect, there was no consistent trend in increasing or decreasing in days to maturity with the interaction effects of compost and NP rates. However, as the level of compost increased while NP is constant, the number of days to maturity increased in most cases (Table 4). The shortest days to maturity (135 days) was recorded at the control plots while the longest (147.3 and 147 days) were recorded at (16/11.5 N/P₂O₅ kg ha⁻¹ and 5 tons ha⁻¹) and (16/11.5 N/P₂O₅ kg ha⁻¹, 7.5 tons ha⁻¹) of NP and compost combination.

The non-consistency could have resulted due to opposite action of N and P on maturity; N may cause delayance while P hastened crop maturity as also indicated by [31] stating that application of N and P significantly influenced days to 75% maturity; N fertilizer prolonged days to 75% maturity of teff, whereas the reverse trend was seen with applied P. The delay in maturity with increase in the rate of compost keeping NP constant could have resulted because of more vegetative growth. This result was in agreement with the findings of [32]. It could also be resulted because of effect of compost in retaining soil moisture. Similar finding was also reported by [33] as residue treated plots delayed in maturity of maize with the same justification given above and the significant increased soil water holding capacity (WHC) from compost and cow dung treated plots than the control [34].

Plant Height was highly significantly ($P < 0.01$) affected by the main effects of NP rates. However, it was not significantly affected either by the compost rates or by the interaction of compost and NP fertilizer. Generally, as the rate of NP fertilizer increased to the highest rate, from 0/0 to 64/46 N/P₂O₅, markedly a linear increase in plant height was observed and thus, the highest plant height of 88.13 cm was recorded at the highest N/P₂O₅ rate of 64/46 kg ha⁻¹ while the shortest height (55.59 cm) was noted from the control plot (Table 5). The increase in plant height with increasing NP could have resulted due to sufficient supply of nutrient which encourages plant growth: nitrogen plays critical role in the structure of chlorophyll, while P is main element involved in energy transfer for cellular metabolism in addition to its structural role [35]. The result was in agreement with the findings of Ref. [36,37].

The non-responsiveness of the compost might be due to the slow release of nutrients at early crop vegetative growth stages. In line with this result, Yihenew reported that the plant height in plot that received 6.5 months old compost prepared from cereal straw performed even less than the control plots reasoned as the type of composting material

Treatments	NPT	TKW(g)	BY (Kg ha ⁻¹)	Harvest index
Compost (t ha⁻¹)				
0.0	5.03	0.300	3259c	0.2908a
2.5	5.23	0.297	3732b	0.2775a
5.0	4.72	0.304	4276a	0.2426b
7.5	4.63	0.301	4458a	0.2428b
LSD (0.05)	NS	NS	192.189	0.0232
N/P₂O₅ (kg ha⁻¹)				
0/0	4.7	0.2925b	2246d	0.286a
16/11.5	5.07	0.3062a	3380c	0.271ab
32/23	4.79	0.306a	4827b	0.235c
64/46	5.04	0.296ab	5274a	0.2616b
LSD	NS	0.0107	192.189	0.0232
CV (%)	32.2	4.3	5.9	10.6

Where, NPT=number of productive tillers, TKW=thousand kernel weight, BY=total biomass yield, NS= non-significant. Means sharing the same letter under the same column are not significant at P=0.05 according to the LSD test.

Table 6: Number of productive tillers per plant, thousand kernel weights, biomass yield and harvest index of teff as affected by the main effects of compost and NP fertilizer rates.

and duration of composting has affected it [38]. Similarly, Abdalla et al. reported that application of different organic fertilizers: compost, vermicompost and farm yard manure, at different rates was not able to affect plant height in the first year of experiment [39]. In contrast to this, Medhn et al. reported significant and superior plant height of teff in plots received organic fertilizers as compared to conventional once [40].

Panicle length

Panicle length was highly significantly (P<0.01) affected by the main effects of NP fertilizer rates. However, neither compost rates nor its interaction with NP fertilizer significantly affected this parameter.

Similar to plant height, panicle length also increased with increasing NP fertilizer rates. The highest panicle length (34.34 cm) was recorded at the highest N/P₂O₅ rate of 64/46 (Table 5). This could be due to similar reason as that of plant height. The positive correlation between N fertilizer and teff panicle length has also been reported by Giday et al. [36]. The higher the panicle length may have also positive contribution to the grain and straw yield since it has a positive correlation to grain yield. In line with this result, Fayera et al. 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 [41].

Lodging index

Lodging index was highly significantly (P<0.001) affected by the main effects of NP fertilizer, however, the main effect of compost rates did not show significant effect on lodging. NP fertilizer and compost also did not interact to affect lodging.

The lodging index was increased with increasing NP rates. The highest lodging (50%) was recorded from the highest N/P₂O₅ rate (64/46) while the lowest lodging index (8.3%) was recorded from the control (Table 5). The increasing lodging index with increasing NP fertilizer could be because of the increase in plant height which in turn resulted from abundant supply of nutrients. This result was in line with the findings of Shiferaw who reported highest lodging of teff (74%) at N/P₂O₅ rate of 64/46 kg ha⁻¹ [26]. Likewise, Fayera et al. reported the highest lodging percentage (79.74%) of teff was recorded in the highest rate of NPK application though the rate the authors reported is much higher (138 kg N/ha+55 kg P/ha) than the present result [41]. Kebebew

and Tams et al. also confirmed that abundant supply of nutrients in the soil can contribute to the process of lodging [42,43].

It has been reported that lodging is the serious problem of teff production that causes high yield reduction because of the use of high amount and unbalanced different rates of NPK fertilizers practiced in the country. On average, lodging accounted about 11-22% total grain yield losses [6]. Though susceptibility to lodging is characteristics of all varieties of teff [44] it could be induced by both external and internal factors like wind, rain, and morphological traits of the crops or by their interactions. Where, NS=non-significant, t=tons. Means sharing the same letter under the same column are not significantly different at P=0.05 according to the LSD test.

Number of productive tillers

Number of productive tillers was not affected neither by the main effects nor the interactions of compost and NP fertilizer.

Generally, there was no difference in number of productive tiller between the levels of compost and NP fertilizer and it did not show any increasing or decreasing trend (Table 6). This result was in agreement with the findings of Shiferaw who reported a non-significant difference in productive tillers between the higher N/P₂O₅ (64/46) rates and the control [26]. In contrast with the result of this study, Fayera et al. found that number of the productive tillers of teff was significantly increased with the increase in the rates of NPK [41]. Giday et al. also reported positive and significant increase in number of productive tillers with increasing rates of N fertilizer on teff [36].

Thousand kernel weight

Thousand kernel weight was significantly (P=0.025) affected by the main effects of NP fertilizer rate but not significantly affected by the compost rates and interaction effects of compost and NP rates. Plots received 16/11.5 and 32/23 N/P₂O₅ showed significantly higher thousand kernel weight (0.31 g) than control plots (0.29 g), However, plots treated with higher dose of N/P₂O₅ (64/46) and control were similar in performance (Table 6) indicating increase in thousand kernel weight to certain rates of applied NP and decreasing for further application dosage (beyond 32/23 N/P₂O₅).

The increase in thousand kernel weight with increasing rate of NP from 0/0 to 32/23 N/P₂O₅ could be related to plant growth, the higher the plant growth the higher the photosynthetic area and so photosynthesis, the higher assimilate translocation to the sink. In another way, the reduction in thousand kernel weight with increasing applied rates of both NP beyond 32/23 N/P₂O₅ might probably be the result of insufficient supply of carbohydrates to individual spikelets due to competition effect resulted by vigorous plant growth and the increased number of its spikelets. This result agreed to the findings of Heluf and Mulugeta who stated as only application of 13.2 kg ha⁻¹ of P fertilization significantly increased thousand kernel weight of rice but N had no effect on this parameter [45]. Similarly, Hasegawa et al. reported that increased number of spikelets and vigorous growth of rice due to high rates of N fertilizer application induced competition for carbohydrate available for grain filling and spikelet formation [46].

Total above ground dry biomass

Total above ground dry biomass was highly significantly (P<0.001) affected by the main effects of NP and compost, but not by their interaction. Generally as the compost rates increased to 7.5 tons ha⁻¹, the total above ground dry biomass yield was also proportionally increased to 4.458 tons ha⁻¹ from 3.259 tons ha⁻¹ in control plots (Table

6). This indicates the about 37% higher biomass yields advantage at 7.5 tons ha⁻¹ than the control. The significant increase of above ground dry biomass yield without increasing the growth parameters (plant height, panicle length and tillers) could be attributed from the secondary branches and leaf number and size which were grown even during grain filling period. The result was in agreement to the findings of Medhn et al. who indicated that a significantly higher mean biomass yield (5.12 tons ha⁻¹) of organic farming compared to the conventional farming (4.01 tons ha⁻¹). In contrary Dejene and Lemlem found no significant variation among the application of 7 tons ha⁻¹ of compost and FYM each separately as compared to the control [16]. The finding from this experiment and the similar results indicated here may indicate that organic fertilizer like compost had a positive contribution in increasing the total above ground biomass yield of teff.

Similarly, increasing the rate of NP from 0/0 to 64/46 N/P₂O₅, the dry above ground biomass yield was also increased to 5.274 tons ha⁻¹ from 2.246 tons ha⁻¹ indicating 134.82% higher than the control (Table 6). The higher total above ground dry biomass yield may be attributed due to the proportional vegetative growth (especially the plant height) as a result of NP. The result was also in line with the findings of Fissehaye et al. who reported as the application of N and P increased the above ground biomass yield to the level of 69 N and 46 P₂O₅, kg ha⁻¹ separately though not significantly different from 46 and 23 kg ha⁻¹ of N and P₂O₅, respectively [39]. However, unlike the findings of Getachew et al. who reported that the application of 50% recommended NP rate and 50% manure and compost as inorganic N equivalence on teff crop resulted in total biomass increments of 113% compared to the control treatment (23/10 kg N/P ha⁻¹), the two component treatments (NP and compost) did not interact to affect the biomass yield in the current study [47].

Grain yield

Grain yield was highly significantly (P<0.01) affected by the main effect of NP fertilizer and the interaction of NP fertilizer and compost, but not significantly affected by the main effect of compost rates. Generally at the rate of 0/0 and 64/46 N/P₂O₅, the increase in compost rate from 0 to 7.5 tons ha⁻¹, brought about increasing trend in mean grain yield though not all increases are statistically significant. However, at the rate of 16/11.5 and 32/23 of N/P₂O₅, the increase in compost rate from 0 to 7.5 tons ha⁻¹ showed no difference in changing the mean grain yield (Table 7). Numerically highest grain yield (1.395 tons ha⁻¹) of teff was obtained at the combination of the highest rate of NP (64/46 kg ha⁻¹ N/P₂O₅) fertilizer and the highest rate of compost (7.5 tons ha⁻¹) while the lowest grain yield of 0.447 tons ha⁻¹ was recorded from non-treated (zero rate of NP and compost) plots. However, the highest grain yield (1.395 tons ha⁻¹) recorded at 7.5 tons ha⁻¹ of compost and 64/46 kg ha⁻¹ N/P₂O₅, was not significantly different from the yield

Compost (t ha ⁻¹)	Fertilizer (N/P ₂ O ₅) rates (kg ha ⁻¹)			
	0/0	16/11.5	32/23	64/46
0.0	0.447h	0.899ef	1.172bc	1.293ab
2.5	0.563h	0.932def	1.154bc	1.382a
5.0	0.713g	0.915ef	1.038cde	1.391a
7.5	0.829fg	0.886f	1.078cd	1.395a
LSD (0.05)	0.149			
CV (%)	8.9			

Table 7: Grain yield (tons ha⁻¹) of teff as affected by the interaction of compost and NP fertilizer rates.

Compost (t/ha)	Fertilizer (N/P ₂ O ₅) rates (kg/ha)			
	0	16/11.5	32/23	64/46
0.0	1.178h	2.132g	2.854de	3.063d
2.5	1.296h	2.223fg	3.524c	3.855bc
5.0	1.965g	2.580ef	4.254a	4.248a
7.5	1.992g	2.954de	4.233ab	4.467a

LSD (0.05)=0.384; CV(%)=5.9; Means in rows and columns sharing the same letter (s) do not differ significantly at P=0.05 according to the LSD test.

Table 8: Straw yield (tons ha⁻¹) of teff as affected by the interaction of compost and NP fertilizer rates.

Means in columns sharing the same letter do not differ significantly at P=0.05 according to the LSD test.

obtained from 0, 2.5 and 5 tons ha⁻¹ of compost combined with 64/46 kg ha⁻¹ N/P₂O₅ (Table 5) indicating the more importance of inorganic NP than the compost in affecting the grain yield.

The increase in grain yield due to interaction effects could be attributed to the positive effects of compost in increasing the efficiency of chemical fertilizer by preventing losses of the nutrients through denitrification, volatilization and leaching and releasing with the passage of time. Compost could also improve the soil structure which leads to better root development which may result in more nutrient uptake from the soil in addition to its gradual/slow release of macro and micro nutrients by itself [39]. Unlike the findings of Dejene and Lemlem (2012) who reported that the application of half recommended dose of NP and FYM (11.5 kg ha⁻¹ N 15 kg ha⁻¹ P and 3.5 tons ha⁻¹ of FYM) gave the highest grain yield of teff than sole application of either FYM or NP, the increase in grain yield as a result of interaction effect was not much higher than the main effect of NP at recommended rate. Getachew et al. also reported that the application of 50% recommended NP (30/10 N/P) rate and 50% compost (3.25 tons ha⁻¹ of compost) resulted in grain yield increments of 122% compared to the control on teff which is comparable to the full NP dose [47]. Likewise, Quansah also indicated that the use of organic (Household waste and Poultry manure Compost) and/or inorganic fertilizers (NP) increased maize grain yield separately, but, the yields obtained by the combined treatments were significantly higher than their sole treatments [48].

Straw yield

Straw yield was highly significantly (P<0.01) affected by the main effects of fertilizer (NP) and compost rates and significantly (P<0.05) by the interaction effects of the two treatments.

The straw yield increased with the increased rate of the compost rate from 0 to 5 tons ha⁻¹ and NP rates from 0/0 to 32/23 N/P₂O₅ kg ha⁻¹. The highest straw yield (4.467 tons ha⁻¹) was recorded at 64/46 N/P₂O₅ kg ha⁻¹ and 7.5 tons ha⁻¹ compost though statistically in par with (5 tons, 32/23 kg), (7.5 tons, 32/23 kg) and (5 tons, 64/46 kg) compost and N/P₂O₅ while the lowest straw yield (1.178 tons ha⁻¹) was recorded from the control (Table 8). The result also indicated that the application of compost beyond 5 tons ha⁻¹ and NP beyond 32/23 kg ha⁻¹ had no significant effect on the straw yield. The increase in straw yield as result of the interaction of compost and NP fertilizer could have resulted due to the positive effects of compost that might have enhance the efficiency of chemical fertilizer.

The result was in line with the findings of Dejene and Lemlem who reported that the highest straw yield was obtained at a combination of half recommended dose for both organic (compost and farm yard manure) and inorganic (NP) fertilizers than the full dose application of each at 7 tons ha⁻¹ of compost and farm yard manure and 23N and 30P though sole application of both compost and farmyard manure

Treatment (C,N/P ₂ O ₅)	Total variable Cost (USD ha ⁻¹)	Grain yield (Kg/ha)	Straw yield (kg/ha)	Gross benefit (USD ha ⁻¹)	Net benefit (USD ha ⁻¹)
0, 0/0	0	446.82	1177.80	371.0711	371.0713
2.5, 0/0	22.374	563.04	1295.63	447.609	425.2349
0, 16/11.5	32.97221	898.70	2132.41	721.2991	688.3269
2.5, 16/11.5	55.34621	932.17	2223.39	749.365	694.0188
0, 32/23	65.94442	1172.02	2853.58	948.3368	882.3924
2.5, 32/23	78.89779	1153.84	3524.03	777.6109	921.0542
2.5, 64/46	154.2628	1382.36	3854.97	117.0179	1016.123
5, 64/46	174.2817	1391.11	4248.00	1216.862	1042.581
7.5, 64/64	194.3005	1395.00	4467.48	1242.267	1047.967

Where, C=compost t ha⁻¹, N/P₂O₅=kg ha⁻¹

Table 9: Partial budget analysis for NP and Compost rates.

at different rates did not show any improvement over inorganically treated plots for straw yields [16]. However, in contrast to this Edwards et al. indicated that the application of 5-15 tons ha⁻¹ was able to increase the straw yield of teff by 53.8 and 8.14% than the control and 120 kg ha⁻¹ mixture of urea and DAP, fertilizer respectively. Similarly, Medhn et al. reported as the organic fertilizer increased straw yield of teff than the conventional and reasoned that could be due to higher plant height of organic teff than the conventional [40]. Many studies [49,50] also reported proportional increase of straw yield of teff with N in sole application.

Straw yield has to be considered while evaluation 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.

Harvest index

Harvest index was highly significantly ($P < 0.001$) affected by the main effects of both compost and chemical fertilizer (NP) rates, but the two factors did not show significant interaction. The harvest index was decreased from 29.08% to 24.26% with increasing compost rates from 0 to 5 tons ha⁻¹ but remained constant at compost rate of 7.5 tons ha⁻¹ (Table 6). Similarly, though the decrease was not consistent, the harvest index showed decreasing trend with increasing NP rates from 0 to 32/23 kg ha⁻¹, hence, the lowest harvest index (23.5%) was recorded at N/P₂O₅ rates of 32/23 while the highest harvest index (28.6%) was recorded at control (0/0 NP).

The decrease in harvest index with increasing rates of both compost and NP fertilizer could be due to the fact that compost and NP fertilizer encouraged more vegetative growth than the grain since the harvest index is the ration of grain yield to dry biomass yield. In line with this result, Heluf and Mulugeta reported that the harvest index consistently declined with increasing levels of applied N up to the highest level (150 kg) of N 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 increase beyond resulted in highly significantly reduction in rice crop [45]. Likewise, Medhn et al. also indicated low harvest index of teff with organic fertilization than the convention [40]. In contrary to this result Gafar et al. reported that the increased harvest index of rice to 12.89% with application of 15 tons ha⁻¹ compost, 83 kg ha⁻¹ of N and 50 kg ha⁻¹ superphosphate from 5.38% in the control [17].

Partial budget analysis

Partial budget analysis is a method of organizing experimental data and information about the costs and benefits of various alternative

treatments. As it is indicated in Table 9, the net farm benefit was calculated taking possible field variable costs and all benefits (grain and straw yield). The maximum farm benefit (22,248 Birr/ha) was recorded at the maximum N/P₂O₅ rates of 64/46 kg ha⁻¹ combined with 7.5 tons ha⁻¹ of compost, though not much higher than 22133.99 Birr/ha and 21572.29 Birr/ha benefit obtained at the next two lower rate (5 tons ha⁻¹ of compost and 64/46 kg ha⁻¹ N/P₂O₅) and (2.5 tons ha⁻¹, 64/46 kg ha⁻¹ N/P₂O₅), respectively. It was also indicated that the relative benefit was declining after the combined level of 2.5 compost tons ha⁻¹ and 64/46 N/P₂O₅ to the increasing rate of compost.

Variable costs are:

Urea (N-source)=56.52 USD/100 kg, DAP (both source of N and P)=70.65 USD/100 kg, Compost estimated as 0.71 USD/100 kg, Compost application cost (labor cost) estimated as 4 man/day/7.5 tons, labor cost for fertilizer application=2 man days/(64/46 kg/ha), labor cost/man/day=2.36 USD and gross output (grain and straw): price of teff grain=0.61 USD/kg, price of straw=0.12 USD/kg [51-54].

Conclusions and Recommendations

Teff is an important cereal crop in Ethiopia particularly in North Shoa whose productivity is being affected by low soil fertility and organic matter depletion. Hence factorial experiment consisting of different levels of compost and inorganic NP fertilizer was conducted in Girar Jarso district in 2014/5 cropping season.

The main effects of compost rates positively affected only total above ground dry biomass, straw yield while negatively the harvest index. Except number of productive tillers, the main effect of NP fertilizer had significantly affected all parameters measured and recorded. Heading was hastened and all other parameters increased proportionally with increasing NP rates with the exception to harvest index which inversely decreased and highest thousand kernel weight attained at two middle rates of NP. This indicates inorganic NP is most important to affect the growth, yield and yield attributes of teff than the compost. Interaction of compost with NP fertilizer also significantly affected: days to maturity, grain yield and straw yield of teff. Numerically the maximum grain and straw yields of 1.395 kg ha⁻¹ and 4.467 tons ha⁻¹ were recorded at the highest rates of both NP and compost. Generally this experimental result fail to support previous reports that the use of compost reduced the recommended NP rates by half, rather the use of full dose of nationally blanket recommended NP rate (64/48 kg of N/P₂O₅) with 7.5 tons ha⁻¹ of compost is most likely combination to attain the optimum grain yield and optimum profit and can be alternative approach for integrated soil fertility management measure instead of the sole application of inorganic fertilizers.

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