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Response of Malt Barley (*Hordeum vulgare* L.) Varieties to Nitrogen Application on Grain Quality and Yield on Nitisols of Welmera District, Ethiopia

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Abstract: Interaction of varieties and nitrogen fertilizer rate on yield and grain quality of barley were studied at Welmera district. The objectives of the experiments were to increase yield with acceptable quality of malt barley varieties to N fertilizer application. The treatments were arranged in a factorial experiments using RCBD and consisting of three varieties (Ebon 174/03, Traveller and HB19-63) with five level of N fertilizer (0, 23, 46, 69 and 92 kg N/ha). The results revealed that there was highly significant difference in yield and yield components and the highest (5736.7 kg/ha) and lowest yield (2609 kg ha^{-1}) was noted from Ebon 174/03 variety from a 92 kg N/ha fertilizer rate and control plot. The lowest (10.2%) and highest (13.3%) protein content was attained from control and 92 kg N ha^{-1} from Ebon 174/03 variety. An increase in N fertilizer increases grain yield and protein content while decrease grain quality. Both variety and fertilizer showed significant effects on yield and quality of malt barley. Economically acceptable net benefit of 41234.1 ETB ha^{-1} was obtained from Traveller variety by application of 92 kg N ha^{-1} which gave MRR 110 with the acceptable grain quality was found economically profitable.

Key words: Protein Content · Grain Yield · Grain Quality · Nitrogen Fertilizer

INTRODUCTION

Malt barley (*Hordeum vulgare* L.) is one of the most substantial cereal crops for used food, feed, malt and income source for many smallholder farmers in the highlands of Ethiopia [1, 2]. Malt barley accounts for about 90% of the raw materials cost in beer production in Ethiopia [3]. Ethiopia has promising environment and substantial market chances' for increased production of high quality malting barley [2, 4]. Though, poor soil fertility and agronomic practices are among the key limitations responsible for the low production of barley in Ethiopia [5]. Poor soil fertility in order caused from farming deprived of replacing nutrients mono cropping or elimination of crop residues and unbalanced use of nutrients [6]. Therefore, a challenge facing malt barley growers is how to use nitrogen (N) fertilizer to increase crop yields without compromising the quality of grain for malting by increasing the grain protein content [7]. So as to, appropriate fertilizer application is required to increase production at required quality to fulfill the increasing demand of the product [4]. Recommendations for N fertilizer are dependent on the yield potential, cultivar sown and the nitrogen status of the soil and the end use of the crop. High grain yields and acceptable grain quality are required for profitable production of malt barley. To achieve this, it is important to understand how crop yield and quality interact under different N management practices. This experiment is described which had the objective to increase the grain yield with acceptable quality of malt crops grown through different rates of nitrogen fertilizer.

MATERIALS AND METHODS

Description of the Study Site: A field experiment was carried out at Welmera district in West Shewa Zone during 2017/ 2018 cropping season. The study sites were located between 08° 50' to 09°20'N and 38°20'to 38°40'E at an altitude of 2400 meters above sea level. Its mean annual

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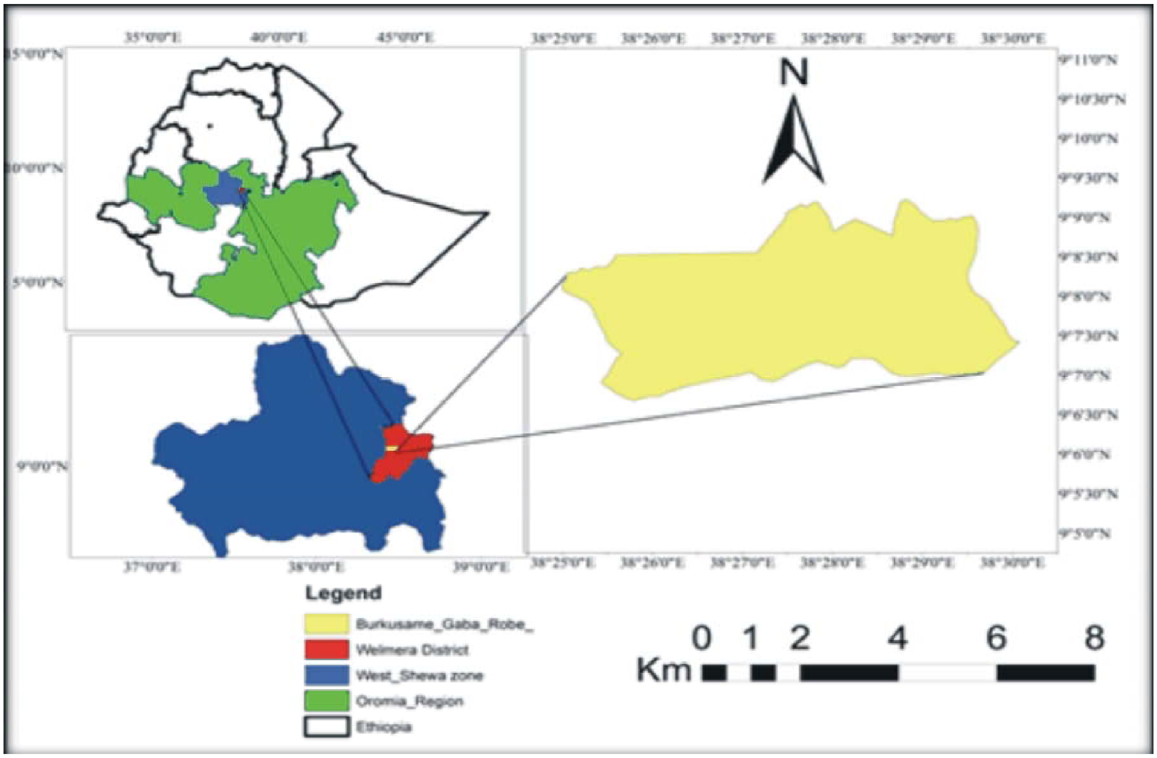

Fig. 1: Location of the study sites

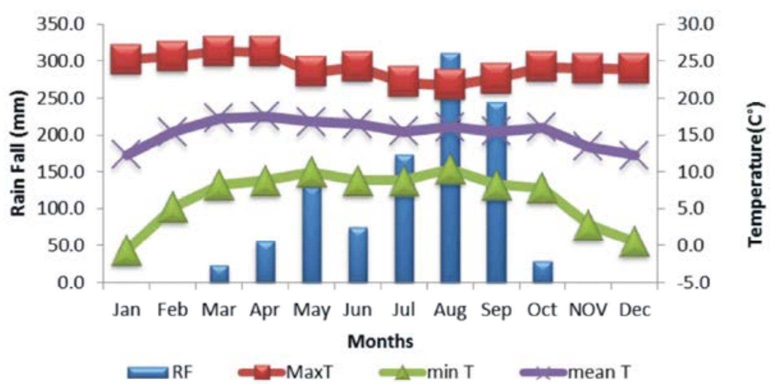

Fig. 2: Mean monthly rainfall, minimum and maximum temperature (°C) of Welmera District

rainfall is 1041.4 mm. Mean maximum and a minimum temperature are 21.7 and 6.7°C, respectively (Figure 2) and with mean relative humidity of 58.7% [8]. The main rainy season is from June to September and accounts for 70% of the annual rainfall and the environment is seasonally humid. The dominant soil at the experimental site is classified as Nitisol [9].

Experimental Design and Treatment: Five rates of nitrogen (0, 23, 46, 69 and 92 kg/ha) and three malt barley varieties (Ibon174/03, Traveller and HB-1963) were arranged in a factorial combination using RCBD with three replication. TSP fertilizer was applied at a uniform rate (20 kg P ha^{-1}) at implanting time while, nitrogen fertilizer applied in splitform1/2 at sowing and 1/2 at tillering Period.

Data Collection and Analysis: All agronomic data were taken from the net harvested plot areas. Plant height at maturity (cm), number of effective tillers, biomass yield and grain yield were collected to measure yield and yield component. The grain moisture, hectoliter weight (HLW) and Thousand-kernel weight (TKW) were determined by a as described in The AACC [10]. Grain protein content was determined from N content [10]. All agronomic data were subjected to statistical Analysis of variance using SAS [11]. Mean separation was done using least significance difference.

Soil Sampling and Analysis: Soil samples were collected from representative points within the experimental field (0-20 cm depth) before planting to make two composite samples. Soil analyses for particular and important parameters to the recent study were analyzed at Holeta Agricultural Research Center soil laboratory.

RESULTS AND DISCUSSION

Soil Physico-Chemical Properties: Soil analysis before sowing was presented in Table 1. According to the soil textural class determination triangle, the study site indicates 17.5% sand, 25.5% silt and 57.5% clay. As stated by Landon [12] the consequence exposed that low organic carbon, strong acidic, low available phosphorus (P), very low K, medium CEC and medium total nitrogen (N).

Yield and Yield Components: Spike length was importantly ($p \leq 0.05$) exaggerated by the N rates (Table 2). The largest (7.8cm) spike length was recorded by application of 92 kg N ha^{-1}, whereas the shortest (6.4cm) was obtained from negative control. There was linear increase in spike length with increase in rate of N from 0 to 92 kg N ha^{-1}. This result was in line with Ejaz *et al.* [13] who found that spike length of barely increases through increasing N rate application.

The analysis of variance designated that, the effect of nitrogen levels besides varieties had a substantial difference ($p \leq 0.05$) on productive tillers per plant (Table 2). The maximum (9.2) numbers of productive tiller was from 92 kg N ha^{-1}, while the lowest (7.4) obtained from negative control. The current studies indicated that as N rates increasing number of productive tillers also increased. This might be due to the role of N fertilizer in accelerating vegetative growth of plants and protein synthesis. The results were in agreement with Mesfin Kassa and Zemach Sors [14] reported shows increasing productive tillers with N fertilization.

Seed per spike reacted significantly to the interaction effect of N rates and varieties (Table 3). In this study, the highest (24.4) seeds per spike were obtained from combination of 69 kg N ha^{-1} with HB-1963 variety, whereas the lowest (17) seed per spike were recorded from Taveller variety without application of N (Table 3). The results of the trial showed that plants had high ability to absorb applied N or to conform N for the synthesis and growth of spikes. This was supported [15] reported that nitrogen increased the number of seed per spike. The study also showed that there was variation among varieties and thus variation of number was come from genotypic variation of barley. In line with this result of Amare Aleminew and Adane Legas [16] reported genotypic differences of barley in spikelet.

Analysis of variance specified significant differences ($P < 0.05$) among N rates and varieties for biomass yield with their interaction effects (Table 3). Biomass yield increased as rate of N applied increased from control to the highest rates. The highest (20528 kg ha^{-1}) biomass yield was recorded from Ebon174/03 variety at a rate of 92 kg N ha^{-1}, while the lowest (11722 kg ha^{-1}) was obtained from Traveler variety from negative control.

Without application of nitrogen, significantly the lowest biomass than the remaining doses whereas, from 92 kg N ha^{-1}, the highest biomass yield recorded over the rest of the nitrogen rates (Table 3). Generally, a linear increase in biomass obtained from 0 to 92 kg N ha^{-1}. Varieties also showed variation in biomass yield production under the same N rate treatments. This was comparable with the research finding of Ejaz *et al.* [13], Mohammadi and Samadiyan [17] who reported that as nitrogen rate increased the biomass yield also increased. Barley yield significantly varied with N rates and varieties (Table 3). Grain yield was significantly ($p \leq 0.01$) affected by the interaction of nitrogen rates and varieties. The minimum (2609 kg ha^{-1}) grain yield was obtained from control treatment (Table 3). The maximum (5736.7 kg ha^{-1}) grain yield was attained from Ebon174/03 variety at the maximum nitrogen rate of 92 kg ha^{-1} (Table 3). Yields of barley increased by increasing N rates from 0 to 92 kg N ha^{-1}. This was supported by Minale Liben *et al.* [18] as reported that the growth parameters as well as grain yield increased as nitrogen rate is increased in barley production. On the same way, it was supported by [14, 19] observed that significantly increasing nitrogen rate increases grain yield and yield components, whereas it decreases grain quality.

Grain Quality Parameters: Application of nitrogen rate showed that there was substantial difference ($p < 0.05$) on the grain quality. Variables indicative of grain yield, grain quality (Moisture content (%), HLW (kg hl^{-1}), TGW, % of Protein content, % of N concentration) were evaluated for response of varieties and N fertilizer rates.

Table 1: Selected soil Physico- chemical properties of the study site

Soil texture				Soil Chemical properties					
Clay (%)	Silt (%)	Sand (%)	Textural Class	pH	OC (%)	TN (%)	P (mg/kg)	K (cmol /kg)	CEC (cmol /kg)
57.5	25.0	17.5	Clay	5.06	1.4	0.17	3.9	0.2	24.1

Table 2: Effect of N rates on Spike length and productive tillers

N rate kg/ha	Spike length (cm)	Number of productive tiller
0	6.4^{b}	7.4^{b}
23	6.8^{ab}	7.9^{ab}
46	7.2^{ab}	8.3^{ab}
69	7.0^{ab}	8.5^{ab}
92	7.8^{a}	9.2^{a}
LSD (0.05)	1.13	1.14
Varieties		
Ebon174/03	6.9^{b}	9.0
Traveler	6.4^{b}	8.0
HB-1963	7.9^{a}	8.2
LSD(0.05)	0.87	NS
CV (%)	16.67	14.39

Means followed by the same letters are not significantly different at $p < 0.05$
NS = non significance difference

Table 3: Interaction effect of N rates and varieties on yield and yield components

Variety	N rate (kg/ha)	BY (kg/ha)	GY (kg/ha)	PH (cm)	Seed per spike
Ebon 174/03	0	14736^{ef}	3059.0^{de}	57^{ef}	17.4^{ef}
	23	16333^{cde}	3847.3^{bcde}	58.7^{ef}	19.4^{cdef}
	46	17611^{cbde}	4569.3^{abcd}	69.3^{dc}	19.7^{bcdef}
	69	19139^{abc}	5542.7^{a}	69.7^{dc}	21.4^{abcdef}
	92	20528^{a}	5736.7^{a}	74b^{c}	21.7^{abcd}
Traveller	0	11722^{g}	2609.0^{e}	40.3^{f}	17.0^{f}
	23	15389de	3239.3^{cde}	46.3^{ef}	20.0^{bcdef}
	46	15528de	4395.0^{abcd}	49^{ef}	18.0^{def}
	69	16500^{cde}	4189.3^{abcde}	56^{e}	22.7^{abc}
	92	17375^{bcde}	4779.3^{abc}	48^{ef}	21.7^{abcd}
HB-1963	0	12722^{fg}	3159.0^{de}	69^{dc}	22.0^{abcd}
	23	18256^{abcd}	3794.0^{bcde}	76.3^{bac}	23.4^{ab}
	46	17285^{bcde}	4891.7^{abc}	84.3^{ba}	23.7^{ab}
	69	17222^{bcde}	5152.7^{ab}	86.4^{ba}	23.0^{abc}
	92	19972^{ab}	5673.3^{a}	87.7^{a}	24.4^{a}
LSD $_{(0.05)}$		3176.7	887.64	6.6	4.1
CV (%)		12.19	12.32	10.6	11.6

Table 4: Response of Grain quality to nitrogen fertilizer application

Combination of variety with N rates		Moisture content (%)	HLW (kg hl^{-1})	(TKW)	Protein (%)	N conc (%)
Ebon 174/03	0	10.7^{d}	64.1^{d}	44.8^{abc}	10.2^{de}	1.7^{de}
	23	11.1^{bcd}	64.5^{cd}	44.1^{abc}	10.9^{bcde}	1.8^{bcde}
	46	11.3^{bcd}	65.9^{abcd}	45.9^{abc}	11.5^{bcd}	1.9^{bcd}
	69	12.1^{ab}	65.7^{abcd}	48.0^{ab}	12.2^{ab}	2.1^{ab}
	92	12.7^{a}	66.8^{abcd}	52.5^{a}	13.3^{a}	2.3^{a}
Traveller	0	10.5^{d}	62.9^{d}	39.0^{c}	9.9^{e}	1.7^{e}
	23	10.7^{bcd}	65.3^{bcd}	39.7^{c}	10.0^{e}	1.7^{e}
	46	10.9^{bcd}	64.1^{d}	40.7^{bc}	11.0^{bcde}	1.9^{bcde}
	69	11.1^{bcd}	64.1^{d}	41.2^{bc}	10.7^{cde}	1.8^{cde}
	92	11.1^{bcd}	63.7^{d}	41.9^{bc}	10.7^{cde}	1.8^{cde}
HB-1963	0	11.3^{bcd}	68.5^{abcd}	44.0^{abc}	10.2^{e}	1.7^{e}
	23	12.1^{ab}	70.9^{ab}	47.0^{abc}	11.1^{bcde}	1.9^{bcde}
	46	11.9^{bcd}	70.5^{ab}	44.3^{abc}	11.1^{bcde}	1.9^{bcde}
	69	11.9^{bcd}	68.3^{abcd}	45.1^{abc}	11.2^{bcde}	1.9^{bcde}
	92	12.7^{a}	70.2^{a}	47.7^{abc}	11.9^{bc}	2.0^{bc}
LSD $_{(0.05)}$		1.2	5.8	8.8	1.3	0.2
CV (%)		5.5	4.2	9.8	5.7	5.6

Table 5: Cost benefits analysis of N application rate on the grain yield of malt barley varieties

Variety	N (kg/ha)	TVC (ETB /ha)	GY (kg/ha)	AGY (kg/ha)	GFB (kg/ha/ ETB)	NB (ETB /ha)	MRR% Ebon
174/03	0	10.00	3059	2753.1	27531.0	27521.0	---
	23	451.73	3847	3462.3	34623.0	34171.3	151
	46	893.45	4569	4112.1	41121.0	40227.6	137
	69	1335.18	5542.7	4988.4	49884.3	48549.1	188
	92	1776.90	5736.7	5163.0	51630.3	49853.4	30
Traveller	0	10.00	2609	2348.1	23481.0	23471.0	-
	23	451.73	3239	2915.1	29151.0	28699.3	118
	46	893.45	4395	3955.5	39555.0	38661.6	226
	69	1335.18	4189	3770.1	37701.0	36365.8	D
	92	1776.90	4779	4301.1	43011.0	41234.1	110
HB-1963	0	10.00	3159	2843.1	28431.0	28421.0	-
	23	451.73	3794	3414.6	34146.0	33694.3	119
	46	893.45	4891.7	4402.5	44025.3	43131.9	214
	69	1335.18	5152.7	4637.4	46374.3	45039.1	8
	92	1776.90	5673	5105.7	51057.0	49280.1	96

TVC= Total Variable Cost, GY=Grain yield, AGY = Adjusted grain yield, GFB =Gross field benefit, MRR = Marginal Rate of Return, (NB) =Net benefit, ETB = Ethiopian Birr

The lowest and highest grain moisture content was obtained from plot received control treatment and 92 kg N ha^{-1} from all varieties, respectively. Fowler [20] Reported that supreme rational industrial requirement of malt barley moisture content for safe packing is 12.5%, while as described by the European Brewery Convention (EBC) standard moisture content lie between 12-13.5 % is accepted. In case of thousand grain weight and hectoliter weight, the variation is very low among the N rate as it known to be by the genetically controlled character. As described by the Ethiopian quality standard [21], the result of thousand kernel weight (TKW) was acceptable for malt quality.

The maximum HLW (kg hl^{-1}) was recorded from HB-1963. This might be due to the suitable genetic performance of variety with the environmental factors which may led to an increase the accumulation of carbohydrates in grain to produce heavy grains and as a result increased grains weight per spike. Grain protein and nitrogen content were increased with increasing nitrogen rate from 0 N to 92 kg N ha^{-1}. The higher grain protein content and nitrogen concentrations were obtained in response to the levels of 92 kg N ha^{-1}. Grain quality, primarily with respect to protein content and % of N concentration, were highly prejudiced by variety and by N fertilization. This was familiar with [20, 21] indicated that in cereal crop generally increased with increasing nitrogen levels.

Furthermore, similar findings indicated that the least and highest grain protein and nitrogen concentration were due to the minimum and maximum nitrogen application rate as reported [14, 22]. Therefore, nitrogen rate treatment at optimal level is required to produce ultimate quality of malt with optimum grain yield; not so plentiful as to increase the grain protein content to an unenviably high level. Genotype and soil conditions had strong influences on final grain protein concentration at any given N availability, but N supply had the single largest effect on both grain yield and protein concentration [23].

Economic Analysis: To evaluate the costs and benefits associated with different treatments the partial budget technique as described by CIMMYT [24]. A grain yield of receiving from each treatment was adjusting yield of barley downwards by 10% to represent the yield obtained by farmers. It is evident from the data that the maximum net benefit was obtained from 92 kg N ha^{-1} for Ebon174/03 variety with net benefit of 49853.4 ETB ha^{-1}.

CIMMYT [24, 25] economic recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit and nor the treatment with the highest yield. Therefore, economically acceptable net benefit of 41234.1 ETB ha^{-1} was obtained from Traveller variety by 92 kg N ha^{-1} which gave marginal rate of return (MRR) 110 per ETB invested with the acceptable grain quality was found economically profitable (Table 5).

CONCLUSSION

Yield and yield component were significantly affected by main and interaction effects. Number of productive tiller and, spike length were significantly affected both main factor variety and N rates, but their interaction effect was not significant. The outcome of these revision exposed that the phenological, growth and yield trait parameters were positively responded to nitrogen fertilization. Therefore, the effects of the study have the potential to increase the level of acceptance of barley for malting in district and thus improve economic revenues for barley growers. Two significant recommendations resulted from the trial. First, it was shown that malt barley varieties can differ in their response to N. The increase in protein concentration in response to N rate was less noticeable with Traveller than with Ebon 174/03 and HB-1963 varieties. Since extreme protein concentration is a major factor in the rejection of barley for malting, farmers should grow varieties that sustain high yields and comparatively low protein in response to N. Second, from the economic point of view farmers should be encouraged to produce high yielder varieties with optimum application of N fertilizer.

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