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Response of Food Barley (Hordeum vulgare L.) Varieties to Rates of Nitrogen Fertilizer in Limo District, Hadiya Zone, Southern Ethiopia

Ketema Niguse[1*] Mulatu Kassaye[2]
1.Debark University, Department of Plant Sciences
2.Debre Markos University, Department of Plant Sciences. Po. box 269

Abstract
Barley is an important food crop in the highlands of Ethiopia. However, its productivity is constrained by a number of problems. Among these inadequate uses of N fertilizer and lack of using improved food barley variety are the most important ones. Therefore, a field experiment was conducted in Limo district, Southern Ethiopia with the objective of evaluating vegetative growth, yield and yield components of three food barley varieties (Local variety (Darshina), HB 1307 and EH 1493) using four different rates of nitrogen fertilizer application (0, 23, 46, and 69 N kg ha^{-1}). The experiment was laid out as a Randomized Complete Block Design (RCBD) with factorial combinations and replicated three times. Data were collected on days to 50% emergence and heading, days to 90% maturity, plant height, spike length, number of total and fertile tillers per m^2, biomass yield, straw yield, grain yield, thousand kernel weight and harvest index. The data were subjected to statistical analysis using SAS and mean differences were compared using Duncan's Multiple Range Test (DMRT). The analysis of variance showed that growth, yield and yield components of all varieties increased across the increasing rate of the nitrogen fertilizer. The results also revealed that rate of nitrogen on food barley varieties had highly significant ($P \leq 0.01$) effect on all the characters whereas grain yield, total and fertile tillers per m^2 was significantly affected by both main and interaction effect except days to 50% emergence which was only significantly affected by barley varieties. The maximum grain yield (4.51 t ha^{-1}) was obtained from variety EH 1493 at the rate of 69 kg N ha^{-1}. However, statistically similar result was recorded from the 46 kg N ha^{-1} and the minimum (1.42 t ha^{-1}) grain yield was obtained from variety HB1307 at nil rate of nitrogen application. The highest economic net return (Birr 32001 ha^{-1}) with acceptable marginal rate of return (MRR) was obtained from variety EH 1493 at rate of 69 kg ha^{-1} nitrogen, thus this can be suggested as effective to maximize productivity of barley. However, to make reliable and acceptable recommendation similar experiment has to be repeated over locations and seasons of the district with the inclusion of more nitrogen rates and varieties.
Keywords: Food barley, grain yield, nitrogen fertilizer

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is a grass of the family Poaceae, the subfamily Pooideae and the tribe triticeae (Voltas *et al*., 1998). Barley is thought to have originated in the Fertile Crescent area of the Near East from the wild progenitor *Hordeum spontaneum* ((Saisho and Purugganan, 2007). Barley is one of the most important cereal crops in the world, ranking fourth in production area next to wheat, maize and rice (USDA, 2017). In Ethiopia, barley is ranked fifth of all cereals, based on area of production, but third based on yield per unit area (Bayeh and Grando, 2011). Barley covers 10% of the land under crop cultivation (ICARDA, 2008; Teshome *et al*., 2008). Barley is an important grain crop in high of Ethiopia and has diverse ecologies being grown from 1800 to 3400 m above sea level under various production systems (Muluken, 2013) and makes Ethiopia being the second largest barley producer in Africa, next to Morocco, accounting for about 26 percent of the total barley production in the continent (FAO, 2014).

In Ethiopia barley is grown mainly as a low input staple food crop in the higher altitudes, on steep slopes, eroded lands or in moisture stress areas. Barley is the major cereal crop grown by subsistence farmers in the highlands above 1800 m mainly under rainfed conditions with minimum or no external inputs (Ejigu, 2012). Barley is produced mainly for human consumption and is one of the most important staple food crops (Grando and Macpherson, 2005). Barley with its long history of cultivation is deeply rooted in consumption habits of the population for it can be utilized in more diverse forms than any other cereals. Barley grain used as human food in the form of bread, *injera, kolo,* porridge, soup and for malting purposes. Among local beverages *Tella* and *Borde* are well-known, and best made from barley grain (Grando, 2005). According to Grando and Macpherson (2005), barley straw is a good source of animal feed, especially during the dry season. It is also a useful material for thatching roofs of houses and for use as beddings.

In spite of the huge importance of barley as food and malt, in its productivity is quite low. According to Bayeh and Stefania (2011), in Ethiopia efforts have been made so far to generate improved production technologies however, productivity of barley in production fields has remained very low, which is 1.96 t ha^{-1} compared with the world average of 2.95 t ha^{-1} (CSA, 2016 and USAD 2017). This is primarily due to the low yielding ability of farmers' cultivars, which are the dominant varieties in use; the influence of several biotic and a biotic stresses; and the minimal promotion of improved barley production technologies. Several a biotic and biotic factors have contributed to this low productivity, such as poor crop management practices; the use of low-yielding cultivars; the limited availability of the very few improved cultivars released; weeds, insects and diseases; and the inherently low yield potential of the prevalent local varieties (Bayeh and Stefania, 2011).

The area under barley cultivation in the southern nation and nationalities and peoples of regional state (SNNPR), Ethiopia is about 80,862 ha and the production is estimated to be about 1,424,373 quintals with mean yield of 1.76 t ha^{-1} in 2015/16 main in cropping season (CSA, 2016). In 2015/16 cropping season the area coverage of barley in Hadiya zone was 7,125.53 ha and its production was 154,558.22 quintals and with average productivity of 2.17 t ha^{-1} (CSA, 2016). In Hadiya zone crop production is mainly rain-feed. The major crop of the area is including cereals (maize, sorghum, barley, wheat, tef), pulses (beans, haricot beans red), and root crop (potatoes). A very small fraction of farmers produces vegetables and fruits (CSA, 2016). Soil fertility is one of the major production constraints of barley production in southern region of Ethiopia. The various factors accounting for the poor soil fertility include topography, soil erosion, deforestation, population pressure and continuous cultivation without soil fertility maintenance (Chilot *et al*., 2002). Even though several researches have been conducted on high land areas of Ethiopia, like Bale, Arsi, Gojam, and central part of the country, there are as yet much barley producing highland areas starving of new technology, including improved varieties and appropriate rate of fertilizer (Wakene *et al*., 2014).

Nitrogen is the key nutrient input for achieving higher yield of barley. Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Alam *et al*., 2007). Similarly, Sinebo *et al.* (2003) also reported that about 65% of grain yield variability in barley was attributed to nitrogen stress. 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 (Franklin *et al*., 2017).

Among the plant nutrients, nitrogen plays a very important role in crop productivity (Oikeh *et al*., 2007; Worku *et al*., 2007). 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 (CSA, 2014). 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 (Shahnaj *et al*., 2014). Moreover, there is a trend by farmer's uses sub optimal rates of nitrogen (0-20 N kg ha^{-1}) in the study area. Hence, it is important to determine optimum Nitrogen rates for released barely varieties for the maximum yield of the crop. However, limited research has been done to evaluate different N rates of barely varieties in the study area.

Therefore, this study was initiated with the following objectives,

- To investigate the effects of mineral nitrogen fertilizer rates on growth, yield and yield components of food barley varieties and,
- To determine economic optimum rates of nitrogen fertilizer for the productivity of the crop.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The experiment was conducted on the experimental field of plant science department, Wachamo University Campus, Limo district, southern of Ethiopia during the 2016 main cropping season. The site is situated at 7^{0}14' to 7^{0} 45' N latitude and 37^{0} 5' to 37^{0} 50' E longitude at about 232 km away south of the capital Addis Ababa and an altitude of 2106 meters above sea level. The mean annual rainfall is 1320 mm and the minimum and maximum annual temperatures are 12^{0}C, and 24^{0}C, respectively. The site has a silt loam soil with a pH of 6.4. The main rainy season extends from June to September, where the maximum rainfall is received in the months of June, July and august (figure 2). The major cereals cultivated in the district include tef (2550 ha), wheat (772 ha), and barley (620 ha) in the decreasing order of area coverage (SNNPR Bureau of Finance and Economic Development, 2009).

The texture of the soil is silt loam with a composition of 26% sand, 50% silt and 24% clay. The soil has slightly acidic reaction (pH = 6.4). According to FAO (2008), the soil pH is within the suitable range for the growth of most crops. Barley grows in different range of soil pH, with permissible ranges of 6 to 7 (Gooding and Davies, 1997). According to Roy *et al.* (2006), the soil had low organic carbon content (1.87%) which indicates that it has low N supplying potential to plants as organic matter content is often used as an index of N availability. Soil had moderate cation exchange capacity (CEC) (20.4 Cmole kg^{-1}) according to Hazelton and Murphy (2007), the. The soil had low available P (9.4 mg kg^{-1}) (FAO, 2008). The soil had low total nitrogen content (0,139%) according to Tekalign, (1991), which indicates that the nutrient is a limiting factor for barley production in the area.

2.2. Materials Used for the Experiment

Three food barley varieties where obtained from Holeta Agricultural Research Center HARC). The food barley varieties (local variety (Darshina), HB 1307 and EH 1493) where used as a test crop (Table 1). Urea and triple super phosphate (TSP) (46% P_20_5) used as sources of N and P, respectively.

Table 1. Food barley varieties used for the experiment.

Variety	Year of release	Breeder	Average plant height	Grain yield t ha^{-1}	
				On station	On farm
LV (Darshina)	-	-	-	-	-
HB 1307	2006	HARC	99.2cm	2.8-3.5	2.5 -2.8
EH 1493	2006	HARC	1.2 cm	2.5-6.1	2.1-2.9

Source: MOA, 2013.

2.3. Treatments and Experimental Design

The treatments were factorial combination of four rates of nitrogen (0, 23, 46 and 69 kg N ha $^{-1}$) and three food barely varieties (local varieties, HB 1307 and EH 1493). The experiments were laid out as a randomized complete block design replicated three times. The gross plot size of 1.6 m x 2 m (3.2 m^2) with 0.2 m row spacing and a total of eight rows were used. The net plots size of 1.2 m x 1.6 m (1.92m^2) leaving one outer most rows of both sides of each plot and 0.2 m row length at both ends as border. The distance between the plots and blocks were used 0.5 m and 1m apart, respectively.

2.4. Experimental Procedures

2.4.1. Land preparation

The land was prepared as per as local farmers practice before planting barely. Accordingly, the field was ploughed three times, the last ploughing was used for sowing in accordance with the specifications of the design, a field layout was prepared and each treatment were assigned randomly to experimental plots.

2.4.2. Application of mineral fertilizer

TSP was applied in band at a uniform rate (20 kg P ha^{-1}) in during sowing while nitrogen fertilizer applied in split half at sowing, and the remaining half at active tillering stage.

2.4.3 Sowing and harvesting

After the seed beds was leveled, seed was sown by manually the crop planted each plot at 20 cm spacing at seed rate of 90 kg ha^{-1}. All the necessary field management practices were carried out as required during the experimental period. Harvesting was done manually using hand sickles at physiological maturity of the crop.

2.5. Crop Data Collection and Measurements

Data was collected from each plot across the treatments by using appropriate sampling method and analytical procedures.

2.5.1.Phenological parameters

Days to 50% emergence: It was determined by counting the number of days from sowing to the time when 50% of the plants started to emerge above the ground through visual observation.

Days to 50% heading: It was determined by counting the number of days from sowing to the time when 50%of the plants started to heading by visual observation.

Days to 90% maturity: It was determined counting number of days from emergence to 90% plants reached to physiological maturity, when leaves senescence, grain easily detached from glumes by pressing between thumb and forefinger.

2.5.2.Vegetative parameters

Plant height (cm): Plant height was measured at physiological maturity from the ground level to the tip of ten randomly selected plants from central rows each plot.

Spike length (cm): It is the length of the spike from the node where the first spikelet emerges to the tip of the spike excluding the awns which was determined from an average of ten selected plants per plot.

2.5.3.Yield and yield components

Total tillers: It was determined by counting the tillers from an area of 0.25 x 0.25 m plants by throwing a quadrate in the middle portion of each plot.

Number of fertile tillers: The number of tillers bearing spikes was determined by counting productive tillers from an area 0.25 cm x 0.25 cm plants by throwing a quadrate in the middle portion of each plot at physiological

maturity.
Biomass yield (t ha^{-1}): It was measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot.
Grain yield (t ha^{-1}): The grain yield was measured by taking the weight of the grains from the net plot area and converted to tone per hectare after adjusting the grain moisture content to 12.5%.
Straw Yield (t ha^{-1}): Straw yield was determined by subtracting grain yield from total above ground biomass.
Thousand kernels weight (g): Thousand kernels weights were measured by taking the mass of counted thousand kernels using a sensitive electronic balance.
Harvest index (%): It was calculated the ratio of grain yield to the aboveground biomass yield of each plot expressed as a percentage.

2.6. Statistical Data Analysis

Data was subjected to analysis of variance using general linear model (GLM) procedures of SAS 9.1.3 (SAS Institute, 2003). Means of significant treatment effects was separated using the Duncan's multiple range test at 5% level of significance. Correlation analysis was carried out by calculating simple correlation coefficients between yields and yield components.

Economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total costs (ETB ha^{-1}). The average price of urea was 1480 Birr per quintal. Labor cost for fertilizer application estimated as two, four and six man-days required to apply 23, 46 and 69 kg N ha^{-1} urea, respectively. Each person-day labour cost 40 Birr. Following the CIMMYT partial budget analysis method, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 100% and the highest net benefit is said to be economically profitable (CIMMYT, 1988).

3. RESULTS AND DISCUSSION

3.1. Phenological parameters

3.1.1. Days to 50% emergence

Days to 50% emergence of barley plant was significantly ($p < 0.01$) affected by the main effect of crop variety but non-significant to main effect nitrogen rate and their interaction (Appendix Table I). Local variety took minimum days (7) to reach 50% emergence over the ground while EH 1493 took maximum days (8) to reach 50% emergence above ground. Statistically, variety HB 1307 was not significantly different from EH 1493 (Table 2). During germination the seedling mostly depends on stored food than on external nutrient. Because of this, significant variation might not be observed on days to emergence by fertilizer application. The significant difference days to 50% emergence were observed between tested barley varieties might attribute to the inherent genotypic difference of the stored food in endosperm, which can influence germination speed of barley seed under the same climatic and soil condition. In line with this result Suleiman *et al.* (2014) reported that days 50% to emergence were significantly affected by wheat varieties.

Table 2. Main effect of barley variety on days to 50% emergence of food barley.

Treatments Varieties	Days to 50% emergence
Local variety	7.0^{b}
HB 1307	7.91^{a}
EH 1493	8.0^{a}
LCR (0.05)	0.14
CV (%)	2.18

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

3.1.2. Days to 50% heading

Days to 50% heading was significantly ($p < 0.01$) affected by the main effects of nitrogen rate and varieties but their interaction was not significant (Appendix Table I). Local variety was took minimum days to 50% heading (65.50 days) while EH 1493 Variety was took maximum (79.5 days). Days to 50% heading showed an increasing tendency with rising N rates. Increasing rates of nitrogen from 0-69 kg N ha^{-1}, days to 50% heading was increased from 71.11 to 73.33 days.

In general, increasing the rate of nitrogen application significantly prolonged the days to heading of the barley plants across all application rates. The maximum number of days to heading was observed at a rate of 69 kg N ha^{-1} while the minimum number of days to heading was observed at zero N treatment (Table 3). The delay in days to 50% heading of barley with increased N rate might be attributed to application of high N rate promoted vigorous vegetative growth and development of the plants possibly due to synchrony of the time of need of the plant for uptake of the nutrient and availability of the nutrient in the soil. The same findings disclosed by Biruk and Demelash (2016) who obtained that detectable difference among barley varieties, in days to 50% heading.

This result is also in line with the finding of Getachew (2004) and Mekonen (2005) who reported that days to 50% heading was significantly delayed by highest N fertilizer rate compared to the lowest rate on wheat and barley crops, respectively. However, Rashid *et al*. (2007) reported that NP application significantly delayed days to heading of barley. Generally, Yohannis (2014) disclosed that the delay in days to heading of wheat plants in response to the increased N rate might be as a result of high N rate application that promoted vigorous vegetative growth and development of the plants possibly due to the availability of sufficient nutrient in the soil for plant uptake.

3.1.3. Days to 90% maturity

Days to 90% maturity of barley plant was highly significantly ($p < 0.01$) affected by both the main effect of variety and N rate while the interaction effect of the two factors did not affect this parameter (Appendix Table I). The current finding revealed that local variety took 110.9 days to 90% maturity while EH 1493 variety needs 126.33 days. This variation may be due to different varieties have different genetic makeup. The maturity of barley plants was hastened under lower N rates than under the higher N rates. Thus, increasing the rate of nitrogen from 0 to 69 kg N ha^{-1} prolonged days to maturity by about 5% over that of zero nitrogen rate. However, increasing the rate of nitrogen from 46 kg N ha^{-1} to 69 kg N ha^{-1} did not further increase the number of days required to reach maturity (Table 3).

More N applied treatments delayed in maturity might be due to extended vegetative growth instead of reproductive growth. Plants treated with N, particularly with the highest level of N, remained slightly green duration while those plants without N showed yellow spike, leaf and stem indicating early physiological maturity which might have been due to depression of cytokinin synthesis or increased production of abscisic acid (ABA) under low N supply (Marshner, 2012). These variations on date of maturity of barley might be, due to shoots maturity was directly affected by the rate of fertilizer application. This result is in line with the report of Brady and Weil (2002) that N applied in excess than required delayed plant maturity. In consistent with this finding Wakene *et al*. (2014) revealed that delay in maturity time of barley was greater at higher rates of nitrogen.

Table 3. Days to 50% heading and days to 90% maturity of food barley as influenced by the main effect of N rate and variety.

Treatments N rate (kg N ha^{-1})	Days to 50% Heading	Days to 90% Maturity
0	71.11^{b}	116.44^{b}
23	72.00^{b}	116.62^{b}
46	73.00^{ab}	119.11^{a}
69	73.33^{a}	119.40^{a}
LCR (0.05)	1.32	1.76
Varieties		
Local variety	65.50^{c}	110.9^{c}
HB 1307	72.08^{b}	116.66^{b}
EH 1493	79.50^{a}	126.33^{a}
LCR (0.05)	1.14	1.52
CV (%)	3.97	5.53

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

3.2. Vegetative Parameters

3.2.1. Plant height

The main effects of nitrogen rate and varieties highly significantly ($p < 0.001$) influenced plant height but their interaction exhibited a non-significant (Appendix Table II). The highest mean plant height (100.7cm) was obtained from local variety followed by HB 1307 (93.1cm) variety. Plant height was increased significantly in response to increasing the rate of N fertilizer from nil up to 69 kg N ha^{-1}. The tallest plants were attained at 69 kg N ha^{-1} (Table 4). The magnitude increment of plant height over the control treatment was 10.7%.

The possible reason might be that optimum nitrogen supply may have played an essential role in plant growth and development (Haftom *et al*., 2009). This result is similar with the finding of Biruk and Demelash (2016) indicated that highly significant plant height differences resulted by main effect of N rate and varieties. This result is also supported by the finding of Hadi *et al*. (2012) reported that taller barley plants recorded on high N treatments applied. Likewise, Fazal *et al.* (2012) revealed that plant height of barley was significantly affected the N fertilizer applications.

3.2.2. Spike length

Spike length was highly significantly ($p < 0.001$) affected by both main effects but non-significantly affected by their interaction (Appendix Table II). The highest spike length was obtained from variety EH1493 (8.06cm), followed by local variety (7.89cm) while the minimum spike length (7.10cm) was recorded HB1307 variety (Table 4).

Spike length was also significantly increased with increasing N level. Spike length varied from 7.16 to 8.34cm as the N level increase from 0 to 69 kg N ha^{-1} (Table 4). The result of this study similar with reports of Aghdam and Samadiyan (2014) indicated that effect of N and variety on spike length was significant at 1% level which means spike length became higher at higher dose of N possibly due to higher availability of nitrogen and genotypic differences between cultivars in terms of their length are concerned. This result agreed with Biruk and Demelash (2016) study spike length varied significantly ($P < 0.001$) among the barley varieties. Similarly, Laghari *et al*. (2010) who reported that spike length of wheat crop became higher at the higher doses of nitrogen.

Table 4. Plant height and spike length of food barley as influenced by the main effect of N rate and variety.

Treatments N rate (kg N ha^{-1})	Plant height(cm)	Spike length (cm)
0	87.97^{c}	7.16^{b}
23	90.82^{bc}	7.32^{b}
46	93.23^{ab}	7.97^{ab}
69	96.52^{a}	8.34^{a}
LCR (0.05)	5.16	0.52
Varieties		
Local variety	100.77^{a}	7.98^{a}
HB 1307	93.05^{b}	7.10^{b}
EH 1493	82.59^{c}	8.06^{a}
LCR (0.05)	4.46	0.45
CV (%)	5.72	6.97

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

3.3. Yield and Yield Components

3.3.1. Total tillers

Number of total tillers was significantly ($p < 0.01$) affected by both main effect of nitrogen and variety. Moreover, this parameter was also significantly ($p < 0.05$) affected by the interaction effect of variety and nitrogen rate (Appendix Table II).

An increasing the rate of nitrogen application up to 69 kg N ha^{-1} significantly increased total tillers number of across to all varieties. The maximum total tillers (336.3) was obtained from EH 1493 variety with combination of 69 kg N ha^{-1} while the minimum number (222.7) of total tiller was obtained from HB 1307 variety with nil N rate. An increasing rate of nitrogen from zero to 69 kg ha^{-1} increased total number of tillers by 40%. Statistically, total tillers number of local (308) and HB 1307 (306.7) varieties combined with 69 kg N ha^{-1} showed the same with response with that of EH 1493 with 69 kg N rate (Table 5).This may be the contribution of N fertilizer, as the treatments that received N responded more total tillers compared with zero N received treatment. This as stated by Bakht *et al*. (2010) might be due to nitrogen is an essential nutrient for growth and development of the plant. A similar result was reported by Suleiman *et al.* (2014) and Wakene *et al.* (2014) N application has significant difference among wheat and barley varieties for tillering respectively.

Besides to these Rashid and Khan (2008) disclosed that number of total tillers of barley varieties was significantly increased by e application of nitrogen fertilizer. Similarly, Munir (2002) reported that tillers numbers of barley varieties were significantly increased with increasing rate of nitrogen fertilizer application.

Table 5. Total tillers of food barley as influenced by the interaction effect of N rate and variety

N rate (kg N ha^{-1})	total tillers/m^2		
	Varieties		
	Local Variety	HB 1307	EH 1493
0	266.3^{bcde}	222.7^{e}	249.3^{de}
23	276.3^{bcd}	252.3^{cde}	267.0^{bcde}
46	276.7^{bcd}	301.0^{abc}	314.7^{ab}
69	308.0^{ab}	306.7^{ab}	336.3^{a}
LCR (0.05)		50.03	
CV (%)		6.0	

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

3.3.2. Number of fertile tillers

The analysis of variance indicated that number of fertile tiller was highly significant ($P < 0.01$) caused by both main effect of the N rate and barley variety and their interaction effect (Appendix Table II). The highest mean number of fertile tiller (323.7) was obtained from EH1493 variety with the highest rate of N fertilizer (69 kg N ha^{-1}) while the minimum number of fertile tillers (207.3) was recorded from variety HB 1307 with zero nitrogen application (Table 6).

Number of fertile tillers plant is the most important character, which ensured highest yield. According to Mangle and Kirkby (1996), nitrogen stimulates tillering, may be due to its effect on cytokine synthesis. Others reported that barely reacts to early N by producing more tillers per plant and by exhibiting a higher percentage survival of tillers (Batey, 1984; Archer, 1988). This result is consistent with finding of Biruk and Demelash (2016) number of fertile tillers highly significantly affected by the difference between barley varieties and rates of nitrogen. It also agreed with Alam *et al.* (2007) study N applied treatments were produced highest number of fertile tillers plant^{-1} irrespective of cultivars and N treatment. Increased level of nitrogen increased number of fertile tillers plant^{-1}. Similarly, Wakene *et al.* (2014) indicated that highly significant differences were observed between plant heights, productive tillers m^{-2}.

Table 6. Numbers of fertile of food barley as influenced by the interaction effect of N rate and variety

N rate (kg N ha^{-1})	Number of fertile tillers/m^2		
	Varieties		
	Local Variety	HB 1307	EH 1493
0	253.3^{de}	207.3^{f}	236.3^{e}
23	262.3^{de}	238.7^{e}	253.4^{de}
46	269.4^{cd}	291.0^{bc}	302.3^{ab}
69	295.5^{abc}	29.7^{bc}	323.7^{a}
LCR (0.05)		28.6	
CV (%)		6.3	

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

3.3.3. Grain yield

Both the main and interaction effect of rates of nitrogen fertilizer application and variety affect grain yield significantly (Appendix Table III). The maximum grain yield (4.51 t ha^{-1}) was recorded from variety EH 1493 at the rate of 69 kg ha^{-1} nitrogen application but statistically it was not significantly different from N rate of 46 kg N ha^{-1} with EH 1493 (4.11 t ha^{-1}). On other hand the minimum grain yield (1.42 t ha^{-1}) was recorded from variety HB 1307 zero N rate (Table 7).

This might be due to high yield capacity of variety EH 1493. Increasing the rate of nitrogen from zero up to 69 kg N ha^{-1} were linearly increased grain yields along all varieties. With similar rates of the nitrogen fertilizer, variety EH 1493 produced significantly higher grain yields than the other two varieties. For example, combined with 69 kg N ha^{-1} and EH 1493 exceeded the grain yields of HB1307 and local varieties by about 39 and 22%, respectively. Similarly, at the highest rate of the nitrogen fertilizer (46 kg N ha^{-1}), the grain yield of EH 1493 exceeded the grain yields of HB 1307 and local varieties by about 37 and 29%, respectively (Table 7).

The increase in grain yield in response with increasing rate of nitrogen could be attributed to enhanced availability of the nutrient for uptake by the plants and increased photoassimilate production that would eventually lead to improved partitioning of carbohydrate to the grains (Gooding and Davies, 1997). The results of this study have indicated that application of nitrogen enhanced the grain yields of all food barley varieties. All tested varieties continued responding up to the highest N level. The significant increase in grain yield in response to the increased application of N fertilizer could be attributed to enhanced availability and uptake of N by the roots of barley plants (Kaizz *et al*., 2012). Grain yield is a complex character depending upon a large number of environmental, morphological and physiological characters. Grain yields also depend upon other yield components. The highest grain yield of any crop is the result of all positive relationships of the yield components (Sorour *et al*., 1998).

Improvement in barley yield with fertilizer application can be attributed to the stimulating effects of nutrients on plant growth that provides ideal condition for crop as the fertilizer N supply to plants need (FAO, 1998), which ultimately increased the grain yield of crop. The current result is in agreement with the achievements of Ahmad *et al*. (2003), Ahmad and Rashid (2004) and Imran *et al*. (2005) who suggested that an introduction of high yielding crop variety with balanced application of NP fertilizer can be increase the grain yield of the crop. On the other hand, highly significant differences were observed between number of tillers and productive tillers m^{-2}, biomass and grain yield as main effect of nitrogen fertilizer rate (Amare and Adane, 2015). Similarly, Grain yield of wheat was highly significantly influenced by the rate of N fertilizer application (Bekalu and Manchore, 2016).

Table 7. Grain yield of food barley as influenced by the interaction effect of N rate and variety

N rate (kg N ha^{-1})	Grain yield (t ha^{-1})		
	Varieties		
	Local Variety	HB 1307	EH 1493
0	1.97^{ef}	1.42^{g}	1.56^{fg}
23	2.54^{cd}	2.26^{de}	2.78^{cd}
46	2.90^{c}	2.36^{de}	4.11^{a}
69	3.51^{b}	2.44^{cde}	4.51^{a}
LCR (0.05)		0.52	
CV (%)		11.51	

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

3.3.4. Biomass yield

Biomass yield was very highly significantly ($P < 0.001$) influenced by the main effect of N rate and variety but the interaction effect was not significantly influence this parameter (Appendix Table III). The maximum of biomass yield (12.31 t ha^{-1}) was obtained from variety EH 1493 and followed by local variety producing 9.81t ha^{-1} while minimum of biomass yield was attained at HB1307 variety which produced 8.95 t ha^{-1} (Table 8).

Biomass yield has positive correlation with growth parameters like; total number of plants, tillers per unit area and final plant height. Variety EH1493 superior in biomass yield because it has higher total tillers and fertile tillers in relation to two tasted barley varieties. Likewise, biomass yield of barley varieties also significantly influenced by nitrogen rate. The highest biomass yield (12.35 t ha^{-1}) was obtained at the highest nitrogen rate (69 Kg ha^{-1}) though not significantly different from 11.37 t ha^{-1} obtained at 46 Kg ha^{-1} N and the minimum (7.78 t ha^{-1}) biomass yield was obtained at nil N rate. Increasing rate of nitrogen up to 69 kg ha^{-1} increased biomass yield of crop by 37 % over the control treatment (Table 8).

This might be significant increases in plant height, tillering, spike length, number of spikelets per spike and grain yield from N application ultimately contributed to the increased crop biomass yield. This result is consistent with study of Mohammad *et al.* (2011) who reported that significance differences were observed on total biomass yield of barley due to various levels of nitrogen fertilizer application. Besides this result also agreed with the finding of Wakene *et al*. (2014) the highest biomass yield of 8.78 t ha^{-1} was recorded at treatment received 120 kg N ha^{-1} while the lowest biomass yield of 6.51 t ha^{-1} was obtained at treatment received zero nitrogen rate. Similarly, Alam and Haider (2006) who indicated that increasing nitrogen level increased total dry matter irrespective of cultivars. Further increase in N levels significantly enhanced the biological yield as nitrogen at 120 kg ha^{-1} yielded maximum (11642.78kg) biological yield followed by 80 kg ha^{-1} (9392.22kg). Minimum (7224.11kg) biological yield was provided by N at 40 kg ha^{-1} (Hadi *et al*., 2012).

3.3.5. Straw yield

Straw yield was highly significantly ($p < 0.001$) influenced by the both main effects of variety and N rate but non-significant to their interaction effect (appendix table III). The highest mean straw yield (9.33 t ha^{-1}) was obtained from EH 1493 variety while the lowest mean straw yield (7.4 t ha^{-1}) from HB 1307 (Table 8). The EH 1493 variety produced straw yield than local and HB 1307 varieties; implying an advantage of the total above ground dry-matter production from the relatively late maturing variety. The straw yield was ranged from 7.34 to 9.27 t ha^{-1} as nitrogen rate is increase from zero to 69 kg ha^{-1} (Table 8). The mean separation revealed that increasing rate of nitrogen was increased straw yield of barley varieties up to higher level of nitrogen application. Similar to the grain yields, the straw yields continued increasing significantly with the increase in N fertilizer rate.

The current result is in line with the finding of Shafi *et al*. (2011) who reported that straw yield of barley affected by different N levels. In consistent with this result Biruk and Demelash (2016) reported that considerable difference in straw yield was attained between barley varieties and nitrogen rates. Similarly, the rate of fertilizer application was significantly affected straw yield of wheat (Bekalu and Mamo, 2016).

Table 8. Biomass and straw yield of food barley as influenced by the main effect of N rate and variety

Treatments N- (kg ha^{-1})	Biomass yield (t ha^{-1})	Straw yield(t ha^{-1})
0	7.78^{c}	6.4^{c}
23	9.73^{b}	7.72^{b}
46	11.37^{a}	8.25^{ab}
69	12.35^{a}	9.27^{a}
LCR (0.05)	1.46	1.10
Varieties		
Local variety	9.81^{b}	6.99^{b}
HB 1307	8.95^{b}	7.7^{b}
EH 1493	12.31^{a}	9.33^{a}
LCR (0.05)	1.26	0.95
CV (%)	14.4	13.9

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

3.3.6. Thousand kernels weight

Thousand kernels weight of barely was significantly ($P \leq 0.05$) influenced by main effect of N fertilizer rate and highly significantly ($p < 0.001$) influenced by the main effect of varieties. However, their interaction did not significantly influence kernels weight (Appendix Table IV). The highest thousand kernels weight (44.46 g) was obtained from variety EH 1493 however the lowest thousand kernels weight (39.10 g) was obtained from variety HB 1307 (Table 9). The average thousand kernels weight was ranged from 41.43g to 43.34g as the rate of nitrogen increase from zero to 69kg N ha^{-1} (Table 9). Thousand kernels weight is an important yield determining component and reported to be a genetic character that is influenced least by environmental factors (Ashraf *et al.,* 1999).

This is consistent with the suggestion of Biruk and Demelash (2016) that suitable genetic behavior of cultivar with environment factors which may led to an increased in photosynthesis process and accumulations of carbohydrate in kernel to produce heavy kernels and consequently increased kernels weight per spike. The finding of Asghari *et al*. (2006) also indicated the increasing rate of nitrogen application was increased thousand kernel weights. Similarly, Biruk and Demelash (2016) reported that thousand kernel weight of barley variety also significantly increased with all levels of fertilizers compared to control.

3.3.7. Harvest index

The main effects of nitrogen rate and variety highly significantly ($p < 0.01$) affect the harvest index but non-significant interaction effect (Appendix table IV). Harvest index is the proportion of commercial yield and biological yield. The maximum mean harvest index (27.85%) was recorded at higher level of nitrogen rate (69kg N ha^{-1}) while the minimum of harvest index (19.73%) was recorded at control treatment (Table 9).Among the varieties, EH1493 variety had higher harvest index (26.6 %) followed by local variety (25.50%) which is statistically similar value but variety HB 1307 had lower (21.53%) harvest index (Table 9). The fact that variety EH 1493 resulted in high harvest index revealed its capacity to efficiently distribute the dry matter produced to sink organ compared to the other varieties. Harvest index as a quantitative trait is an indicator of plant efficiency to distribute dry matter in grain (Shahryari and Mollasadeghi, 2011).

Riggs *et al*. (1981) who reported that high significant and positive relation between harvest index and grain yield in barley. Higher harvest index implies higher partitioning of dry matter into seed. The minimal competition within the grains per spikes of might have facilitated the movement of nutrients into the grain. Similarly, Taye *et al*. (2002) disclosed mean harvest index of about 50% with a positive trend due to increasing N rate in Ethiopia.

Table 9. Harvest index and thousand kernels weight of food barley as influenced by the main effect of N rate and variety

Treatments N rate (kg N ha^{-1})	Harvest index (%)	Thousand kernels weight (g)
0	19.73^{c}	41.43^{c}
23	23.43^{bc}	41.90^{bc}
46	26.64^{ab}	42.93^{ab}
69	27.85^{a}	43.34^{a}
LCR (0.05)	4.12	1.22
Varieties		
Local variety	25.50^{a}	40.90^{c}
HB 1307	21.53^{b}	42.50^{b}
EH 1493	26.6^{a}	43.87^{a}
LCR (0.05)	3.56	1.05
CV (%)	17.13	2.94

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

3.4. Correlation Analysis

Grain yield was positively and significantly associated with plant height (r=0.47**), spike length (r=0.53), total tillers (r=0.54**), number of fertile tillers (r=0.59**), biomass yield (r=0.87**), straw yield (r=0.33*), thousand kernels weight (r=0.55**) and harvest index (r=0.61**) (Table 10). Total biomass yield of barley was positively and significantly correlated with plant height (r=0.42*), thousand seeds weight (r=0.57**) and straw yield (r=0.63**), total tillers (r=0.67**), number of fertile tillers (r=0.74**), and harvest index (r=0.48) (Table 10). Number of fertile tillers per m^2 was significantly and positively correlated with some yield and yield traits of barley such as; harvest index (r=0.47**), plant height (r=0.51**), spike length (r=0.38*), thousand kernels weight (r=0.45**) and Harvest index (r=0.47**) (Table 10). Harvest index was also significantly and positively correlated with some parameters of barley, such as: plant height (r=0.54**), straw yield (r=0.39*) and thousand seeds weight (r=0.43**)(Table 10).

The present result is in agreement with the finding of Bishaw *et al.* (2014) who reported a positive association between biomass yield and plant height. Similar correlations were reported in barley by Bekalu and Mamo (2016) and Alam *et al.* (2005).

Table 10. Correlation analysis among growth, yield and yield components of food barley as influenced by N rate and variety

	PHT	SL	TT	NFT	BY	GY	TKW	SY	HI
PHT	1	0.42*	0.34*	0.51**	0.42*	0.47**	0.49**	0.37*	0.54**
SL		1	0.32*	0.38*	0.26^{ns}	0.53**	0.05^{ns}	0.28^{ns}	0.14^{ns}
NTT			1	0.89**	0.67**	0.54**	0.23^{ns}	0.64**	0.21^{ns}
NFT				1	0.74**	0.59**	0.45**	0.25^{ns}	0.47**
BY					1	0.87**	0.57**	0.63**	0.48**
GY						1	0.55**	0.33*	0.61**
TKW							1	0.32^{ns}	0.43**
SY								1	0.39*
HI									1

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed), NS=Non Significant, PHT= Pant Height, SL= Spike Length, TT= Total Tillers, NFT= Number of Fertile Tiller, BY= Biomass Yield, GY=Grain yield, TKW= Thousand Kernels Weight, SY= Straw Yield, HI= Harvest Index.

3.5. Economic Analysis

The results of economic analysis showed that the maximum net benefit (Birr 24437 ha^{-1}) with an acceptable MRR was obtained from mineral N fertilizer application of 69 kg N ha^{-1} for local variety. This has resulted in a net benefit advantage of Birr 9381 ha^{-1} over control treatment (Table 11). In the case of variety HB 1307, the maximum net benefit (Birr 16449 ha^{-1}), with an acceptable MRR was obtained at mineral N fertilizer at 23 kg N ha^{-1}. This has resulted in a net benefit advantage of Birr 5599 over the control treatment (Table 11).

The maximum net benefit (Birr 32001 ha^{-1}), with an acceptable MRR was obtained from the application of 69 kg N ha^{-1} for EH 1493 variety. This has resulted in a net benefit advantage of Birr 20081 over the control treatment (Table 11). An increase in output will always raise profit as long as the marginal rate of return is higher than the minimum rate of return *i.e.* 100% (CIMMYT, 1988). Because the marginal rate of return was above the minimum level (100%).

Application of mineral N fertilizer for the three food barley varieties had positive net benefit over the nil nitrogen treatment, which implies a very high increase in farmers' income with a simple improvement in crop nutrient management strategy. Thus, EH 1493 food barley variety with 69 kg ha^{-1} N fertilizer applied is economically beneficial compared to the other treatments.

Table11. Economic analysis for effect of nitrogen fertilizer on yield of food barley varieties

Varieties	N (kg ha^{-1})	Average yield (kg ha^{-1})	Adjusted Yield (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
	0	1970	1773	17730	2677	15053	
LV	23	2540	2286	22860	4272	18588	222
(Darshina)	46	2900	2610	26100	5581	20519	188
	69	3520	3168	31680	7243	24437	205
	0	1420	1278	12780	1930	10850	
HB 1307	23	2260	2034	20340	3891	16449	286
	46	2360	2124	21240	4847	16393	190
	69	2440	2196	21960	5776	16184	139
	0	1560	1404	14040	2120	11920	
EH 1493	23	2800	2520	25200	4625	20575	345
	46	4110	3699	36990	7225	29765	350
	69	4510	4059	40590	8589	32001	310

GB= Gross benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return. Sale price of barley grain ETB 10 kg^{-1}; Cost of harvesting, threshing and winnowing ETB 140 per 100 kg; Packing and material cost Birr 6 per 100 kg and transportation Birr 5 per 100 kg.

4. SUMMARY AND CONCLUSSION

Barley is the most important staple food crop in the study area. However large numbers of farmers are not using improved technologies such as, improved variety and fertilizer. It has been selected as one of the target crops in the strategic goal of attaining national food self- sufficiency, income generation, poverty alleviation and achieving socio-economic growth of the county.In Limo district, barley is a major crop produced by small holder farmers. However, its production and productivity is low due to the use of inappropriate nitrogen fertilizer rate and local low yielding varieties in the study area. This indicates that the need to conduct research and determine the optimum nitrogen rate for maximum productivity of food barley crop. Therefore, this study was conducted at Limo District, Hadiya Zone, Southern Ethiopia to investigate response of food barley varieties to rates of nitrogen fertilizer with the objectives of to evaluate the effects of mineral nitrogen fertilizer rates on growth, yield and yield components of food barley varieties and, to determine economic optimum rates of nitrogen fertilizer for the productivity of the crop.

The result of this study revealed that the phenological, growth and yield trait parameters were positively responded to nitrogen fertilization. Days to 50% emergence were significantly influenced by the main effect of variety but N rate and their interaction did not significant influence on this parameter. Days 50% heading and days to 90% maturity were significantly affected by both effects of N rate and varieties but non-significant to their interaction effect. Variety EH 1493 was late in all phenological parameters in contrast to other varieties. Plant height, spike length, biomass yield, grain, straw yield, thousand kernels weight and harvest index were significantly affected by both main factor variety and N rates but their interaction effect was not significant. Total tillers, number of fertile tiller and grain yield were significantly affected by main and interaction effects.

Barley variety EH1493 was more superior to the other varieties on most of the phenological, growth, yield and yield components parameters of barley. The highest grain yield (4.51 t ha^{-1}) was obtained from EH 1493 variety with 69 kg N ha^{-1} while the lowest grain yield (1.42 t ha^{-1}) was from HB1307 variety with control treatment. The maximum total biomass (12.35 t ha^{-1}) and straw yield (9.27 t ha^{-1}) were obtained from application of 69 kg ha^{-1} of nitrogen. The highest number of total tillers (336.3) and fertile tillers (323.7) per m^2 were obtained from EH 1493 variety with application of 69 kg of nitrogen rate. The economic analysis revealed that highest net benefit of Birr 28791.5 ha^{-1} was recorded in the treatment that received 69 N kg ha^{-1} for variety EH 1493. In conclusion plants treated with 69 kg of N rate with EH 1493 variety resulted in more number of total and fertile tillers, grain yield, biomass and straw yield, maximum thousand kernels weight and harvest index coupled with the best economic benefit or profitability. Therefore, this treatment combination can be suggested for use by barley farmers in the study area. To be come with concrete recommendation similar experiment has to be repeated over locations and seasons of the district with the inclusion of more nitrogen rates and varieties with consideration of the economic evaluation, under diverse management practices, which may facilitate fine-tuning of fertilizer recommendations.

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6. APPENDIXES

Appendix Table I. Mean squares of ANOVA for days to 50% emergence, days to 50% heading, and days to 90% maturity of food barley varieties and N rates

Source of Variation	Df	Days to 50% Emergence	Days to 50% heading	Days to 90% Maturity
Rep	2	0.02^{NS}	0.18^{NS}	12.4^{*}
Variety (V)	2	3.65^{**}	528.43^{**}	728.36^{**}
Nitrogen (N)	3	0.027^{NS}	7.728^{*}	12.31^{*}
V x N	6	0.0277^{NS}	3.06^{NS}	0.215^{NS}
Error	22	0.027	1.83	3.239

Where *, ** and NS denote significant differences at $P < 0.05$ and $P < 0.01$ and Non-Significant difference, respectively. DF = Degree of Freedom. ANOVA = Analysis of Variance

Appendix Table II. Mean squares of ANOVA for plant height, spike length, total tillers and number of fertile of food barley varieties and N rates

Source of Variation	Df	Plant height	Spike length	Total tillers	Number of fertile tillers
Rep	2	225.22^{*}	0.18^{*}	3427.12^{**}	3510.2^{**}
Variety (V)	2	999.37^{**}	3.017^{**}	9095.41^{**}	1367.8^{**}
Nitrogen (N)	3	118.37^{**}	2.87^{**}	1345.44^{**}	9712.6^{**}
V x N	6	11.82^{NS}	0.048^{NS}	833.63^{*}	793.7^{**}
Error	22	27.86	0.289	284.01	286.2

Where *, ** and NS denote significant differences at $P < 0.05$ and $P < 0.01$ and Non-Significant difference, respectively. DF = Degree of Freedom. ANOVA = Analysis of Variance

Appendix Table III. Mean squares of ANOVA for grain yield, biomass yield, and straw yield of food barley varieties and N rates

Source of Variation	Df	Grain yield	Biomass yield	Straw yield
Rep	2	0.37^{NS}	12.21*	5.21*
Variety (V)	2	3.11**	30.54**	12.97**
Nitrogen (N)	3	5.31**	35.27**	6.33**
V x N	6	0.594*	1.48^{NS}	0.71^{NS}
Error	22	0.20	2.22	1.28

Where *, ** and NS denote significant differences at $P < 0.05$ and $P < 0.01$ and Non-Significant difference, respectively. DF = Degree of Freedom. ANOVA = Analysis of Variance

Appendix Table IV. Mean squares of ANOVA for thousand kernels weight and harvest index of food barley varieties and N rates

Source of Variation	Df	Thousand kernels weight	Harvest index
Rep	2	1.67^{NS}	71.12*
Variety (V)	2	23.960**	75.19**
Nitrogen (N)	3	6.22**	127.56**
V x N	6	1.51^{NS}	22.558^{NS}
Error	22	1.56	17.68

Where *, ** and NS denote significant differences at $P < 0.05$ and $P < 0.01$ and Non-Significant difference, respectively. DF = Degree of Freedom. ANOVA = Analysis of Variance