

Effects of Seed Rates and Nitrogen Fertilizer Levels on Yield, Yield Components, and Grain Quality of Malt Barley (*Hordeum Vulgare L.*) in the Central Highlands of Ethiopia

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Abstract

Soil and climatic conditions in West Shoa are on the margins of agricultural capability due to low soil fertility and soil acidity. The overall objective of this research was to develop guidelines for the production of barley in West shoa, with the goal of establishing modern agronomic recommendations. We conducted a 3-year study in Welmera Wereda to examine the effect of seeding rate and nitrogen fertilization rate on malt barley (*Hordeum vulgare L.*) yield components and grain yield. Increasing seeding rate from 75 kg ha⁻¹ to 175 kg ha⁻¹ did not alter grain yield and other yield component traits. Increasing N fertilization from 0 to 69 kg N ha⁻¹ increased productive tillers and spike length at harvest, resulting in linear increases in grain yield. Highest N rates had greatest lodging. Based on our results, agronomic recommendations for West Shoa now include barley seeding rates of as low as 75 kg ha⁻¹, with N applications up to at least 46 kg N ha⁻¹.

Keywords: nitrogen fertilizer, seed rate, quality, malt barley

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INTRODUCTION

Barley (*Hordeum vulgare L.*) is one of the most important cereal crops in the world, ranking fourth after wheat, maize, and rice in terms of production (Shah *et al.*, 2009). Barley one of the most important food crops predominantly grown from 1500 to 3500 m above sea level in Ethiopia (Lakew *et al.*, 1996). It covers an area of about 1.13 million ha, but its national average yield is low at 1.7 t ha⁻¹ (CSA, 2014). In the central highlands of Ethiopia barley is an important grain crop for food in the forms such as bread, porridge, soup, roasted grain and preparing alcoholic and non-alcoholic drinks. It is an important food grain and malting crop in the Ethiopian highlands, with malting barley a major source of income for smallholder farmers (Yirga *et al.*, 1998). In recent years, the demand for malting barley has increased significantly because of the increase in demand from breweries (Mohammed & Legesse, 2003). According to the Ethiopian standard authority and Asella malt factory (AMF), the protein level of the raw barley quality standard for malt should be between 9-12% (EQSA, 2006).

Although there is a considerable potential for increased production of high quality malting barley, the production of malting barley in Ethiopia has not expanded enough to benefit most barley growers. The factors constraining the productivity of barley in the different barley production systems have been identified and documented (Mulatu & Lakew, 2011). The most important abiotic stresses include low soil fertility, low soil pH, poor soil drain age, drought, and poor agronomic practices.

Nitrogen (N) is one of the most essential and vital elements in plants and is also a major limiting factor in crop production (Kraiser *et al.*, 2011). Plants take up N from soil and utilize it for a variety of metabolic purposes, including synthesis of proteins, enzymes, phyto-hormones, nucleic acids ribonucleic acid and deoxyribonucleic acid (RNA and DNA), and other biological molecules. It particularly influences malting barley yield and grain protein content and consequently malting quality (Spaner *et al.*, 2001). Excess soil N may raise the protein content of the kernel, which is undesirable for malting. It is also reported that excessive N rates reduce grain yields probably due to a lower efficiency in the remobilization of photo assimilates from the vegetative organs to the grains (Yang *et al.*, 2001; Yang and Zhang, 2006). Maximum yield is obtained by the application of N fertilizer at the higher end of current recommendations. So in malting barley production there is often a conflict between the aim of growing crops to meet the requirements of malting industries and of achieving the highest gross margin if the standard for grain N content is not met. After anthesis, no more effective grain sites can be formed so the N is deposited in the grain. If for example, many grains are formed but the grain size is limited by the available carbohydrate after anthesis, the limited by the available carbohydrate after anthesis, the resulting high grain N concentration and low mean grain weight are undesirable for malting.

In Ethiopia, where pH, organic carbon, and N content of most soils are low, N fertilizer rates applied for malting barley production vary between 18 and 41 kg N ha⁻¹. In other part of the world the N fertilizer is usually applied to malt barley varies between 25 and 60 kg N ha⁻¹ (Lázzari *et al.*, 2007). The N rate above 41 kg ha⁻¹ in Ethiopia has been considered to produce higher grain N content. Manipulating plant density is an effective practice to optimize tiller and main stem competition for light, water, and nutrition, therefore enhancing grain yield and N

use efficiency (Chen and Neill, 2006). One potential problem with increased sowing density is the risk of an increase in fungal pathogens, especially in row pattern (Olsen and Weiner, 2001). High seeding rates also make the seeds shriveled and increase its protein and decrease its malting quality.

To maximize yield and quality of malting barley, it has been shown that N management practices should be adjusted according to anticipated availability of water and N in the soil (McKenzie *et al.*, 2005) and the needs of particular cultivars (Edney *et al.*, 2012). Management strategies for malting barley must therefore maintain a balance between achieving economic yield responses and maintaining the grain protein concentration within a desirable range, which is possible under appropriate conditions of N application (Fathi, McDonald, and Lance, 1997). Thus, management of N and seeding rate is a critical issue for yield and quality of malting barley. Although it is expected that N fertilizer rates and seeding rate are important, little is known about their effects and interactions in the Ethiopian context. Therefore, the objective of this study was to determine the effects of seeding rates and N fertilizer rates on the yield and quality of malting barley under rain-fed conditions in the Ethiopian highlands.

MATERIALS AND METHODS

The trial was conducted on farmers' fields from 2014-2016 during the main cropping seasons in West Shewa, Welmera Wereda in the central highlands of Ethiopia. The rainfall is bimodal with long-term average annual rainfall 1100mm, about 25% of which falls from June to September and the rest from January to May and average minimum and maximum air temperature of 6.2 and 22.1 °C, respectively. The environment is seasonally humid and major soil type of the trial sites is Eutric Nitisol (IUSS Working Group WRB, 2006). Treatments were a factorial combinations of five level of seed rates (75, 100, 125, 150 & 175 kg ha⁻¹) and four levels of N fertilizer (0, 23, 46, 69 kg N ha⁻¹). Treatments were laid out in randomized complete block design (RCBD) with three replications. The plot size was 3m by 3m (9 m²) and the spacing between plots and blocks were 0.5m and 1m, respectively. The recommended phosphorus fertilizer amount (46 kg P ha⁻¹) was uniformly applied as triple super phosphate (TSP) to all plots at sowing. Urea was used as the source of N which was applied in two doses; half at sowing and half at mid tillering stage. Other agronomic practices were applied based on local research recommendations.

Statistical analysis

The data were subjected to analysis of variance using the procedure of the of SAS statistical package version 9.0 (SAS Institute, 2001). Means for the main effects were compared using the means statement with least significant difference (LSD) test at the 5% level.

RESULTS AND DISCUSSION

Table 1: Table of means for main effects of seeding rate and N fertilizer application rate on malt barley crop parameters

Treatments (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Biomass yield (kg ha ⁻¹)	Protein content (%)	Productive tiller (m ²)	Spike length (cm)
Seeding rate					
75	2487	7892.9	10.59	280	6.6
100	2431	7706.4	10.52	284	6.4
125	2501	8177.1	10.74	290	6.4
150	2542	8207.1	10.35	293	6.4
175	2594	8243.9	10.54	309	6.2
Sig.	ns	ns	ns	ns	ns
Nitrogen rate					
0	1611c	6528c	10.20c	233c	5.9c
23	2194b	8099b	10.35bc	272b	6.3b
46	3204a	8854a	10.95a	335a	6.6a
69	3035a	8701a	10.68ab	322a	6.8a
Sig.	***	***	***	***	***
CV (%)	19.5	16.2	5.2	15.5	5.9

Within each column, means with different letters are significantly different at $p < 0.05$; CV, coefficient of variation

Analysis of variance (ANOVA) result showed that seeding rate did not significantly ($p > 0.05$) affected grain yield, biomass yield, and yield components of barley like productive tiller and spike length (Table 1). Protein content was also not significantly ($p > 0.05$) affected by seed rate though the highest protein content was obtained at 125 kg ha⁻¹. ANOVA result showed that N rate has significantly ($p < 0.001$) affected grain and biomass yield of barley (Table 1). 46 kg ha⁻¹ N rate gave significantly higher grain yield though it did not show significant difference with that of 69 kg N ha⁻¹. As N rate increases from 0 to 46 kg N ha⁻¹ the grain yield also showed consistent increment. This result were in agreement with Amare and Adane, 2015 reports who mentioned that

significant increases in grain yields of malt barley crop with increasing levels of N fertilizer. Significantly higher biomass yield was obtained with the N application rate of 46 kg ha⁻¹ though it was statistically similar with N rate of 69 kg ha⁻¹. Nil application of N significantly ($p < 0.001$) brought about lower grain and biomass yield followed by 23 kg N ha⁻¹. N rate has significantly ($p < 0.001$) affected protein content of malt barley. Significantly higher protein content was recorded by the of application 46 kg ha⁻¹ though it was not significantly different from 69 kg N per ha. As N rate increased protein content also increased up to 46 kg N ha⁻¹ then it started to decrease (Table 1). Similarly, Amare and Adane, 2015 found that with low available nitrogen in the soil, malt barley responds well to applied fertilizer, showing increases in both grain yield and protein content. Increasing in protein may increase steep times, create undesirable qualities in the malt, excessive enzymatic activity and low extract yield (Johnston *et al.*, 2007). ANOVA result also indicated that N rate has significantly ($p < 0.001$) affected productive tillers of barley (Table 1).

Significantly higher productive tillers were recorded by the application of 46 kg N ha⁻¹ though it was statistically at par with 69 kg N ha⁻¹. Significantly lowest tillers were recorded by nil application of N followed by 23 kg N ha⁻¹. Number of productive tillers increased with increment of nitrogen level in this research work. This might be due to the role of N fertilizer in accelerating vegetative growth of plants and nitrogen stimulates tillering, that could be due to its effect on cytokine/protein synthesis. The results were in agreement with Abdullatif *et al.* (2010) reported increasing in the number of productive tillers with nitrogen fertilization. Similarly, Evans *et al.* (1975) found that tillering is enhanced by increased light and N availability during the vegetative crop phase. ANOVA result also revealed that N rate levels has significantly ($p < 0.001$) affected spike length of barley (Table 1). Significantly higher spike length was recorded by the application of 69 kg N ha⁻¹ though it was not statistically different from that of 46 kg N ha⁻¹. Significantly higher spike length was recorded by 69 kg N per ha nil application of N followed by 46 kg N ha⁻¹. Seeding rate by N rate interaction did bring significant differences in any of dependent variables tested in this study.

Table 2: Economic analysis for seeding rate and nitrogen fertilizer application

Treatments (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Total Cost (Birr ha ⁻¹)	Gross Income (Birr ha ⁻¹)	Net Benefit (Birr ha ⁻¹)
Seeding rate				
75	2487	4500	20304	17882
100	2431	4750	22554	17125
125	2501	5000	23193	17505
150	2542	5250	23805	17629
175	2594	5500	24201	17850
N rate				
0	1611	5550	15084	8952
23	2194	6050	22779	13694
46	3204	6550	26955	22283
69	3035	7050	27306	20263

Economic analysis revealed that optimum seeding rate has brought about economical advantages. The economic analysis revealed that optimum seeding rate was important due to the fact that it gave the highest net economic benefit (Table 2). Seeding rate of as low as 75 kg ha⁻¹ have the highest monetary advantage in Ethiopian birr over the recommended seeding rate (125 kg ha⁻¹), 150 and 175 kg ha⁻¹. Economic analysis also indicated that N application was also observed to be economically advantageous. The economic analysis revealed that N fertilizer 46 kg ha⁻¹ was the optimum N application rate due to the fact that it gave the highest net economic benefit (Table 2). N application of 46 kg ha⁻¹ gave a 21% monetary advantage in Ethiopian Birr 23 kg N per hectare.

CONCLUSION

Results of the study indicate that application of 46 kg N ha⁻¹ gave better yield with acceptable protein content. A seeding rate of 75 kg ha⁻¹ also gave higher grain yield with acceptable protein content. Use of 75 kg ha⁻¹ seeding rate and 46 kg N ha⁻¹ was more economically beneficial than other seeding and N rate. Farmers could use 75 kg ha⁻¹ seed rate and 46 kg ha⁻¹ for higher grain yield and best quality of malt barley on Nitisols of West Shoa under rainfed conditions. As the current research was done on the specific location, further trials replicated over seasons and across locations are needed to recommend agronomical optimum and economically feasible level of N fertilizer with better grain yield and quality of malt barely varieties in general.

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