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Effects of seeding and nitrogen rate on yield, yield related traits and grain quality of malt barley varieties in the highlands of Bale

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A B S T R A C T

The experiment was conducted at major barley growing districts (Sinana,Goba and Dinsho) of Bale zone for three years from 2016-2018 during the main cropping season with the objective of elucidating the effects of seeding and nitrogen rate on agronomic performance and grain protein content of the improved malt barley varieties. The experimental design in all locations was a split-plot with three replications. Two malt barley varieties (Grace and Traveler) were randomly assigned as main plot factor. On the other hand, factorial combinations of three seeding rates (100,125 and 150 kg ha-1) and four levels of nitrogen fertilizer (0, 23, 46 and 69 kg N ha-1) were arranged in sub-plot factors. The main effects of seeding rate significantly influenced Bio-mass yield and TKW, while main effects of nitrogen rate significantly ($P < 0.05$) influenced plant height, spike length, kernels per spike, bio-mass yield, harvest index TKW, HLW and grain protein content. The main effects of seeding rate and nitrogen rate interacted to significantly influenced grain yield of malt barley varieties. The grain yield ranged from 1905 kg ha-1to 3957kg ha-1. The lowest grain(1905 kg ha-1)d was obtained from the interaction effect of the lowest seeding rate and nil nitrogen rate. The highest (3957kg ha-1) was obtained from the interaction effects of the highest seed and nitrogen rate. The second highest grain yield was recorded from the interaction effects of the second and the highest nitrogen rate in statistical parity with the grain yield from the interaction effects of the highest seed rate and the second nitrogen rate. Main effects of nitrogen rate significantly and variably influenced TKW and grain protein contents of malt barley. The highest TKW (40.2g) and grain protein content (12.2%) were obtained from the highest nitrogen rate(69 kg N ha-1). The lowest TKW (36.1g) and grain protein content (9.2g) was recorded from nil nitrogen rate. According the result of this study optimum malt barley grain yield was obtained at seeding rate of 150kg ha-1and economic analysis also indicated that optimum grain yield and quality of the improved malt barley varieties were obtained at the rate of nitrogen application (46 kg N ha-1). Therefore, malt barley farmers in the study area should use seeding rate of 125 kg ha-1and nitrogen rate 46 kg N ha-1 to realize maximum grain yield and grain quality of the crop.

1. Introduction

Ethiopia is the only country in tropical Africa, where barley is among the major crop (Onwueme and Sinha, 1999). The most important use of Barley is for food and malting, which is mainly used in making alcoholic beverages. For this reason, Barley is considered to be the best of small grains for malting purpose. Barley grain yield and quality are exposed to different factors varying on the large scale. The genotypic traits for a variety and growing climatic conditions are the key factors influencing grain yield and its quality (Leistrumaite and paplauskiene, 2005).The first step to success in the growing system of Barley in a given environment is the choice of suitable cultivar. The varietal effect account for 25 to 40%of variety performance compared to growing conditions (Dudas, 1994). Stability of grain yield performance is an important characteristics in the selection of new crop varieties (Costa and Bodlero, 2001).

The impact of seeding rate on malt barley quality, including plumpness is an important factor in selecting barley for malt with plump seeds generally having higher starch and lower protein levels. The reason plumpness is so important is that maltsters wanted to produce more extract, which means more beer. Optimum seeding rate resulted in more uniformity of barley kernals, which improves the modification process and produces higher quality malt. According to O'Donovan (2008) optimum seeding rate also reduced beta-glucan levels while friability and homogeneity were improved all positive factors for maltsters.

The third most important factor, but the one posing the most challenges and additional questions to researchers, is related to Nitrogen. The major growers' management strategies for producing malt barely is to maximize grain yield and kernel plumpness while maintaining protein content at the acceptable limit(Lauer and Partrigde, 1990; Weston et al., 1993). High Nitrogen usually increase protein levels, but at protein levels higher than 11.5 percent, the sample will be rejected for malt. High nitrogen rate also increase beta-glucan levels, while other factors such as plumpness, friability and modification are decreased at higher nitrogen rates, all having negative effect on quality.

Higher nitrogen rates, sometimes increase the days to maturity, which can cause problems in years where there is a higher risk of frost or other conditions that will reduce malt barley quality. Research findings show that reducing nitrogen rates will improve malt barley quality. In principle, processors of malting barley are concerned about the effects of management factors on grain protein and other malting characteristics (Lauer and Partridge, 1990). Often, management strategies that maximize grain yield will not optimize grain protein (Lauer and Partridge, 1990; Ayoub et al., 1997; Metho et al., 1997) and malt quality (Lauer and Partridge, 1990).

At present, the level of production in Ethiopia is not sufficient to meet the demands of the malting factories both for quality and quantity. As a result, the factories are continuously importing the grain from foreign countries. Nevertheless, there are ample opportunities in Ethiopia in general and in Bale in particular in terms of favorable environmental conditions. Development of appropriate agronomic practices like seeding rate and nitrogen management is among the intervention areas where a research centers play a great role. So far, there was no information generated on varietal differences in response to different seeding and nitrogen fertilizer rates as well as their interaction effects to optimize malt barley quality and quantity of production in bale highlands. This project is, thus, initiated to fill the information gap with objective of interaction effects of nitrogen fertilizer and seed rate with respect to cultivars for the desired malt barley yield and quality.

The rising market demand for malt barley appears a bright venture for farmers as well as others involved in commercial farming. The favorable environmental condition for production of the crop is another opportunity prevailing in Bale. Despite this, integrated agronomic management practices including seeding and fertilizer rate for the varieties are lacking in the area to optimize malt barley production in terms of yield and grain quality. These calls for an urgent need to determine integrate effects of seeding and nitrogen fertilizer rates along with improved varieties in order to optimize yield and grain quality.

Objectives

- ✓ To determine the effects of seed and nitrogen rate on yield, yield related traits and grain quality of improved malt barley varieties
- ✓ To determine economically optimum N application rate for higher grain yield and quality of Malt barley

2. Materials and Methods

The experiment was conducted for three years (2016-2018) at three locations (Sinana on-station, Goba and Dinsho) in main cropping season. The experimental design in all locations was a split-plot with three replications. Two malt barley varieties (Grace and Traveler) were randomly assigned as main plot factor. On the other hand, factorial combinations of three seeding rates (100,125 and 150 kg ha-1) and four levels of nitrogen fertilizer (0, 23, 46 and 69 kg N ha-1) were arranged in sub-plot factors. The entire arrangement of treatments (2x3x4) twenty four treatment combinations were replicated three times. The size of each plot was (1.8x2.5m=4.5m2) and the distance between plots and blocks is kept at 0.5 m and 1.5 m respectively. Field activities such as land preparation, weeding was carried out accordingly. Planting was done using row planting, phosphorous fertilizer in the form of TSP at the recommended rate of 69 kg P2O5 ha-1 was applied equally for all plots. The highest rates of Nitrogen were splited to 1/3 at planting and 2/3 at tillering.

3. Statistical Data Analysis

Analysis of variance (ANOVA) was done using Gen Stat 15th edition and means comparisons for the significantly different variables were made among treatments using least significant differences (LSD) test at 0.05 level of significance.

4. Results and Discussion

4.1. Soil analysis before planting

Selected physico-chemical properties of the soil were determined for composite surface soil (0-30 cm) samples collected before sowing (Table1). Accordingly, the texture of the soil of the experimental site is dominated by the clay fraction. The clay texture indicates the high degree of weathering that took place in geological times and the high nutrient and water holding capacity of the soil.

Soil pH values for both locations varied from 5.68 to 6.45 for soils of the experimental sites (Table 1). pH status was categorized as moderately to slightly acidic soil Jones (2003). Based on these results the pH value is optimum range for most crop production since most plant prefer the pH range 5.5 to 7.0. Soil Organic matter values for both locations varied from 2.29 to 4.98 for soils of the experimental sites (Table 1). As the rating range established by Tekalign,(1991) soil organic matter content categorized under low to moderate for Dinsho on-farm and Sinana on- Station, respectively. Soil Total Nitrogen values for both locations varied from 0.17 to 0.33. As ratings suggested by Landon (1991) for soil total nitrogen soils of the experimental site were rated into low and moderate for Dinsho on-farm and Sinana on- station, respectively. Available Phosphorous values for both locations varied from 10.54 to 20.58 (Table1). According to the rating established by Cottenie (1980) the studied soils have moderate to high phosphorus content for Dinsho on-farm and Sinanaon-station, respectively. Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity.

Cation exchange capacity values were ranged from 20.45 to 38.53 for soils of the experere imental sites. Based on the rating established by Hazelton (2007) the soil of the study sites were moderate and high for Dinsho on-Farm and Sinana on-station, respectively.

Table 1
Soil physico-chemical properties of the Sinana on- station and Sinana on-farm.

Location	Textural class	pH	OM (%)	TN (%)	Available P (ppm)	CEC (cmol kg^{-1})
Sinana on-station	Clay	6.45	4.98	0.33	20.58	38.53
Dinsho on-farm	Clay	5.68	2.29	0.17	10.54	20.45

4.2. Grain yield

Analysis of variance indicated that seeding rate and nitrogen rate interacted to significantly influenced (P < 0.05) the grain yield of improved malt barley varieties (Table 2).

The interaction effect of seeding rate and nitrogen rate significantly influenced the grain yield of the malt barley varieties. The grain yields from all seeding rates increased significantly and variably across the increasing rates of the nitrogen fertilizer. The grain yields also increased across the increased seeding rate for all nitrogen levels. The highest grain yield (3957 kg ha -1) was obtained at the highest seed rate (150 kg ha-1) and nitrogen rate (69kg N ha-1). The second highest grain yield (3702 kg ha-1) was recorded at (125kg ha-1) and (69kg N ha-1) in statistical parity with (150kg ha-1) and (46 kg N ha-1).The lowest grain yield (1905kg ha-1) was produced from the interaction effects of the lowest seed rate (100kg ha-1) and the control (0 kg N ha-1).

Table 2
Interaction effect of seeding and nitrogen rate on grain yield of improved malt barley varieties.

	Nitrogen rate(kg N ha-1)				
Seeding rate(kg ha-1)	**0**	**23**	**46**	**69**	**Mean**
100	1905i	2378g	2663f	2878de	2456
125	2165h	2704ef	3365c	3702b	2984
150	2369g	2898d	3597b	3957a	3205
Mean	2146	2660	3208	3512	
LSD=183.6 CV(%)=15.9					

Means with the same letter are not significantly different at 5% level of significance; NS= non-significant; LSD=Least Significant Difference at P<0.05; CV% = Coefficient of variation (%).

4.3. Plant height

The analysis of variance showed that the main effects of nitrogen rate differed significantly (P < 0.05) in plant height. However, the main effect of seeding rate and the interaction effect did not influence plant height (Table3).

The highest nitrogen rate 69 kg N ha-1 recorded the highest plant height 67.7cm in statistical parity with 46 kg N ha-1. The lowest was obtained from the control treatment 0 kg N ha-1 in statistical parity with the lowest rate 23 kg N ha-1. The increased plant height in response to increasing the rate of nitrogen application was probably due to the availability of more nitrogen in the soil, which may have promoted vegetative growth of the barley plants.

4.4. Bio-mass yield

Analysis of variance indicated significant differences (P < 0.05) for main effects of seeding and nitrogen rate in biomass yield (Table 3).

Increasing the seeding rate proportionally increased biomass production. The highest bio-mass yield 7993 kg ha-1 was obtained from the highest seeding rate 150 kg ha-1. The lowest 6299 kg ha-1was obtained from the lowest seeding rate 100 kg ha-1. Similarly, nitrogen rate increase proportionally the bio-mass yield. The highest (8614 kg ha-1) was recorded with the highest nitrogen rate (69 kg N ha-1), the lowest (5671 kg ha-1) was by the control(Table1). These results indicate that the varieties responded to the N fertilizer application variably in terms of biomass production. The result is in agreement with the findings of Amanuel et al. (1991) who reported a significant increase in biomass yield as a result of increasing in the rate of nitrogen application.

4.5. Thousand Kernel weight and grain protein content

The result showed significant differences (P < 0.05) among nitrogen rate treatments and seeding rate for TKW and nitrogen rate for grain protein content while their interaction was non-significant (Table3).

The seeding rate treatments caused a slight increase in TKW .The maximum TKW was observed for treatment 150kg ha-1 (39.2 g) which was statistically at par with 125 kg ha-1.The lowest (37.1g) was recorded with the lowest seeding rate (100kg ha-1).Increasing nitrogen levels proportionally increased thousand kernel weight and grain protein content which was statistically differed and varied from each other (Table 1). The highest TKW (40.2 g) was obtained at the highest nitrogen rate (69kg N ha-1). The lowest (36.1g) was recorded by the control treatment. Similarly, the highest grain protein content (12.2%) was obtained at the highest rate (69kg N ha-1). The lowest (9.2%) was recorded by the control treatment. This might be attributed to a better nutritional status of the plants which resulted in good grain filling and development.

Table 3
Seeding and nitrogen rate effect on selected agronomic traits and quality of improved malt barley varieties.

Treatments	PH(cm)	SL(cm)	KPS	BM(kg)	HI (%)	TKW(g)	HLW(kg hl-1	GPC (%)
Variety								
Grace	66.4	8.3	28.5	7149	0.41	38.3	68.0	10.7
Traveller	65.3	8.2	28.3	7211	0.43	38.5	67.9	10.6
LSD(P<.05)	NS	NS	NS	NS	NS	NS	NS	NS
Seeding rate(kg/ha)								
100	66.1	8.3	28.6	6299c	0.41	37.1b	67.7	10.7
125	65.1	8.3	28.3	7249b	0.43	38.8a	67.9	10.7
150	66.3	8.1	28.1	7993a	0.41	39.2a	68.3	10.6
LSD(P<.05)	NS	NS	NS	304	NS	0.5	NS	NS
Nitrogen rate (kg N/ha)								
0	63.7c	8.1	27.9	5671d	0.40	36.1d	67.5	9.2d
23	65.2bc	8.1	28.3	6761c	0.43	37.7c	67.8	10.2c
46	66.6ab	8.3	28.4	7674b	0.42	39.5b	68.1	10.9b
69	67.7a	8.4	28.7	8614a	0.41	40.2a	68.4	12.2a
LSD(P<.05)	1.6	NS	NS	351	NS	0.58	NS	0.15
Mean	65.8	8.2	28.3	7180	0.42	38.4	67.95	10.0
CV (%)	10.6	15.4	10.3	21.1	27.7	6.6	4.3	6.0

N=Nitrogen; PH=Plant height; SL=Spike length; KPS=Kernels per spike; BM=Bio-mass; TKW=Thousand kernel weight; HLW=Hectoliter weight; HI=Harvest index; P (%) =Protein in percentage; Means with the same letter are not significantly different at 5% level of significance; NS = non-significant; LSD = Least significant difference at P<0.05; CV (%) = Coefficient of variation (%).

4.6. Economic analysis

The economic analysis was based on the procedures by CIMMYT (CIMMYT, 1988). Partial budget and marginal analysis were performed for nitrogen fertilizer and seeding rate and the decision for selecting the profitable treatments were made based on the highest marginal rate of return (Table4& 5). The Marginal analysis indicated that for nitrogen rate changing from the second treatment (23 kg N ha-1) to the third treatment (46 kg N ha-1) has resulted the highest marginal rate of return (350%), which means that investing 1 birr in treatment number three acquire a return of 3.50 birr. The marginal analysis for seeding rate also revealed that treatment number two (125kg ha-1) gave the highest marginal rate of return (1713%). There for, the best nitrogen and seeding rate for malt barley productivity and profitability in the high lands of bale are 46 kg N ha-1 and 125 kg/ha, respectively.

Table 4
Partial budget analysis result for nitrogen rate study on Malt barley varieties.

Treatments (Nitrogen kg/ha)	**0**	**23**	**46**	**69**
Average yield(kg/ha)	2146	2660	3210	3515
Adjusted yield(kg/ha)	1931	2394	2889	3164
Gross field benefits(Birr/ha)	23172	28728	34668	37968
Cost of Nitrogen(Birr/ha)	0	750	1500	2250
Cost of labour to apply Nitrogen (Birr/ha)	0	35	35	70
Harvesting, packing and transportation (Birr/ha)	2221	2753	3322	3639
Total costs that vary(Birr/ha)	2221	3538	4857	5959
Net benefits (Birr/ha)	20951	25190	29811	32009
MRR%		322	350	199

Cost of urea 1500 Birr 100 kg-1or (32.60 Birr kg-1 N); urea application cost of 23,46 kg N ha-1 one person@ 35 Birr /day; 69 kg N ha-1 two person@ 35 Birr /day; harvesting, packing and transportation 115 Birr per 100 kg; sale price of malt barley 1200 Birr per 100 kg.

Table 5
Partial budget analysis result for seeding rate study on Malt barley varieties.

Treatments (Seedrate kg/ha)	**100**	**125**	**150**
Average yield(kg/ha)	2456	2984	3205
Adjusted yield(kg/ha)	2210	2686	2885
Gross field benefits(Birr/ha)	26520	32232	36620
Cost of barley(Birr/ha)	1200	1500	1800
Sowing and transportation (Birr/ha)	50	65	80
Total costs that vary(Birr/ha)	1250	1565	1880
Net benefits (Birr/ha)	25270	30667	34740
MRR%		1713	1293

Sowing and transportation cost 50 Birr per 100 kg; sale price of malt barley 1200 Birr per 100 kg (12 birr/kg).

5. Conclusion and Recommendations

An experiment was conducted with the objectives of assessing the effect of seeding and nitrogen rate on grain yield, yield components and grain protein accumulation of malt barley varieties. The experimental design was a split-plot with three replications. Two malt barley varieties (Grace and Traveler) assigned as main plot factor and factorial combinations of three seeding rates (100,125 and 150 kg ha-1) and four levels of nitrogen(0, 23, 46 and 69 kg N ha-1) were assigned as sub-plot Factors. The results of the experiment revealed that seeding and nitrogen rate significantly influenced some important malt barley agronomic traits and grain quality attributes.

Therefore, from the results of three years' data over locations, it was observed that the second seeding rate (125kg ha-1) and the second nitrogen rate (46 kg N ha-1) were the most promising and economically feasible seeding and nitrogen rate for the two malt barley varieties (Grace and Traveler).Malt barley producing Farmers advised to use 125 kg ha-1 seed rate and 46 kg N ha-1 fertilizer rate to realize maximum grain yield and grain quality of the crop.

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