5. Refining Nitrogen Rate for Yield and Quality of Malt Barley under Balanced Fertilization at Basona Warana District, North Shewa Zone, Ethiopia

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Abstract

The present experiment was conducted at Basona warana district during the main rainy season of 2017/18-2018/19 to determine the effect of different doses of N on yield and quality attributes of malt barley (var. Sabine). The treatment consists: control (0), 23, 46, 69, 92, 115, 138 and 161 Kgha^{-1} N with combination of 46 P_20_5, 30 S, 0.5 B, 2 Kgha^{-1} Zn and 2 Kgha^{-1} Cu. The design was completely randomized block with three replications. Every year the 8 treatments of Nitrogen levels were assigned to plots of each block randomly. The result indicated that Nitrogen rates significantly affected growth, yield and quality component of malt barley as compared to the control treatment with balanced fertilization. The effect of N rate was consistently and positively increasing plant height. Application of Nitrogen at a rate of 161 Kgha^{-1} gave significantly higher grain and straw yields compared to all other rates. Even though the economic analysis result revealed that the highest net return of 64,173.5 ETBha^{-1} and the marginal rate of return 1258.5% was obtained from 138 Kgha^{-1} N, lower friability percentage of malt barley was recorded from 138 Kgha^{-1} which was lower than Ethiopian malt quality standards. Hence, application of 115 Kgha^{-1} N under balanced fertilization is recommended for cultivating malt barley in the study area with minimum acceptable malt quality parameter.

Keywords*: **balanced fertilization, food barley, growth, Nitrogen, yield***

Introduction

Barely (*Hordeum vulgare* L.) is one of the most important food crops produced in the world (Meints, B. & Hayes, 2019). It assumes the fourth position in total cereal production in the world after wheat, rice and maize (FAO, 2011). Russia, Canada, Germany, Ukraine and France are the major barley producers, accounting for nearly half of the total world production (FAOSTAT 2016). Ethiopia is also considered to be the origin and center of diversity for barley (source?). Barley is one of the most important staple food crops produced in the highland areas of Ethiopia (Zemede, 2000). Its grain is used for the preparation of different foodstuffs, such as *injera, kolo, bread, porridge and* local drinks, such as *tela, borde* and beer. The straw is used as animal feed, especially during the dry season. Barley has various useful functions in addition to being used as food, feed, and beverage. According to Emebiri *et al*., (2003), malted barley is also added to the food process of the biscuit factory and has also sufficient protein content for animal feed.

Malt barley is adapted to wide environmental condition, matures early and has high yield market potential (Hailu and Luer Joop, (1996); Getachew *et al*., (2006)). In Ethiopia, malting process was started by St. Georgis Brewery factory in 1974 ((Legese *et al*., 2007). ORDA (2008) reported that estimated annual production of malt barley is 15,945 tonnes but the annual consumptions of six brewery factories is 48,330 tonnes. Hence, 69% of the demand of malt barley is fulfilled from imports. Recently, the production of malt barley met only 35% of the demand and the remaining imported at a cost of $38 million (Lakew, 2016). The potential of malt barely production in Ethiopia covers about 150,000 ha with an estimated yield of 375,000 tons (ICARDA, 2017). Based on the information of Ethiopian standard authority, the protein level of standard quality for malt should be between 9–12% (EQSA, 2006). The protein content below 9% and above 12% is not accepted for processing because there is strong inverse correlation between protein and carbohydrate content; this may lead to low malt extract level (Fox *et al*., 2003) so that acceptable grain N content of malt barely should not be greater than 1.6–1.8% (Zhao *et al*., 2006)

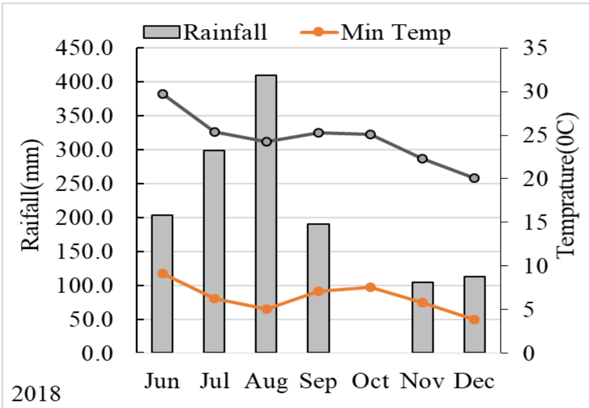
Despite, the importance of barely and its many useful characteristics, there are several factors affecting its production. The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, water logging, drought, frost, soil acidity, diseases and insects, and weed competition (ICARDA, 2008). Poor soil fertility and low pH are among the most important constraints that threaten barley production in Ethiopia. Since the major barley producing areas of the country are mainly located in the highlands, severe soil erosion and lack of appropriate soil conservation practices in the pasthave resulted in soils with low fertility and pH particularly deficiency of Nitrogen and Phosphorus is the main factor that severely reduces the yield of barely (Taye *et al.*, 1996).

Fertilizers constitute an integral part of improved crop production technology and their proper management to crops is important for maximum yield and minimum contamination to environment (Corbeels *et al.,* 1999). In Ethiopia, commercial fertilizer mainly in the form of urea and DAP was introduced in the 60s by higher learning institutions through limited laboratory and research activities (Murphy, 1968). Results of several studies also have shown that Nitrogen fertilizer increases grain yield and its protein. Asadi *et al*., (2013) investigated the effects of different levels of Nitrogen and competition on grain yield and reported that with increase of Nitrogen grain yield increased.

No systematic attempthas been made so far with regard to N with balanced fertilization of malt barley in the soils of the study areas. Thus, field research was imitated to determine the optimum N rate for yield and quality parameters of malt barley under balanced fertilization

Materials and Methods

Description of Study Area: The field trial was conducted in Basona warana district, North Shewa Zone of the Amhara Regional State during the main seasons of 2017/18-2018/19. Geographically, the experimental sites were located at a range of 09^0 36’ to 09^0 48’N and 39^0 39’ to 39^0 50’E with a mean altitude of 2650-2868m. According to the climatic records by Ethiopian National Meteorological Agency from 1985 to 20118, the study area has a unimodal rainfall which starts in June and ends in December and received the average long term annual rainfall of 1539.1 mm. The long term mean annual minimum and maximum air temperatures were 9.13 and 19.49 respectively. The total amount of rainfall for 2017 and 2018 were 1469.0 mm and 1621.8 mm respectively (Figure 1).



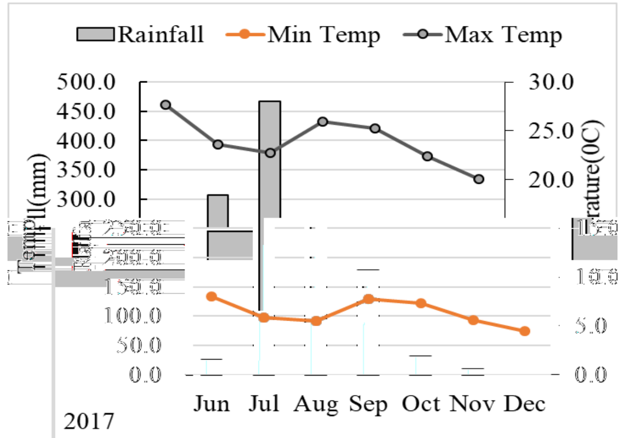


Figure 1 Rainfall minimum and maximum temperature for the growing seasons DBARC- Andit tid meteorological station)

Experimental Design and Procedures: The treatment consisted of eight levels of N (0, 23, 46, 69, 92, 115, 138, and 161 Kgha^{-1} N for with combination of 69 P_2O_5, 30S, 0.5B, 2 Zn and 2 Cu. The experiment was laid out in randomized complete block design with three replications. The experimental field was prepared with oxen power tiller according to farmers' conventional plowing practice. Nitrogen was applied as per each treatment level specification. The full amount of P, S, Micronutrients (Zn, B, and Cu) and half of N from each level were applied at the time of planting in the forms of triple superphosphate (TSP), muriate of potash (KCl), gypsum ($CaS0_4$), ZnS04, Borax and CuS04 and urea respectively. Remaining half urea for N was applied as top dress at 45 days after sowing (at tillering stage). The variety (Sabine) used seed was drilled in line (20 cm apart between raw) at the rate of 100 Kgha^{-1}.The seeds were treated with fungicides (Apron star) to prevent disease with recommended rates labeled on the product. The plot size was 3.6mx3.4 m while the net plot size was 2x3.4 m^2 (ten central rows) and was used for data collection. The spacing between the plots and adjacent replication (blocks) were 0.5 m and 1 m respectively.

Initially composite soil samples (0-20 cm depth) were collected from the experimental plots, air dried, labeled and passed through 0.5 mm for the analysis of TN and OC through 2 mm sieve for the analysis of other parameters. Soil pH was measured with a glass electrode; samples were diluted in water (the ratio of soil to water was 1:2.5) (Van Reeuwijk 1992). Total Nitrogen was determined using the micro Kjeldahl procedure as described by Bremmer and Mulvaney (1982). Soil organic carbon was determined using the Wet Oxidation Method of Walkley and Black described by Nelson and Sommers (1982). Available Phosphorus was determined following Olson and exchangeable Potassium by extraction with 1 N ammonium acetate (method of Morgan) and determined by reading with a fame photometer (Knudsen *et al.*, 1982).

Data collection and Analysis: Agronomic data: such as Growth (plant height, Spike length, fertile tiller, total tiller, kernels per spike), yield (grain, straw and harvest index and thousands kernel were collected and malt quality analyses were performed (grain protein content, malt extractable, friability and ß-Glucan content) with a near infrared reflectance spectrometer (Foss NIRS-500, Foss GmbH, Rellingen, Germany) at Holeta Agricultural Research Center Malt barley quality analysis laboratory. Moisture content of the grain yield was adjusted to 12.5% and converted to kilogram per hectare. The collected data were subjected to the analysis of variances and significant treatment means were separated by Least Significant Difference (LSD) by using Statistical Analysis System (SAS) package (2002).

Partial Budget Analysis: Partial budget analysis with dominance and marginal rate of return was carried out (CIMMYT, 1988). To estimate the economic value of the output (grain and straw yield), the average market price during the two consecutive years for malt barley was 13 ETB (Ethiopian ETB) per Kg. Average input price and labor force applying the nutrients including: N, P_2O_5, S, were 26, 30.4 and 40 respectively. And also micro nutrients (B + Zn + CU) was 200 ETB per ha.

Results and Discussion

Selected Physical and Chemical Soil Properties: Analysis of soil physico-chemical properties prior to planting is presented in Table 1. The lab analysis result indicated that the texture was loam and clay loam. Soil pH (H_2O) was ranged from slightly acidic to acidic which is optimum pH range (6.0 to 7.0) for barley production (CLDB, 2001).

The available Phosphorus content of the experimental soil was rated as medium to low (Olsen *et al.*, 1954) while the exchangeable Potassium content was rated as high to very high (Landon, 1991). Likewise, the mean soil organic carbon and total Nitrogen contents of the experimental soil were rated as low to very low based on Landon's classification (Landon, 1991).

Table 1. Selected physical and chemical properties of the experimental soil at Basona Warana District, 2017/18 and 2018/19

Year	Site	pH (1:2.5)	OC (%)	TN (%)	Av.P (ppm)	Exch.K ($CmolKg^{-1}$)	C	Si	S	Textural Class
2017/18	Mush	6.40	1.54	0.17	6.40	0.31	24	34	42	Loam
	Abamotie	6.70	1.68	0.20	6.70	1.84	44	34	22	Clay
2018/19	Mush	5.70	1.67	0.16	3.74	0.60	52	34	14	Clay loam
	Andit tid	6.32	1.34	0.17	2.02	0.64	38	40	22	Clay loam

Effect of Nitrogen on Malt Barley Growth, Yield and Quality: Since growth parameters are the major yield contributing characters, in the present study, plant height, spike length, total tiller, fertile tiller and number of seeds per spike increased by increasing Nitrogen level (Table 2). The highest mean plant height (87.4 cm), spike length (7.94 cm), total tiller number per 1m^2 (873), number of fertile tillers per 1 m^2 (814), number of seeds per spike (26.6) were obtained from the application of the highest N rate (161 Kgha^{-1} N). This result is in line with the findings of Amare and Adane (2015) and Haftom *et al.,* (2009) with the possible reason of application of Nitrogen have played an essential role in plant growth and development.

Table2. Mean response of malt barley growth parameters for different rates of N fertilizer under balanced fertilization over years at Basona Warana District

N (Kgha^{-1})	PH (cm)	SPL (cm)	Total Tiller (m^2)	Fertile Tiller (m^2)	Number of Kernels (Spike^{-1})
0	61.0^{f}	5.91^{ce}	496^{d}	455^{e}	22.9^{e}
23	65.9^{ef}	6.16^{e}	585^{cd}	535de	22.7^{e}
46	71.9^{de}	6.56^{cd}	610^{c}	565^{cd}	23.8^{de}
69	76.1^{cd}	7.11^{c}	631^{c}	600^{cd}	25.3^{bc}
92	77.2^{bcd}	7.03^{c}	679^{bc}	653^{c}	25.0^{cd}
115	81.8^{abc}	7.36^{bc}	679^{bc}	631^{cd}	25.5^{abc}
138	84.0^{ab}	7.56^{b}	778^{ab}	727^{a}	26.4^{ab}
161	87.4^{a}	7.94^{a}	873^{a}	814^{a}	26.6^{a}
CV (%)	12.13	6.07	18.89	20.60	6.36
LSD (0.05)	7.5	0.34	102.3	104.2	1.3

Grain yield increased significantly with increased N rate (0 to 161 Kgha^{-1}). Therefore, the highest grain yield (5430.8 Kgha^{-1}) was obtained from the highest N rate (Table 3). Similarly, the straw yield increased with increasing N levels (Table 3). Several studies reported positive, linear and quadratic responses of grain yield to incremental rates of N (Gauer *et al*., 1992; and Ali, 2010). Birhan (2017), also reported at South Gonder, Farta district of Amhara region grain and total above ground biomass yield and quality of malting barley were significantly improved when using 150 Kgha^{-1} N.

Harvest index is the proportion of economical yield to biological yield (Ortiz-Monasterio *et al.*, 1997). The harvest index to N rate was also significant (Table 3). The plots which received 92 Kg N ha^{-1} had the highestharvest index. This could be explained by increased aboveground biomass yield as a result of incremental N fertilizer rates, as compared to grain yield. In Ethiopia, however, a mean HI of about 50% with a positive trend due to increasing N rate had previously been reported (Taye *et al*., 2002). This finding is also in accordance with the study reported by Munir (2002) and Biruk *et al.,* (2016) which indicated thatharvest index decreased with increased N rate.

under balanced fertilization over all sites at Basona Warana District, 2017/18 & 2018/19

N (Kgha^{-1})	Grain Yield Kgha^{-1}			Straw Yield Kgha^{-1}			HI (%)
	2017/18	2018/19	Mean	2017/18	2018/19	Mean	
0	2148.3^{e}	3450.7^{d}	2799.5^{d}	2584.6^{e}	3854.4^{d}	3219.5^{c}	45.6^{a}
23	2569.9^{e}	3769.2^{d}	3169.5^{cd}	3159.3^{e}	4203.9^{d}	3681.6^{c}	45.7^{a}
46	3627.5^{d}	4383.9^{c}	4005.7^{bc}	4579.7^{d}	6000.5^{cd}	5290.1^{b}	43.3^{c}
69	4072.3^{cd}	4468.6^{bc}	4270.5^{abc}	5138.5^{cd}	5498.3^{cd}	5318.4^{b}	44.3^{ac}
92	4508.6^{c}	4607.7^{abc}	4558.2^{ab}	5690.0^{c}	4891.9^{bcd}	5290.9^{b}	47.0^{a}
115	5208.3^{b}	4770.4^{abc}	4989.4^{ab}	6809.3^{b}	5159.7^{abc}	5984.5^{b}	44.9^{ac}
138	5770.8^{ab}	5081.6^{a}	5426.2^{a}	8058.8^{a}	7015.6^{abc}	7537.2^{a}	41.7^{cd}
161	5873.8^{a}	4987.8^{ab}	5430.8^{a}	8737.3^{a}	7657.2^{ab}	8197.3^{a}	39.5^{d}
CV (%)	12.64	11.08	11.90	10.79	25.65	34.20	9.69
LSD (0.05)	624.3	576.3	385.5	706.2	1686.0	1203.8	3.47

As shown in Figure 2, year 2 predicts the lowest yield response to N as compared to year 1 in slope and predicted malt barley yield. However, optimal malt yield occurs about the same N level, 138 Kgha^{-1}for both years.

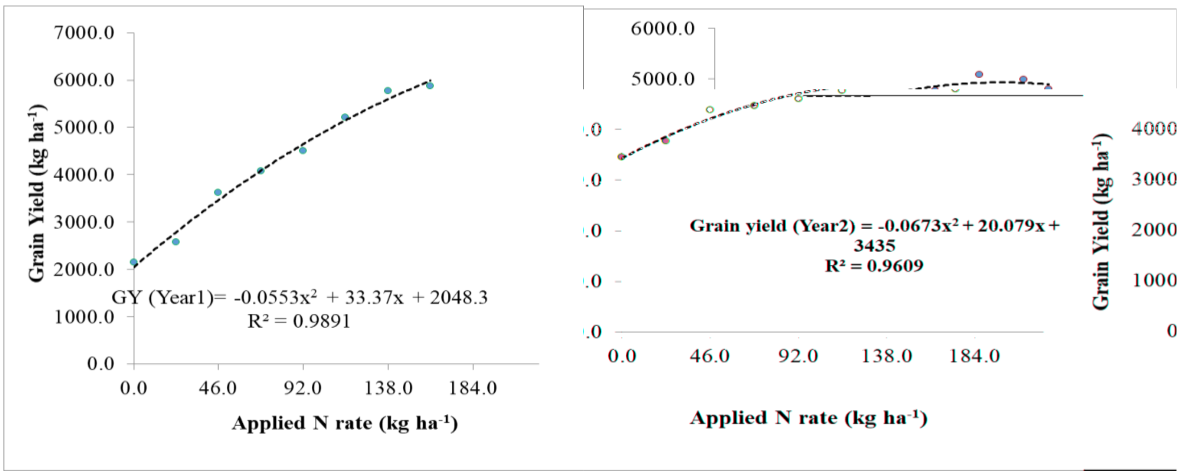


Figure 2. Regression curve for applied Nitrogen (2017 left side and 2018 right side)

The analysis of variance revealed that grain protein content was significantly influenced by Nitrogen rates (Fig. 3). The highest protein content in grain was obtained from the highest Nitrogen rate (161 N Kgha^{-1}). Generally, mean protein content significantly increased N rate. Application of the higher Nitrogen rate resulted in 11.2% (Table 3). Even though grain protein content is within Ethiopian malt barley standard of quality requirement; the mean effect of all N rates on protein content was significant. Protein content increased in proportion to the N rates up to the highest rate of 161 Kgha^{-1} N. According to Biruk ., (2016), application of 98.5 Kgha^{-1} N resulted in grain protein content within the acceptable range on Sabine variety.

Malt extract yield determines the amount of beer produced after malting. The highest value for the trait was obtained from the application of Nitrogen at the rate of 46 Kgha^{-1} and the lowest from 161 Kgha^{-1} N (Table 3). Eagles *et al*., (1995) reported that malt extract would decrease with increased N application rate due to more increase of grain protein concentration. It is implied that higher N level in soil and plants leads to more protein synthesis and accumulation in barley grains, as a result causing a reduced ability of grain components to be decomposed during malting and mashing process (Wang *et al*., 2003).

Table 4. Combined effect over years of different rates of N fertilizer under balanced fertilization on quality parameters of malt barley at Basona Warana District

N ($Kgha^{-1}$)	TSW* (g)	Extract content [% dm]	Friability [%]	Protein content [% dm]	ß-Glucan content [mg/L]
0	45.7	81.4[a]	64.4[ab]	8.5[ef]	271.9[b]
23	44.9	81.0[a]	70.5[a]	8.1[f]	282.0[b]
46	47.2	81.2[a]	63.3[ab]	8.6[edf]	259.0[b]
69	47.4	81.0[ab]	62.1[ab]	9.3[cde]	216.6[b]
92	46.9	80.4[abc]	63.1[ab]	9.4[cd]	377.1[ab]
115	46.7	79.9[bcd]	60.1[bc]	9.9[bc]	318.4[b]
138	48.1	79.4[cd]	52.2[c]	10.6[ab]	529.9[a]
161	46.6	78.9[d]	54.9[bc]	11.2[a]	378.1[ab]
CV (%)	12.85	1.98	19.24	11.49	46.16
LSD (0.05)	ns	1.29	9.57	0.88	146.5
EQSA, 2006	35-46	73.8-80.9	>60%	9-12	

**TSW=thousnds kenel weight, MEC=Malt Extract content, Fria= Friability, PC=Protein content and ß-G=ß-Glucan content*

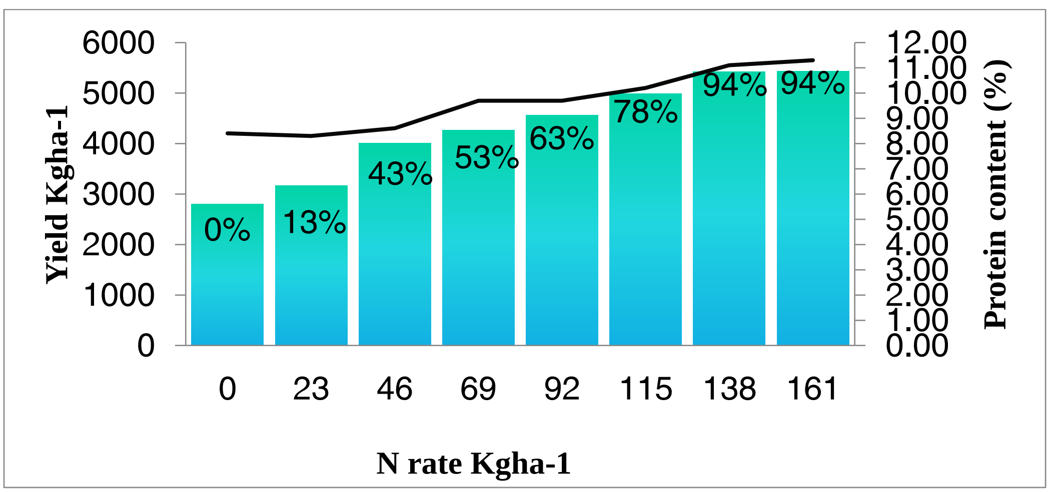


Figure 3 Relationship of Maltbarley yield and grain protein contente as influeced by Nitrogen fertilizer rate, 2017/18

Correlation among Quality Parameters of Malt Barley: Correlation analysis among quality parameters of malt barley revealed highly significant positive and negative associations among the quality parameters studied (Table 4). Accordingly, malt extract was significantly and positively correlated (r = 0.82) with friability. This means when malt friability increased, malt extractable was increasing, on the contrary malt extractable also negatively affected by increasing protein content (-0.95) and its b-glucan content (-0.76) was also increased. In similar manner, the level of Nitrogen was highly significantly and negatively correlated (r = -0.96) with friability and this indicated that when friability of malt is decreasing, its malt extract content was also decreasing.

Table 5. Correlations among Nitrogen -glucan, and friability malt properties

	Nitrogen	Malt Extract	Friability	Protein content
Malt Extract	-0.96**			
Friability	-0.85*	0.82*		
Protein content	0.96**	-0.95*	-0.92**	
ß-glucan	0.69ns	-0.76*	-0.73*	0.68ns

Partial Budget Analysis: The highest net benefit was obtained from the application of 138 Kgha^{-1} N (Table 6). The maximum net benefit of 64173.5 ETB ha^{-1} with the optimum marginal rate of return (1258.5%) was recorded from 138 Kgha^{-1} N, followed by Nitrogen 115 Kgha^{-1} N (Table 6). However from quality perspective, application of 138 Kgha^{-1} N and beyond resulted in lower friablility percentage of malt barley which had negative impact on total malt extract content that in turn negatively affected total beer production. Thus, application of 115 Kg N ha^{-1} is more preferable with minimum acceptable quality parameters for beneficiaries

Table 6. Partial budget analysis of Nitrogen rates on malt barley at Basona Warana District

N ($Kgha^{-1}$)	TVC ($ETBha^{-1}$)	GY ($Kgha^{-1}$)	Ad.GY ($Kgha^{-1}$)	StY ($Kgha^{-1}$)	GB ($ETBha^{-1}$)	NB ($ETBha^{-1}$)	MRR %
0	1425	2799.5	2519.5	3219.5	33888.1	32463.1	
23	2023	3169.5	2852.6	3681.6	38465.8	36442.8	665.5
46	2621	4005.7	3605.1	5290.1	50334.4	47713.4	1884.7
69	3219	4270.5	3843.4	5318.4	52793.8	49574.8	311.3
92	3817	4558.2	4102.3	5290.9	55308.9	51491.9	320.6
115	4415	4989.4	4490.4	5984.5	61062.6	56647.6	862.2
138	5013	5426.2	4883.6	7537.2	69186.5	64173.5	1258.5
161	5611	5430.8	4887.7	7797.3	69929.5	64075.5	-16.4

Conclusion and Recommendation

According to the current study result, Nitrogen rates had significant effect on growth, yield and quality component of malt barley as compared to the control treatment with balanced fertilization techniques. The effect of N rate was consistently and positively increasing growth parameters. Application of Nitrogen at a rate of 161 $Kgha^{-1}$ also produced significantly higher grain and straw yield than all rates. Even though the economic analysis result revealed that the highest net return of 64,173.5 $ETBha^{-1}$ and the marginal rate of return 1258.5% was obtained in the treatment that received 138 $Kgha^{-1}$, friability percentage values were found below the Ethiopian malt barley quality standard (>60%). But, application of 115 $Kgha^{-1}$ N under balanced fertilization is recommended for the production of malt barley in the study area with minimum acceptable malt quality parameter especially acceptable friablity percentage.

Acknowledgements

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