academicJournals

Vol. 8(14), pp. 1218-1224, 18 April, 2013
DOI: 10.5897/AJAR12.2237
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

*Full Length Research Paper*

# Improving and sustaining soil fertility by use of enriched farmyard manure and inorganic fertilizers for hybrid maize (BH-140) production at West Hararghe zone, Oromia, Eastern Ethiopia

**Zelalem Bekeko**

Department of Plant Sciences, Haramaya University Chiro Campus, P. O. Box 335, Chiro, Ethiopia.

Accepted 8 April, 2013

**A study was conducted at the Haramaya University Chiro Campus to determine the effect of enriched FYM and inorganic fertilizers on grain yield of maize and soil chemical properties. FYM was used either alone or in combination with inorganic fertilizers as follows: Control (zero fertilizers and FYM), 10 tons/ha FYM, 8 tons/ha FYM and 25 kg/ha of N + 20 kg/ha P, 6 tons/ha FYM, 50 kg/haN + 40 kg/ha P, 4 tons/ha FYM, 75 kg/ha N + 60 kg/ha P, 2 tons/ha FYM, 100 kg/ha N+80 kg/ha P, 100 kg/ha N + 100 kg/ha P. The treatments were arranged in randomized complete block design with four replications from 2008 to 2011. Result showed that 59.60 Cmole/kg, 4.58%, 0.82%, 62.7 ppm, cation exchange capacity (CEC), %OC, total N, and available P, respectively were noted after FYM application over years indicating improved soil chemical properties. Similarly, combined analysis of variance on hybrid maize (BH-140) yield over years showed no significant difference among treatments in comparison with 10 tons/ha FYM and 100 kg/ha N + 100 kg P/ha ($p < 0.05$). But 4 tons/ha FYM and 75 kg/ha N+60 kg/ha P increased maize yield from 5.1 tons/ha in 2009 to 8.15 tons/ha in 2010. From this finding, it was noted that enriching FYM with inorganic fertilizers can boost hybrid maize grain yield significantly through improving the physicochemical properties of the soil. On the basis of these results, it can be concluded that enriched FYM should be used for hybrid maize production at Western Hararghe in order to get maximum grain yield and sustain soil productivity. Thus, it is recommended that application of 4 tons/ha FYM incorporated with 75 kg of N and 60 kg of P at Chiro can significantly increase hybrid maize (BH-140) yield and sustain its productivity over years. Besides, it also reduces the cost of inorganic fertilizers which is becoming a bottle neck to smallholder farmers of Eastern Ethiopia. However, profitability of this technology needs to be tested at different locations and in different seasons.**

**Key words:** Soil fertility, farm yard manure, Hybrid maize (BH-140), cation exchange capacity (CEC) inorganic fertilizers

## INTRODUCTION

Maize is one of the most important cereals broadly adapted worldwide (Christian et al., 2012). In Ethiopia, it is grown in the lowlands, the mid-altitudes and the highland regions. It is an important field crop in terms of area coverage, production and utilization for food and feed purposes. However, maize varieties mostly grown in

*Corresponding author. E-mail: zelalembekeko@yahoo.com. Tel: +251911810622. Fax: +251255510182.

the highlands (1,700 to 2,400 m.a.s.l) of Ethiopia are local cultivars with poor agronomic practices (Beyene et al., 2005; Soboksa et al., 2008). They are low yielding, vulnerable to biotic and a biotic constraint and also exhibit undesirable agronomic performances such as late maturity and susceptibility to root rot and stalk lodging (Legesse et al., 2007; Soboksa et al., 2008). Enhancement of maize production and productivity can be achieved through identification of potentially superior inbred line combinations in the form of hybrids along with proper supplementation of plant nutrition (Worku et al., 2001; Betran et al., 2003; Wonde et al., 2007; Shah et al., 2009; Achieng et al., 2010).

One of the major problems affecting food production in Africa including Ethiopia is the rapid depletion of nutrients in smallholder farms (Badiane and Delgado, 1995; Achieng et al., 2010). Soil nutrient replenishment is therefore a prerequisite for halting soil fertility decline. This may be accomplished through the application of mineral and organic fertilizers (Wakene et al., 2005). Animal manures are valuable sources of nutrients and the yield-increasing effect of manure is well established (Leonard, 1986; Wakene et al., 2005; Silvia et al., 2006). Organic matter in the soil improves soil physical conditions by improving soil structure, increases water-holding capacity, and improves soil structure and aeration, as well as regulating the soil temperature (Gachene and Gathiru, 2003; Wakene et al., 2005). Organic matter contains small varying amounts of plants nutrients, especially nitrogen, phosphorus and potassium which are slowly released into the soil for plant uptake (Gachene and Gathiru, 2003; Achieng et al., 2010).

Chemical fertilizers are used in modern agriculture to correct known plant nutrient deficiencies, to provide high levels of nutrition, which aid plants in withstanding stress conditions, to maintain optimum soil fertility conditions, and to improve crop quality. Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns (Leonard, 1986). The broad aim of integrated nutrient management is to utilize available organic and inorganic sources of nutrients in a judicious and efficient manner. Based on the evaluation of soil quality indicators, Dutta et al. (2003) reported that the use of organic fertilizers together with chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and hence soil health. Sutanto et al. (1993) in their studies on acid soils for sustainable food crop production noted that farmyard manure (FYM) and mineral fertilizer produced excellent responses. Boateng and Oppong (1995) studied the effect of FYM and method of land clearing on soil properties on maize yield and reported that plots treated with poultry manure and NPK (20-20-0) gave the best yield results.

Soil fertility depletion on smallholder farms is one of the fundamental biophysical root causes responsible for declining food production in eastern part of Ethiopia (Heluf et al., 1999). Especially, in the highlands of Hararghe, where maize is grown among the major cereals in the high rainfall areas such as Chiro, Doba, Tullo, Mesela, Gemechis, Kuni, Boke Habro and Daro Labu, its productivity is severely constrained by poor soil fertility and poor crop management practices. Yield is too small usually less than 2 tons/ha as compared to a potential yield of over 5 tons/ha in the region (Zelalem, 2012). Particularly, nutrient deficiency is one of the major constraints to maize production and productivity in these areas. Intercropping is widely used in these areas by combining maize or sorghum with perennial crops like Khat (*Chata edulis*) which exposes the soil to rampant nutrient degradation leading to poor crop yield (Heluf et al., 1999; Fininsa, 2001; Ararsa, 2012).

Application of FYM and inorganic fertilizers N and P significantly increases grain yield of hybrid maize cultivars and improves some soil chemical and physical properties such as available P, cation exchange capacity (CEC), total nitrogen, the texture, structure and water holding capacity of the soil (Debelle et al., 2001; Wakene et al., 2005; Shah et al., 2009; Tesdale et al., 1993; Heluf et al., 1999; Asfaw et al., 1998; Achieng et al., 2010).

The recycling and the use of nutrients from organic manure have been given more consideration for insuring sustainable land use in agricultural production development (Ararsa, 2012). The positive influence of organic fertilizers on soil fertility, crop yield and quality has been demonstrated in the works of many researchers (Hoffman, 2001). Organic materials are a good source of plant nutrients and have a positive effect on improvement of the soil physical structure (Silvia et al., 2006; Zelalem, 2012). Application of animal manures to agricultural fields is a widely used method of increasing soil organic matter and fertility (Debelle et al., 2001; Wakene et al., 2005; Heluf et al., 1999; Khaliq et al., 2009). Most solid livestock manures can be applied directly to crop fields or piled for composting. In organic farming, nitrogen is supplied through organic amendments in the form of manure. Applying organic nitrogen fertilizer without prior knowledge of nitrogen mineralization and crop needs can result in nitrate-nitrogen ($NO_3$-N) leaching below the root and potential groundwater contamination(Debelle et al ., 2001).

The incorporated use of organic sources of nutrients not only supply essential nutrients but also has some positive interaction with chemical fertilizers to increase their efficiency and thereby to improve the soil structure (Elfstrand et al., 2007). Integrated use of chemical fertilizers and organic material may be a good approach for sustainable production of crops. Integrated use of organic matter and chemical fertilizers is beneficial in improving crop yield, soil pH, organic carbon and available N, P and K in sandy loam soil (Rautaray et al., 2003).

Khaliq et al. (2009) used partially decomposed cattle and chicken manure amended with wood ash and reported that higher plant yield of fodder maize was obtained by the use of chicken manure. In western part of Ethiopia, Wakene et al. (2005) and Debelle et al. (2001)reported the benefit of FYM in maize production and soil maintainace. But no investigation was made at eastern part of Ethiopia where the soil fertility is highly depleted using FYM and inorganic fertilizers for yield sustenance and soil health.

Hybrid maize variety (BH-140) was deployed to the farmers of Western Hararghe zone, Eastern Ethiopia during the last 5 years through the Oromia Bureau of Agriculture to boost the production and productivity of maize in the zone. However, the response of this hybrid maize (BH-140) cultivar to FYM and inorganic fertilizers and effect of these fertilizers on some soil properties at Western Hararghe zone is not studied. Therefore, the present investigation was carried out to evaluate the effects of FYM and inorganic fertilizers on grain yield of hybrid maize (BH-140) as well as soil chemical properties at Western Hararghe zone, Oromia Regional State, Ethiopia.

## MATERIALS AND METHODS

### Description of the study area

Western Hararghe is located between 7°55' N to 9°33' N latitude and 40°10' E to 41°39' E longitude. The major crops grown in the study area are sorghum, maize, chat, field beans, potato and tef. The area is characterized by Charcher Highlands having undulating slopes and mountainous in topography. The mean annual rainfall ranges from 850 to 1200 mm/year with minimum and maximum temperatures of 12 and 27°C, respectively.

### Treatment details

The response of hybrid maize variety (BH-140) was used as test crop, to N and P fertilizers. FYM was used either alone or in combination with inorganic fertilizers as follows: control (zero fertilizers and FYM), 10 tons/ha FYM, 8 tons/ha FYM and 25 kg/ha of N + 20 kg/ha P, 6 tons/ha FYM, 50 kg/haN + 40 kg/ha P, 4 tons/ha FYM, 75 kg/ha N + 60 kg/ha P, 2 tons/ha FYM, 100 kg/ha N + 80 kg/ha P, 100 kg/ha N + 100 kg/ha P. The treatments were arranged in randomized complete block design with four replications at the Haramaya University Chiro Campus from 2008 to 2011 cropping seasons.

### Experimental procedures

The experimental field was prepared by using local plough according to farmers' conventional farming practices. The field was ploughed four times each year during the experimental seasons. A plot size of 4 m length by 4.5 m width with six rows per plot was used. Spacing was 0.75 and 0.25 m between rows and plants, respectively. Planting was done in May 2008, 2009, 2010 and 2011 at a rate of 25 kg/ha. Enriched FYM was prepared by adding 10 kg of urea by pit method in 12 $m^3$ pit from cattle manure subjected to microbial fermentation for 90 days (Debelle et al., 2001; Achieng et al., 2010).

Urea (46-0-0) and triple superphosphate (TSP) (0-46-0) were used as sources of N and P, respectively. All P fertilizer and half dose of N fertilizer as per treatment were applied as basal application at planting and the remainder N was top-dressed at 35 days after planting and FYM was applied each year 1 month before the sowing date. Seeds of hybrid maize (BH-140) were sown on $10^{th}$ of May 2008, at $20^{th}$ of May 2009 and $15^{th}$ of May 2010 at the rate of 25 kg/ha. Sowing was completed on the same day. Then after, all necessary cultural practices were employed to raise a successful crop.

An area of 5.65 $m^2$, corresponding to 32 plants in the central four rows, was harvested immediately after physiological maturity for grain yield. During harvests, border plants at the ends of each row were excluded to avoid border effects. Grain moisture percent (MOI%) was estimated using a Dickey-John multi grain moisture tester. Grain yield (GY t $ha^{-1}$) was calculated using shelled grain and adjusted to 12.5% moisture (Mosisa et al., 2007).

Forty-six (46) surface soil samples (0 to 30 cm depth) were collected from representative spots of the entire experimental field after final plough and composited to two replicate samples for each analysis. These were analyzed for soil texture, pH, CEC, organic carbon, available P and total N. Similarly, surface soil samples at the same depth were collected at blooming stage (75 days after planting at the end of the final experimental seasons, 2011). One representative soil sample was taken from every plot, using auger to make composite sample per treatment for the analysis of total N and available P.

Soil texture was expressed by using Bouyoucos hydrometer method (Tesdale et al., 1993). Available P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen et al. (1954). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil: water mixture by using a pH meter, and organic carbon was determined by following Walkley and Black (1934) wet oxidation method as described by Jackson (1958). CEC was measured by using 1 M-neutral ammonium acetate. Total nitrogen was determined by using Kjedahl method as described by Jackson (1958).

In order to record the soil profile characteristics at the experimental site, a 2 m by 1.5 and 1.60 m deep pit was excavated adjacent to the experimental field and soil profile was described *in situ*. Soil samples were taken from all the identified horizons and pH, texture, organic matter content, total N, available P and CEC were analyzed using the same procedures. Bulk density, particle density and pore spaces were also determined.

### Statistical analysis

The data recorded in this study were subjected to statistical analysis. Analyses of variance were carried out using MSTATC soft ware. Significant differences between and/or among treatments were delineated by least significant differences (LSD). Interpretations were made following the procedure described byGomez and Gomez (1984)

## RESULTS

### Grain yield

Combined analysis of variance on grain yield of hybrid maize (BH-140) over years showed no significant difference between Treatments 2 and 7 (10 t/ha FYM and 100 kg/ha N +100 kg/ha P) (Tables 2 and 3) and also the result indicated that all proportions of FYM and inorganic fertilizer treatments significantly increased maize grain yield as compared to the control treatment (Tables 1 and

**Table 1.** Effect of enriched FYM on grain yield (mean values) of hybrid maize (BH-140) at Chiro, Western Hararghe from 2008 to 2011.

| Treatment | Mean grain yield of maize (kg/ha) | | | | | |
|---|---|---|---|---|---|---|
| | $Rep_1$ | $Rep_2$ | $Rep_3$ | $Rep_4$ | Total | Mean |
| Control (0 FYM and 0 N and P) | 1563 | 1784 | 1586 | 1657 | 6590 | 1647.5 |
| 10t/ha FYM+0 N and P | 6579 | 6934 | 6601 | 6496 | 26610 | 6652.5 |
| 8 t/ha FYM and 25 kg/ha N + 20 kg/ha P | 5546 | 5955 | 6266 | 5661 | 23428 | 5857 |
| 6 t/ha FYM and 50 kg/ha N + 40 kg/ha P | 5497 | 5353 | 4978 | 4854 | 20682 | 5170.5 |
| 4 t/ha FYM and 75 kg/ha N + 60 kg/ha P | 7601 | 8155 | 8042 | 8836 | 32634 | 8158.5 |
| 2 t/ha FYM and 100 kg/ha N + 80 kg/ha P | 7269 | 6837 | 6228 | 6340 | 26674 | 6668.5 |
| 100 kg/ha N + 100 kg/ha P | 6568 | 6821 | 7343 | 7256 | 27988 | 6997 |
| Total | 4063 | 41839 | 41044 | 41100 | 164606 | 6858.58 |

**Table 2.** Analysis of variance (mean value) for the effect of enriched FYM and inorganic fertilizers on grain yield of hybrid maize (BH-140) at West Hararghe zone, Oromia, Eastern Ethiopia (2008 to 2011).

| Sources of variation | DF | SS | MS | $F_{cal}$ | $F_{tab}$ |
|---|---|---|---|---|---|
| Treatment | 6 | 104302819.7 | 17383803.28 | | |
| Replication | 3 | 109453.84 | | | |
| Error | 18 | 2497295.16 | 138738.62 | 125.29* | 3.26 |
| Total | 27 | 106909568.7 | | | |
| CV (%) | 5.43 | | | | |
| LSD = 0.05 | 571.53 | | | | |

*Significant at 5%.

**Table 3.** Mean separation (Duncan's multiple range test) for the effect of enriched FYM and inorganic fertilizers on grain yield of hybrid maize (BH-140) at Western Hararghe zone, Oromia, Eastern Ethiopia (2008 to 2011).

| | 1647.5 | 6652.5 | 5857 | 5170.5 | 8158.5 | 6668.5 | 6997 |
|---|---|---|---|---|---|---|---|
| 1647.5 | 0 | -5005* | -4209.5* | -3523* | -6511* | -5021* | -5349.5* |
| 6652.5 | | 0 | $795.5^{ns}$ | $1482^{ns}$ | -1506* | -16* | -344.5* |
| 5857 | | | 0 | $686.5^{ns}$ | -2301.5* | -811.5* | -1140* |
| 5170.5 | | | | 0 | -2988* | -1498* | -1826.5* |
| 8158.5 | | | | | 0 | $1490^{ns}$ | $1161.5^{ns}$ |
| 6668.5 | | | | | | 0 | -328.5* |
| 6997 | | | | | | | 0 |

*Significant at 5%; $^{ns}$, non significant at 5%.

2) and the highest grain yield (8158 kg/ha) was obtained in the Treatment 4 (4 ton/ha FYM + 75 kg/ha N and 60 kg/ha P) and the lowest grain yield (1647.5 kg/ha) was obtained in the control plots (Table 1).

The analysis of variance also elucidated no significant difference among Treatments 2, 6 and 7 (10 t/ha FYM + 0 N and P, 2 t/ha FYM and 100 kg/ha N + 80 kg/ha P and 100 kg/ha N + 100 kg/ha P), respectively (Table 3) at ($p < 0.05$) on grain yield of hybrid maize (BH-140). But 4 ton/ha FYM and 75 kg/ha N + 60 kg/ha P increased maize yield from 5.1 t/ha in 2009 to 8.15 t/ha in 2010 (Table 1).

### Effect on chemical properties of soil

Result showed that 59.60 Cmole/kg, 4.58%, 0.82%, 62.7 ppm, CEC, %OC, total N, and available P, respectively over years indicating improved soil chemical properties after application of FYM (Table 5). From the analysis over 4 years, total N, available P and CEC increased by 2-fold as compared to their respective value before application of FYM and inorganic fertilizers in 2008 cropping season (Table 4). The percentage in OC did not significantly increased during the experimental seasons but the value of the soil pH showed slight decline (Tables 4 and 5).

**Table 4.** Chemical and physical properties of soil at Chiro, Western Hararghe before FYM and inorganic fertilizers application at 2008 cropping season

| Depth (cm) | Horizon | Particle size distribution (%) | | | Textural class | PD G ($cm^3$) | BD G ($cm^3$) | PS (%) | pH | OC (%) | Total N (%) | Av.P (ppm) | CEC Cmol/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Clay | Sand | Silt | | | | | | | | | |
| 0 - 30 | AP | 50 | 38 | 12 | Clay | 2.38 | 0.99 | 57.9 | 8.01 | 4.04 | 0.35 | 37.9 | 39.71 |
| 30 - 90 | Bt1 | 18 | 56 | 26 | Sand | 2.50 | 1.38 | 46.8 | 8.45 | 0.48 | 0.56 | 34.8 | - |
| 90 - 150 | Bt2 | 20 | 54 | 26 | Sand | 2.50 | 1.34 | 46.4 | 8.78 | 0.45 | 0.34 | 33.8 | - |

**Table 5.** Effect of enriched FYM and inorganic fertilizers on Chemical properties of soil at Chiro, western Hararghe (2008 to 2011)

| Depth (cm) | Horizon | Particle size distribution (%) | | | Textural class | PD g ($cm^3$) | BD g($cm^3$) | PS (%) | pH | OC (%) | Total N(%) | Av.P (ppm) | CEC Cmol/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Clay | Sand | Silt | | | | | | | | | |
| 0 - 30 | AP | 50 | 38 | 12 | Clay | 2.38 | 0.99 | 57.9 | 7.31 | 4.58 | 0.82 | 62.3 | 59.6 |
| 30 - 90 | Bt1 | 18 | 56 | 26 | Sand | 2.50 | 1.38 | 46.8 | 7.89 | 0.58 | 0.76 | 36.7 | - |
| 90 - 150 | Bt2 | 20 | 54 | 26 | Sand | 2.50 | 1.34 | 46.4 | 8.20 | 0.40 | 0.47 | 34.0 | |
| BAP | | | | | | | | | | 4.01 | 0.44 | 37.9 | 39.71 |
| AP | | | | | | | | | | 4.58* | 0.82* | 62.7* | 59.6* |

*Significant at 5%

## DISCUSSION

The long-term effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yield have been demonstrated by many workers (Chen et al., 1988). Wang et al. (2001) reported that organic and inorganic fertilizers showed great benefits not only for the increase in the N uptake by the plant but also in the improvement of the fodder yield on maize.

Intensive cultivation of high yielding hybrid maize varieties requires application of plant nutrients in large quantities. Supplying these nutrients from chemical fertilizers has got certain limitations and inherent problems. Further, these chemical fertilizers can supply only a few plant nutrients like nitrogen, phosphorus and potash and also they are becoming very expensive for resource poor farmers. Silvia et al. (2006) reported that non-inclusion of organic manures such as FYM, compost, green manures, etc. in the manurial schedule have resulted in the depletion of fertility status of the arable soils and their consequent degradation. Debelle et al. (2001) also reported organic manures, especially FYM, have a significant role for maintaining and improving the chemical, physical and biological properties of soils and in sustaining maize yield in western part of Ethiopia. They also reported that 10 ton/ha of FYM is statistically at par with current agronomic recommendation of inorganic fertilizers N and P for maize. In the present finding, it is also observed that 10 tons/ha of FYM and 100 kg/ha N + 100 kg/ha P showed no significant difference on yield (Tables 1 and 3).

Wakene et al. (2005) indicated that the urgency of using organic manure has been gaining ground in the wake of increasing cost of fertilizer with every passing year and certain other inherent limitations with the use of chemical fertilizers. FYM is the oldest organic manure used by man ever since he involved in farming. It has stood the test of time and is still very popular among the poor and marginal farmers. It consists of litter, waste products of crops mixed with animal dung and urine. Therefore, it contains all the nutrient elements present in the plant itself and returns these nutrients to the soil when it is applied to the field for the benefit of succeeding crop.

This study also confirms the role of FYM and chemical fertilizer combinations in increasing grain yield of maize and the results showed that manure and chemical fertilizer can increase grain yield of maize but a combination of them has more effect on increase in grain yield (Tables 1 and 2). In a recent evaluation of the direct effects of cattle manure on corn, it was verified by Silvia et al. (2006) that manure increased green ear yield and grain yield in two corn cultivars in Brazil. Dutta et al. (2003) also reported the benefit of organic matter application on soil in enhancing the soil microbial population and soil health.

Cattle manure also increased water retention and availability, phosphorus, potassium and sodium contents in the soil layer from 0 to 20 cm (Silva et al., 2006). Therefore, the present finding is in agreement with their report in which the total N, available P and CEC of the soil increased in the soil layer from 0 to 30 cm depth (Table 5). In the present finding also, the pH of the soil has declined after application of FYM from 8.01 (Table 4) in 2008 to 7.31 (Table 5) in 2010 which is in agreement with the reports of Khaliq et al. (2004). Similarly, Wakene et al. (2005) also reported addition of organic matter especially FYM into tropical soils enhances the development of soil acidity from the release of organic acids into the soils over years. Thus, the present finding is also inline with their report. The residual effect of organic fertilizers on yield, including FYM manure, has been found to be positive in sorghum (Partidar and Mali, 2002), corn (Ramamurthy and Shivashankar, 1996) and *Brassica juncea* (L.) (Rao and Shaktawat, 2002). Therefore, there was a direct effect of FYM manure on grain yield of maize (Khaliq et al., 2004; Onasanya et al., 2009). Similarly, Rautaray et al. (2003) reported integrated use of organic matter and inorganic fertilizers is beneficial in improving crop yield, soil pH, organic carbon and available N, P and K in sandy loam soils which is in agreement with this finding.

## Conclusion

From this finding, it is concluded that enriching FYM with inorganic fertilizers boost hybrid maize (BH-140) grain yield significantly through improving the physicochemical properties of the soil. Thus, it is recommended that application of 4 t/ha FYM incorporated with 75 kg of N and 60 kg of P at Chiro can significantly increase hybrid maize (BH-140) yield and sustain its productivity over years. However, profitability of this technology needs tobe tested at different locations and in different seasons in eastern part of Ethiopia.

## ACKNOWLEDGEMENTS

The author is grateful to the Ministry of Agriculture and Rural Development of the Federal Democratic Republic of Ethiopia Chiro ATVET College for funding this research project, the Ethiopian National Soil Laboratory for Soil analysis, Professor Temam Hussein for his technical advice during the field experiment, Nemomsa Beyene for his moral support and sound comments on the article, Belay Dinsa, Tedila Mulu, Bacha Reda, and Tadesse Bedada for their assistance during the field data collection.

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