Effect of Mineral Fertilizer, Farmyard Manure, and Compost on Yield of Bread Wheat and Selected Soil Chemical Properties in Enderta District, Tigray Regional State, Northern Ethiopia

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Abstract: Soil nutrient depletion as a result of continuous cultivation of the land without adequate addition of external fertilizer inputs is one of the major problems that constrain the yield of bread wheat and sustainable productivity of the soil in Tigray Regional State. A field experiment was conducted to elucidate the effect of mineral nitrogen and phosphorus fertilizer (NP), farmyard manure (FYM), and compost on the productivity of bread wheat and selected soil chemical properties. The treatments consisted of three bread wheat varieties (Kakaba, Paven 76, and Mekelle I) and eight fertilizer combinations [control (0, 0), blanket recommended NP fertilizer (RNP) (41 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1}), 10 t ha^{-1} FYM, ½ of RNP (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 10 t ha^{-1} FYM, ½RNP (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 5 t FYM ha^{-1}, 7 t compost ha^{-1}, ½ RNP (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 7 t compost ha^{-1}, and ½ RNP (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 3.5 t compost ha^{-1}]. The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment. Data were collected on yield and yield components of the crop and selected soil chemical properties, namely, contents of soil organic carbon (OC), available phosphorus (P), total nitrogen (TN), cation exchange capacity (CEC), soil reaction (pH), and electric conductivity (EC). The results revealed that the yield and yield components of wheat significantly ($P \leq 0.01$) responded to application of the fertilizers. Combined application of 10 or 5.0 t ha^{-1} FYM with half of the recommended mineral nitrogen and phosphorus fertilizer (i.e., 20.5 kg N + 23 kg P_2O_5 ha^{-1}) increased grain yield of the crop by 185 and 170%, respectively, over the control treatment. Similarly, combined application of 7.0 or 3.5 t ha^{-1} compost with half of the recommended mineral nitrogen and phosphorus fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1}) increased grain yield significantly by 159 and 148%, respectively, over the control treatment. The highest net benefits of 37290 ETB, 33002 ETB, and 30835 ETB ha^{-1} with acceptable marginal rates of return were obtained in response to applying half of the blanket recommended miner NP fertilizer (½ RNP) ha^{-1} + 5 t FYM ha^{-1} to Kakaba, Mekelle I, and Paven 76, followed by application of the full blanket recommended NP fertilizer (RNP) ha^{-1} and ½ RNP ha^{-1}+ 5 t ha^{-1} compost. It is, thus, concluded that combined application of half of the blanket recommended NP fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1}) with 5 t FYM ha^{-1}or with 3.5 t ha^{-1} compost led to the most economically optimum bread wheat yield as well as improved soil physico-chemical properties for sustainable production of the crop in the future. Analysis of the selected soil chemical properties at harvest indicated that, compared to the available phosphorus and total nitrogen contents of the soil in plots to which no any fertilizer was applied (control treatment), the total nitrogen and phosphorus contents of the soil to which 10 t ha^{-1} FYM and 7 t ha^{-1} compost were applied increased by about 100% whereas that of organic matter increased by about 300%. The results indicate that the soils of the study area are deficient not only in mineral nutrients such as nitrogen and phosphorus but also in soil organic carbon and its constituents that are important to maintain soil quality and health. This implies that there is a need for judicious soil ameliorative measures using both mineral and organic fertilizers to enhance productivity of crops in the region.

Keywords: Blanket recommended NP (RNP) fertilizer; Compost; Economic analysis; Farmyard manure; NP fertilizer; Bread wheat variety; *Triticum aestivum L;* Yield

1. Introduction

Wheat (*Triticum aestivum* L.) is widely cultivated in mid and highland areas of Tigray, northern Ethiopia. Bread wheat ranks third in production area following sorghum and *tef* with over 105,308 hectares (ha) with a total production of about 200169 tons (CSA, 2013). Bread wheat production has steadily increased over the last decade, which could be attributed to both expansion of production area and improvement in yield (CSA, 2013).

Despite its relatively large area coverage in the country, yields of the crop are still low. The average grain yield of bread wheat in Tigray Regional State amounts to 1.94 t ha^{-1} (Mesay *et al.*, 2012), which is less than the national average yield of 2.4 t ha^{-1}. Still the national average yield of wheat in Ethiopia is 13% lower than the African average wheat yield and 32%

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lower than the world's average yield (Gashaw *et al*., 2014). Therefore, what production is insufficient to meet the increasing demand for food for the ever-increasing population (GAIN, 2014).

Though numerous factors are responsible for low crop yields, low soil fertility is a major problem that affects crop production in the Ethiopian highlands. The decline in crop yields in the country primarily results from loss of nutrients through soil erosion, cultivation of marginal lands, continuous cultivation with limited external inputs, less manure use and overgrazing (Atakilte *et al*., 2006). These problems result in reduced soil organic matter which is lower than 1% (Fassil and Yamoah, 2009). In addition, organic amendments are insufficient to offset the rapid loss in soil organic matter (SOM), leading to unsustainable farming system. This situation is considered to be a major threat to food security and natural resource conservation in Ethiopia.

Soil nutrient replenishment is, therefore, a prerequisite to halting soil fertility decline. This may be accomplished by the application of mineral and organic fertilizers (Wakene *et al*., 2004). In Ethiopia, the rates of application of mineral N and P fertilizer are generally low due to steep prices and untimely availability of the fertilizer input (Dercon and Christiaensen, 2007; Kassie *et al*., 2008) and fear of burning effect by mineral fertilizers in case of moisture inadequacy in the soil or erratic rainfall after application of fertilizer (Hailu, 2010).

One of the possible options to reduce the use of mineral fertilizer without nitrogen deficiency could be recycling of organic wastes. Some studies in Ethiopia have shown the importance of organic matter (OM) in improving soil productivity (Wakene *et al*., 2001). Further, the mobilization of nutrients through SOM decomposition makes an important and, in some cases, a sole contribution to maintaining or enhancing soil fertility in areas where mineral fertilizers are scarce (Assefa, 2008). Likewise, the use of OM increases the capacity of the soil for moisture retention which enables the crop to access water even during the dry spells (Balesh *et al.,* 2007; Edwards *et al*., 2007). Thus, the use of organic fertilizer is important for the region like Tigray, where crop productivity is severely affected by erratic rainfall. But the availability of organic fertilizer as nutrient sources is limited by their competing end-uses such as fuel wood, construction, feed as well as scarcity of labor required to collect and apply it to farm fields. In addition, organic residues most available to farmers have low nutrient concentrations or need prolonged time to release nutrients for plant uptake (Godara *et al.,* 2012). Hence, organic resources used alone offer insufficient nutrients to sustain crop yields and build soil fertility. Yet, they will continue to be a critical nutrient source as smallholder farmers in the tropics are unable to afford mineral fertilizers because of escalating fertilizer prices (Palm, 2001).

High prices of mineral fertilizers together with the challenges of limited supply of organic inputs, therefore, calls for combined use of organic and mineral sources of plant nutrients (Devi *et al.,* 2007, Wakene *et al*., 2007). Several studies in the country reported that integrating organic and inorganic fertilizers improved soil fertility and productivity (Edwards *et al*., 2007, Getachew and Chilot, 2009, Dejene *et al.,* 2010, Abay and Tesfaye, 2012, Medhn *et al*., 2013). While numerous studies have been conducted in Tigray to examine the effect of organic and inorganic fertilizers, no research has so far been done in the study area to elucidate the influence of applying mineral NP and organic fertilizers (both FYM and compost) on the productivity of bread wheat and physico-chemical properties of the soils. This research was, therefore, aimed at studying the effect of mineral and organic fertilizers on the productivity of bread wheat and its concomitant effect on selected physico-chemical properties of the soil.

2. Materials and Methods

2.1. Description of the Experimental Site

The study was conducted in Enderta district. Geographically, the site is located in the southeast of Tigray at 130 5'N latitude, 390 5'E longitudes and at an altitude of 1970 meters above sea level.

The long-term (1995-2013) average annual precipitation was 522 mm while the total rainfall of the 2013 growing season was 398 mm of which 317 mm was received during the main cropping season which was below the long term average. In 2014, the annual rainfall of the season was 782 mm of which 537 mm was received during the growing season (Fig 1). The study site has a mono-modal rainfall pattern with an extended rainy season from March to November with the peak occurring in the month of August. The main rainy season is between June and September, during which about 83% of the annual rainfall occurs. The area is characterized by heavy and erratic rainfall distribution. The area has mixed farming system (crop and livestock) with crop dominance. The dominant crops growing around the experimental area are wheat (*Triticum aestivum L*.), Maize (*Zea mays L*.), barley (*Hordeum vulgare*), tef (*Eragrostis tef*) and some legumes and vegetable crops.

The soil of the experimental site is *Vertisol* with a clay content of 48% (Rowell, 1994). According to the rating of Tekalign (1991), the soil reaction is neutral (7.23), organic carbon content is low (1.31%); and the total nitrogen content is very low (0.02%). According to the rating of Cottenie (1980), the available phosphorus content is low (5.33 ppm). Based on the rating of Hazelton and Murphy (2007), the CEC of the soil is high (37 $cmol_{(+)}\ kg^{-1}$ soil).

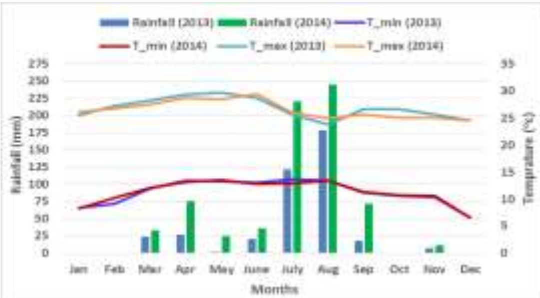

Figure 1. Monthly total rainfall (mm) and monthly average air temperature ranges (T^0), in 2013 and 2014 cropping seasons. Source; Mekelle Research Meteorological service.

2.2. Planting Material

Three bread wheat varieties, namely, Kakaba, Mekelle I, and Paven 76 were used as test crops. Kakaba was released by Kulumsa Agricultural Research Centre (KARC) in 2005. It needs >500 mm rainfall for optimum growth and is adapted to altitudes ranging between 2000 and 2900 meters above sea level. The variety requires 90-120 days to reach maturity. The average plant height of Kakaba is 89-95 m. On-station grain yield of Kakaba ranges between 4.0 to 5.5 t ha^{-1} whereas its on-farm grain yield ranges between 3.0 to 4.0 t ha^{-1}. Mekelle I was released by Mekelle Agricultural Research Centre (MARC) in 2011. It is a semi-dwarf variety known for drought tolerance, but performs better under good rainfall conditions. It requires between 300 and 500 mm rainfall for optimum growth and is adapted to altitudes ranging between 1980 and 2500 meters above sea level. The variety needs 90-95 days to reach maturity (Hintsa et al., 2011). The average height of Mekelle I plants ranges between 77 and 79 m. On-station grain yield of Mekelle I ranges between 3.0 and 3.5 ha^{-1} whereas its on-farm grain yield ranges between 2.2 and 2.7 t ha^{-1}. Paven 76 was released by Kulumsa Agricultural Research Centre (KARC) in 1982. It needs >500 mm rainfall for optimum growth and is adapted to grow at altitudes ranging between 750 and 2500 meters above sea level. The variety needs between 120 and 135 days to mature. On-station grain yield of Paven 76 ranges between 4.0 to 4.5 t ha^{-1} whereas its on-farm grain yield ranges between 3.5 to 4.0 t ha^{-1}. The three varieties were selected based on differences in maturity time, yield potential, adaptability, and the fact that they are commonly cultivated by smallholder farmers in the region.

2.2. Treatments and Experimental Design

The treatments consisted of eight fertilizer combinations [control (no fertilizer application), blanket recommended NP fertilizer (RNP): 100 kg ha^{-1} DAP plus 50 kg ha^{-1} urea (41 kg N + 46 kg P_2O_5 ha^{-1}), 10 t ha^{-1} FYM, ½ RNP fertilizer (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 10 t FYM ha^{-1}, ½ RNP fertilizer (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 5 t FYM ha^{-1}, 7 t ha^{-1} compost alone, ½ RNP fertilizer (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 7 t ha^{-1} compost, ½NP fertilizer (20.5 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}) + 3.5 t ha^{-1} compost and three bread wheat varieties [Mekelle I, Kakaba, and Paven76]. The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment.

2.3. Fertilizer Material

Farmyard manure (FYM): Well-decomposed FYM (15% moisture content) was collected from Mekelle Livestock Research Center.

Compost: The compost was made from FYM, crop residues, household refuse, ash, weeds and grasses on a farmer's field and used as fertilizer. The organic materials used for composting were collected depending on their availability in the study area. For a quick start of microbial activities, all sides of the walls of the composting pit were painted with semi-liquid mixture of dung, water, and animal urine. About 15 cm height layer of the mixed dry and green materials were put first and a mixture of different animal manure with about 5 cm height was added. Water was then sprinkled to wet the dry matter. Again dung slurry was spread. Lastly some fertile soil was added over the whole layer. This process was repeated four times to fill a1 m x 1.5 m x 1.5 m pit. Lastly, the heap was covered by a mixture of soil and dung and wide leaves were used as cover to protect the compost from sun and wind. The compost was turned over after one month and the moisture was again maintained. It was turned over for the second time. The compost matured in a period of three months (Hailu, 2010).

Mineral fertilizer: Urea [$CO\ (NH_2)_2$] (46% N) and triple super phosphate (TSP) [$Ca\ (H_2PO_4)_2$] (20% P) were used as sources of nitrogen and phosphorus, respectively.

2.3. Experimental procedure

2.3.1. Soil sampling and analysis

Prior to planting, surface soil samples (0–20 cm), from twelve spots across the experimental field, were collected, composited, and analyzed for soil physico-chemical properties following the standard laboratory procedures. The N and P contents of FYM and compost used in the experiment were also determined in the laboratory (Table 1).

2.3.2. Crop Management

The experimental field was ploughed three times using ox-driven implements followed by manual seed-bed preparation.

The compost and farmyard manure were applied to the soil one month before planting. The application was done by mixing the FYM and compost in the upper 15-

20 cm of the soil layer. The rates were identified considering the highest and the lowest application rates of FYM and compost as described by Edward (2007), Dejene *et al.* (2010), and Hailu (2010). The blanket recommended fertilizer rate of 41 kg N + 46 kg P_2O_5 ha^{-1} was used. All the mineral P and half of the N fertilizer were applied at planting. The remaining half of the mineral N fertilizer was applied at the tillering stage of growth.

Seeds of the bread wheat varieties were hand-drilled at the rate of 150 kg ha^{-1} on 19 and 12 July 2013 and 2014 cropping seasons, respectively. The size of each plot was 3 m x 2 m (6 m^2). Weeds were removed by hand two times 30 and 55 days after crop emergence. Harvesting was done manually using hand sickles.

Table 1. Chemical composition of FYM and compost used in the experiment.

Year	Farmyard manure				Compost			
	pH	TN (%)	P (ppm)	OM (%)	pH	TN (%)	P (ppm)	OM (%)
2013	8.14	1.49	0.89	34.60	7.50	1.02	0.79	25.20
2014	8.23	1.75	0.95	36.66	7.60	1.49	0.82	22.79
Average	8.18	1.62	0.92	35.63	7.55	1.26	0.805	23.99

Note: OM = organic matter; TN = Total Nitrogen; P = Phosphorus

2.4. Data Collection and Measurement

Data on grain and biomass yields per plot were collected from the middle 6 rows. Aboveground biomass was sun- and air-dried for three days. The grain yield (kg ha^{-1}) was determined after threshing the sun-dried plants harvested from each net plot area and the yield was adjusted to 12.5% moisture content.

Harvest index (HI) was calculated as the ratio of grain to the above ground dry biomass yield. Kernels $spike^{-1}$ (NKPS) was determined from 10 randomly sampled plants per plot at physiological maturity. Thousand kernel weight was determined and partial cost benefit analysis associated with the treatments was conducted (CIMMYT, 1988). Economic analysis was done using the prevailing average market prices for inputs at planting and for outputs at the time of crop harvest. The average local market price of wheat was 11.29 Birr (ETB) kg^{-1}; that of the straw was 0.68 Birr kg^{-1}. The cost of Farmyard Manure was 225 Birr t^{-1}. The recommended dose of the mineral NP fertilizers was 19.30 Birr kg^{-1}. The cost of compost and farmyard manure was 166 Birr t^{-1}. Transportation and application cost of compost and farmyard manure was 10 Birr/100 kg. The net benefit (NB) was calculated as the difference between the gross benefit (GB) and the total cost that varied (TCV). Actual grain and straw yields were readjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers would expect to get from the same treatment. All costs and benefits were based on the average of the two-year yields. Percent marginal rate of return (MRR) was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost).

2.5. Statistical Analysis

All data were analyzed following statistical procedures of SAS version 9.2. Whenever treatment effects were significant, the means were separated using the least significant difference (LSD) test at 5% level of significance

3. Results

3.1. Soil Chemical Properties after Harvest

The results showed that application of mineral and organic fertilizers significantly increased the contents of soil organic matter (SOM), phosphorus (P), and total N (TN) of the soil in both cropping years. In the 2013 cropping season, in response to the application of 10 t ha^{-1} FYM and 7 t compost ha^{-1}, the total nitrogen and available phosphorus contents of the soil increased by about two-fold (100%) whereas that of organic matter increased by about three-fold (300%), compared to the plots to which did not receive any fertilizer (control treatment). Similarly, in the 2014 cropping season, the total nitrogen and organic matter content of plots treated with 10 t ha^{-1} FYM and 7 t compost ha^{-1} increased by about two-fold (by 100%) whereas the available phosphorus content increased by about half-fold (50%) (Table 3). In response to the application of both organic and mineral fertilizers, the pH of the soil also increased slightly whereas the Ec and CEC of the soil increased significantly (Table 4).

Table 3. Effect of applying organic and mineral fertilizers on some soil chemical properties of the experimental soil after harvest during the 2012 and 2013 main cropping season in Enderta district, Tigray Regional State, Ethiopia.

Treatment	Soil chemical property					
	2013			2014		
	TN%	P (ppm)	OM%	TN%	P(ppm)	OM%
Recommended NP (41kg N + 46 kg P_2O_5 ha^{-1}	0.17^{b}	5.13^{d}	1.22^{b}	0.19^{b}	6.19^{b}	2.12^{ab}
10 t FYM ha^{-1}	0.16^{b}	5.76^{bcd}	1.38^{ab}	0.19^{b}	6.35^{ab}	2.10^{ab}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 10 t FYM ha^{-1}	0.20^{a}	7.30a	1.62^{a}	0.22^{a}	6.71^{ab}	2.19^{ab}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1}	0.18^{ab}	7.21^{abc}	1.56^{a}	0.20^{ab}	7.12^{a}	2.15^{ab}
7 t compost ha^{-1}	0.16^{b}	5.07^{d}	1.48^{ab}	0.18^{b}	7.00^{ab}	2.07^{b}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 7 t compost ha^{-1}	0.18^{ab}	7.26^{ab}	1.57^{a}	0.21^{ab}	6.35^{ab}	2.27^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 3,5 t compost ha^{-1}	0.18^{ab}	5.73^{cd}	1.39^{ab}	0.20^{ab}	6.88^{ab}	2.27^{ab}
Control (unfertilized)	0.08^{c}	2.55^{e}	0.43^{c}	0.11^{c}	5.14^{c}	0.89^{c}
LSD(0.05)	0.03	1.19	0.28	0.03	0.86	0.19
CV%	16.02	27.62	22.47	14.02	14.09	10.22

Note: Means followed by the same letter within a column are not significantly different at 5% level of significance according to the LSD Fishers Protected Test; TN% = total nitrogen; AVP = available phosphorus; OM = organic matte

Table 4. Effect of organic and mineral fertilizers on pH, electrical conductivity (EC) and cation exchange capacity (CEC) of the soil after harvest of bread wheat in Enderta district, Tigray Regional State, Ethiopia.

	2013			2014		
Treatment	pH	EC(dS m^{-1})	CEC*	pH	EC(dS m^{-1})	CEC*
Blanket recommended NP rate (41kg N + 46 kg P_2O_5 ha^{-1})	7.28^{bc}	0.16^{c}	38.51^{b}	7.16^{b}	0.19^{c}	44.29^{b}
10 ton ha^{-1}Farmyard manure (FYM)	7.30^{bc}	0.17^{ab}	42.58^{a}	7.17^{b}	0.20^{bc}	48.36^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 10 ton ha^{-1}FYM	7.45^{ab}	0.15^{c}	36.96^{b}	7.19^{b}	0.25^{a}	42.74^{b}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 5.0 ton ha^{-1}FYM	7.40^{abc}	0.16^{bc}	37.48^{b}	7.27^{b}	0.24^{a}	43.26^{b}
7.0 ton compost ha^{-1}	7.3^{7bc}	0.19^{a}	38.17^{b}	7.29^{b}	0.22^{ab}	43.95^{b}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 7.0 ton ha^{-1}compost	7.60^{a}	0.15^{c}	38.61^{b}	7.69^{a}	0.23^{ab}	44.39^{b}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 3,5 ton ha^{-1}compost	7.34^{bc}	0.17^{abc}	37.85^{b}	7.25^{b}	0.23^{ab}	43.26^{b}
Control (unfertilized)	7.20^{c}	0.11^{d}	26.03^{c}	7.13^{b}	0.16^{d}	32.03^{c}
LSD(0.05)	0.20	0.02	3.61	0.20	0.03	3.55
CV%	2.94	13.26	10.35	2.92	14.57	8.78

*Note: * = CEC cmol$_{(+)}$ kg soil^{-1}; Means followed by the same letter within a column are not significantly different at 5% level of significance according to the LSD Fishers Protected Test*

3.2. Aboveground Dry Biomass Yield

Total aboveground dry biomass yield was significantly ($P < 0.01$) influenced by the main effects of variety, fertilizer, year, and by the interaction of year and fertilizer as well as variety. In 2013, the total aboveground dry biomass yield increased by about 124% in response to the application of mineral NP fertilizers together with 10 t ha^{-1} FYM while in 2014 the increase was, higher, i.e., 153%. Combining half of the blanket recommended NP fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1}) plus 10 t ha^{-1} FYM, 5 t ha^{-1} FYM, 7 t ha^{-1} compost, and 3.5 t ha^{-1} compost increased the aboveground dry biomass yield by 27%, 19%, and 14% during the 2013 cropping season and by 15%, 9 % and 7% in 2014 over the full dose of the blanket recommended NP fertilizer (41kg N + 46 kg P_2O_5 ha^{-1}), respectively (Table 5).

3.3. Grain Yield

Grain yield of the crop responded significantly to the fertilizers applied, variety, and year, but not to the interaction effects of any of the three factors (Table 6). Combining half dose of the blanket recommended mineral NP fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1}) with 10 and 5.0 t FYM ha^{-1} led to the production of the highest grain yields, which are in statistical parity. In general, combining half of the blanket recommended NP fertilizer with 10 and 5 t ha^{-1} FYM, and 7 and 3.5 t ha^{-1} compost increased wheat grain yield by 185%, 170%, 160% and 149%, respectively, over the control treatment. The increments in grain yield obtained in response to the application of the aforementioned fertilizer combinations also led to significant grain yield increments of 19, 25, 14, and 9.0%, respectively, over the grain yield obtained in response to application of full dose of the blanket recommended mineral NP fertilizer. The respective increments in grain yield over the grain yield obtained in response to the application of full dose of FYM (10 t ha^{-1}) were 36, 29, 24, and 19%.

Similarly, the highest grain yields obtained in response to the combined application of half dose of mineral NP fertilizers with 10 t FYM and 5 t FYM ha^{-1}, resulted in the production of about twice as much wheat grain yield as the average wheat grain yield obtained in the region of the study area (additional increments of 80 and 90%, respectively), which is 1.4 t ha^{-1}. Similarly, the wheat grain yields obtained at the aforementioned combined application of the fertilizers resulted in increments of about 45 and 53%, respectively, over the national bread wheat grain yield, which is 2.4 t ha^{-1}.

Table 5. Interaction effects of year by fertilizer and variety on total biomass yield of bread wheat in 2013 and 2014 cropping seasons in Enderta district, Tigray Regional State.

Fertilizer rate and Variety	Above ground biomass yield (kg ha^{-1})	
	2013	2014
Fertilizer		
41 kg N + 46 kg P_2O_5 ha^{-1})	6771.7^{gh}	8076.6^{cde}
10 ton ha^{-1}FYM	6225.7^{hi}	7776.6^{def}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 10 t ha^{-1}FYM	8618.0^{abc}	9342.6^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 5 t ha^{-1}FYM	8084.6^{cde}	8834.5^{ab}
7 t compost ha^{-1}	5680.6^{i}	7495.2^{efg}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 7 t ha^{-1}compost	7730.9^{def}	8664.8^{abc}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 3.5 t ha^{-1}compost	7174.3^{efg}	8416.9^{bcd}
Control (unfertilized)	3845.6^{j}	3681.0^{j}
LSD (0.05)	736.22	
Variety		
Mekelle I	6774.4^{c}	7883.7^{b}
Paven 76	6666.5^{c}	7092.2^{c}
Kakaba	6858.4^{c}	8382.2^{a}
LSD (0.05)	450.84	
CV%	10.80	

Note: Means followed by the same letter within a column and row of each factor are not significantly different at 5% level of significance

3.4. Straw Yield

Straw yield of the crop responded significantly ($P < 0.01$) to the fertilizers applied, variety, year and interaction of variety by year (Table 6). Application of NP, organic fertilizers and their combinations significantly increased the straw yield. Application of half of the blanket recommended NP fertilizers combined with 10, 5 t ha^{-1} FYM, and 7 t compost ha^{-1} increased the straw yield over the control treatment by about 142, 100, and 96% respectively. Straw yield of bread wheat was also significantly influenced by the interaction of variety and year in which straw yields were higher for all varieties in 2014 than in 2013 (Table 6).

3.5. Harvest Index

Harvest index significantly varied in response to application of the fertilizers, variety, and year and due to the interaction of year and variety (Table 6). It ranged from 34.25% to 41.06%. The highest harvest indices were recorded for all combined application rates of the three fertilizers whereas the lowest were recorded for the application of lone full dose of the blanket recommended mineral NP fertilizers (41 kg N + 46 kg P_2O_5 ha^{-1}), lone full dose of FYM (10 t ha^{-1}), and the control treatments. For the bread wheat varieties, the harvest indices ranged from 42% for Kakaba in 2014 to 36% for Paven 76 in 2013 (Table 7). However, the harvest index of Kakaba was significantly higher than the harvest indices of the two other bread wheat varieties (Tables 6 and 7).

3.6. Partial Budget Analysis

The treatment having MRR below 100% was considered low and unacceptable to farmers thus eliminated (CIMMYT, 1988). This was because such a return would not offset the cost of capital and other inputs while still giving an attractive profit margin to serve as an incentive.

The economic analysis revealed that the highest net return with acceptable marginal rates of return of 37290 ETB, 33002 ETB, and 30835 ETB ha^{-1} were obtained in response to the application of half of the blanket recommended rate of NP fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1})+ 5.0t FYM ha^{-1}. The highest net returns were recorded at the aforementioned rate of fertilizer for the varieties Kakaba, Mekelle I, and Paven 76, in a decreasing order as stated here (Table 8).

Table 6. Mean grain yield, straw yield, and harvest index (HI) of bread wheat varieties as influenced by application of mineral and organic fertilizers, variety and year of cultivation in the 2013 and 2014 main cropping seasons in Enderta, Tigray Regional State, Ethiopia.

Fertilizer rate	NKPS (No.)	TKW (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI%
41 kg N + 46 kg P_2O_5 ha^{-1}	36.58^{c}	36.82^{bc}	2928.70^{c}	4495.50^{bcd}	39.20^{b}
10 t FYM ha^{-1}	35.45^{c}	35.31^{bc}	2700.00^{de}	4301.20^{cd}	38.35^{b}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 10 t FYM ha^{-1}	41.84^{a}	39.97^{a}	3678.50^{a}	5301.80^{a}	40.94^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 5.0 t FYM ha^{-1}	41.63^{a}	38.96^{ab}	3486.6^{ab}	4972.90^{ab}	41.06^{a}
7.0 t compost ha^{-1}	34.58^{c}	34.37^{c}	2547.60^{e}	4040.30^{d}	40.58^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 7.0 t compost ha^{-1}	40.49^{ab}	40.50^{a}	$3346.5b^{c}$	4851.30^{ab}	40.76^{a}
20.5 kg N + 23 kg P_2O_5 ha^{-1} + 3.5 t compost ha^{-1}	38.87^{b}	38.64^{ab}	3206.00^{c}	4589.60^{bc}	41.07^{a}
Control (unfertilized)	28.67^{d}	28.37^{d}	1289.00^{f}	2474.30^{e}	34.25^{c}
LSD (0.05)	2.18	2.78	248.90	492.99	1.54
Variety					
Mekelle1	37.32^{b}	36.07^{b}	2868.63^{b}	4460.44^{a}	38.67^{b}
Paven 76	35.20^{c}	35.56^{b}	2650.32^{c}	4229.00^{b}	38.01^{b}
Kakaba	39.27^{a}	38.24^{a}	3174.65^{a}	4445.60^{ab}	41.14^{a}
LSD (0.05)	1.33	1.70	152.42	231.86	0.94
Year					
2013	35.87^{b}	33.99^{b}	2592.75^{a}	4173.68b	38.09^{b}
2014	38.66^{a}	39.26^{a}	3202.97^{b}	4583.06a	40.46^{a}
LSD(0.05)	1.09	1.39	124.45	188.00	0.77
CV%	8.86	11.48	23.54	12.99	6.22

Note: Means of the same parameter in a column followed by the same letter are not significantly different at P = 0.05 according to LSD Fishers Protected Test. NKPS = number of kernels per spike, TKW = Thousand kernel weight HI = harvest index

Table 7. Interaction effect of variety and year on harvest index and straw yield of bread wheat in 2013 and 2014 main cropping seasons in Enderta, Tigray Regional State, Ethiopia.

Variety	Straw yield (kg ha^{-1})		Harvest index (%)	
	2013	2014	2013	2014
Mekelle I	4230.41^{b}	4690.53^{a}	37.35^{c}	40.00^{b}
Kakaba	4065.55^{b}	4825.83^{a}	40.61^{ab}	41.67a
Paven 76	4225.20^{b}	4232.90^{b}	36.31^{c}	39.71^{b}
LSD(0.05)	325.12		1.33	
CV%	12.99		5.92	

Note: Means in a column followed by the same letter are not significantly different at 5% level of significance according to LSD Fishers Protected Test

4. Discussion

The increase in soil organic matter, total nitrogen, and available phosphorus observed in this study in response to the application of FYM and compost are in line with the findings of Aziz *et al*. (2010), Dinesh *et al*. (2012) and Kwadwo et *al*. (2015) who reported enhanced contents of soil organic matter and plant available nutrients in response to the application of organic fertilizers. Similarly, these results are in agreement with that of Wondimu et *al*. (2006) who reported that FYM application increased soil organic matter over the control treatment and improved soil fertility status at Sirinka Agricultural Research Centre in northern Ethiopia.

The enhanced crop growth and productivity due to the application of integrated organic manure and mineral fertilizer may be attributed to improved soil physical conditions, enhanced soil fertility and gradual release of plant nutrients and increased nutrient uptake by the plant to support growth. Similar results were also reported by Afifi *et al*. (2003), Matsi *et al*. (2003), and Rehman and Khalil (2008) who obtained higher aboveground biomass yield from the application of organic manure and mineral fertilizer, which could be attributed to improved root growth and increased uptake of nutrients favoring better growth and delayed senescence of leaves of the crop.

Table 8. Estimated marginal rate of return (%) for mineral and organic fertilizer treatments on bread wheat during the 2013 and 2014 cropping seasons in Enderta District, Tigray Regional State, Ethiopia.

Treatment	TCV (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Raised benefit (ETB ha^{-1})	Raised Cost (ETB ha^{-1})	MRR%
	Variety Mekelle I				
Control(check)	0.00	14564.04	-	-	-
RNP (41 kg N + 46 kg P_2O_5 ha^{-1})	2130.15	30242.05	15678.01	2130.15	736%
½ RNP + 3.5 compost t ha^{-1}	2146.32	31040.20	798.15	16.17	4936%
½ RNP + 5 t FYM ha^{-1}	2790.07	33002.07	1961.87	643.75	305%
½ RNP + 10 t FYM ha^{-1}	4415.07	33838.12	836.05	1625.00	51%
	Variety Kakaba				
Control(check)	0.00	15422.41	-	-	-
RNP (41 kg N + 46 kg P_2O_5 ha^{-1})	2130.15	30770.98	15348.57	2130.15	721%
½ RNP + 3.5 compost t ha^{-1}	2146.32	32708.30	1937.32	16.17	11981%
½ RNP + 5 t FYM ha^{-1}	2790.07	37290.80	4582.50	643.75	712%
½ RNP + 10 t FYM ha^{-1}	4415.07	37134.16	1625.00	1625.00	100%
	Variety Paven76				
Control(check)	0.00	12367.32	-	-	-
RNP (41 kg N + 46 kg P_2O_5 ha^{-1})	2130.15	26720.23	14352.91	2130.15	674%
½ RNP + 3.5 compost t ha^{-1}	2146.32	27288.20	567.97	16.17	3512%
½ RNP + 5 t FYM ha^{-1}	2790.07	30835.38	3547.18	643.75	551%
½ RNP + 10 t FYM ha^{-1}	4415.07	31416.23	580.85	1625.00	36%

Note: RNP = Recommended Fertilizer Rate; TVC = Total variable cost; MRR = Marginal Rate of Return

Increase in total aboveground biomass and grain yields in response to application of the mineral and organic fertilizers could be attributed to enhanced uptake of nutrients and water by the plants as a result of improved availability in the soil. This result is consistent with that of Sarwar *et al.* (2008), who reported enhanced growth and yield of rice in response to application of compost

The significantly higher yield and dry biomass yield of Kakaba in comparison to the other two bread wheat varieties could be attributed to the genetic constitution of the variety as indicated by Sharshar and Said (2000). The other possibility may have been differential uptake of nutrients by the varieties. Kakaba may have increased its total aboveground biomass yield through more uptake and efficient utilization of the available nutrient (data not shown). The difference in the grain yield of wheat varieties might be due to the differences in their yield components like spike length, kernels per spike, number of effective tillers produced per plant and harvest index that may have contributed to the highest grain yield of the former. Corroborating this result, Iftikhar *et al.* (2002) and Jemal *et al.* (2015) showed enhanced grain production of wheat varieties due to better production of fertile tillers, number of grains per spike, and maximum 1000-grain weight. It is obvious that high yielding wheat varieties demand ample nutrient supply to produce maximum grain yield (Ali and Yasin, 1991). In the same way, Dalrymple (1986) reported that semi-dwarf wheat varieties were shown to attain increased yields through more efficient utilization of assimilates associated with crop lodging.

Furthermore, varying yields between the growing seasons might be attributed to differences in rainfall variability in which the mount (522 mm) and distribution of rainfall in 2014 was apparently more adequate than the one that fell in the 2013 cropping season which amounted to 398 mm, and was less by about 24% than the rainfall that was received in 2014. Thus, the observed increase in grain yield components in the 2014 growing season could be ascribed to enhanced water and nutrient availability in the soil, which may have concomitantly improved uptake of nutrients by the wheat plants, thereby leading to enhanced production and translocation of dry matter contents from source to sink (Ebaid *et al.*, 2007). Similar results were also reported by Dejene *et al.* (2010) in which grain yield of tef was significantly influenced by fertilizer type and year. On the other hand, the low biological yields of the crop plant in the 2013 cropping season may be attributed to the relatively lower amount of rainfall received than the amount received in the 2014 cropping season. Consistent with this suggestion, Muurinen *et al.* (2007) also indicated that seasonal differences in rainfall accounted for year x genotype and year x N rate interactions.

Likewise, the varying grain yields between the years could also be attributed to the varying dry matter production contributed by higher nutrient uptake (data not shown) for increased metabolic activity.

Similar observations were also made by Alam (2007) where varieties responded differently to differences in nutrient supplies in the soil. On the other hand, Sharshar and Said (2000) reported that different varieties responded differently to their genotypic characters, input requirements, growth process and the prevailing environment during the growing season. A similar result was also reported by Alam (2007). The increase in grain yield of wheat in response to combined application of mineral fertilizers either with FYM or compost might be attributed to possible improvement in moisture retention capacity, soil physical properties, enhanced soil fertility and better utilization of nutrients (Edward, 2007; Tayebeh *et al*., 2010; Chuan *et al.,* 2013; Assefa, 2015; Tewodros and Belay, 2015). The beneficial effect of organic manure on yield may be due to the increased organic matter content of the soil (Wilkinson, 1979) and improvement in the soil structure conditions, which encourages the plant to have good root development by improving the aeration and moisture holding capacity of the soil (Arisha *et al*., 2003). This suggestion is concurrent with the results of Murage *et al.* (2000) who reported that soil organic matter is a surrogate for total soil nitrogen. Sharma *et al.* (1990) also reported that the application of manure made the soil more porous and pulverized it which allows better root growth and development and significantly increased the root CEC at each stage of growth.

Besides, compost not only releases nutrients slowly but also prevents losses of mineral fertilizers through denitrification, volatilization and leaching by binding to nutrients and releasing them with the passage of time, thereby improving nutrient uptake by plants and crop yields (Arshad *et al*., 2004). Increased grain yields in response to the integrated use of organic and mineral fertilizer as opposed to their sole application were reported by various researchers (Getachew and Taye , 2005; Våje, 2007; Bandyopadhyay *et al.,* 2009, Dejene *et al*., 2010).

The increased yield attributes might be due to induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters (Hidayatullah *et al*., 2013; Sharma *et al*., 2013). In addition, it is evident from the results obtained in this experiment that combining mineral fertilizer with FYM was more productive than combining with compost. This might be attributed to the difference in nutrient concentration of the FYM and compost used in the experiment, in which N, P and organic matter contents in farmyard manure were higher than the compost which may have induced better growth as reported by Chong (2005) and Dejene *et al.* (2010).

The increment in HI from combined fertilizer application might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning into straw. Mitiku *et al.* (2014) also indicated that FYM and inorganic NP increased HI of barley. Similarly, Mooleki *et al.* (2004) reported the same on rice. Thus, factors which make up grain yield such as kernel weight and kernel number have great effect on harvest index. Thus, the highest harvest index of the variety Kakaba may be attributed to its higher kernel weight, number of kernels and higher grain yield as compared to the other two varieties. Similarly, the moisture supply during the 2014 growing season may have impacted up on higher kernel weight and kernel number as compared to 2013, which in turn may have impacted on harvest index. The highest agronomic yields, however, did not bring about the highest profit as the value of the increase in yield was not enough to compensate for the increase in costs (TVC) of the treatments.

5. Conclusion

The results of this study have demonstrated that applying mineral NP fertilizer combined with FYM and compost enhanced growth and yield of bread wheat as well as increased contents of soil organic carbon, total nitrogen, and available phosphorus. Furthermore, the results have shown that variety Kakaba is superior to both Mekelle I and Faven 76 in grain and biomass yields, indicating high potential of the variety for adoption and cultivation in the study area.

Concerning the fertilizer application, combined supply of the blanket recommended NP fertilizer with 10 and 5 t ha^{-1} FYM, and 7 and 3.5 t ha^{-1} compost increased the grain yield of the crop significantly by 185%, 170%, 160% and 149% over the control treatment, respectively. In addition, application of the aforementioned rates of combined fertilizers led to grain yield increments of 19, 25, 14, and 9.0%, respectively, over the grain yield obtained in response to application of full dose of the blanket recommended mineral NP fertilizer. Specifically, the cost benefit analysis also indicated that applying half of the blanket recommended mineral NP fertilizer (20.5 kg N + 23 kg P_2O_5 ha^{-1}) combined with 5.0 t FYM ha^{-1} led to the production of optimum grain and straw yields. These two combined fertilizer rates resulted in the production of twice as much grain yield of the crop as the average grain yield obtained in the region (i.e., 100% increment), which is 1.4 t ha^{-1} and in about a 50% additional grain yield increment over the national bread wheat grain yield in the whole country, which is 2.4 t ha^{-1}.

The results of the study generally imply that optimum yields of the crop and sustainably enhanced chemical properties of the soil, namely, soil organic matter, total nitrogen, and available phosphorus are ensured not merely by application of full dose of the blanket recommended mineral NP fertilizer but by combining half of it with at least 5.0 t FYM ha^{-1}. However, dearth of FYM due to scarcity and competing end-users may hinder widespread use of this fertilizer in the study area. Therefore, policy makers and development agents need to focus on promoting application of organic fertilizers to crop fields as a customary practice by providing other options to replace the use of manure and crop residues as fuel wood, construction, animal feed etc. The variations in grain and strain yields across the two seasons indicated that adequate rainfall during a growing season is necessary to realize enhanced productivity of crops through fertilizer application. Therefore, supplementary irrigation needs to be promoted to enhance the benefit that farmers could get from application of fertilizers. Future research work has to be geared towards elucidating the effect of using varied rates of combined mineral NP and organic fertilizers with different water regimes for optimization of productivity of the crop and its water and fertilizer use efficiencies in the study area.

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7. References

Abay Ayalew and Tesfaye Dejene. 2012. Combined application of organic and inorganic fertilizers to increase yield of barley and improve soil properties at Fereze, in Southern Ethiopia. *Innovative Systems Design and Engineering,* 22 (1): 25-34.

Afifi, M. H, Manal, F. M. and Gomaa, A. M. 2003. Efficiency of applying biofertilizers to maize crop under different levels of mineral fertilizers. *Annals of Agricultural Science Moshtohor*, 41(4):1411-1420.

Alam, M. S., Nesa, M. N., Khan, S. K., Hossain, M. B. and Hoque, A. 2007. Varietal Differences on Yield and Yield Contributing Characters of Wheat under Different Levels of Nitrogen and Planting Methods. *Journal of Applied Sciences Research*, 3 (11): 1388-1392.

Ali, R. and Yasin, M. 1991. Response of wheat to nitrogen and phosphorus fertilization. *Pakistan Journal of Agricultural Research,* 12: 130–133.

Arisha, H. M. E., Gad, A. A. and Younes, S. E. 2003. Response of some pepper cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. *Zagazig J. Agricultural Research*, 30: 1875-1899.

Arshad, M., Khalid, A., Mahmood, M. H., Zahir, Z. A. 2004. Potential of nitrogen and L-tryptophan enriched compost for improving growth and yield of hybrid maize. *Pakistan Journal of Agricultural Science,* 41: 16-24.

Aseefa Abegaz. 2008. Indigenous soil nutrient supply and effects of fertilizer application on yield, N, P and K uptake, recovery and use efficiency of barley in three soils of Teghane, the Northern Highlands of Ethiopia. *African J. Agricultural Research,* 3 (10): 688-699.

Assefa Workineh. 2015. Response of Barley (*Hordium vulgare L.*) to Integrated Cattle Manure and Mineral Fertilizer Application in the Vertisol Areas of South Tigray, Ethiopia. *Science Publishing group Journal of Plant Science,* 3(2): 71-76.

Atakilte Beyene, Gibbon, D. and Mitiku Haile, 2006. Heterogeneity in land resources and diversity in farming practices in Tigray, Ethiopia. *Agric. Syst.,* 88 (1): 61-74.

Aziz, T., Ullah, S., Sattar, A., Nasim, M., Farooq, M. and Mujtabakhan, M. 2010. Nutrient Availability and Maize (*Zea mays*) Growth in Soil Amended with Organic Manures. *Inter. J. Agr. Biolo.,* 12 (4): 621-624.

Balesh Tulema., Bernt, A. J. and Breland, T. 2007. Availability of organic nutrient sources andtheir effects on yield and nutrient recovery of tef [*Eragrostis tef* (Zucc.)Trotter] and on soil Properties. *J. Plant Nutrition and Soil Science,* 170: 543–550.

Bandyopadhyay, K. K., Ghosh, P. K., Hati, K. M. and Misra, A. K. 2009. Efficient utilization of limited available water in wheat through proper irrigation scheduling and integrated nutrient management under different cropping system in a Vertisols. *Journal of the Indian Society of Soil Sciences,* 57(2): 121-128.

Central Statistics Agency (CSA). 2013. Agricultural Sample Survey, Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 532, Addis Ababa.

Chong, R. 2005. Using organic fertilizer. Food and Fertilizer technology center for the Asia and Pacific regions, China.

Chuan, L., Ping, H., Mirasol, F. P., Adrian, M. J., Jiyun, J., Xinpeng, Xu., Shicheng, Z., Shaojun, Q. and Wei, Z. 2013. Establishing a scientific basis for fertilizer recommendations for wheat in China: Yield response and agronomic efficiency. *Field Crops Research*. 140: 1-8.

CIMMYT (International Maize and Wheat improvement Center). 1988. From Agronomic Data to Farmers Recommendations: *Economics Training Manual*. Completely Revised ed, CIMMYT, Mexico. D.F.

Cottenie A. 1980. Soil and plant testing as a basis of fertilizer recommendation. FAO Soils Bulletin No. 38. Rome, Italy FAO.

Darlymple, D. G.1986. Development and spread of high-yielding wheat varieties in developing countries. *Bureau for Science and Technology Agency for International Development,* Washington. D.C.

Dejene Kassahun., Dereje Asefa and Daniel G/Kidan. 2010. Synergistic Effect of a Combined Application of Organic and Inorganic Fertilizers on Yield and Yield Components of Tef (*Eragrostis tef* (Zucc.)Trotter) Under Terminal Drought at Adiha, Northern Ethiopia. *J. Drylands,* 3(1): 158-164.

Dercon, S. and Christiaensen, L. 2007. "Consumption Risk, Technology Adoption, and Poverty Traps: Evidence from Ethiopia." World Bank Policy Research Working Paper 4527. Washington, D.C: World Bank.

Devi, R, Kumar, A. and Bishaw Deboch. 2007. Organic farming and sustainable development in Ethiopia. *Scientific Research and Essay*, 2 (6): 199-203.

Dinesh, R., Srinivasan, V., Hamza, S. and Manjusha, A. 2012. Short-term incorporation of organic manures and biofertilizers influences biochemical and microbial characteristics of soils under an annual crop [Turmeric (*Curcuma longa* L.)]. *Bio resource Technology,* 101 (12): 4697-4702.

Ebaid, R. A. and El-refaee, I. S. 2007. Utilization of rice husk as an organic fertilizer to improve productivity and water use efficiency in rice fields. *African Crop Science Conference Proceedings*, 8: 1923-1928.

Edwards, S. 2007: Greening Ethiopia: Ecological Agriculture with Smallholder Farmers in Ethiopia.

Edwards, S. A., Arefaine Asmelash and Tewoldebrhan Gebre-Egziabher. 2007. Impact of Compost Use on Crop Production in Tigray, Ethiopia. Rome: FAO, Natural Resources Management and Environment Department.

Fassil Kebede and Charles, Y. 2009. Soil Fertility Status and Numass Fertilizer Recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia. *World Applied Sciences J.,* 6 (11):1473-1480.

Gashaw Tadesse., Alan, de.B., Nicholas, M. and Tangu, B.2014. The Impact of the Use of New Technologies on Farmers Wheat Yield in Ethiopia: Evidence from a Randomized Controlled Trial, IFPRI.

Getachew Agegnehu and Chilot Yirga. 2009. Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, pp. 24. Holetta Research Center, Ethiopia.

Getachew Agegnehu and Taye Bekele. 2005. On-farm integrated soil fertility management in wheat on Nitisols of central Ethiopian highlands. *Ethiopian J. Natural Resources,* 7: 141-155

Global Agricultural Information Network (GAIN). 2014. Report: ET1401, Addis Ababa: USDA.

Godara, A. S., Gupta, U. S. and Singh, R. 2012. Effect of integrated nutrient management on herbage, dry fodder yield and quality of oat (*Avena sativa* L.). *Forage Research,* 38 (1): 59-61.

Hailu Araya. 2010. The effect of compost on soil fertility Enhancement and yield increment under smallholder farming, The case of Tahtai-Maichew district-Tigray region, Ethiopia, University of Hohenheim, Germany, PhD Thesis, pp. 186.

Hazelton, P. and Murphy, B. 2007. Interpreting soil test results: What do all the numbers mean? 2nd Edn.. CSIRO Publishing. Pp. 152.

Hidayatullah, A. J., Amanullah, J. and Zahir, S. 2013. Residual Effect of Organic Nitrogen Sources Applied to Rice on the Subsequent Wheat Crop. *Intr J. Agronomy and Plant Production,* 4 (4): 620-631.

Hintsa Gebru, Abraha Hailemariam and Tesfay Belay. 2011. Genotype by environment interaction and grain yield stability of early maturing bread wheat (*Triticum aestivum* L.) genotypes in the drought prone areas of Tigray region, northern Ethiopia. *Ethiopian Journal of Applied Science and Technology,* 2 (1): 51-57.

Iftikhar, H. M., Shamshad, H. S., Sajjad, H. and Khalid, I. 2002. Growth, Yield and Quality Response of Three Wheat (*Triticum aestivum* L.) Varieties to Different Levels of N, P and K. *Intr. J. Agriculture and Biolo.,* 4 (3): 362-364.

Jemal Abdulkerim, Tamado Tana and Firdissa Eticha .2015. Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Seeding Rates at Kulumsa, South Eastern Ethiopia. *Asian J. Plant Sciences,* 14 (2): 50-58.

Kassie, M., Yesuf, M. and Köhlin, G. 2008. The Role of Production Risk in Sustainable Land-Management Technology Adoption in the Ethiopian Highlands, EfD Discussion Paper 08-15. Washington, D.C. Resources for the Future.

Kwadwo A., Boateng G. and Christian L. A. 2015. The Effect of Organic Manures On Soil Fertility and Microbial Biomass Carbon, Nitrogen and Phosphorus Under Maize-Cowpea Intercropping System Discourse. *Journal of Agriculture and Food Sciences,* 3 (4): 65-77.

Matsi, T. A., Lithourgidis, S. and Gagianas, A. A. 2003. Effect of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. *Agronomy J.,* 95: 592-596.

Medhn Berhane, Fassil Kebede, Ibrahim Fitiwy and Zenebe Abreha. 2013. Comparative productivity and profitability of organic and conventional tef *[Eragrostis tef (*Zucc.)Trotter] production under rainfed condition: Tigray, Northern Ethiopia. *World Journal of Agricultural Sciences,* 1 (10): 303-311.

MesayYami, Fekadu Fufa, Terfe Fita and Sultan Usman. 2012. Prospects and Challenges of Wheat Production in Ethiopia: Evidence from Major Wheat Producing Regions of the Country Wheat

Regional Center of Excellence (WRCoE) Eastern Africa Agricultural Productivity Project (EAAPP) Wheat for Food security in Africa Conference October 8-12, 2012, Addis Ababa, Ethiopia.

Mitiku Woldesenbet, Tamado Tana, Singh, T.N and Teferi Mekonnen. 2014. Effect of Integrated Nutrient Management on Yield and Yield Components of Food Barley (*Hordeum vulgare* L.) in Kaffa Zone, Southwestern Ethiopia. *Science, Technology and Arts Research J.,* 3 (2): 34-42.

Mooleki, S. P., Schoenau, J. J., Charles, J. L. and Gwen, G. 2004. Effect of rate, frequency and incorporation of feedlot cattle manure on soil nitrogen availability crop performance and nitrogen use efficiency in east-central Saskachwan. *Canadian J. Soil Science,* 84: 199-210.

Murage, E. W., Karanja, N. K., Smithson, P. C. and Woomer, P. L. 2000. Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. Agriculture. *Ecosystems and Environment,* 79: 1–8.

Muurinen, S., Kleemola, J. and Peltonen-Sainio, P. 2007. Accumulation and translocation of nitrogen in spring cereal cultivars differing in nitrogen use efficiency. *Agronomy J.,* 99: 441-449.

Palm, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G. and Giller, K. E. 2001. Organic inputs for soil fertility management in tropical agro-ecosystems: application of an organic resource database. *Agriculture, Ecosystems and Environment,* 83: 27–42.

Rehman, S. and Khalil, S. K. 2008. Organic and inorganic fertilizers increase wheat yield components and biomass under rain-fed condition. *Sarhad J. Agriculture*, 24 (1): 11-20.

Rowell, D. 1994. Soil Science; Methods and Application, Longman Scientific and Technical, 350p

Sarwar, G., Hussain, N., Schmeisky, H., Muhammad, S., Ibrahim, M. and Safdar, E. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. *Pakistan J. Botany,* 40: 275-282.

SAS (Statistical Analysis System) Institute.2003. "SAS Version 9. 1.2 © 2002-2003". SAS Institute, Inc., Cary, North Carolina, USA.

Sharma, G. D., Risikesh, T., Som, R. A. J., Kauraw, D. L. and Kulhare, P. S. 2013. Impact of Integrated Nutrient Management on Yield, Nutrient Uptake, Protein Content of Wheat (*Triticum aestivum*) and Soil Fertility. *A Typic Haplustert Bioscan,* 8(4): 1159-116.

Sharma, P. K., Verma, T. S. and Gupta, J. P. 1990. Ameliorating effects of phosphorus, lime and animal manure on wheat yield and root cation exchange capacity in degraded Alfisols of North-West Himalayas. *Fertilizer Research*, 23: 7-13.

Sharshar, M. S. and Said, A. E. 2000. Evaluation of some wheat cultivars and lines under low and high inputs. Mansoura University *Journal of Agricultural Science*, 25 (6): 3109-3127.

Tayebeh, A., Abass, A. and Seyed, A. K. 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. *Australian J. Crop Science*, 4 (6): 384-389.

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis.Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa.

Tewodros Mulualem and Belay Yebo.2015.Review on integrated soil fertility management for better crop production in Ethiopia. *Sky J. Agricultural Research*, 4 (1): 21 – 32.

Våje, P. I. 2007. Soil fertility issues in Blue Nile Valley, Ethiopia. Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities. Springer Publishing, Dordrecht, the Netherlands, pp: 139-148.

Wakene Negassa, Fite Getahun, Abdenna Deressa and Berhanu Dinsa. 2007. Integrated Use of Organic and Inorganic Fertilizers for Maize Production. Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs. University of Rostock, Institute of Land Use, Justus-von-Liebig Weg 6, 18059, Rostock, German.pp.1 - 18.

Wakene Negassa, Tolera Abera, Firesen D. K., Abdenna Deressa and Berhanu Dinsa. 2004. Evaluation of Compost for Maize Production under Farmer's Condition, Bako Agricultural Research Center, West Shoa, Ethiopia. pp. 382 – 386.In*: Proceedings of the Seventh Eastern and Southern Africa Regional Maize Conference, 11-17 February, 2002, Nairobi, Kenya*: CIMMYT:

Wakene Negassa, Tolera Abera, Firesen D. K., Abdenna Deressa and Berhanu Dinsa. 2001. Evaluation of Compost f or Maize Production under Farmer's Condition, Bako Agricultural Research Center, West Shoa, Ethiopia. In Seventh Eastern and Southern Africa Regional Maize Conference. pp. 382 – 386.

Wilkinson, S. R. 1979. Plant nutrient and economic value of animal manures. *J. Animal Science,* 48: 121-133.

Wondimu Bayu, Rethman, N. F. G., Hammes, P. S. and Getachew Alemu. 2006. Application of Farmyard Manure Improved the Chemical and Physical Properties of the Soil in a Semi-Arid Area in Ethiopia. *Biological Agriculture and Horticulture,* 24 (3): 293-300.