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Interaction Effects of In-organic N- Fertilizer and Seed Rates on Yield and Quality Traits of Malt Barley Varieties in the Highland of Tigray, North Ethiopia.

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Abstract
A new brewery factory has been constructed in Tigray region. In response, farmers are concerned to produce and earn premium price from malt barley. Besides, quality prerequisites for malting barley are objectively strict and mostly controlled by the growers crop management practice. However, there is limited/no information on the fertilizer and seed rate requirement of the crop that can achieve high quality malt without compromising yield and profit. Therefore, this research was aimed to determine the appropriate levels of inorganic N-fertilizer and seed rate on the yield and quality of malt barley varieties in three districts of Southern Tigray, North of Ethiopia. Treatments include two malt barley varieties (V1=Bekoji-1 and V2=Bhatty), seven N- rates (N0=0, N1=23, N2=34, N3=46, N4= 57.5, N5= 69 and N6=80.5 Kg N ha^{-1}) in the form of Urea and two levels of seed rates (SR1=100, SR2=150 kg ha^{-1}). The design was split-split plot with three replications. Varieties were put as a main plot, seed rate as a sub plot and the N-rates as a sub sub-plot treatment. The analysis of the separate and combined over locations revealed significant differences on grain yield (GY) and malt quality traits due to the main effect of treatments and some interactions. The effect of variety and seed rate were non-significant in response to GY. Highest value of grain yield (GY), hectoliter weight, plumpness, thousand kernel weight and acceptable grain protein content (GP) for malt barley was recorded at N5. The treatment without N-fertilizer application showed the least performance in above ground biomass and grain yield and malt quality traits. From the interaction of factors acceptable GP and higher grain yields were obtained from combinations: V2xSR1xN5 (GP=11.22%) and V1xSR1xN5 (GP=12.50%) at Ofla and V2xSRIxN6 (GP=12.28%) and V2xSRIxN5 (GP=12.09%) at Enda-Mekoni and V1xSR1xN5 (GP=11.94%) and V2xSR1xN5 (GP=11.44%) at Emba-Alaje. V2 x SR1 x N5 was selected as best combination in all locations. Bekoji-1(V1) at higher N-rates (N5 & N6) and SR1 at Enda-Mekoni was beyond the maximum acceptable limit in grain protein content. Regarding the profitability of the package highest net benefit and MRR were obtained from the application of N5 fertilizer rate at SR1 for both varieties in all study areas. Therefore, under similar environmental conditions the combination of V2 x SR1 x N5 is the best agronomic package for both grain yield and acceptable malt quality at all locations. In addition combinations of V1xSR1 xN5 can also be recommended for Ofla and Emba-Alaje districts.
Keywords: Grain Protein, grain yield, N-fertilizer, Profit, seed rate, variety

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fourth important cereal crop in the world and fifth important cereal in Ethiopia (Bayeh and Birhane, 2006). It is largely grown as a food crop in the central and northern parts of Ethiopia, with Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and People's Region (SNPPR) as the main areas of production (ATA, 2012). The use of malt barley as a row material in brewery factory has increased its value and the demand of farmers to produce. (ATA, 2012). Barley malt is the perfect combination of starch, enzymes, flavors, and aromas for brewing. There are many types of barley malt – from light to dark but all are variations on two principal themes: germination and kilning. Different end-uses require different malt quality specifications. Some of the principal characteristics used to define malting quality are protein (low, moderate, or high), malt extract (high), enzyme activity (moderate tohigh), and beta glucan (low).

Despite the immense potential for producing malt barley in Ethiopia, only about 2% of total barley produced goes into malt factory for the six local breweries in the country (Tefera, 2012). Only one third can be supplied from locally produced barley. The remaining two-thirds are imported primarily from Belgium and France (ATA, 2012). Given the quantity needed, by brewery factories in Ethiopia (BGI-Castel, Diageo (Meta, Zemen), Dashen, Bedele, Heineken (Harar and Walya) and Raya beer) demand for malt barley is expected to reach 110,000 to 130,000 MT in the year 2016. The reason for the low production of malt barley in domestic market is mainly due to the emphasis given to limited areas. The Arsi and Bale highland has been the only areas chosen for the production of malt barley for many years. This limits the expansions in area coverage to other potential areas. Therefore, it is crucial and timely to expand the malt barley production in different barley growing regions of the country to satisfy the ever-growing demand for raw materials by the beverage industry and reduce the volume of imported malt barley.

Despite the available conducive environment in the country, there have been limited researches done to evaluate the yield and malt quality traits of the barley varieties in response to different rates of nitrogen fertilizer and agronomic practices. The most important limiting factors which highly affect the yield and the malt quality of barley are variety, fertilization, seed rate, sowing time, and soil moisture (Grant, 2000). Nitrogen (N) fertilizer is the main input necessary for production of high quality malt barley. Therefore, the objective of this study was to investigate response of two varieties of malt barley to different rates of nitrogen fertilizer (N) and seed rates across three locations in the highland of Southern Tigray, Northern Ethiopia.

2. MATERIALS AND METHODS

Site Description: Field experiment was conducted to investigate response of two malt varieties to different rates of nitrogen fertilizer (N) and seed rates across three locations. The experiment was conducted in 2013 growing season under rain fed conditions. The Experimental fields were located in Ofla district at Awlie-Gara research station, Emba-Alaje districts at Ayba farmers' training center and Enda-Mehoni district at Mekan on farmer's land. The geographic location and agro-ecological condition of the study sites is mentioned in Table 1 and Figure 1..

Table 1 Area description of the experiment sites

Study site	Lat.(N)	Long.(E)	Alt.(masl)	Mean RF(mm) Jun-Sept	Oct-May	Min T (°C)	Max. T (°C)
Ofla	12° 31'	39° 33'	2546	654.42	345.96	5.4	20.2
Endamekoni	12° 44'	39°32'	2423	462.05	250.31	10.3	22.6
Emba-Alaje	12°54'	39°31'	2724	518.55	67.28	10.3	22.6

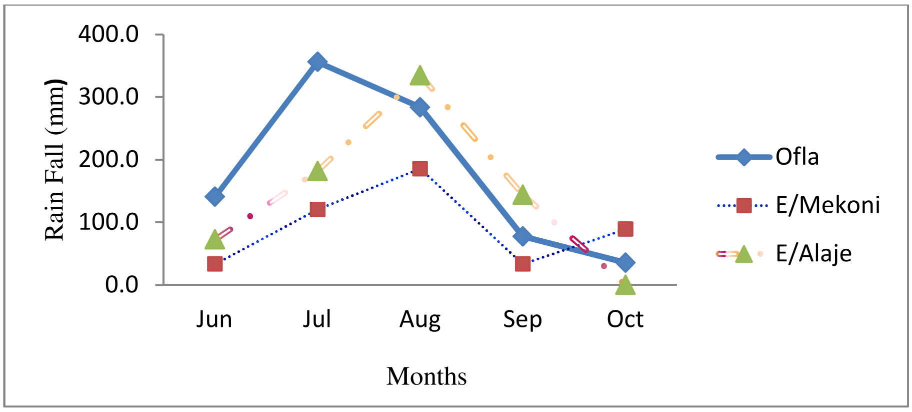

Figure 1. Monthly rain fall distribution of the research sites during the study (2013)
Source: National Meteorological Agency

Soil physical and chemical properties: Soil texture, pH, total N, available P, cation exchange capacity, organic carbon and electrical conductivity were determined for the composited soil samples collected from the experimental field at 0-30 cm depth before sowing indicated below in Table 2.

Treatments and Experimental Design: The experiment include two malt barley varieties (V1=Bekoji-1 and V2= Bhatty), seven Nitrogen fertilizer rates (N0=0, N1=23, N2=34, N3=46, N4= 57.5, N5= 69 and N6=80.5 Kg N ha^{-1}) and two levels of seed rates (SR1=100, SR2=150 kg ha^{-1}). The design was a split-split plot with three replications. Varieties were put as a main plot, seed rate as a sub plot and the N-rates as a sub sub-plot treatment. Plot size was 2*2.5m^2 (10 rows), harvestable plot size 1.6*2.5m^2 (8 rows). Spacing between rows sub-sub- plots, sub- plots, main plots and replications was 0.2, 1, 1, 1.0 and 1.5 meter respectively. Nitrogen in the form of urea (46%N) was applied in three splits i.e. at planting, at first weeding and anthesis stage and TSP-46% P_2O_5 as phosphorus source. Phosphorus was applied uniformly for all treatments at the rate of 46 P_2O_5 kg ha^{-1}.

Data collection: Agronomic data were collected on grain yield and **b**iological yield. In addition malt quality trait datas were collected on thousand kernel weights, hectoliter weight, Sieve test/Kernel Plumpness and grain protein content. Hectoliter weight was determined using a standard laboratory hectoliter weight apparatus (EASY-WAY hectoliter weight test machine) and electronic balance according to the AACC (2000) Method 55-10 and the obtained values were adjusted to a moisture content of 12.5% basis. Sieve test/Kernel Plumpness; Barley grain sample (100 g) from each plot was sieved on 2.8, 2.5, and 2.2 mm slotted sieve. The mass left on each sieve size was measured and the percentage was computed as described in the European Brewery Convention (EBC, 1987). Total grain protein content was determined by multiplying Grain N-content x 6.25. Grain N- content; determined by micro-Kjeldahl method as percentage of dry matter as stated in the ESA method ES 669-2001(ESA, 2001).

Statistical analysis: All data are presented as mean values of three replicates. Data were analyzed statistically following the method described by Gomez & Gomez (1984). Analysis of variance (ANOVA) was carried out using Genstat (13th edition) computer software package to determine level of significance at 95%. Fisher's protected LSD test at 5% probability was used for the mean comparison when the analysis of variance indicated the presence of significant differences.

3. Results and Discussions

Soil test results: According to the fertility classification of Landon (1991), the soil analysis of the locations shows that the soils of the experimental sites were vertisol, slightly acidic, low to medium content of organic carbon (OC), very low content of available P and total N content, medium to high CEC and nono salin soil for crop growth (Table 2).

Table 2. Major soil properties of the experimental sites before planting,

	Location			
Soil Properties	Ofla	Enda-Mekoni	Emba-Alaje	Method
pH	6.167^{sa}	6.538^{sa}	6.155^{sa}	pH meter (1:25
OM (%)	2.343^{L}	2.652^{L}	3.473^{Opt}	Walkley & Black
OC (%)	1.359^{L}	1.539^{L}	2.014^{Opt}	Walkley & Black
Total N (%)	0.1372^{VL}	0.133^{VL}	0.1946^{VL}	Kjeldahl
C:N	9.91^{m}	11.57^{m}	10.35^{m}	%TN:%OC
P (ppm)	13.6^{VL}	10.32^{VL}	35.96^{Opt}	Olisen II
CEC	19.2^{m}	36.4^{h}	31.4^{h}	Amm. Acet extraction
ECe (mS/cm) (1: 2.5)	0.17^{ns}	0.16^{ns}	0.16^{ns}	ESSP
Soil Texture	Clay loam	Loam	Clay loam	Sieve test
Soil type	Vertisol	Vertisol	Vertisol	-

h=high, m=medium, vh= very high, L= low, vl= very low, sa=slightly acidic, N=Neutral, ns=non-salin
Sources: Ethio SIS team analysis, 2013.

Biomass and Grain Yield of Malt Barley: The analyses of variance showed that varieties do not exhibit significant difference on the above ground biomass except in Emba-Alaje (App. Table 1). Comparisons of treatment means at Emba-Alaje indicated relatively higher above ground biomass yield was ecorded from variety Bhatty (14197 vs. 13798 kg ha^{-1}) (Table 3).The effect of seed rate on the above ground biomass was found to be significant at Ofla (P<0.05) and Enda-Mekoni (P<0.01) but not at Emba-Alaje (App.Table 1). Highest biomass was recorded from the highest seed rate at Ofla (12980 vs. 11435 kg ha^{-1}). In contrast, highest biomass was recorded from the lower seed rate at Enda-Mekoni (12292 vs. 12124 kg ha^{-1}) (Table 3). This shows that response of biomass yield to seed rate varied across locations and is generally can be lower or higher depending on the soil moisture content and fertility status of the experimental fields. Grain yield response was non-significant due to variation of seed rate and variety. The effect of seed rate has been documented previously in barley (Jedel and Helm, 1995), in wheat (Stougaard and Xue, 2004) and malt barley (O'Donovan et al., 2011 and 2013) that under similar environments variety and seed rate have non-significant in effect on grain yield.

However, analysis of variance showed that N-fertilizer rate was significantly (P≤0.001) in response to biological and grain yield of malt barley (Table 3) at all locations. Comparison of treatment means combined from three locations indicated that biological yield generally increased with the increase in the rate of N-fertilizer. Hence, maximum biological yield was obtained from 80.5 kg N ha^{-1} whereas the lowest biomass yield was obtained from plants grown without N-fertilizer (Table 3). Plants supplied with highest rate of N had biological yields exceeding by 66.5% from plants in the control treatment (Table 3). The result was in line with Alam et al., (2005) who reported accumulation of dry matter of barley increased with higher doses of N-fertilizer rate. Malt barley grain yield generally increased with an increase in rate of nitrogen up to 69 kg ha^{-1}. Hence, highest grain yield at Ofla (3322 kg ha^{-}1) and Emba-Alage (5615 kg ha^{-}1) was obtained from 69 kg ha-^{1}. In the case of Enda-Mekoni the highest grain yield (3534 kg ha^{-}1) was recorded at the maximum rate of N-fertilizer (N6). Lowest grain yield in all experimental fields was obtained from the control (N0) (Table 3). The grain yield obtained from N5 exceeded by an additional 67% increment of the one obtained from the control treatment (Table 3) this indicates that deficiency of N is evident in the reduction of light interception by decreasing leaf area index, which results in lower grain yield. This result was in support of many authors: Moreno *et al*., 2003; Alam *et al*., 2005 and Shafi *et al*., 2011 in barley. Similarly Shafi *et al*., (2011) also reported Nitrogen applied at the rate of 60 kg ha^{-1} resulted in maximum grain spike^{-1}, thousand grain weight, biological yield, grain yield, and grain and plant N-content. Conversely grain yield was reduced by 43.6, 44.4 and 35% from the highest recorded in the absence of N-fertilizer in the control at Ofla, Enda-Mekoni and Emba-Alaje respectively. This was in support of Stewart (2002) who reviewed that approximately 41% (in corn), 27% (in rice), 19 % (in barley and sorghum), 16 % (in wheat) yield reduction was contributed by eliminating N-fertilizer on the above mentioned crop yields. The interaction of variety to seed rate was significant in response to BM and GY. At higher seed rate variety Bekoji-1 achieves more grain yield and vice versa. Moreover, the third level interaction of variety, seed rate and N-fertilizer rate was significant in response of GY at Emba- Alaje. Highest average GY was recorded from the interaction of V1 x SR2 x N5 and V2 x SR1x N5 (Table 5). The result of this study confirmed that rate of N-fertilizer is the most influential factor in biomass and grain yield of malt barley. Similar results were reported in (Ahmad, 1999; Miao *et al*., 2006 and Oikeh *et al*., 2007) who reported nitrogen plays a very important role in crop productivity.

Table 3. The Main effects of N-rate, seed rate and variety on biomass and grain yield

	Biomass (Kg ha^{-1})				Grain Yield (kg ha^{-1})			
Treatment	Ofla	Enda-Mekoni	Emba-Alaje	Mean	Ofla	Enda-Mekoni	Emba-Alaje	Mean
N-Rates (kg ha^{-1})								
0	8850^{f}	8990^{f}	10900^{g}	9580^{g}	1874^{d}	1966^{e}	3598e	2479e
23	10590^{e}	10040^{e}	12260^{f}	10960^{f}	2289^{c}	2354^{d}	4451d	3031d
34.5	11050^{e}	11100^{d}	13160^{e}	11770^{e}	2536^{c}	2671^{c}	4708d	3305c
46	12060^{d}	12030^{c}	14000^{d}	12690^{d}	2930^{b}	3052^{b}	5052c	3678b
57.5	13210^{c}	13130^{b}	14770^{c}	13700^{c}	3001^{ab}	3169^{b}	5207bc	3793b
69	14260^{b}	14890^{a}	15840^{b}	15000^{b}	3322^{a}	3490^{a}	5615a	4142a
80.5	15430^{a}	15280^{a}	17040^{a}	15920^{a}	3231^{ab}	3534^{a}	5352ab	4039a
SE (M)±	341.4	238.3	169.6	232.8	170	124.7	134.6	97.1
LSD $_{0.05}$	686.5	479.1	341.0	459.6	341.8	250.8	270.7	191.8
Seed rates (kg ha^{-1})								
100	11435	12292	13994	12574	2596	2907	4833	3445.89
150	12980	12124	14001	13035	2870	2875	4877	3544.78
SE (M)±	508.4	60.5	164.2	124.4	111.9	113.4	64.6	51.9
LSD 0.05	1411.5	167.9	ns	245.7	ns	ns	Ns	Ns
Variety								
Bekoji-1	12132	12357	13798	12762	2611	2866	4878	3451.72
Bhatty	12284	12059	14197	12846	2870	2916	4831	3538.95
SE (M)±	651.2	192.1	61.5	124.4	95.7	29.8	134.5	51.9
LSD 0.05	Ns	Ns	264.7	Ns	Ns	ns	Ns	ns
CV	690	480	3	770	15.2	10.6	6.8	11.7
GM	12208	12208	13997	12804	2740	2891	4855	3504.86

ns=non-significant, SE (M) ±=standard error of mean, LSD least significant difference, CV=coefficient of variation, GM= Grand mean
Columns not connected by similar letters have significant difference

Table 4. Effect of Variety and Seed rate interaction on biomass and grain yield

Treatments		Biomass (Q ha-1)				Grain Yield (kg ha^{-1})			
Seed rate (kg ha^{-1})	Variety	Ofla	Enda-Mekoni	Emba-Alaje	Mean	Ofla	Enda-Mekoni	Emba-Alaje	Mean
100	Bekoji-1	11040^{c}	12180^{a}	13610^{c}	12280^{c}	2630^{b}	2851	4779^{abc}	3410.27
	Bhatty	11830^{b}	12400^{a}	14380^{a}	12870^{b}	2624^{b}	2963	4886^{ab}	3481.52
150	Bekoji-1	13220^{a}	12530^{a}	13990^{b}	13250^{a}	2650^{b}	2881	4977^{a}	3493.18
	Bhatty	12740^{a}	11720^{b}	14020^{b}	12820^{b}	3173^{a}	2869	4776^{bc}	3596.38
SE (M)±		826.2	2.014	137.4	176.0	131.2	117.3	105.7	73.421
LSD		2219.3	7.407	275.5	347.4	263	ns	211.8	ns
CV %		9.5	4.8	3.2	7.7	15.4	10.6	7.1	11.8

ns=non-significant, SE (M) ±=standard error of mean, LSD least significant difference, CV=coefficient of variation, GM= grand mean
Columns not connected by similar letters have significant difference

Table 5. Interaction of variety, seed rate and N-rate on grain yield

N-Rate (Kg ha^{-1})	Seed rate (Kg ha^{-1})	Grain yield (kg ha^{-1}) Ofla		Enda-Mekoni		Emba-Alaje		Mean	
		Var-1	Var-2	Var-1	Var-2	Var-1	Var-2	Var-1	Var-2
0	100	1628	2049	2010	2183	3785	3396	2474	2543
	150	1737	2080	1910	1762	3488	3721	2378	2521
23	100	1987	2245	2285	2362	4462	4447	2911	3018
	150	2103	2820	2455	2315	4336	4560	2965	3232
34.5	100	2412	2348	2492	2723	4634	4686	3179	3253
	150	2435	2950	2598	2872	4740	4772	3258	3531
46	100	2808	2612	2992	2882	4833	5113	3544	3536
	150	2913	3386	3162	3175	5053	5209	3709	3923
57.5	100	3008	2905	3128	3190	5062	5199	3733	3765
	150	2644	3447	3182	3177	5660	4908	3829	3844
69	100	3262	3043	3442	3623	5503	5813	4069	4160
	150	3322	3663	3323	3570	5876	5266	4174	4167
80.5	100	3101	2965	3607	3777	5175	5551	3961	4098
	150	3195	3662	3538	3213	5687	4996	4140	3957
GM		2611	2870	2866	2916	4878	4831	3452	3539
		VxSRxNR							
	LSD 0.05	Ns		Ns		560.5		ns	
	SE (M)±	347.1		262.9		279.6		194	
	CV	15.5		11.1		7.1		11.8	

Var-1= Bekoji-1 an Var-2 = Bhatty

Malt Quality Traits: The main effect of N-rate, seed rate and variety were significant on most of malt quality traits (Table 6 and 7). In this study the varieties had an acceptable range of grain protein concentration in reference to Canadian grain commission (CGC) and Ethiopian standard agency (ESA) standards except in some of third level treatment interactions at Ofla and Enda- Mekoni. Variety Bekoji-1 was relatively higher in grain protein accumulation in all experimental fields (Table 6). The variation in grain protein of malt barley varieties grown side by side was in support of many authors (O'Donovan et al., 2011; O'Donovan et al., 2013). Relatively higher Grain protein (GP), hectoliter weight (HLW), kernel plumpness (KP) and thousand kernel weight (TKW) were recorded from 100 kg ha^{-1} (SR1) (Table 7). Grain protein content, TKW, KP and HLW had a positive response to N-fertilizer rate and was higher at N5 fertilizer application while low values obtained from the control (N0) (Figure 2). Low value of TKW, KP and HLW indicate poor grain filling. Slight increases in specific weight in response to N- application have been reported by most authors (Pushman and Bingham, 1976; Gooding and Davies, 1997) under more favorable growing conditions (figure 1). In addition McKenzie and Jackson (2005) reported an increase in N-fertilizer supply resulted in an increase in grain yield and grain protein. However, GP in all main effect of treatments was within the acceptable standard range for malt barley. This may be due to the genetic nature of the varieties for malt purpose. Emphasis should be given for the third level interaction of treatments as far as the quality standard is the objective. Interaction of V1 x SR1 x N6, (GP=12.72%) at Ofla, V1 x SRI x N5 (GP=12.81), V1 x SR1 x N6 (GP=13) (GP=13.0), V1 x SR2 x N5 (GP=12.69) and V1 x SR2 x N6 (GP=12.75) at Enda- Mekoni were treatment combinations with grain protein content above maximum acceptable limit for malt barley (Table 8). According the standards of CGC and ESA grain protein content >12.5% is unacceptable for malt purpose. In general, Emba-Alaje was suitable environment in response to grain protein for malt purpose while yield was enhanced. Moreover, Variety Behatty has relatively low grain protein accumulation nature even at higher N-rate and seed rate.

Partial budget analysis: According partial budget analysis (PBA) technique of CIMMYT (1988) of N-fertilizer on malt barley highest net benefit was obtained from the application of 69 N5 kg N ha^{-1} at all locations. However, highest marginal rate of return (MRR) was recorded from 46 kg N ha^{-1} (N3), and N5 at Ofla and Enda-Mekoni while N5 at Emba-Alaje (Table 9). Finally N5 for both varieties can be selected for its high net benefit and optimum to highest MRR at all locations.

Table 6. Analysis of variance for TKW, grain protein and HLW of malt barley at each location

Source of Variation	Mean squares for source of variation								
	TKW (gm)			% GPC			HLW		
	Ofla	E/Mekoni	E/Alaje	Ofla	E/Mekoni	E/Alaje	Ofla	Mekan	E/Alkaje
Rep (1)	36.0833	0.9048	0.7262	0.0444	4.3055	2.6839	13.26	1.51143	0.05786
NR(6)	0.0476ns	0.7619ns	0.7619ns	4.2258***	5.2999***	3.8996***	2.7304***	3.8795***	4.9307***
SR(1)	2.5833	0.7619	0.5119	0.7622+	1.9515**	0.0279ns	1.1286**	0.02571ns	0.52071***
Var(1)	40.0476**	48.7619***	1.1905+	21.7077***	5.2361***	4.316***	1.8036***	0.18286**	0.20643**
NRxSR(6)	0.0476ns	5.7619**	0.0476ns	0.077ns	0.0149ns	0.1065ns	0.1294ns	0.03571ns	0.05738*
NRxVar(6)	0.9762	0.5476	0.1905	0.1642ns	0.064ns	0.0216ns	0.0694ns	0.01952ns	0.0231ns
SRxVar(1)	24.746***	27.0675***	40.6032***	0.3816ns	0.0223ns	0.0428ns	0.01ns	0.10286*	0.315***
NRxSRxVar (6)	0.9921ns	0.5119ns	0.0952ns	0.0586ns	0.0493ns	0.0335ns	0.1059ns	0.01286ns	0.03833+
Residual(27)	2.6032**	0.2897ns	1.3016ns	0.1868	0.1844	0.2692	0.1137	0.0181	0.01786

TKW=1000 kernel weight, GPC=grain protein content and HLW hectoliter weight (kg ha^{-1})

Table 7. The effect of variety and seed rate on grain protein, hector liter weight and 1000 kernel weight of malt barley

	Grain Protein (%)				Hectoliter Weight (Kg HL^{-1})				1000 kernel weight (gm.)			
Treatment	Ofla	Enda- Mekoni	Emba-Alaje	Mean	Ofla	Enda-Mekoni	Emba-Alaje	Mean	Ofla	Enda-Mekoni	Emba-Alaje	Mean
Seed rate (Kg ha^{-1})												
100	11.358	11.577	11.18	11.37	61.9	62.7	63.2	62.585	44.24	45.02	45.64	44.97
150	11.125	11.203	11.135	11.16	61.6	62.7	63.0	62.412	42.86	43.50	45.41	43.92
SE (M)±	0.1155	0.1148	0.1387	0.0835	0.0901	0.036	0.0357	0.054	0.2156	0.1615	0.0952	0.1203
LSD	Ns	0.24	Ns	0.17	0.19	Ns	0.07	0.11	0.6	0.45	ns	0.24
Variety												
Bekoji-1	11.864	11.696	11.435	11.05	61.6	62.8	63.1	62.478	43.57	44.36	45.62	44.52
Bhatty	10.619	11.084	10.88	11.48	61.9	62.7	63.0	62.52	43.52	44.17	45.43	44.37
SE (M)±	0.1155	0.1148	0.1387	0.0835	0.0901	0.036	0.0357	0.054	0.3507	0.1905	0.1561	0.1203
LSD 0.05	0.24	0.24	0.29	0.17	0.19	0.07	0.07	0.11	1.51	ns	ns	ns
CV	3.8	3.8	4.7	4.8	0.5	0.2	0.2	0.6	2.0	1.7	1.9	2.1
GM	11.24	11.39	11.16	11.26	61.7	62.7	63.1	62.5	43.55	44.26	45.52	44.44

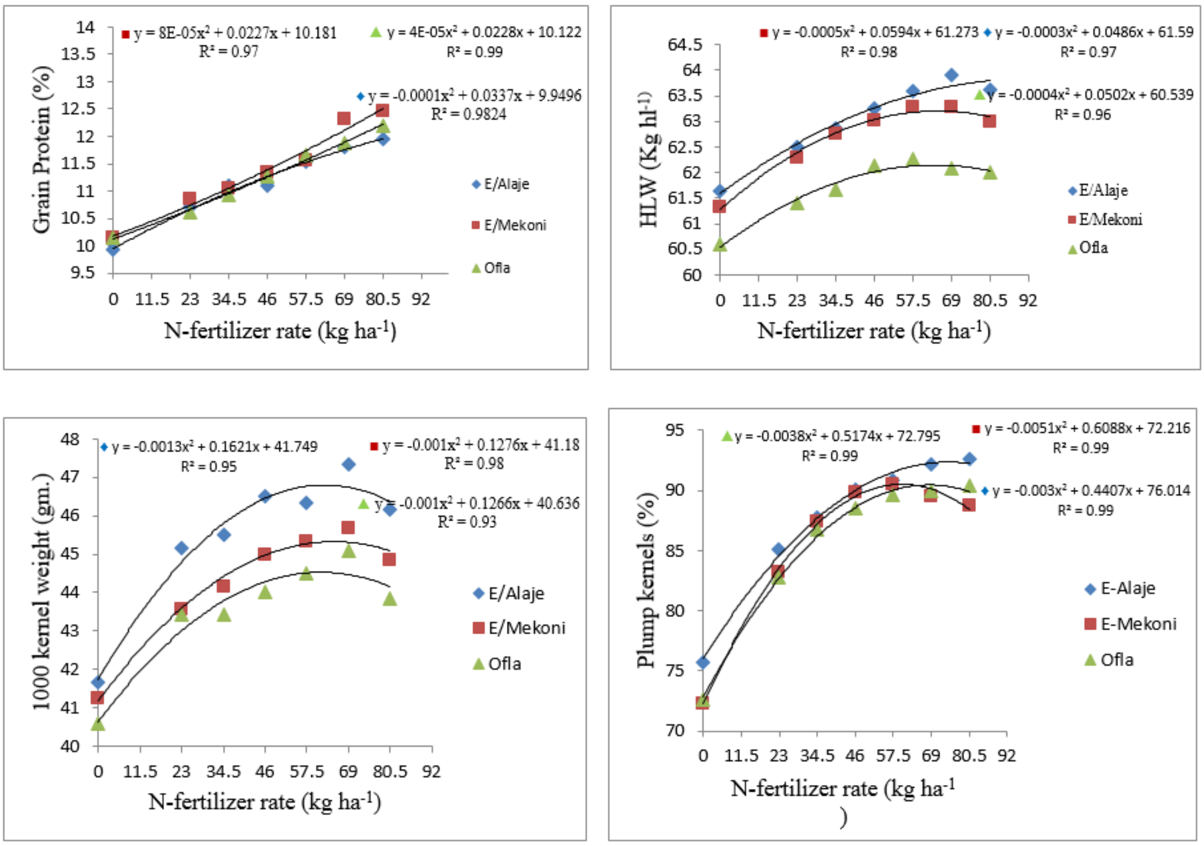

Figure 1. Effect of N-fertilizer rate on grain protein content, HLW, TKW and % of plump kernels of malt barley

Table 8. Interaction effect of N-rate, seed rate and variety on grain protein across location

N-Rate kg ha^{-1}	Ofla				Enda- Mekoni				Emba-Alaje			
	100 kg ha^{-1}		150 kg ha^{-1}		100 kg ha^{-1}		150 kg ha^{-1}		100 kg ha^{-1}		150 kg ha^{-1}	
	Bekoji-1	Bhatty	Bekoji-1	Bhatty	Bekoji-1	Bhatty	Bekoji-1	Bhatty	Bekoji-1	Bhatty	Bekoji-1	Bhatty
0	11.17	9.48	10.43	9.53	10.60	10.03	10.19	9.75	10.19	9.73	10.073	9.69
23	11.57	9.87	11.09	9.90	11.40	10.72	10.82	10.50	11.102	10.712	10.776	10.243
34.5	11.98	10.34	11.40	9.99	11.69	10.91	11.00	10.60	11.469	10.875	11.394	10.671
46	12.19	10.79	11.89	10.23	11.78	11.16	11.32	11.10	11.5	10.899	11.37	10.587
57.5	12.32	11.01	12.14	11.14	12.03	11.57	11.66	11.03	11.55	11.287	12.073	11.193
69	12.50	11.22	12.26	11.57	12.81	12.09	12.69	11.66	11.948	11.443	12.136	11.687
80.5	12.72	11.88	12.44	11.72	13.00	12.28	12.75	11.78	12.25	11.562	12.261	11.737
Mean	12.21	10.85	11.87	10.76	12.12	11.46	11.71	11.11	11.64	11.13	11.67	11.02

Table 9 Partial budget analysis of N- fertilizer rates on malt barley production

N-Rate (kg ha^{-1})	Ofla			E/Mekoni			E/Alaje		
	TVC	NB	MRR	TVC	NB	MRR	TVC	NB	MRR
0	0	19957	-	0	20801.3	-	0	35445.2	-
23	750	23437	463.95	750	23829.8	403.8	750	42646.2	960.1
34.5	1125	2546	539.5	1125	26636.7	748.5	1125	44914.7	604.9
46	1475	28924	989.95	1475	29948.4	946.2	1475	47894.5	851.3
57.5	1825	29697	x	1825	31092	x	1825	49379	x
69	2175	32557	817.07	2175	34271.2	908.4	2175	53338.9	1131.4
80.5	2525	31956D	x	2525	34470.8	x	2525	50783.75D	x

TVC=total variable cost (Birr ha^{-1}), NB=Net benefit per hectare Birr ha^{-1}, MRR=Marginal rate of return(%)

Conclusion

The study was aimed to develop improved agronomic package for malt barley production. for producers in Tigray region in response to the newly constructed brewery factory (Raya Beer). Therefore, based on the performance in grain yield, malt quality traits and net profit and assuming similar environmental conditions the interaction of variety Behatty at 100 kg ha^{-1} seed rate and 46/69 kg ha^{-1} N/P_2O_5 was better agronomic package at all locations. In addition, combinations of Bekoji-1 at 100 kg ha-1 seed rate and 46/69 kg ha^{-1} N/P_2O_5 can be recommended for Ofla and Emba-Alaje districts.

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