

Effect of Combined Organic and Inorganic Fertilizer on Yield and Yield Components of Food Barley (Hordeum Vulgare L.)

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Abstract
Barley is an important food and beverage crop in the highlands of Ethiopia. Despite many importance of barley and its many useful characteristics, there are several factors affecting its production. Low Soil fertility is one of the major constraints affecting its production. Integrated nutrient management, where both natural and man-made sources of plant nutrients are used, is the best approach to supply adequate and balanced nutrients and increase barley productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. With this in view, integrated applications of organic and inorganic fertilizer sources on yield and yield components of barley were assessed in this review. By this maintaining soil fertility is one of the main factors affecting the sustainability of barley production. The advantages need to be integrated in order to make optimum use of organic and inorganic fertilizer achieve balanced nutrient management for barley yield. This review study showed that balanced fertilization application using both organic and inorganic fertilizers is important for maintenance of yield and yield components of barley. The basic concept underlying the combined applications of fertilizers is the adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired barley productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. Therefore, increased attention should be being paid to developing an integrated soil fertility management that maintains or enhances soil productivity through balanced use of all sources of nutrients, including organic and inorganic fertilizers.
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1. Introduction

Food Barley (*Hordeum vulgare* L.) is one of the most ancient crops among cereals and has played a significant role in the development of agriculture in the world (Alnarp, 2013). It is one of the most important, economically valuable and widely used cereal crops, which belongs to the family Poaceae with a diploid chromosomes number (Alnarp, 2013). Barley (*Hordeum vulgare*) ranks fourth among cereals in the world and is grown annually on 48 million hectares in a wide range of environments. Ethiopia is the second largest producer of barley in Africa next to Morocco, accounting for about 26 percent of the total barley production in the country (Shahidur *et al*., 2015). CSA (2017) reported that barley is the fifth most important cereal crop after teff, wheat, maize, and sorghum in total production in the country.

Barley (*Hordeum vulgare*) is one of the most important crops for food, feed, malt and income generation for many smallholder farmers in the highlands of Ethiopia (Bayeh Mulatu and Berhane Lakew 2011). Despite its importance and many useful characteristics, there are several factors affecting its production (Melle Tilahun *et al*., 2015). The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, water logging, drought, frost, soil acidity (low soil pH), diseases and insects, poor crop management practices, limited availability of improved varieties and weed competition (Assefa Workineh *et al*., 2017). Poor soil fertility and use of low yielding varieties are among the most important constraints that threaten barley production in Ethiopia (Paul *et al*., 2011). Assefa Workineh *et al*. (2017); Gete Zeleke *et al*. (2010); Tolera Abera *et al*. (2011) reported that, soils in the highlands of Ethiopia usually have low levels of essential plant nutrients, especially low availability of nitrogen and it is the major constraint to cereal crop production.

To maximize yield and quality of barley, it has been shown that nutrient management practices should be adjusted according to anticipated availability of nutrients to the crop (Edney *et al*., 2014). Integrated soil fertility management (ISFM) can give benefit to production and livelihood of farmers; the resilience of cropping system to climate change impacts and mitigation of greenhouse gas from fertilizers and soil (Melle Tilahun *et al*., 2015).

Getachew Agegnehu *et al*. (2014) reported that continuous applications of inorganic fertilizers alone resulted in deterioration of soil health in terms of physical, chemical, and biological properties of the soil. Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients including micronutrients as well as improving physical, chemical, and biological properties of the soil, thereby providing a better environment for root development by improving the soil structure (Dejene Kasahun and Lemlem

Semungus, 2012). As a result integrated use of organic and inorganic fertilizers for tackling soil fertility depletion and sustainably increasing crop yields had a paramount importance (Gete Zeleke *et al*., 2010; Getachew Agegnehu and Tilahun Amede, 2017).

Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity (Godara *et al*., 2012). Integrated soil fertility management involving the judicious use of combinations of organic and inorganic resources is a feasible approach to overcome soil fertility constraints and contribute high crop productivity in agriculture (Abedi *et al*., 2010; Hintsa Meresa *et al*., 2016). So the objective of this review is to assess the effect of organic and inorganic fertilizers application on yield and yield components of barley.

2. Barley Production and Productivity in Ethiopia

Ethiopia is ranked twenty-first in the world in barley production with a share of 1.2 percent of the world's total production. According to Shahidur *et al*. (2015) Ethiopia is the second largest producer of barley in Africa next to Morocco, accounting for about 26 percent of the total barley production in the continent. According to these authors, about 4.5 million smallholder farmers grew barley on more than 1 million hectares of land.

2.1. Integrated Soil Fertility Management (ISFM)

According to Vanlauwe and Zingare (2011) ISFM was defined as a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. Thus; ISFM includes combination of both organic and inorganic source in a sustainable way to improve crop productivity (Abedi *et al*., 2010; Hintsa Meresa *et al*., 2016).

Hintsa Meresa *et al*. (2016) revealed that Waste lands are converted to high fields on the same lands for many years by using integrated soil fertility management, better use of organic materials available on farm to build up soil organic matter. Vanlauwe *et al*. (2015) identified that there are considers of the knowledge of farmers towards intensification options in agricultural production including integrated options such as combined use of organic and inorganic inputs, legume-cereal integration through rotations and intercropping, conservation agriculture and agro forestry options.

2.1.1. Inorganic Fertilizers

Fertilizers are concentrated sources of essential nutrients in a form that is readily available for plant uptake (Fairhurst, 2012). Abedi *et al*. (2010) inorganic fertilizers are fertilizers, either natural or manufactured, containing nutrients essential for the normal growth and development of plants. Moreover, the common fertilization system is focused on providing a limited number of macronutrients, while it is scientifically known that plants need at least 13 available minerals in the soil (Atiyeh *et al*., 2000).

Yoshida *et al*. (2016) shown that the excessive and unbalanced use of chemical fertilizers in the long run decreases crop yield, biological activity, soil physical properties, and increases accumulation of nitrates and heavy metals and soil acidity. In connection Ghimire *et al*. (2017) proven that continued use of inorganic fertilizers reduces crop yield due to soil acidification, loss of soil physical and chemical characteristics, and the lack of appropriate micronutrients in these fertilizers.

In contrast to the above discussion, Mekonen Asrat (2005); Rashid *et al*. (2007) reported that a day to heading was significantly delayed when N fertilizer was applied at the highest rate for barley production compared to the lowest rate and Minale Liben *et al*. (2011) and Wakene Tigre *et al*. (2014) who reported that plant height of barely was increase with increasing rates of N fertilizer. Also Assefa Workineh *et al*. (2017) reported that nitrogen increased the number of grains per spike and this parameter is the best indicator of barley response to nitrogen.

In addition inorganic fertilizers stimulate the availability of nutrients in organic manures (Kumar and Sreenivasulu, 2004). Gopinath *et al*. (2008) who reported that decreased soil pH in plots treated with inorganic fertilizers than those treated with organic manures. Likewise, Wokocha and Sopruchi (2010) reported that the application of mineral fertilizer alone reduced the soil pH where it was more pronounced under recommended N dose.

2.1.2. Organic Fertilizer

In organic source the nutrient is released at slower rate when compared with mineral fertilizers because to make the nutrient available they should decomposed with microorganisms (Hintsa Meresa *et al*., 2016). The use of organic source helps to increase crop response to mineral fertilizers, improving moisture ability of soils, adding nutrients that do not contained by mineral fertilizer, creating better rooting environment, replenishing soil organic matter (Fairhurst, 2012). Study indicated that use of organic fertilizers increases soil organic matter, improves microbial activity, and provides both macro- and micronutrients required for the plant in a more efficient way (Angin *et al*., 2017). Diacono and Montemurro (2011); Fageria (2012) found that soil organic matter (SOM) plays a crucial role in maintaining sustainability of cropping systems by improving soil physical, chemical and biological properties.

2.1.2.1. Compost

Organic matter (compound) introduced with the compost to the soil and produced by the subsequent biological activity work to promote soil aggregation and enhance aggregate stability (Bot, 2005). Regarding to its effect in chemical properties of soil, Buzie-Fru (2010) stated that when compost is incorporated in soil there are immediate calculable changes in the concentrations of nutrients trace metals and other chemical compounds. Fijalkowski *et al*. (2012) discussed the role of compost in changing PH of the soil due to their content of carbonate and organic matter; the carbonate makes rise in PH while the organic matters buffers the system somewhere neutral. It is indicated that regular addition of organic materials, particularly the composted ones, increased soil physical fertility, mainly by improving aggregate stability and decreasing soil bulk density (Diacono and Montemurro, 2011). On the other hand, composts can have direct effects against disease, as well as stimulation of the competing microorganisms and also development of resistance in plants against diseases (Ebrahimi *et al*., 2018).

2.1.2.2. Farm Yard Manure (FYM)

Organic agriculture is a production system which relies on ecosystem management and ecological processes rather than on the external flow of agricultural inputs (Foissy *et al*., 2013). Jarvan *et al*. (2017) reported that FYM is one of the more valuable organic fertilizers maintaining soil fertility in the systems of alternative agriculture. Maintenance and improvement of soil potential fertility are closely related to the maintenance of soil organic matter and organic carbon balance (Baksiene *et al*., 2014). On organic farms, where the importation of materials to build and maintain soil fertility is restricted, it is important that a balance between inputs and outputs of nutrients is achieved to ensure both short-term productivity and long-term sustainability (Foissy *et al*., 2013). Farmyard manures are the major source of nutrient supply also on small farm holdings (Fageria, 2012). Ibrawuchi *et al*. (2007) reported that the application of FYM in soil modified the pH of soil from acidic condition to neutral.

2.1.2.3. Green Manuring

Green manure is a type of cover crop grown primarily to add nutrients and organic matter to the soil. Pandey and Singh (2016) defined green manuring as a practice of ploughing or turning into the soil un-decomposed green plants or their residue for the purpose of improving physical structure and fertility of a soil. Complete dependence on chemical fertilizers is making the soil unfertile and less productive in absence of organic material besides soils (Nayak and Vaidya, 2018). A green manure crop is grown for specific period of time and then ploughed under and in corporate in the soil (Hintsa Meresa *et al*., 2016). A green manure is a crop used primarily as a soil amendment and a nutrient source for subsequent crops (Cherr *et al*., 2006). Zaccheo (2016) indicated that the practice of green manure provides many improvements in chemical, physical and biological characteristics, through increases in organic matter content and microbial activity, nutrient cycling, disruptions of compacted layers, decreased erosion, incidence of pests and diseases, and suppression of weed plants for sustainable fruit production system.

2.2. Integrated Effect of Organic and Inorganic Fertilizers on Food Barley Production

Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per unit area (Roberts, 2010). Emerging evidence indicated that integrated nutrient management involving the judicious use of organic and inorganic resources is a feasible approach to overcome soil fertility constraints (Abedi *et al*., 2010). Kaur *et al*. (2008) stated that a judicious combination of organic amendments and inorganic fertilizers is widely recognized strategy of integrated nutrient management to sustain agronomic productivity and improve soil fertility. Arif *et al*. (2014) stated, the higher yield obtained with integrated use of organic manure and inorganic fertilizers was attributed to increased nutrient availability and uptake, resulting in greater number of fertile tillers, number of grains per panicle, number of panicles per hill, filled grains per panicle, 1000 grain weight, biological yield, grain yield and harvest index. Also Tolera Abera *et al*. (2018) who reported significantly higher grain yield and biomass yield of barley were obtained with the application of sole recommended NP and the integrated use of 50: 50% vermin compost and conventional compost with recommended NP.

Getachew Agegnehu *et al*. (2016); Assefa Workineh (2015) revealed that integrated use of organic and inorganic fertilizers resulted in yield benefits greater than using them alone. The improved yields of barley due to combined application of organic and mineral amendments resulted from positive changes to the soil, including increased soil pH, available P and total N, and possibly other macro- and micronutrients (Kassu Tadesse *et al*., 2018).

Hence, under low soil fertility condition, integrated application of organic and mineral fertilizers is highly required because of their additive effects (Getachew Agegnehu *et al*. 2016; Liu *et al*. 2012). According to Woubshet Demissie *et al*. (2017); Mitiku Woldesenbet *et al*. (2014), the number of productive tillers of barley

m^{-2} was improved with integrated application of organic and mineral fertilizers and indicated that the smallest numbers of tillers per plant could be attributed to the limited supply of plant nutrition from compost and/or FYM at the initial stages of growth.

2.2.1. Barley Growth Parameters

Plant Height: Woubshet Demissie *et al*. (2017) found significantly higher plant height of barley with the integrated application of organic and inorganic fertilizers in Wolmera district. Correspondingly, Mitiku Woldesenbet *et al*. (2014) found a significant effect of combined application of organic and inorganic fertilizers on plant height barley at Adiyo and Ghimbo with the application of 5 t·ha^{-1} farmyard manure + 75% of recommended NP and 5 t·ha^{-1} vermicompost and 75% of recommended NP. Likewise, Getachew Agegnehu (2009) reported that the use of organic manures in combination with mineral fertilizers maximized the plant height of barley.

2.2.2. Phenological Parameters of Barley

Days to 50% Emergence: The mean day to 50% emergence of barley is significantly affected by application of sole and integrated organic and inorganic fertilizer (Tariku Beyene *et al*., 2018). The minimum (5) and maximum (6) days to 50% emergence of barley were obtained by 100% NPS and control. Because of, the chemical fertilizer was increased the reaction of germination and emergence than 0% treatments (Tariku Beyene *et al*., 2018). Similarly, Tisdale *et al*. (2002) reported that application of fertilizer near the seeds at the time of planting has the added advantage of stimulating seed germination and seedling emergence.

Days to 50% Heading: Longer (77) days to 50% heading of barley was observed under non-fertilized plots (Tariku Beyene *et al*., 2018). This is in agreement with the research result of Manna *et al*. (2005) who reported that combined application of NP and organic fertilizers promoted vegetative growth, leading to prolonged days to heading. The mean days to 50% heading of barley was significantly affected by application of integrated nutrient management (Tariku Beyene *et al*., 2018). Likewise, Ofosu and Leitch (2009) reported the application of fertilizers of any source, regardless of their doses accelerated days to heading as compared to no fertilizer application. Similarly, Abdur and Khan (2008) reported that NP application significantly affects days to heading of barley.

Days to 90% Maturity: Woinshet Tamiru (2007) reported that N delays maturity. The application of integrated nutrient significantly affected the number of days to 90% maturity of barley (Tariku Beyene *et al*., 2018). The higher amount of chemical fertilizer applied, the lower days to maturity. Similarly, Lelissa Gurmessa (2002) found the number of days required to reach physiological maturity by the plants was also decreased with increasing rates of applied organic and inorganic fertilizers.

2.2.3. Yield and Yield Components of Barley

Spike Length: Application of inorganic and organic fertilizer alone or integrated were produced taller spike length of barley (Tariku Beyene *et al*., 2018). Getachew Agegnehu *et al*. (2016) found that the integrated application of organic fertilizer with N fertilizer rate significantly improved productive tillers of barley at Holetta and Robgebeya. Likewise, the application of 5 t·ha^{-1} FYM combined with 75% inorganic NP gave the highest number of productive tiller m^{-2} (Mitiku Woldesenbet *et al*., 2014). Kumar (2009) reported that the number of total tillers was significantly increased with the application of nitrogen fertilizer.

Arif *et a1*. (2006) reported significant increase in number of grains per spike of barley by applying manure and mineral fertilizer in combination as compared to inorganic fertilizer alone. Also, Sepat *et al*. (2010) reported spikes density variety were higher in organically managed field than as well as increases in spike per plant could be the consequence of the increase in number of tillers per plant.

Effective Tillers: The attainment of higher number of effective tillers might be due to the synergetic combination effects of organic and inorganic fertilizers (Wubshet Demissie *et al*, 2017). This is consistent with Mitiku Woldesenbet *et al*. (2014) who observed that application of 5 t ha^{-1} farmyard manure along with 75% of recommended NP gave highest number of productive tillers m^{-2} and highest number of grains per spike at *Adiyo* and *Ghimbo*, respectively.

Number of Kernel: The mean number of kernel per plant was significantly affected by application of NPS and FYM and result the applied treatment indicated integrated nutrient management (Tariku Beyene *et al*., 2018). According to Tariku Beyene *et al*. (2018) applications of sole and integrated nutrient management were produced higher number of kernel plant^{-1} as compared to non-fertilized. Likewise, application of 5 t ha^{-1} FYM combined with 75% inorganic NP gave the highest number (37 and 36.7) of grain number spike^{-1} (Mitiku Woldesenbet and Tamado Tana (2014). Similarly, Arif *et al*. (2006) have reported significant increases in the number of grain spike^{-1} by applying both organic manures and inorganic fertilizer applications. Godara *et al*. (2012) reported neither inorganic fertilizers nor organic sources alone can result in sustainable productivity. Therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (Tariku Beyene *et al*., 2018).

Thousand Seed Weight: Higher 1000 seed weight was obtained from sole and integrated nutrient application as

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compared to non-fertilized (Tariku Beyene *et al*., 2018). Similarly, Saidu *et al*. (2012) also obtained the highest 1000 grain weight, from application of 5 t ha^{-1} FYM in combination with 50% inorganic NP while the lowest 1000 grain weight was recorded from no fertilizer application. Non-significantly lower thousand seed weight of barley was obtained from sole application of NPS and FYM as compared to integrated nutrient management (Tariku Beyene *et al*., 2018). Godara *et al*. (2012) concluded that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity. This justifies integrated application of inorganic and organic fertilizers had considerable contribution for thousand seed weight of barley, which might be due higher nutrient concentration both fertilizer sources when integrated. Combination organic and inorganic fertilizers increased thousand seed weight from 10 g to 44 g (Woubshet Demissie *et al*, 2017).

Dry Biomass Yield: A study reported by Tariku Beyene *et al*. (2018) found that the dry biomass yield of barley was significantly affected by application of integrated nutrient management and the highest 15917 kg ha^{-1} dry biomass barley was obtained with integrated application of 66.6:33.4% NPS: FYM. Likewise, the application of 5 t ha^{-1} FYM in combination with 75% inorganic NP gave the highest biomass yield of 8259 and 8065 kg ha^{-1} of barley at Adiyo and Ghimbo, respectively (Mitiku Woldesenbet and Tamado Tana, 2014). The lowest (5396 kg ha-1) dry biomass yield of barley was obtained from non-fertilized followed 8684 kg ha^{-1} by application 100% of FYM (Tariku Beyene *et al*., 2018). The use of combined applications of organic and inorganic fertilizers can be kept at optimum level of dry biomass yield (Saidu *et al*., 2012). Furthermore, Shiferaw Bokore and Anteneh Fikadu, (2014) found that application of all combinations of fertilizers, either alone or combined, significantly increased barley yield over untreated control.

Grain Yield: According to Tariku Beyene *et al*. (2018) higher (6496 kg ha^{-1}) grain yield was obtained from application of integrated nutrient application (66.6:33.4% NPS: FYM). Similarly Mitiku Woldesenbet *et al*. (2014) who reported application of inorganic fertilizers (NP or NPK) with FYM gave a better yield of barley than the application of 100% inorganic fertilizers alone. Likewise, increase in grain yield by combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (to holding water capacity, to control soil erosion, to keep soil moisture, to control soil cracking and drying then soil come to rehabilitation) (Godara *et al*., 2012). Equally, Farah *et al*. (2014) found higher yield with integrated use of chemical and organic fertilizers as compared to sole chemical fertilizer and have demonstrated the beneficial effect of integrated nutrient management in justifying the deficiency of several macro and micro-nutrients which affected the grain yields.

Application of organic fertilizer with inorganic fertilizer could directly increase yield, improve soil fertility status, and reduce the cost production. improved yields of barley due to combined application of organic and mineral amendments resulted from positive changes to the soil, including increased soil pH, available P and total N, and possibly other macronutrients and micronutrients (Kassu Tadesse *et al*., 2015; Getachew Agegnehu *et al*., 2016).

3. Conclusion

Organic fertilizers enhance effect use of inorganic fertilizers and it also reported that integrated use of organic residues with inorganic one helps to reduce the cost. Furthermore, use of inorganic soil ameliorates in conjunction with slow release mineral has the advantages of increasing the nutrient storage capacity of the soil. In developing countries like Ethiopia with low input utilization of fertilizers, integrated use of organic and inorganic fertilizers can be a solution. Therefore, by integrating inorganic fertilizers and organic fertilizers which are available or prepared by using local material yield increment can be attained with sustainable soil fertility management. Future research could be give due attention to developing an integrated plant nutrition system that maintains or enhances soil productivity through balanced use of all sources of nutrients, including chemical fertilizers, organic fertilizers and bio fertilizers. The integrated use of inorganic NP with organic fertilizer sources significantly improved yield and yield components of barley.

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