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Review on Role and Effects of Blended NPSB Fertilizer on Food Barley (*Hordeum vulgare* L.) Production and Productivity in Central Highlands of Ethiopia

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Abstarct: Blending fertilizer is defined as the mechanical mixing of two or more granular fertilizer materials to produce mixtures containing nitrogen (N), phosphorus (P), sulfur (S) and other essential plant nutrients. It allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner toward contributing additional profit for farmers and improving the environment because it provides balanced fertilization. Barley (*Hordeum vulgare* L.) is most important cereals in the world in terms of both quantities produced and cultivated areas, annually harvested area was about 140 million tons, obtained from 50 million hectares. Barley production in the world was around 15.87 million tons more than previous year's projection, compared to last year production, represent an increase of 15.87 million tons or 12.33% in barley production around the globe. Barley is a cool-season crop that is adapted to high altitudes. It is grown in a wide range of agro climatic regions under several production systems. At altitudes of about 3000 m.asl or above. In Ethiopia barley is one of the most important widely used staple food cereal crop next to tef, maize, wheat and sorghum that belong to the family Gramineae. It has an immense cultural and nutritional position it can be used as food, fodder and beverages in 20 different ways. For instance, it can be used to make bread, porridge, soup and roasted grain and for preparing alcoholic and non-alcoholic drinks. In Ethiopia, barley production covered total area of 811, 782.08 hectares and total annual production of about17, 675, 184.47quintals and productivity of 21.7qtha^{-1} in main season. The low yield of food barley is primarily related to the depletion of soil fertility due to continuous nutrient uptake of crops, low fertilizer use especially N and P due to continuous cropping and insufficient organic matter application, soil pH, poor agronomic practices and deficiency of nutrients and low levels of fertilizer application. Balanced fertilization is the key to sustainable food barley crop production and maintenance of soil health which has both economic and environmental consideration. However, information on the application of blended NPSB fertilizer rate, especially for food barley, was not reviewed in central highlands of Ethiopia.

Key words: Blended NPSB Fertilizer・Productivity・Food Barley

INTRODUCTION

Barley (*Hordeum vulgare* L.) is most important cereals in the world in terms of both quantities produced and cultivated areas, annually; harvested area was about 140 million tons, obtained from 50 million hectares [1]. Ethiopia is considered as a center of diversity for barley [2]. In the world, it ranks the fourth (wheat, maize and rice) most grain crops. It was categorized among the top ten crop plants in the world [3]. Similarly, barley production in the world was around 15.87 million tons more than previous year's projection, compared to last year production, represent an increase of 15.87 million tons or 12.33% in barley production around the globe. Its average yield globally, changed during the time starting from 1.39 t ha^{-1} (in 1960) to 2.99 t ha^{-1} in 2018 [4]. European Union, Russia, Canada, USA and Argentina are the top five barley producers globally; European Union produces the greatest quantities of barley with an estimated production of 20.5 million tons followed by Russian

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federations with a production of about 8 million tons, whereas Canada, USA and Argentina barley production was estimated 7.3, 3.1 and 2.8 million tons, respectively [5].

In Africa continent, Morocco, Ethiopia, Algeria, Tunisia and South Africa were the top five largest barley producers for the year 2016 with estimated production of approximately 2.2, 2.1, 1.3, 0.5 and 0.31 million tons, respectively [6]. Ethiopia is the second largest producer in Africa, next to Morocco, accounting for about 25% of the total barley production in the continent [7].

In Ethiopia barley is one of the most important widely used staple food cereal crop next to tef, maize, wheat and sorghum [8] that belong to the family *Gramineae*. Barley cultivation is reported to have started 5000 years ago in Ethiopia and was probably first cultivated by Agew people in about 3, 000 B.C. [9]. In highlands areas of Ethiopia, like Bale, Wello, North Shewa and some parts of Arsi areas have bimodal pattern of rainfall allowing barley production twice a year in summer and winter season [10].

In Ethiopia, barley has an immense cultural and nutritional position, it can be used as food, fodder and beverages in 20 different ways [11, 12]. For instance, it can be used to make bread, porridge, soup and roasted grain and for preparing alcoholic and non-alcoholic drinks. Furthermore, its straw conserves as animal feed, especially during the dry season, thatching roofs and bedding [13].

In Ethiopia, barley production was covered total area of 811, 782.08 hectares and total annual production of about17, 675, 184.47 quintals and productivity of 21.7qtha^{-1} in main season [14]. At Oromia Regional State level, an area covered by barley in 2018/19 was 386, 569.22 ha, production 9, 325, 076.44 qt and productivity of 24.12qt ha^{-1} [14], of these 90% was food barley and 10% was malt barley [15]. The average yield is above the national average yield but which is still very low as compared to the potential yield goes up to 6 tha^{-1} on experimental plots [16].

The low yield of food barley is primarily related to the depletion of soil fertility due to continuous nutrient uptake of crops, low fertilizer use especially N and P due to continuous cropping and insufficient organic matter application, soil pH, poor agronomic practices and deficiency of nutrients and low levels of fertilizer application [17] and several biotic factors have contributed to this low productivity, such as use of low yielding cultivars, the limited availability of the very few improved cultivars released, weeds, insects and diseases [18].

In addition, for the last three decades, Ethiopian agriculture depended solely on imported fertilizer products namely urea and di-ammonium phosphate (DAP) which is source of N and P although most Ethiopian soils lack other macro and micro-nutrients [19].According to Assefa *et al.* [20] soils in the highlands of Ethiopia usually have low levels of essential plant nutrients, especially low availability of nitrogen; it is the major constraint to food barley production. Hence, low soil fertility is a major bottleneck to sustainable food barley production and productivity in Ethiopia. It is exacerbated by soil fertility depletion through nutrient removal with harvest, tillage, weeding and losses in runoff and soil erosion [21]. Many farmers are unable to compensate for such losses, which resulted in negative nutrient balances [22].

Fertilizer use trends in Ethiopia has been focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of Di-ammonium phosphate (DAP) (18-46-0) and Urea (46-0-0) or blanket recommendation for the major food barley crop. Continuous application of nitrogen (N) and phosphorus (P) fertilizers without due consideration of other nutrients led to the depletion of other important nutrient elements such as potassium (K), magnesium (Mg), calcium (Ca), sulfur (S) and micronutrients like (B) in soils [23]. An imbalanced fertilizer use results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment [23].

Moreover, recently acquired soil inventory data revealed that the deficiencies of most of nutrients such as, nitrogen (86%), phosphorus (99%), sulfur (92%), born (65%) and zinc (53%) are widespread in Ethiopian soils and similarly in study area [24]. Recently Ministry of Agriculture (MoA) has introduced a new brand of NPSB fertilizer having proportion of 18.9%N, 37.7 % P_2O_5, 6.95%S and 0.1%B as main source of phosphorous, substituting DAP for adoption by farmers which is useful in improving the efficiency of fertilizer recovery there by resulting in higher crop yield and quality to overcome the problem. So balanced fertilization is the key to sustainable food barley crop production and maintenance of soil health which has both economic and environmental consideration [23]. However, information on the application of blended fertilizer rate (NPSB), especially for food barley, was not reviewed in central highlands of Ethiopia. Therefore, the review was done to assess the role and effects of Blended NPSB fertilizer on food barley production and productivity in central highland of Ethiopia.

Food Barley Production in Ethiopia: In Ethiopia, barley (*Hordeum vulgare* L.) is one of the first domesticated cereals, most staple and subsistence crop cultivated in about 811, 782.08ha with a total annual production of 1.77million tons [14]. Ethiopia is considered as a center of diversity for barley, it can be cultivated at altitudes between 1500 and 3500m. According to Kaso and Guben [25] barley is a staple food crop for many Ethiopians, especially for highlanders and it is also able to grow at all elevations and cultivated by small holders in every region of Ethiopia. However, it performs best at the higher elevations in the northern and central regions of the country.

Ethiopia is ranked twenty-first in the world in barley production with a share of 1.2 percent of the world's total production. Barley cultivation is widely distributed across the country on over one million hectares of land and by more than four million small holder farmers. Barley is a high-opportunity crop, with great room for profitable expansion, particularly when connected with the country's commercial brewing and value added industries. Since the major barley producing areas of the country are mainly located in the highlands[26]. Ethiopia is the second largest barley producer in Africa and accounts nearly 25% of the total production in Africa [27]. According to Kemelew and Alemayehu [28] among the major cereals, barley ranks fifth in area, productivity and total production in Ethiopia. In Ethiopia in 2018/19 the national area coverage, production and productivity of barley were estimated to be 811, 782.08 ha, 17, 675, 184.47qt and 2.17 tons/ha, respectively [14].

Importance of Food Barley: In Ethiopia, barley has an immense cultural and nutritional position; it can be used for both food and malt in Ethiopia. Ethiopia produces mostly food barley, with its share estimated to be 90%, while that of malt barley having a share of 10% [15]. According to Abraha *et al.* [12] barley is used for making local recipes, bread, porridge, soup and roasted grain and for preparing alcoholic and non-alcoholic beverages in 20 different ways. Its straw is a good source of animal feed. It is also used for thatching of roofs and bedding [13].

Agro-Ecological Requirements of Barley: Barley is a cool-season crop that is adapted to high altitudes. It is grown in a wide range of agro climatic regions under several production systems. At altitudes of about 3000 m.asl or above, it may be the only crop grown that provides food, beverages and other necessities to many millions of people. It is grown in a diverse soil and climatic conditions together with the long-term geographic isolation may have likely contributed to the morphological variation between landraces [29]. As a result, the Ethiopian barley germplasm has continuously been an important source of valuable genes in the world [30].

Nowadays, Ethiopian farmers grow barley in various climatic and soil types with an elevation ranging from 1, 400 to over 4, 000m above sea level (m.a.s.l) [31]. Although it grows on wide range of altitudes, it performs best at higher elevation areas of the Northern and central regions of the country [25]. Barley is drought resistant can be grown in a region of even minimum rainfall 200-250mm. In Ethiopia the plant gives the best results in areas with an annual average rainfall 1, 000 to 1, 700mm with 650 to 700 mm well distributed during the growth period. Barley is a source of food in low rain fall area; however, its productivity is too low. This is due to the reason that farmer cultivate local variety which is less resistance to water stress and low yield and also hybrid lines which released from different research center hadn't been evaluated along wider environment, special at low rain fall area in Ethiopia [32]. Most of cereals cultivation undertaken in area nitisols and vertisols that have characteristics of good drainage with red sandy clay soils is suitable for food barley [33]. Food barley is commonly cultivated in stressed areas where soil erosion, occasional drought or frost limits the ability to grow other crops.

Major Barley Producing Areas in Ethiopia: Barley produced in all regions of Ethiopia, but the major producers are Shewa, Gojam, Arsi, Gonder, Wollo and Bale, from where more than 85% of the total production comes [34]. In some parts of Ethiopia, barley is produced twice annually (bimodal rainfall), i.e. during the main rainy season, *Meher* (from June to September) and the short rainy season, *Belg* (from February to April). Belg barley is important in Wollo, Bale and Shewa. Barley has a number of attributes that makes it desirable among farming communities in the country because it is a source of food and suitable for the Belg season; it performs well in marginal areas; provides an earlier harvest than some other cereals; and requires low investment.

Food Barley Production Constraints: Despite its great significance in the farming system of the country, barley production is constrained by many confounding factors. The major production limiting concerns are poor soil fertility, frost, water logging and insect pests like aphids and barely fly, leaf diseases like: scald, blotch, smuts and leaf rust, moisture stress, low-yielding varieties and inadequate agronomic practices [13]. As a result, assuming the genetic potential of the crop, the national average (2.17 tha^{-1}) is relatively lower than the world average (2.99t ha^{-1}) [4].

Biotic stresses like disease, insect pests and weed infestations contribute to lower rates of yields in Ethiopia. Diseases (such as scald, net blotch, spot blotch and rusts) and insect pests (such as aphids and barley shoot fly) reportedly can cause yield losses of up to 67 and 79 % respectively [35]. Yield gains from weed control, on the other hand, ranges from 14-60 % depending on the location and type of weed [36]. Similarly, abiotic or non-biological stresses like poor distribution of rainfalls in lowland areas and low soil fertility due to soil erosion and poor soil drainage are named as causes of significant yield losses in food barley production [37].

General Soil Fertility Concept: Soil fertility refers to the ability of the soil to supply the nutrients needed by the plants. The study of soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant and factors that influence their uptake. This, in turn leads to a study of the measures that can be taken to improve soil fertility and crop yields by supplying nutrients to the soil-plant system. This is usually done by adding fertilizers, manures and amendments to the soil but sometimes by supplying nutrients directly to the plant parts by means of sprays. A mineral element is considered essential to plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element; if usually the plant exhibits a visual symptom indicating a deficiency in specific nutrient, it can be corrected or prevented by supplying that nutrient [38]. Fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population. Fertilizer application results in marked crop yield increases, which for most crops can be more than 100%. The extent to which fertilizers are used still differs considerably between various regions of the world [39]. The quantity of fertilizer nutrients required for optimum crop production depends on the inherent capacity of the soil to supply adequate levels of nutrients to growing plants, the yield potential of the crop variety grown, the availability and cost of fertilizers and the climatic conditions prevailing during the crop growing season [40].

The Need for Blended Fertilizer: Blending fertilizer is defined as the mechanical mixing of two or more granular fertilizer materials to produce mixtures containing nitrogen (N), phosphorus (P), sulfur (S), Boron (B) and other essential plant nutrients [41]. It allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner toward contributing additional profit for farmers and improving the environment because it provides balanced fertilization [42]. Since fertilizers were introduced to Ethiopia in 1960s through programs such as the Freedom from Hunger Campaign, virtually all fertilizers used in Ethiopia are limited to DAP and urea. However, recent completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea [43].

Role of Blended NPSB Fertilizer on Yield and Yield Components: Macronutrient includes nitrogen (N), phosphorus (P), potassium (K), sulfur (S), magnesium (Mg) and calcium (Ca), which are needed in large amounts and large quantities have to be applied if the soil is deficient in one or more of them. The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B).

According to Bereket *et al.* [44] as increasing the application of blended NPSB fertilizers, highest yield and yield components of food barley like plant height, spike length, number of tillers per square meter and number of kernel per spike were obtained from application of 200 NPSB kg ha^{-1} blended fertilizers. Several authors, Dewal and Pareek [45], Gupta *et al.* [46] report that macro and micro nutrients (Nitrogen, Phosphorous with Sulfur and Born) fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination.

Blended fertilizer supply had a marked effect on the aboveground biomass, grain yield and straw yield. According to Woubshet *et al.* [47] the maximum aboveground biomass was obtained from 200kg ha^{-1}NPSB of blended fertilizer application. However, the lowest aboveground biomass was recorded from control or unfertilized plot. This could be due to Sulfur which enhanced the formation of chlorophyll and encouraged vegetative growth and Boron helps in nitrogen absorption.

Klikocka *et al.* [48] also found that a positive reaction of N and S fertilization on grain yield, which was the highest grain yield, was obtained due to application of 80 N kg ha^{-1} increasing by 1.30 t ha^{-} (13.1%) with respect to the control and S fertilization increased grain yield by 3.58%. Likewise, according to Malakouti [49] reported that the grain yield increased due to application of boron was also witnessed by the combined application of boron with micro nutrients, with the benefits 4 to 11% yield.

According to Tahir *et al.* [50] articulated that a higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced. The higher barley harvest index with increased fertilizer rate might be due to higher grain yield per plant at higher fertilizer rates. Application of different types of blended fertilizers significantly in?uence apparent nutrient recovery and agronomic nutrient use efficiency on barley. Both apparent nutrient recovery and agronomic nutrient use efficiency consistently decreased with increasing blended fertilizers rates. According to Jones *et al.* [51] matching appropriate essential macro and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. Malakouti [52] also reported that application of suitable micronutrients increases use efficiency for different crops.

Role of Nitrogen in Barley Production: Nitrogen (N) is the most abundant mineral nutrient in plants. It constitutes 2-4% of plant dry matter [53]. It is the key nutrient input for achieving higher yields of barley. Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization. Nitrogen plays a central role in plant biochemistry. A low supply of Nitrogen has a profound influence on crop growth and may lead to great loss in grain yield [54]. Nitrogen occupies a conspicuous place in plant metabolism system. All vital processes in plants are associated with protein, of which nitrogen is an essential for plant growth as it is a constituent of all proteins and nucleic acids. It is an integral component of many essential plant compounds such as amino acids which are building blocks of all protein including enzymes, nucleic acids and chlorophyll [55]. Since nitrogen is present in many essential compounds, it is not surprising that growth without added nitrogen is slow in plants [56].

Nitrogen plays a key role in agriculture by increasing of crop yield [57]. According to Alam *et al.* [58] the most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids which are the most important building and information substances from which the living material or protoplasm of very cell is made. Nitrogen not only enhances the yield but also improves the food quality [59]. Consequently to get more crop production, nitrogen application is indispensable.

Plants require nitrogen in the largest amounts among the soil nutrients for growth and development. The quantity of nutrients required to optimize or sustain crop production depends on the inherent capacity of the soil to supply adequate levels of nutrients to the growing plants, the yield potential of the crops, the variety grown and the availability and cost of fertilizers. Among the macro nutrients, N is ranked first in limiting sustainable crop production [60].

Generally, N is involved in cell multiplication, giving rise to the increase in size and length of leaves and stems, especially the stalks of grains and grasses; increases in chlorophyll contents, giving the leaves their dark green color; plays a part in the manufacture of proteins in the plant and is part of many compounds in the plant, including certain types of basic acids and hormones; and improves the quality and quantity of dry matter protein in grain crops.

Effect of Nitrogen on Food Barley Production: Nitrogen is a key nutrient input for achieving higher yield of food barley. Food barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization [58]. The most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances from which the living material or protoplasm of every cell is made. Nitrogen increased leaf area, tiller formation, leaf area index and leaf area duration and this increasing is led to much greater production of dry matter and grain yield [61].

Among the plant nutrients, nitrogen plays a very important role in crop productivity [62]. Although judicious dose of nitrogen elevates the yield and quality of seed but excessive dose causes the economic loss as well as reduced yield and quality of barley seeds. Barley farmers in Ethiopia have not fully adopted modern inputs like fertilizer and modern seeds that help boost production [63]. The yield attributes and quality of food barley seed is therefore, dependent on appropriate dose of nitrogen. Sustaining soil and soil fertility in intensive cropping systems for higher yields and better quality can be achieved through optimum levels of fertilizer application. Thus, information on fertility status of soils and crop response to different soil fertility management is very crucial to come up with profitable and sustainable crop production. Besides to this, optimum dose of nitrogen depends on the climate and soil of the location as well as variety used [64].

Table 1: Grain yield of food barley as influenced by the interaction effect of nitrogen rate and Varieties

	Grain Yield (t ha^{-1})		
	Varieties		
N rate (kg N ha^{-1})	Local Variety	HB 1307	EH1493
0	1.97ef	1.42g	1.56fg
23	2.54cd	2.26dc	2.78cd
46	2.90c	2.36de	4.11a
69	3.51b	2.44cde	4.51a
LCR (0.05)			0.52
CV (%)			11.51

Source: [65]

Means with the same letter(s) in the same column are not significantly different at 5% probability level, CV= Coefficient of Variation, LCR= Least Critical Range

Role of Phosphorus in Barley Nutrition: Phosphorus has great importance in plant nutrition. It involves in the processes of energy transformations, genetic inheritance, protein synthesis and cell division. Moreover phosphorus enhances root development and strengthening of straw, affects flowering, fruiting, seed formation and crop maturation. Inline to this availability of phosphorus in soil, it is affected by different factors like soil reaction and climate. In Ethiopia Phosphorus application as fertilizer is important in increasing crop production of barley. Based on the various findings of P fertilization results the yield and yield components of barley and were increasing with increasing P fertilizer application rates. The critical level (optimum level) of P fertilizer rate after which crop response declines or not significant in economic point of view is different for variety type, soil type and agro ecology. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly development of lateral roots and fibrous rootlets [55]

Eylachew [66] reviewed different reports and stated that the availability of soil phosphorous is influenced by soil reaction, soil type, amount and forms of phosphorous as well as many other factors. Oxisols high in iron oxides and aluminum oxides and many sandy soils low in humus content, for instance, have low available phosphorous [67]. Addition of organic matter indirectly reduces phosphorous adsorption by inhibiting aluminum oxide and to certain extent Fe-oxide crystallization, while addition of manure and fertilizer phosphorous reduces phosphorous fixation by increasing saturation of adsorption sites.

According to Boeggaad *et al.* [68] in acid soils with high Al and Fe contents, phosphoric acid and soluble phosphorous fertilizer transformed into insoluble forms of phosphorous so quickly that plants can derive very little from phosphorous fertilized treatments [69]. Brady and Weil [55] indicated that at pH lower than 5.5, the retention results largely from the reactions with Fe, Al and their hydrous oxides resulting into low forms of available phosphorous. At pH higher than 7.0, high concentration of Ca, Mg and their carbonates cause precipitation of the added phosphorus and reduce the availability of phosphorous [70]. Large addition of phosphorous is required to reach a given level of solution phosphorous in fine textured compared to coarse textured soils. Consequently, high clay calcareous soils will often require more fertilizer phosphorous to optimize yields compared to loam soils. Soils containing large quantities of clay will fix more phosphorous than soils with low clay content. In other words, the more surface area exposed with a given type of clay, the greater is the tendency to absorb P [60].

Effects of Phosphorus on Growth and Yields of Food Barley: Phosphorus is an essential plant nutrient which involves in all physiological activities of the crop production. Phosphorus fertilizer on yield and yield components of barley indicated promising effect in various parts Ethiopia. Research conducted on food barley at Ella vertisols of Northern Ethiopia depicted that yield and yield components of barley was increased with increasing Phosphorus fertilizers and increment of grain yield from 740.75kg ha^{-1} at the control plot to 1119.60kg ha^{-1} at the rate of 20kg ha^{-1} P with 50kg ha^{-1} of urea was observed.

Number of productive tiller was increased with increasing of Phosphorous levels. According to Wakene *et al.* [71] who reported that number of productive tillers/plant was affected significantly by Phosphorus fertilizer application. They indicated that highest number of tillers was recorded at Phosphorous level of 46 kg ha^{-1} which was not statistically different from Phosphorous level of 69 kg ha^{-1}. Similar results were also reported by Prystupa *et al.* [72] from their research on barley. Similarly, experiment conducted on the effects of different phosphorus fertilizer levels on yield and yield components of food barley at south eastern Oromia, Bore, in 2009 cropping indicated that Phosphorous application significantly influenced all the parameters of growth and development of barley and the highest total biomass of 8.91 Kg ha^{-1} was obtained from the highest Phosphorous level of 69 Kg ha^{-1} [71].

Table 2: Main effect of phosphorus fertilizer application rate on food barley crop production in central high land of Ethiopia

Treatments	Grain Yield (kg/ha)	Biomass Yield (Kg/ha)	Thousand Seed Weight (g)
P_2O_5 Rate(kg/ha)			
0	2923c	7149c	40.8c
10	3551b	8113b	41.8c
20	3636b	8158b	41.5c
30	3788b	8408b	43.6
40	4268a	9120a	46.4a
50	4168a	9166a	46.2a
CV	18.3	18.6	6.2
P linear	***	***	***

Source: [76]. Within each column, means with different letters are significantly different at p<0.05; CV = coefficient of variation

Biomass of barley significantly increased with increasing Phosphorous levels. This trait was highest at 40 kg ha^{-1} Phosphorus application per hectare. While the lowest value of biomass was obtained at 0 kg ha^{-1} Phosphorous application per hectare [73]. Grain yield of barley significantly increased with increasing Phosphorous levels. Mesfin and Zemach [74] who reported that applications of Phosphorous fertilizer significantly increase the grain yield of barley. This may be due to the fact that the important roles of phosphorus on photosynthesis, respiration and nutrient uptakes [75].

Role of Sulfur in Barley Growth and Development: Sulfur is essential for the growth and development of all crops, without exception. Sulfur is a constituent of three S-containing amino acids (cysteine, cystine and methionine), which are the building blocks of protein. Sulfur is also a key ingredient in the formation of chlorophyll and about 90% of plant sulfur is present in these amino acids [48]. Sulfur is a macronutrient required for proper growth and development of plants. It is increasingly being recognized as the fourth major plant nutrient after N, P and potassium (K) in crop production.

Sulfur is reported to be a macro-nutrient that is taken-up by grain crops in amounts similar to and sometimes beyond those of P, 10-30 kgha^{-1} [77] and is considered to be one of the most limiting nutrient element for crop production. It is usually present in relatively small amounts in soils in the available forms [78] and also reported that at lowest Sulfur rate, N uptake was 42%, but increased to 70% as S fertilizer was increased. It enhances other nutrients use efficiency and ranks second only to N in importance for optimum crop yield and quality [79] also stated that Sulfur application from the leaf had a minimum effect on the grain yield of barley. Sulfur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients, therefore, the yield increases.

Effects of Sulfur on Food Barley Growth and Production: Sulfur plays many important roles in the growth and development of plants.

Fageria and Gheyi [80] summarized the important functions of the sulfur in the plant. Sulfur also improves milling and baking quality of cereal crops; enhance oil content of oilseed crops; maintain winter hardiness and drought tolerance in plants; controls certain soil borne diseases and decreases fungal diseases in many crops [81, 82] helps in formation of glycosides that give characteristic odors and flavors to onion, garlic and mustard; necessary for the formation of vitamins and synthesis of some hormones and glutathione; involves in redox reactions; improves tolerance to heavy metal toxicity; components of sulfolipids.

According to Sutaliya *et al.* [83] revealed that the highest plant height was obtained from the rate of 45 kg sulfur ha^{-1} in food barley. The sulfur application improved the soil structure and it increased the usefulness of other plant nutrients. Dewal and Pareek [45] stated that the plant height increased as the doses increased and the highest plant height was obtained from the 40 kg sulfur ha^{-1}. [84] reported that the highest plant height was obtained from 60 kg S ha^{-1} application in wheat. Sutaliya *et al.* [83] stated that the highest spike length was obtained from 45 kg sulfur ha^{-1}application. Dewal and Pareek [45] reported that the plant height increased as the sulfur doses increased and the highest spike length was obtained from the 40 kg sulfur ha^{-1} application in the food barley. According to Gupta *et al.* [46] reported that the highest spike length was obtained from 45 kg sulfur ha^{-1} application. Number of seed per spike ranged between 16.4 -20.4 for two year. The lowest seed numbers/ spike were obtained from the control plots for both years. Highest seeds numbers/spike was obtained from 160 kg ha^{-1} sulfur in the first year and 120 kg ha^{-1} sulfur in the second year.

Table 3: Main effect of Sulphur fertilizer application rate on food barley crop production in central high land of Ethiopia

Treatments	Fertile tillers plant^{-1} (kg/ha)	Grain Yield (Kg/ha)	Straw Yield (kg/ha)
S- Rate(kg/ha)			
0	5.7	4028.0c	5452.7c
10	6.2	4620.1ab	6543.2ab
20	6.1	4840.8a	6833.1a
30	6.1	4577.0ab	6290.9b
40	6.2	4665.4a	6278.3ab
50	5.9	4658.3a	6121.5b
CV (%)	11.98	14.62	13.17
LSD <0.05)	ns	604.3	523.7

Source: [86]. Within each column, means with different letters are significantly different at p<0.05; CV= coefficient of variation

The lowest biological yield was obtained from the control plots and the highest biological yield was obtained from the 200 kg sulfur ha^{-1} application. Withers *et al.* [85] reported that inorganic sulfur application increased straw yield of cereals by 34%. Sulfur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients. Therefore, the yield increases. According to Gupta *et al.* [46] reported that the highest 1000 seed weight was obtained from 45 kg sulfur ha^{-1} application.

Role of Boron in Barley Production: The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B) (Fageria, 2009). They are part and parcel of the key substances in plant growth and are comparable with the vitamins in human nutrition. Being taken up in minute amounts, their range of optimal supply is very small. Their plant availability depends primarily on the soil reaction. In crop production boron is one of the essential micronutrient required for normal growth of most of the crops. Boron fertilization improves photosynthetic activity, enhances activity of enzymes and plays significant role in protein and nucleic acid metabolism. Boron (B) is an essential micronutrient for plants and plant requirements for this nutrient are lower than the requirements for all other micronutrients except molybdenum and copper. It is the only non-metal among the micronutrients and also the only micronutrient present over a wide pH range as a neutral molecule rather than an ion [87].Boron is an essential element for better utilization of macro-nutrients by plants and there by greater translocation of photo-assimilates from source to sink during growth period [88]. Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material. It influences transportation through the control of sugar and starch formation [89].

Effect of Boron on Food Barley Production: Ali *et al.* [88] reported that significant variations for number of spikes m^{-2} for application of boron. Deficiency of boron can also cause reduction in crop yield and inferior crop quality [89]. As the range between deficiency and toxicity limits of B for plants is very narrow, any change in B equilibrium concentration may turn to considerable influence on plant growth and this aspect should be taken into account when B nutrition of plants is adjusted by fertilization [90]. Boron supply strongly promoted water and nutrient uptake as well as biomass formation. Ahmad and Irshad [91] also reported that application of B increased significantly number of kernels spike^{-1} in wheat. As B application reduces spike sterility, this increase in grains may be due to reduced spike sterility.

Boron deficiency affects vegetative and reproductive stages of plant growth. In the vegetative stage, B deficiency leads to the inhibition of growth, the death of growing meristems and the inhibition of the development of vascular bundles [92]. Cereal crops are relatively tolerant to B deficiency during vegetative growth phase. Nonetheless, during reproductive phase, B deficiency may cause severe yield losses through sterility [93]. Considering the range between deficiency and toxicity of B is quite narrow, application of B can be extremely toxic to plant at concentrations only slightly above the optimum rate [94]. Several earlier investigations revealed that application of boron significantly enhanced the growth, yield and quality of various food barley crops [95]. Therefore, an adequate supply of B is necessary to achieve better nutrient balances and more biomass production.

CONCLUSSION

Based on this review, the following conclusions are drawn. Depletion of soil fertility, inadequate of improved varieties and poor agronomic practices are among the major challenges responsible for the low productivity of food barley in the highlands of Ethiopia. Balanced fertilization is the key to sustainable food barley crop production and maintenance of soil health which has both economic and environmental consideration. Moreover, application of lime had increased soil pH and the availability of nutrient and also application of NPSB fertilizer improved soil productivity and grain yield of food barley in the study area. As increasing the application of blended NPSB fertilizers, highest yield and yield components of food barley like plant height, spike length, number of tillers per square meter and number of kernel per spike were obtained from application of 200 NPSB kg ha^{-1} blended fertilizers. Several authors reported that macro and micro nutrients (Nitrogen, Phosphorous, Sulfur and Born) fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination. Blended fertilizer supply had a marked effect on the aboveground biomass, grain yield and straw yield

Recommendations: Application of 200 kg ha^{-1} NPSB fertilizer gave maximum grain yield (4.7 t ha^{-1}), in the central highlands of Ethiopia. Hence, farmers in highland area of Ethiopia with the same agroecology and soil type can be advised to use 200 kg ha^{-1} NPSB fertilizer to improve the production, productivity and quality of food barley as compared to low and midlands of Ethiopia. As my opinion, it is advisable to undertake further research across soil types, season and locations to draw sound recommendation on a wider scale and for longer duration and variable cropping systems

REFERENCES

1. FAOSTAT, 2018. Food and Agricultural Organization of the United Nation. Crops. Internet. www.fao.org/faostat/en/#data/QC Accessed: March 19, 2018.
2. Lakew, B. Asfaw, H. Gebre and F. Alemayehu, 1997. Barley production and research in Ethiopia. In Barley Research in Ethiopia.
3. ICARDA, 2011. Dry land cereals. A global alliance for improving food sufficiency, nutrition and economic growth for the world's most vulnerable poor. A CGIAR Research ICRISAT and ICARDA to the CGIAR Consortium Board, 2014. Food and Agriculture Organization (FAO). Foodbalancesheets. Faostat.Rome.(http://faostat3.fao.org/download/fb/fbs/e) accessed date: May 07, 2015.
4. United State Department of Agriculture (USDA/FAS), 2018. United States Department of agriculture, Foreign Agricultural Systems. Market and Trade Data Online CustomQuery.https://apps.fas.usda.gov/psdonline/app/index.html#app/Accessed March 10, 2018.
5. United State Department of Agriculture (USDA), 2017. Ethiopia Grain and Feed Annual Report. Global Agricultural Information Network (grain) Report ET-1503. Foreign Agricultural Service, USDA, Washington, DC. Retrieved July22, 2017, from http://wwwfas.usda.gov/data/ethiopia-grain-and feed-annual.
6. FAO, 2016. Agriculture Organization of the United Nations, 2011. FAO, Retrievedamfrom.http://faosat3.fao.org/faostatgateway/go/to/download/Q /QC/S. Accessed in 2018.
7. FAOSTAT. (Food and Agriculture Organization), 2014. Food Balance Sheets. FAOSTAT. Rome. http://faostat3.fao.org/download/FB/FBS/E.accessed in 2018.
8. Central Statistical Agency (CSA), 2017. Agricultural Sample Survey 2016/17 (2009 E.C.). Volume 1. Report on area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 584. Addis Ababa, Ethiopia.
9. Zemede Asfaw, 1996. Barley in Ethiopia: the link between botany and tradition, pp: 182-192, in: Hailu Gebre and J.A.G. Van Leur (eds.). Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of the 1st Barley Research Review Workshop, 16-19 October 1993, Addis Ababa.
10. Alemeyehu, D., K. Kelemu and B. Lakew, 2011. Trends and prospects of malt barley value chains in Ethiopia. In: Rashid S, Abate GT, Lemma S, Warner J, Kasa L, Minot N, editors. The barley value chain in Ethiopia. International Food Policy Research Institute (IFPRI), Washington DC. Https: //reap.ifpri .info/files /2015/09/Barley Value Chain in Ethiopia.
11. Shewayrga, H. and P.A. Sopade, 2011. Ethnobotany, diverse food uses, claimed health benefits and implications on conservation of barley landraces in North Eastern Ethiopia highlands. J. Ethnobiol and Ethnomed, 7(19): 1-15.
12. Abraha, A., A. Uhlen, F. Abay, S. Sahlstrom and A. Bjornstad, 2013. Genetic variation in barley enables a high-quality injera, the Ethiopian staple flat bread, the Ethiopian staple flat bread, comparable to Tef. Crop Sci., 53(5): 2040-2050.
13. Bekele, B., F. Alemayehu and L. Berhane, 2005. Food barley in Ethiopia. In: Grandson S, HG, Macpherson, 2005. Food Barley: Importance, Uses and Local Knowledge.Proceedings of the International Workshop on Food Barley Improvement. 14-17, January 2002.

14. Central Statistical Agency (CSA), 2019. Agricultural sample survey volume I, report on area and production of major crops (private peasant holdings, meher season), Statistical Bulletin, pp: 589.
15. Alemu, D., K. Kelemu and B. Lakew, 2015. Trends and prospects of malt barley value chains in Ethiopia. In: Rashid S, Abate GT, LemmaS, Warner J, Kasa L, Minot N, editors. The barley value chain in Ethiopia. International Food Policy Research Institute (IFPRI), Washington DC. Https: //reap.ifpri .info/files /2015/09/Barley Value Chain in Ethiopia.
16. Habtamu, A., G. Heluf, B. Bobe and A. Enyew, 2014. Fertility Status of Soils under Different Land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. Agri. Fores. and Fisher, 3(5): 410-419.
17. Agegnehu, Getachew, Minale Liben, Adamu Molla, Abraham Feyissa, Agdew Bekele and Fite Getaneh, 2011. Research achievements in soilfertility management in relation to barley in Ethiopia. Barley Reser. and Develo. in Ethio, pp: 137-152.
18. Woldeyesus, S., Y. Chilot and F. Rezene, 2002. On-farm fertilizer trial on food barley in Wolemera area. pp: 266-279, Proceedings of a client-oriented research evaluation workshop. Holetta Agricultural Research Centre, Holetta, Ethiopia.
19. EthioSIS (Ethiopian Soil Information System), 2014. Soil Fertility and Fertilizer recommendation Atlas of Tigray Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA). ds of Ethiopia. Amer J. Pl. Nutri. Ferti. Tech., 5(1): 1-15.
20. Assefa, F., M. Maqsood, M. Akbar and N. Yousaf, 2017. Effect of urea fertilizer on growth response of food barley. Inter. of J. Agri. Bio., 3(1): 59-66.
21. Bai, Z., D. Dent, L. Olsson and M. Schaepman, 2008. Proxy global assessment of land degradation. Soil Manag., 24(3): 223-234.
22. Cobo, J., G. Dercon and G. Cadisch, 2010. Nutrient balances in African land use systems across different spatial scales: a review of approaches, challenges and progress. AgriEcosys Environ., 136(1-2): 1-15.
23. Abiye, A., M. Tekalign, D. Peden and M. Diedhiou, 2004. Participatory on-farm conservation tillage trial in Ethiopian highland vertisols: Impact of potassium application on crop yield. Experi. Agri., 40(3): 369-379
24. Ethio-SIS (Ethiopia Soil Fertility Status), 2016. Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia, pp: 81.
25. Kaso, T. and G. Guben, 2015. Review of Barley Value Chain management in Ethiopia. Journal of Biological Agriculture Health, 5: 84-97.
26. Grando, S. and H.G. Macpherson, 2005. Food Barley: Importance, Uses and Local Knowledge. Proceedings of the International Workshop on Food Barley Improvement, 14-17 January 2002, Hammamet, Tunisia. ICARDA, Aleppo, Syria, x+156 pp. En.
27. FAO, 2014. Grain: World Markets and Trade. Foreign Agriculture services, office of global analysis.
28. Kemelew, M. and A. Alemayehu, 2011. Diversity and agronomic potential of barley (*Hordeum vulgar* L.) Landraces in variable production system, Ethiopia: World J. Agri. Sci., 7(5): 599-603.
29. Mekonnon, B., B. Lakew and T. Dessalegn, 2014. Morphological diversity and association of traits in Ethiopian food barley (*Hordeum vulgare* L.) landraces in relation to region of origin and altitudes. Journal of Plant Breeding and Crop Science, 7(2): 44-54. doi:10.5897/JPBCS2014.0480.
30. Bonman, J.M., H.E. Bockelman, L.F. Jackson and B.J. Steffenson, 2005. Disease and insect resistance in cultivated barley accessions from the USDA National Small Grains Collection. Crop Sci., 45: 1271-1280.
31. Asfaw, Z., 2000. The Barleys of Ethiopia, in Brush, S.B. (Ed.), Genes in the Field: On-farm conservation of crop diversity. Lewis Publishers, Boca Raton, pp: 77-108.
32. Abdi, A., 2011. Barley Genetic Resources Collection and Conservation in Ethiopia. Ethiopian Institute of Agricultural Research, International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. 92-9127-249-3, pp: 19-20.
33. Solomon, Y., 2006. Characteristics, classification and agricultural potentials of soils of Gonde micro-catchment, Arsi highlands, Ethiopia.
34. Adugna Abdi, 2008. Barley for food: characteristics, improvement and renewed interest. J. Cereal Sci., 48: 233-242.
35. Sinebo, W. and C. Yirga, 2002. Participatory client-orientation of research in low input cropping systems of Ethiopia, pp: 27-43, in: GemechuKenini, Yohannes Gojjam, Kiflu Bedane, Chilot Yirga and Asgelil Dibabe (eds.). Towards Farmers' Participatory Research: Attempts and Achievements in the Central Highlands of Ethiopia. Proceedings of a Client-Oriented Research Evaluation Workshop. Holetta Agricultural Research Centre, Holetta, Ethiopia.

36. Negewo, T., A. Feyissa, M. Liben and B. Zemichael, 2011. Achievements of research on weeds and their management in barley in Ethiopia. In: Mulatu, B. and Grando, S. (eds). 2011. Barley Research and Development in Ethiopia. Proceedings of the 2nd National Barley Research and Development Review Workshop, 28-30 November 2006, HARC, Holetta, Ethiopia. ICARDA, PO Box 5466, Aleppo, Syria.
37. Abera, T., A. Molla, A. Feyissa, M. Liben, A. Woyema, L. Admassu and A. Bekele, 2011. Research achievements in barley cultural practices in Ethiopia. In: Mulatu, B. and Grando, S. (eds). 2011. Barley Research and Development in Ethiopia. Proceedings of the 2nd National Barley Research and Development Review Workshop. 28-30 November 2006, HARC, Holetta, Ethiopia. ICARDA, PO Box 5466, Aleppo, Syria.
38. Patricia Arguedas, G. and E. Lisette van, 2008. Survey on the Nutritional and Health Aspects of Tef (Eragrostistef). Memorias Red-Alfa Lagrotech Comunidad Europea, Cartagena, pp: 319-382.
39. Berhan, A., 2012. Agronomic and economic effects of blended fertilizers under planting method on yield and yield components of tef: M.Sc. Thesis, Mekelle University, Mekelle, Ethiopia.
40. Ghulam Mustafa, L. Fateh Chand, O. Shamasuddin Tunio, Allah Wadhayo, G. Muzzammil and O. Sono Mal, 2015. Growth, yield and nutrient uptake of various wheat cultivars under different fertilizer regimes. Sarhad J. Agri., 26(4): 489-497.
41. Beaton, 1997. Soil Fertility and Fertilizer Use, Better Crops International 11(1, May 1997 Kelowna, British Columbia, Canada
42. James, D., 1997. Bulk blending of dry fertilizer materials for China. Better Crops. International., 11(1): 18-19.
43. Agricultural Transformation Agency (ATA), 2013. Transforming the Use of Fertilizer in Ethiopia: Launching the National Fertilizer Blending Program; February 12, 2013.
44. Bereket, H., H. Dawit, H. Mehretab and G. Gebremedhin, 2014. Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat on the Sandy Soils of Hawzen District, Northern Ethiopia. Agriculture, Forestry and Fisheries, 3(3): 189-198.
45. Dewal, G.S. and R.G. Pareek, 2004. Effect of phosphorus, sulfur and zinc on growth, yield and nutrient uptake of wheat (*Triticumaestivum*). Indian J. Agr., 49(39): 160-162.
46. Gupta, V.K., S. Kumar and A.K. Singh, 2004. Yield and quality of wheat (*Triticumaestivum*) as influenced by sulfur nutrition and weed management. Indian J. Agr. Sci., 74(5): 254-256
47. Woubshet, D., K. Selamyihun and V. Cherukuri, 2017. Effect of integrated use of lime, blended fertilizer and compost on productivity, nutrient removal and economics of barley (*Hordeum vulgare* L.) on acid soils of high lands in West Showa Zone of Ethiopia. Int. J. Life Sci., 5(3): 311-322.
48. Klikocka, H., M. Cybulska, B. Barczak, B. Narolski, B. Szostak, A. Kobiałka, A. Nowak and E. Wojcik, 2016. The effect of Sulfur and nitrogen fertilization on grain yield and technological quality of spring wheat Plant, Soil and Environment, 61: 399-404.
49. Malakouti, M., 2000. Balanced nutrition of wheat: An approach towards self-sufficiency and enhancement of national health. “A compilation of papers”. Ministry of Agriculture, Karaj, Iran, pp: 544.
50. Tahir, M., A. Tanveer, T. Shah, N. Fiaz and A. Wasaya, 2009. Yield response of wheat (*Triticumaestivum* L.) to Boron application at different growth stages. Pakistan J. Life Soci. Sci., 7: 39-42.
51. Jones, C., R. Olson and C. Dinkins, 2011. Nutrient uptake timing by crops: to assist with fertilizing decisions. Montana State University, pp: 2-8.
52. Malakouti, M., 2008. The effect of micronutrients in ensuring efficient use of macronutrients. Turk J. Agri., 32: 215-220.
53. FAO, 2006. Plant nutrition for food security. Rome Italy. Bulletin no.16. ISBN 92-5- 105490-8. http://www.fao.org/tempref/docrep/fao/009/a0443e/a0443e00.
54. Ottman, M., 2009. Response of wheat and barley varieties to phosphorus fertilizer. University of Arizona, USA.
55. Brady, N.C. and R.R. Weil, 2002. The Nature and Properties of Soils.13th edition. Pearson Education Ltd, USA.
56. Dobermann, A. and T. Fairhurst, 2000. Rice: Nutrient Disorder and Nutrient Management; Hand Book Series. Potash and Phosphate Institute of Canada and International Rice Research Institute.
57. Massignam, A., S. Chapman, G. Hammer and S. Fukai, 2009. Physiological determinants of maize and sunflower achene yield as affected by nitrogen supply. Field Crop Res., 113: 256-267.

58. Alam, M., S. Haider and N. Paul, 2007. Yield and yield components of barley (*Hordeium vulgare* L.) cultivaries in relation to nitrogen fertilizers. J. Appl. Sci. Res., 3: 1022-1026.
59. Ullah, M.A., M. Anwar and A.S. Rana, 2010. Effect of nitrogen fertilization and harvesting intervals on the yield and forage quality of elephant grass (*Pennisetumpurpureum* L.) Under mesic climate of Pothowar plateau. Pak. Jour. Agri. Sci., 47: 231-234.
60. Tisdale, S., W. Nelson, J. Beaton and J. Haulin, 2002. Soil Fertility and Fertilizers, P633. Macmillan publishing company. New York, Toronto, Oxford and Singapore.
61. Franklin, O., C.A. Cambui, L. Gruffman, S. Palmroth, R.Oren and T. Nasholm, 2017. The carbon bonus of organic nitrogen enhances nitrogen use efficiency of Plants, 25-35. https://doi.org/10.1111/pce.12772 accessed date May 31, 2016.
62. Oikeh, S., V. Chude, G. Kling and W. Horst, 2007. Comparative productivity of nitrogen-use efficient and nitrogen inefficient maize cultivars and traditional grain sorghum in the moist Savanna of West Africa. Afri. J. Agri. Res., 2: 112-118.
63. Central Statistical Agency (CSA), 2014. Agricultural sample survey: area and production of major crops, Meher season. Vol. I. Addis Ababa, Ethiopia.
64. Shahnaj, Y., A. Moushumi and H. Belal, 2014. Yield and Seed quality of barley (*Hordeum vulgare* L.) as affected by variety, nitrogen level and harvesting time. Int. J. Agri. and Cro. Sci., 7(5): 262-268.
65. Ketema, N. and K. Mulatu, 2018. Response of Food Barley (*Hordeum vulgare* L.) Varieties to Rates of Nitrogen Fertilizer in Limo District, Hadiya Zone, Southern Ethiopia. J. Nat. Sci. Res., 8(15): 17-31.
66. Eylachew, Z., 1987. Study on Phosphorus Status of Different Soil Types of Chercher Highland, S.E. Ethiopia. Ph.D. Dissertation, der Justus University at Grie Ben, pp: 186.
67. Miller, R.W. and R.L. Danahaue, 1995. Soils in our environment. Prentice Han of India private limited, New Delhi, pp: 342.
68. Boeggaad, O. Jorgensen and J. Moberg, 1990. Influence of organic matter on P adsorption by Al and Fe- oxides in sandy soils. J. Soi. Sci., 41: 443-449.
69. Sinha, T., 1999. Field crop production in tropical Africa: Wageningan, Netherlands, pp: 189.
70. Mengel, K. and E.A. Kirkby, 1996. Principle of plant nutrition. Panimo publishing yields, in a Mediterranean climate. J. Agri., 86(2): 221-226.
71. Wakene, T., W. Walelign and H. Wassie 2014. Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at Bore District, Southern Oromia. Am. J. Life Sci., 2(5): 260-266
72. Prystupa P. Slafer and A. Savin, 2004. Leaf appearance, tillering and their coordination in response to NxP fertilization in barley. Springer, Netherlands.
73. Noori, M., M. Adibian, A. Sobhkhizi and K. Eyidozehi, 2014. Effect of phosphorus fertilizer and mycorrhiza on protein percent, dry weight, weight of 1000 grain in wheat. Int. J. Plant, Anim. Envi. Sci., 4(2): 561-564.
74. Mesfin, K. and S. Zemach, 2015. Effect of Nitrogen and Phosphorus Fertilizer Rates on Yield and Yield Components of Barley (*Hordeum vugarae* L.) Varieties at Damot Gale District, Wolaita Zone, Ethiopia. Am. J. Agri. and Fores., 3(6): 271275.
75. Uchida, R., 2000. Essential nutrients for plant growth: nutrient functions and deficiency symptoms. Plant nutrient management in Hawaii's Soils, pp: 31-55.
76. Legesse, A., 2017. Response of phosphorous fertilizer and its recommendation for food barley (*Hordium vulgare* L.) production on Nitisols of central Ethiopian highlands. Afr. J. Agric. Res., 12(7): 467-476.
77. Jamal, A., Y.S. Moon and M.Z. Abdin, 2012. Sulfur a general overview and interaction with nitrogen.Austr. J. Cro. Sci., 4(7): 523-529.
78. Brady, N.C. and R.R. Weil, 2008. The Nature and Properties of Soils. (14th Edition), Pearson Education, Inc., Upper Saddle River, New Jersey, USA, pp: 736.
79. Zorb, C., K. Muhling, M. Hasler, V. Godde, K. Niehaus, D. Becker and C.M. Geilfus, 2013. Metabolic responses in grain, ear and straw of winter wheat under increasing sulfur treatment. J. Pl. Nut and Soil Sci., 176: 964-970.
80. Fageria, N. and H. Gheyi, 1999. Efficient crop production. Federal University of Paraiba, Campina Grande, Brazil, pp: 547.
81. Klikocka, H., S. Haneklaus, E. Bloem and E. Schnug, 2005. Influence of sulfur fertilizer on infection of potato tubers with Rhizoctoniasolani and Streptomyces scabies. J. Plan. Nutr., 28: 819-833.
82. Haneklaus, S., E. Bloem and E. Schnug, 2007. Sulfur and plant disease. In: Mineral nutrition and plant disease, L. E. Datnoff, W. H. Elmer and D. M. Huber, Eds., St. Paul, MN: Am. Phy. Path. Soci, pp: 101-118.

83. Sutaliya, R., A.K. Gupta and R.N. Singh, 2003. Yield attributes of barley as influenced by phosphorus, sulfur and their correlation and regression with yield. Crop Research, 25(3): 585-586.
84. Chaudhary, P.D., R.S. Jat and H.S. Sharma, 2003. Interaction effect of phosphorus, sulfur and PSB inoculation on growth, yield and nutrient uptake of wheat. J. Agri. Res., 24(1): 12-16.
85. Withers, P., F. Zhao, S. McGrath, E. Evans and A. Sinclair, 1997. Sulphur inputs for optimum yields of cereals. Aspects of Applied Biology, 50: 191-198.
86. Shawl, A., S. Beza, Y. Kassie and G. Lisanu, 2021. Growth, yield components and yield response of food barley (*Hordeum vulgare* L.) to the application of sulfur nutrient under balanced fertilization at North Central Highland of Ethiopia. J. Crop Sci and Biot., 24: 461-467
87. Epstein, E. and A. J. Bloom, 2005. Mineral nutrition of plants: Principles and perspectives, 2nd edition. Sunderland's, MA: Sinauer Associate.
88. Ali, M., N. Tariq, N. Ahmed, M. Abid and A. Rahim, 2013. Response of Wheat (*Triticumaestivum* L.) to Soil Applied Boron and Zinc Fertilizers under Irrigated Conditions. Pakistan, J. Agri. Vet. Sci., 29(2): 114-125.
89. Singh, L., R. Yadav and T. Abraham, 2015. Studies on the effect of Zinc levels and methods of boron application on growth, yield and protein content of Wheat (*Triticumaestivum* L.). Bulletin of Environment, Pharmacology and Life Sciences, 4(2): 108-113.
90. Matula, 2009. Boron sorption in soils and its extractability by soil tests (Mehlich 3, ammonium acetate and water extraction). Plant, Soil and Envi., 55: 42-49.
91. Ahmad, R. and M. Irshad, 2011. Effect of boron application time on yield of wheat, rice and cotton crop in Pakistan. Soil Envi., 30(1): 50-57.
92. Godfray, C. Beddington, I. Crute, L. Haddad, D. Lawrence, J. Muir, J. Pretty, S. Robinson, S. Thomas and C. Toulmin, 2010. Food Security: The Challenge of Feeding 9 Billion People Science, 327(5967): 812-818.
93. Uraguchi and Fujiwara, 2011. Significant contribution of boron stored in seeds to initial growth of rice seedlings. Plant and Soil, 340(1-2): 435-442.
94. Gupta, U., 2002. Boron and its role in crop production. Boca Ratow: Turk J. Agri., 27: 329-335.
95. Kabir R., S. Yeasmin, A. Islam and M. Sarkar, 2013. Effect of phosphorus, calcium and boron on the growth and yield of groundnut (*Arachis hypogea* L.). Inter. J. Bio-Sci. and Bio-Tech., 5(3): 51-59.