Grain yield and malting quality of barley in relation to nitrogen application at mid- and high altitude in Northwest Ethiopia

*Minale Liben, Alemayehu Assefa and Tilahun Tadesse

Adet Agricultural Research Center, Ethiopia

Abstract

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In the main cropping seasons of 2006-2007, a two-year field experiment on the response of malting barley varieties to nitrogen (N) application was conducted on nitosols of the Laie-Gaint, Gozamen and Yilmana-Denssa areas of northwestern Ethiopia. The aim was to determine the optimum N application rate for malting barley production. The experiment was a complete factorial arrangement in RCB with three replications. It consisted of 12 factorial combinations of four N rates (46, 69, 92, 115 kg N ha^{-1}), and three recently released malting barley varieties (HB-52, HB-1533 and Miscale-21). A blanket application of 46 kg ha^{-1} P (as P_2O_5) was applied across all treatments at the time of sowing. Grain yield and its protein content in all locations increased almost linearly as the N rate increased. Based on the findings of the experiment, it is recommended that fertiliser rates of 115/46 kg N/P_2O_5 ha^{-1} for HB-52, and 92/46 kg N/P_2O_5 ha^{-1} for Miscale-21, are economically optimum rates, with an acceptable grain quality standard in the Laie-Gaint, Yilmana-Denssa and Gozamen areas. For variety HB-1533, fertiliser rates of 92 kg N ha^{-1} and 115 kg N ha^{-1} are recommended, with acceptable grain quality in the Laie-Gaint and Gozamen areas, respectively. It is not recommended to grow the variety HB-1533 in the Yilmana-Denssa area, owing to its high protein content. Selection of appropriate varieties for different localities was also found to be crucial for maintaining the grain quality of malting barley at its standard level.

Keywords: Nitrogen application rates, Malting barley varieties, Protein content, Nitosols.

*Corresponding author: Adet Agricultural Research Center, P.O. Box 8, Bahir Dar, Ethiopia

Introduction

Barley (*Hordeum vulgare*) is one of the most important cereal crops, mainly grown by smallholder farmers at mid- and high altitudes in NW Ethiopia, predominantly between 2200–3000 m a.s.l (Asmare *et al.*, 1998.). Malting barley is used for preparing alcoholic beverages, mainly beer. ORDA (2008b) estimated that about 15,945 tons of malting barley is produced annually in Ethiopia. By contrast, the combined annual malting barley consumption of the six breweries in the country, was estimated at 48,330 tons, which is expected to double owing to the expansion of the existing breweries. Most of the demand for malt is met through imports, which account for 69% of the total annual requirement (ORDA, 2008a).

To satisfy the ever-increasing demand for raw materials by the beverage industry, and to ensure dependable and higher cash returns to the farmers, expansion of the malting barley production area is very important. Immense potential areas are available for malting barley production to meet the national demand. However, its production has not expanded, and productivity at farm level has remained low. One reason for the low productivity of the crop is the poor soil fertility of farmland, which is aggravated by continuous cropping, overgrazing, high soil erosion and removal of field-crop residues, without any soil amelioration. Nitrogen is deficient in most Ethiopian highland soils (Taye *et al.*, 1996). Particularly at farmers' level, an increase in crop production must achieve a high yield per unit area, which will require the application of improved technologies. Fertiliser application is a lead practice in the introduction of improved technologies for increasing crop yield.

Quality requirements for malting barley are fairly strict, and directly related to processing efficiency and product quality in the malting and brewing industries. Important characteristics for malting quality include grain protein concentration, grain size, malt extract and diastatic power (Henry, 1990). Grain protein content depends on soil fertility, and, more specifically, on the availability of N in the soil and in the plant for its conversion into grain protein. Excessively higher protein content is undesirable, because of the strong inverse correlation between protein and carbohydrate content; thus high protein content leads to a low malt extract level (Fox *et al.*, 2003). Grain N content is a determining factor of malt quality; high grain N content not only means lower carbohydrate content and lower malt extract level, but also makes the barley more difficult to modify, causing problems for the maltster. The preferred grain N level is not greater than 1.6–1.8% (Atherton *et al.*, 1984). Grain size is also an important malting quality parameter, because small grain contains less carbohydrate, and leads to a low malt extract level (Zhao *et al.*, 2006).

A high N application rate significantly increases grain yield, grain protein and grain N content, and decreases kernel weight and kernel plumpness. Split application of N at the anthesis stage of the crop also increases grain protein (Eagles *et al.*, 1995). Recommendations for an optimum level of N fertiliser, which ensures optimum grain yield without affecting the necessary malting barley qualities, are needed. Cultivars differ in malting quality characteristics, and are also influenced by environmental factors, including N nutrition (Weston *et al.*, 1993). Therefore, the identification of appropriate varieties of malting barley and the use of appropriate production practices are critical to the production of quality malting barley. Malting barley varieties have been released nationally. However, there are no studies on the interaction between N fertiliser rate and different malting barley varieties under different environmental conditions in the major barley-growing areas of the country. The present investigation was conducted with the aim of recommending appropriate malting barley varieties, with their respective optimum level of N fertiliser, for the major barley-growing areas of northwestern Ethiopia.

Materials and Methods

The study areas

The experiment was carried out on nitosols in three localities: Laie-Gaint (South Gondar), Yilmana-Denssa (West Gojam) and Gozamen (East Gojam) districts of NW Ethiopia during the main cropping season (May–October) of two consecutive years (2006 and 2007). The altitudes of the experimental areas are 3000, 2600 and 2240 m a.s.l. for Laie-Gaint, Gozamen and Yilmana-Denssa, respectively. The mean total annual rainfall (which mainly falls in the cropping season) is 1060 mm at Laie-Gaint, 1318 mm at Gozamen and 1133 mm at Yilmana-Denssa. The rainfall pattern of the areas is unimodal; the effective rainy period extends from May to October, with the peak during July. Mean monthly maximum and minimum temperatures are 18.3 and 8.0 °C at Laie-Gaint, 22.8 and 10.4 °C at Gozamen and 26.0 and 9.7 °C at Yilmana-Denssa, respectively (Table 1).

The experiment was conducted at 12 representative sites in total; five in Laie-Gaint, two in Gozamen and five in Yilmana-Denssa. The cropping pattern of the experimental areas is dominated by cereal crops. Pre-sowing soil samples were collected from each site, to estimate fertility status. A composite soil sample was taken at 0–20 cm, and analysed for its content of total nitrogen (N), pH, Organic Carbon (OC), Organic Matter (OM) and available phosphorus (P).

Treatments and experimental design

The experimental treatment consisted of 12 factorial combinations of three recently released malting barley varieties (HB-52, HB-1533 and Miscale-21), and four N rates (46, 69, 92 and 115 kg ha^{-1}). The treatments were laid out in a randomised complete block design (RCBD), in a complete factorial arrangement with three replications. Forty-six kg ha^{-1} of P (as P_2O_5) was applied across all treatments as a blanket application at the time of planting. The N application was split, half of the N being applied at sowing and the remaining half at the tillering stage of the crop. The sources of N and P were urea and DAP, respectively. Malting barley seed was broadcast-sown at a rate of 125 kg ha^{-1}. The gross plot was 5×4 m (20 m^2), and the net plot 4×3 m (12 m^2), respectively. Land preparation and time of sowing were according to the farmers' practice. The sowing date ranged between early and mid-June in both experimental years.

Data collection and analysis

Data were collected on grain yield, plant height, thousand-kernel weight, and hectolitre weight. The height of five randomly selected plants in each plot was measured, and average plant height was calculated. Analysis of variance was undertaken for all collected data by means of SAS statistical software. The Duncan multiple-range test was employed for

Table 1. *Total precipitation during the growing season and mean temperature averaged over the years 1998–2004*

Location	Total precipitation mm	Mean temperature °C	
		Max.	Min.
Laie-Gaint	897	17.5	8.3
Gozamen	1146	21.0	10.8
Yilmana-Denssa	1042	24.6	11.5

mean comparisons among treatments. A grain sample was taken at one representative site of each location for determination of grain protein content. The grain N content was analyzed by the Kjeldahl method, and the result was multiplied by 5.7 to obtain the grain protein content. The agronomic efficiency (AE) of applied N was also computed, as kg grain produced per kg N added.

The mean grain yield data were reduced by 10% to adjust the yield to the farmers' management conditions, and subjected to partial budget and sensitivity analysis (CIMMYT, 1988). The average market price of malting barley grain for the three months December–February during the experimental periods of 2006 and 2007 was used. The cost of urea fertiliser was considered as a variable cost for the economic analysis. The cost varied for each treatment, and treatments were ranked in order of ascending variable cost. Dominance analysis was used to eliminate those treatments which cost more, but which produced a lower net benefit, than the next lowest-cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment, and a minimum acceptable MRR of 100% was assumed (CIMMYT, 1988). A sensitivity analysis was made on the basis of the assumption that the cost of the fertiliser may increase by 50%, while simultaneously the grain price increases by 20% (Table 2).

Table 2. *The mean cost (Ethiopian Birr, ETB) of input and the price of raw barley grain at the experimental locations during the experimental periods*

Cost of input and price of output	Current market situation	Assumption for sensitivity analysis
Cost of urea fertiliser (ETB kg^{-1})	3.74	5.61
Price of grain (ETB kg^{-1})	3.81	4.57

Results and Discussion

According to the fertility classification of Landon (1991), the soil analysis of the locations shows that the soils of the experimental sites were acidic, with low pH, low to medium content of Organic Carbon (OC), medium content of available P and low total N content (Table 3).

The ANOVA results for the grain yield for each site within the three locations are shown in Table 4. The grain yield of malting barley exhibited statistically significant differences in response to N rate at almost all sites of the locations. In the Laie-Gaint area, two of the five sites, and in the Yilmana-Denssa area, all sites except one, showed significant differences in grain yield between varieties, whereas in the Gozamen area, none of the sites exhibited a significant yield difference due to variety. The interaction Variety×Nitrogen (V×N) showed non-significant differences in grain yield at almost all sites of the locations. The mean grain yield obtained from application of the lowest N rate (46 kg ha^{-1}) ranged between 1155–2612 kg ha^{-1} at Laie-Gaint, 285–1285 kg ha^{-1} at Yilmana-Denssa, and 1003–1249 kg ha^{-1} in the Gozamen area. The high yield potential of the sites is manifested in the application of the highest N rates (92 and 115 kg ha^{-1}). The highest mean yield ranged from 2394–5832 kg ha^{-1} at Laie-Gaint, 1965–2729 kg ha^{-1} at Yilmana-Denssa and 1823–2467 kg ha^{-1} at Gozamen (Table 4).

Table 3. *Mean value of important soil parameters, as measured on soil sample taken just before sowing at the experimental locations*

Location	**Total N %**	**O.C. %**	**O.M. %**	**Available P ppm**	**pH**
Laie-Gaint	0.22	2.12	3.65	9.5	4.94
Gozamen	0.18	1.52	2.62	10.1	4.68
Yilmana-Denssa	0.17	1.59	2.74	6.37	5.08

Table 4. *Results of analysis of variance for grain yield of individual sites at the three locations*

Source of variation	**Laie-Gaient**					**Yilmana-Denssa**					**Gozamen**	
	Site-1	Site-2	Site-3	Site-4	Site-5	Site-1	Site-2	Site-3	Site-4	Site-5	Site-1	Site-2
Variety (V)	*	*	NS	NS	NS	NS	*	**	**	**	NS	NS
Nitrogen (N)	**	NS	*	*	NS	*	NS	**	*	*	**	*
V×N	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Lowest mean yield	2612	2569	1169	1155	2612	1285	933	320	285	613	1003	1249
V×N for lowest yield	V2×N1	V2×N1	V3×N1	V2×N1	V2×N1	V1×N2	V1×N1	V1×N1	V1×N1	V1×N1	V1×N1	V1×N1
Highest mean yield	5832	4442	3229	2394	3430	2641	2729	2218	1965	2174	1823	2467
V×N for highest yield	V3×N3	V3×N4	V1×N4	V1×N2	V3×N3	V2×N3	V3×N2	V3×N4	V2×N4	V1×N4	V2×N4	V2×N4
CV %	19.58	26.08	30.42	24.90	29.08	24.5	28.8	22.4	24.6	25.7	20.08	30.5

The results of the combined analysis of variance (across the experimental sites at each locality) for grain yield, plant height, thousand-kernel weight and hectolitre weight are shown in Table 5. Site, variety, N and their interactions significantly affected most crop parameters in all of the locations, with the exception of the Site×N (S×N) interaction in the Laie-Gaint area. A significant Site×N interaction effect in other locations suggests that heterogeneity among the sites in initial soil N levels may have exerted a differential effect on the response of the crop to N application. It has been reported that the N-use efficiency of a crop is enhanced as a result of important soil factors that may affect available P, soil moisture and the nature and amount of clay in the soil (Desta, 1988).

Grain yield increased almost linearly in response to applied N in all the locations. The increase was 31, 48 and 80% at Laie-Gaint, Gozamen and Yilmana-Denssa, respectively, as the N application rate increased from 46 to 115 kg ha^{-1}. The agronomic efficiency of applied N was 12 for the first interval (*i.e.* from 46 to 69 kg N ha^{-1}), 15.3 for the second interval (69 to 92 kg N ha^{-1}) and 4.5 for the third interval (92 to 115 kg N ha^{-1}) in the Laie-Gaint area. Similarly, the AE was 14.3, 11.8, 12.0 in the Yilmana-Denssa area and 8.9, 7.1, 10.7 in the Gozamen area for the first, second and third intervals, respectively (Figure 1). The varieties responded differently at these three locations. The variety HB-52 gave the highest yield at Laie-Gaint, whereas HB-1533 and Miscale-21 did so at Gozamen and Yilmana-Denssa, respectively. The highest mean grain yield, 3437 kg ha^{-1} at Laie-Gaint, 2072 kg ha^{-1} at Yilmana-Denssa and 2145 kg ha^{-1} at Gozamen, were obtained from the respective variety with the application of the highest N rate (Table 6). There was an increase of 62%, 185% and 91% over the lower rate at Laie-Gaint, Yilmana-Denssa and Gozamen, respectively. Among the locations, the lowest grain yield was recorded in the Yilmana-Denssa area, which might be due to the relatively higher temperature there (Table 1), compared to the other two locations.Schelling *et al.* (2003) stated that temperature had the strongest influence on the duration of grain filling; yield reductions between 4.1 and 5.7% have been calculated for every 1°C increase in the diurnal mean temperature.

Plant height increased in all varieties and in all locations as N rates increased (Figure 2 and 3). Variety Miscale-21 had the greatest plant height, compared to the other varieties (Figure 2). The greatest and least plant height among the locations was recorded at Laie-Gaint and Yilmana-Denssa, respectively (Figure 3). The record plant height (110.6 cm) was from the variety Miscale-21 at the highest N application rate in the Laie-Gaint area. Plant height is strongly correlated with grain yield, and showed a similar trend in all locations. The correlation across locations, as indicated in Figure 4, was positive and significant (P = 0.0001).

Thousand-kernel weight and hectolitre weight are more affected by variety than by the N application rate. As the N application rate increased, thousand-kernel weight increased in the Laie-Gaint and Yilmana-Denssa areas. The highest thousand-kernel weight was recorded in varieties HB-1533 and Miscale-21, as compared to HB-52, at all locations (Table 7). According to the Ethiopian quality standard, the acceptable grain size (thousand-kernel weight) and test weight (hectolitre weight) for raw barley are in the range 25–35 g and 48–62, respectively (EQSA, 2006)**.** The results of the present experiment exhibited an acceptable thousand-kernel weight and hectolitre weight in all varieties for all N application rates at all locations (Tables 7 and 8).

Table 5. *Results of combined analysis of variance for all measured crop parameters at the three locations*

Source of Variation	Laie-Gaint				Yilmana-Denssa				Gozamen			
	Grain yield kg ha^{-1}	Plant height cm	Thousand-kernel wt g	Hectolitre wt	Grain yield kg ha^{-1}	Plant height cm	Thousand-kernel wt g	Hectolitre wt	Grain yield kg ha^{-1}	Plant height cm	Thousand-kernel wt g	Hectolitre wt
Site (S)	**	**	**	**	**	**	**	**	NS	*	*	-
Variety (V)	**	**	**	**	**	**	**	**	*	**	**	*
V×S	NS	**	**	NS	*	**	**	**	NS	**	*	-
Nitrogen (N)	**	**	*	NS	**	**	**	*	**	**	NS	NS
N×S	NS	NS	NS	NS	*	*	NS	NS	NS	*	NS	-
V×N	*	*	*	NS	*	*	*	*	*	*	NS	NS
V×N×S	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	-
Lowest value	2124	82.5	39.3	63.3	728	64.7	31.4	61.5	1126	76.2	31.3	57.8
Highest value	3437	110.6	43.5	68.3	2072	92.2	40.9	64.5	2145	95.0	38.7	63.2
V×N for highest value	V2×N4	V3×N4	V3×N4	V3×N4	V3×N4	V3×N4	V3×N4	V3×N4	V2×N4	V3×N3	V2×N4	V3 x N4
CV %	25.94	6.71	6.62	4.74	26.51	9.45	6.66	2.93	31.07	6.76	8.06	4.16

Note: *, ** significant difference at 5%, 1% probability levels, respectively NS-Non-significant
V1= HB-52 V2 = HB-1533 V3 = Miscale-21 N1 = 46 kg N ha^{-1} N2 = 69 kg N ha^{-1} N3 = 92 kg N ha^{-1} N4 = 115 kg N ha^{-1}

Table 6. *Effect of N application rate on the grain yield of malting barley varieties at the three locations*

N (kg ha^{-1})	Laie-Gaint				Gozamen				Yilmana-Denssa			
	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean
46	2555	2124	2496	2391	1126	1561	1183	1290	728	982	1575	1095
69	2838	2354	2810	2667	1421	1574	1492	1495	1148	1336	1786	1423
92	3050	2794	3211	3018	1520	1813	1879	1737	1441	1657	1986	1695
115	3437	2832	3097	3122	1652	2145	1914	1904	1890	1950	2072	1971
Mean	2970	2526	2904		1370	1773	1617		1302	1481	1855	
	V	N	V×N		V	N	V×N		V	N	V×N	
Std Err	93.76	108.27	187.53		100.6	116.2	201.3		52.9	61.1	105.8	
LSD (0.05)	262.8	303.4	525.6		289.9	331.2	573.7		148.3	171.2	296.6	

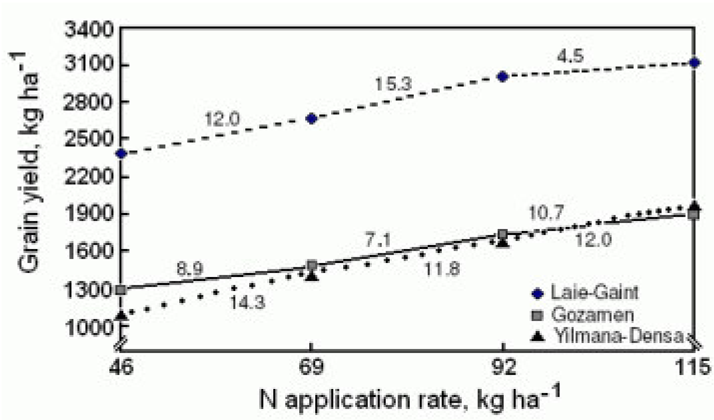

Figure 1. Grain yield response and agronomic efficiency of malt barley to N application rates in the three localities.

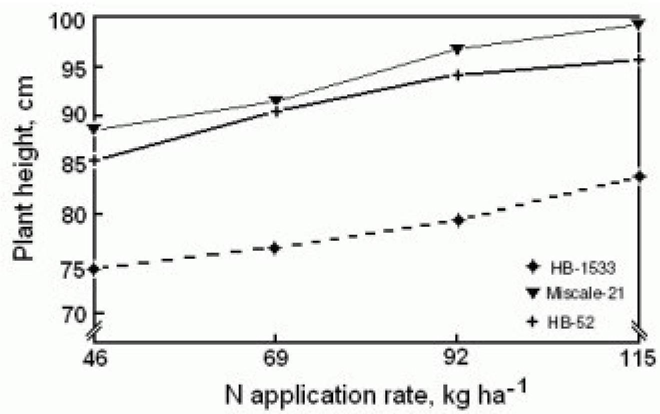

Figure 2. Plant height response of malt barley varieties to N application rates across the localities.

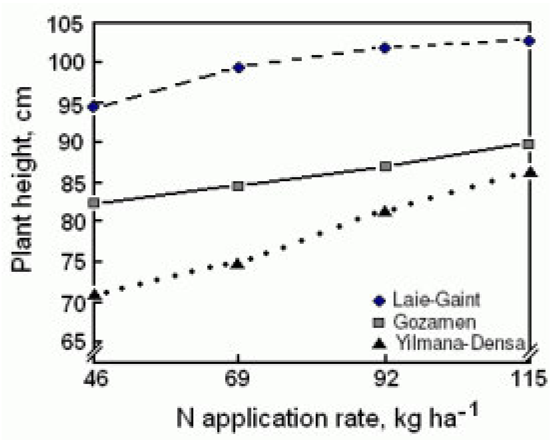

Figure 3. The overall plant height response of malt barley to N application rates in different localities.

Grain protein content increased with higher N application rates in all varieties at all locations (Table 9). For variety HB-52, grain protein content ranged from 8.9% in Gozamen with the application of 46 kg N ha^{-1}, to 11.8% in Laie-Gaint, at the highest N rate (115 kg N ha^{-1}). For variety HB-1533, grain protein content ranged from 9.4% in Gozamen at 46 kg N ha^{-1}, to 13.3% in Yilmana-Denssa at 92 kg N ha^{-1}, whereas for variety Miscale-21 the range was from 8.9% in Gozamen, at 46 kg N ha^{-1}, to 11.3% in Yilmana-Denssa, at 92 kg N ha^{-1}. Grain

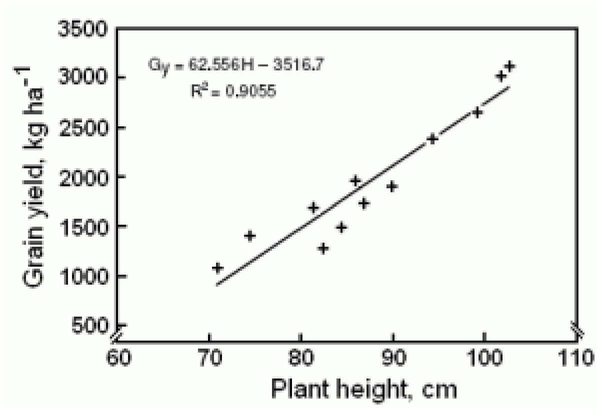

Figure 4. The relationship between grain yield (G_y) and plant height (H) of malt barley across the localities.

protein content was highest in variety HB-1533 as compared to the other two varieties. According to the Ethiopian standards authority, the raw barley quality standards for malt have a protein level between 9–12%**.** The results of the experiment showed that all varieties, except HB-1533 at the highest N rate (115 kg N ha^{-1}), gave a grain protein content within the acceptable range in the Laie-Gaint area. In the Gozamen area, all varieties, except at the lowest rate (46 kg N ha^{-1}) for HB-52 and Miscale-21, had a grain protein content within the acceptable range. By contrast, in Yilmana-Denssa, HB-52 and Miscale-21 exhibited an acceptable grain protein content at all N application rates, but HB-1533 did not do so, owing to its high protein content (Table 9). The superior protein content of the grain in Yilmana-Denssa was possibly due to the high temperature in that area, as compared to the other locations (Table 1). Eagles *et al.* (1995), Savin & Nicolas (1996) and Wallwork *et al.* (1998) indicated that high temperatures during grain-filling appear to reduce grain quality in malting barley, owing to the reduction in starch accumulation and the increase in the N% of the grain. Savin *et al.* (1996) also stated that high temperature reduced the amount of 'maltable' grain, by reducing grain size and increasing the screening percentage, and reduced malt extract by 3–7%, which represents a large decrease for the malting industry.

The results of the partial budget analysis (Tables 10, 11, 12) revealed that the economically optimum fertiliser application rate varies in relation to the varieties and locations. Since grain quality is the major concern of this paper, the economical application rates that are within the acceptable level of grain protein content, thousand-kernel weight and hectolitre-weight, are to be selected. For varieties HB-52 and Miscale-21, the fertiliser rates 115 and 92 kg N ha^{-1}, respectively, are economical rates, with acceptable grain quality at all locations. For variety HB-1533, fertiliser rates of 92 kg N ha^{-1} and 115 kg N ha^{-1} were economical rates, with acceptable grain quality in the Laie-Gaint and Gozamen areas, respectively. In the Yilmana-Denssa area, none of the fertiliser rates for variety HB-1533 was optimum for retaining the desired grain quality. The protein content of HB-1533 in the Yilmana-Denssa area was beyond the limit, and none of the N application rates gave a grain protein content within the acceptable range. Moreover, an economic sensitivity analysis was carried out to test the sensitivity of the recommended fertiliser rates to changes in input cost and output price. The economically optimum rates remain profitably recommendable even under worst cost and price assumptions at all the tested locations.

Table 7. *Effect of N application rate on thousand-kernel weight of malting barley varieties at the three locations*

	Laie-Gaint				Gozamen				Yilmana-Denssa			
N (kg ha^{-1})	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean
46	39.3	40.8	42.4	40.8	31.3	36.0	35.7	34.4	31.4	36.1	39.2	35.4
69	39.8	41.6	41.8	41.1	32.0	36.5	37.6	35.4	32.2	37.3	39.2	36.2
92	39.6	42.1	42.2	41.3	29.4	37.5	36.6	34.5	32.2	38.3	39.8	36.8
115	40.9	43.5	43.4	42.6	30.4	38.7	36.9	35.3	33.7	40.4	40.9	38.3
Mean	39.9	42.0	42.4		30.8	37.2	36.7		32.4	38.0	39.8	
	V	N	V×N		V	N	V×N		V	N	V×N	
Std Err	0.35	0.40	0.70		0.57	0.66	1.14		0.31	0.36	0.63	
LSD (0.05)	0.99	1.14	2.10		1.64	NS	3.27		0.88	1.02	1.76	

Table 8. *Effect of N application rate on hectolitre weight of malting barley varieties at the three locations*

	Laie-Gaint				Gozamen				Yilmana-Denssa			
N (kg ha^{-1})	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean	HB-52	HB-1533	Miscale-21	Mean
46	66.7	63.4	65.9	65.4	60.3	59.3	59.9	59.8	61.9	61.5	63.1	62.2
69	66.4	63.3	65.9	65.2	60.5	58.9	63.2	60.9	62.0	61.9	62.3	62.1
92	66.7	63.4	65.1	65.1	57.8	62.0	62.5	60.7	61.7	60.2	63.9	62.6
115	67.0	64.2	68.3	66.5	58.5	62.0	63.2	61.2	62.9	63.5	64.5	63.6
Mean	66.7	63.6	66.4		59.3	60.8	62.2		62.1	62.2	63.5	
	V	N	V×N		V	N	V×N		V	N	V×N	
Std Err	0.40	0.46	0.80		0.73	0.84	1.45		0.23	0.27	0.47	
LSD (0.05)	1.63	NS	NS		2.13	NS	NS		0.66	0.76	1.32	

Table 9. *Grain protein content of malting barley varieties as influenced by N application rate at the three localities*

Treatments	Protein content %		
	Laie-Gaint	Gozamen	Yilmana-Denssa
HB-52 + 46 N/46 P_2O_5 ha^{-1}	9.4	8.9	10.1
HB-52 + 69 N/46 P_2O_5 ha^{-1}	9.4	9.4	10.8
HB-52 + 92 N/46 P_2O_5 ha^{-1}	10.3	9.4	10.2
HB-52 + 115 N/46 P_2O_5 ha^{-1}	11.8	10.1	10.8
HB-1533 + 46 N/46 P_2O_5 ha^{-1}	10.6	9.4	12.8
HB-1533 + 69 N/46 P_2O_5 ha^{-1}	11.2	10.6	12.9
HB-1533 + 92 N/46 P_2O_5 ha^{-1}	11.5	10.9	13.3
HB-1533 + 115 N/46 P_2O_5 ha^{-1}	12.3	11.7	12.4
Miscale-21 + 46 N/46 P_2O_5 ha^{-1}	9.7	8.8	10.6
Miscale-21 + 69 N/46 P_2O_5 ha^{-1}	10.2	9.0	10.8
Miscale-21 + 92 N/46 P_2O_5 ha^{-1}	10.9	9.4	11.3
Miscale-21 + 115 N/46 P_2O_5 ha^{-1}	10.8	9.9	10.3

Table 10. *Results of the economic analysis of N application rate on the grain yield of malting barley in the Laie-Gaint area*

Variety	N rates kg ha^{-1}	Economic analysis			Sensitivity economic analysis		
		TVC (ETB)	NB (ETB)	MRR (%)	TVC (ETB)	NB (ETB)	MRR (%)
HB-52	46	227.6	8533.5		335.3	10173.4	
	69	414.6	9316.9	418.9	610.8	11061.9	322.5
	92	601.6	9856.8	288.7	886.3	11658.3	216.5
	115	788.6	10996.9	609.6	1161.8	12974.5	477.8
HB-1533	46	227.6	7055.6		335.3	8400.7	
	69	414.6	7657.2	321.7	610.8	9071.2	243.4
	92	601.6	8979.0	706.8	886.3	10605.4	556.9
	115	788.6	8922.3 **D**		1161.8	10486.2 **D**	
Miscale-21	46	227.6	8331.2		335.3	9930.7	
	69	414.6	9220.9	475.8	610.8	10946.7	368.8
	92	601.6	10408.9	635.3	886.3	12320.5	498.7
	115	788.6	9831.0 **D**		1161.8	11576.1 **D**	

Note: TVC= Total Variable Cost, NB= Net Benefit, MRR= Marginal Rate of Return, D= Dominated treatment. Values in Ethiopian Birr (ETB).

Table 11. *Results of the economic analysis of N fertiliser application rate on the grain yield of malting barley in the Yilmana-Denssa area*

Variety	N rates kg ha^{-1}	Economic analysis			Sensitivity economic analysis		
		TVC (ETB)	NB (ETB)	MRR (%)	TVC (ETB)	NB (ETB)	MRR (%)
HB-52	46	227.6	2303.0		335.3	2700.1	
	69	414.6	3521.9	651.8	610.8	4110.9	512.1
	92	601.6	4339.6	437.3	886.3	5040.5	337.4
	115	788.6	5692.2	723.3	1161.8	6611.7	570.3
HB-1533	46	227.6	3139.7		335.3	3703.6	
	69	414.6	4166.5	549.1	610.8	4884.1	428.5
	92	601.6	5080.2	488.6	886.3	5928.9	379.2
	115	788.6	5897.9	437.3	1161.8	6858.5	337.4
Miscale-21	46	227.6	5173.1		335.3	6142.6	
	69	414.6	5709.6	286.9	610.8	6735.0	215.0
	92	601.6	6208.4	266.7	886.3	7282.1	198.6
	115	788.6	6316.3	57.7	1161.8	7360.3	28.4

Note: TVC= Total Variable Cost, NB= Net Benefit, MRR= Marginal Rate of Return, D= Dominated treatment. Values in Ethiopian Birr (ETB).

Table 12. *Results of the economic analysis of N fertiliser application rate on the grain yield of malting barley in the Gozamen area*

Variety	N rates kg ha^{-1}	Economic analysis			Sensitivity economic analysis		
		TVC (ETB)	NB (ETB)	MRR (%)	TVC (ETB)	NB (ETB)	MRR (%)
HB-52	46	227.6	3633.4		335.3	4295.9	
	69	414.6	4458.0	440.94	610.8	5233.7	340.41
	92	601.6	3797.8 **D**		886.3	5365.4	47.80
	115	788.6	4876.1	111.79	1161.8	5632.8	97.07
HB-1533	46	227.6	5125.1		335.3	6085.1	
	69	414.6	4982.6 **D**		610.8	5863.0 **D**	
	92	601.6	5615.2		886.3	6570.5	88.11
	115	788.6	6566.6	508.79	1161.8	7660.5	395.65
Miscale-21	46	227.6	3828.9		335.3	4530.3	
	69	414.6	4701.5	466.6	610.8	5525.8	361.3
	92	601.6	5841.5	609.6	886.3	6842.0	477.8
	115	788.6	5774.5 **D**		1161.8	6710.4 **D**	

Note: TVC= Total Variable Cost, NB= Net Benefit, MRR= Marginal Rate of Return, D= Dominated treatment. Values in Ethiopian Birr (ETB).

Conclusions and Recommendations

The grain yield and quality of malting barley vary with locality. Laie-Gaint is an ideal area for malting barley production, compared to the Gozamen and Yilmana-Denssa areas. The variety HB-1533 is not recommended for cultivation as malting barley in the Yilmana-Denssa area, because of its high protein content. Therefore, the selection of appropriate varieties for different localities is one of the issues to be considered in the future, so as to maintain the grain quality of malting barley at its standard level. Grain quality, especially with respect to protein content, is highly influenced by variety and by N fertilisation. The determination of a specific N application rate for malting barley varieties is essential to the production of malting barley grain of acceptable quality. Fertiliser application rates of 115/46 kg N/P_2O_5 ha^{-1} for HB-52, and 92/46 kg N/P_2O_5 ha^{-1} for Miscale-21, are economically optimum and recommendable rates for malting barley production in the Laie-Gaint, Yilmana-Denssa and Gozamen areas.

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