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Determination of Appropriate Rate and Time of Nitrogen Application to Improve Productivity of Malt Barley (Hordium disticum L.) in Arsi Highland of Ethiopia

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Abstract
Barley is produced in Ethiopia in a wide range of environments and it is produced on 0.95 million hectares. But production of malt barley is quite low in Ethiopia which is 2378010.3 tones per year. There are many reasons for low yield of barley in Ethiopia, among which low soil fertility is a major reason for low productivity of this crop. This experiment was conducted to determine the appropriate rate and time of nitrogen fertilizer application for malt barley at Kofele district of Arsi zone under rain fed condition for three years. The treatments consisted of four nitrogen fertilizer rates (23kg/ha, 46kg/ha, 69kg/ha and 92kg/ha) and three different times of nitrogen application (½ at planting and ½ at tillering, 1/3 at planting and 2/3 at tillering and all at planting). Malt barley variety Ebon was used for this experiment. Randomized complete block design with split plot arrangement of treatments with three replications was used. The three years combined data indicated that biological yield and grain yield was not significantly affected by both nitrogen fertilizer rate and time of nitrogen application. But the highest biological yield (25624 kg/ha) and grain yield (7316.0kg/ha) of malt barley were recorded at the (92 kg/ha) and 46kg/ha of nitrogen fertilizer application, respectively. The combined data analysis indicated that nitrogen application rate significantly affected harvest index. The highest harvest index of malt barley 36.7 was obtained at 23 kg/ha of nitrogen application. Plant height showed highly significant difference and significance difference to nitrogen rate and timing of nitrogen application, respectively. The highest plant height (97.2cm) was recorded at 69 kg/ha of nitrogen. From timing of nitrogen application treatments, all at planting gave the highest plant height of malt barley which is 96.7cm. Spike per 50cm showed significant difference to nitrogen fertilizer rate and highest spike per 50cm of malt barley was recorded at 69 kg/ha. Even though, economic analysis was not done, 46kg/ha of nitrogen fertilizer and ½ at planting and ½ at tillering application time of nitrogen can be recommended for improving yield of malt barley at Kofele district.
Keywords: Experiment, Nitrogen fertilizer, Malt barley, Yield
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1. Introduction

Barley (*Hordeum vulgare* L.) is the fourth most cultivated crop of the world (Giraldo *et al*., 2019). Barley production is estimated to be 141.7 million tons in the world (USDA, 2017). It is one of an important cereal crop which ranks fifth in area coverage. This crop is produced in Ethiopia in a wide range of environments with an altitude range of 1500 to 3500 m.a.s.l. (Bekele et al., 2005, Yirga, *et al*. 1998). But it is mainly grown from 2000 to 3000m a.s.l. (Lake *et al*., 1993). Ethiopia ranks second in barley production in Africa next to Morocco (Shahidur *et al*., 2015). Barley is produced on 0.95 million hectares and its production was 2.053 million tons in Meher (CSA, 2018).

In Ethiopia, barley is eaten in many different forms like porridge, soup, injera, roasted grain and bread and used to make drinks (Grando and Macpherson, 2002). There is two species of barley (food barley: used mainly as food and malt barley: used mainly to prepare beverages) (Biruk and Demelash, 2016). Production of malt barley is quite low in Ethiopia (Biruk and Demelash, 2016) and breweries and malt factory are importing malt and malting barley from abroad, respectively (Hassena and Legesse, 2003). Area coverage, production and productivity of malt barely are 950742.01 hectares, 2378010.3 tones and 2.52 tones ha^{-1} in the country, respectively (CSA, 2020).

The main reasons for low yield of barley in Ethiopia are low-yielding cultivars, the influence of biotic and abiotic stresses. Among several abiotic factors low soil fertility is a major reason for low productivity of barley. There is no information on nitrogen fertilizer rate and time of application of this fertilizer in this experimental area. Therefore the objective of this experiment is to determine the appropriate rate and time of nitrogen fertilizer application for malt barley at Kofele district of Arsi zone.

2. Material and Methods

2.1. Study sites description

This Experiment was conducted for three consecutive years (2018, 2019 and 2020) in main cropping season at

Kofele, Kulumsa Agricultural Research Center (KARC) sub-station compound. It is located in Kofele district of West Arsi Zone, Oromia Regional State, and Southeastern Ethiopia. The experimental site is located at 07º04′27″N latitude and 38º46′45″E longitude, 2660 meters above sea level. It receives average annual rainfall of 1211mm. The average annual minimum and maximum temperatures are 7.9 and 16.6 °C, respectively (Tamene, 2017). The soil type is pellic vertisol (IUSS Working Group WRB, 2014).

2.2. Experimental Design and treatments

The treatments consisted of four nitrogen rates and three different times of nitrogen application. Nitrogen rates used are 23kg/ha, 46kg/ha, 69kg/ha and 92kg/ha. Times of nitrogen application are ½ at planting and ½ at tillering, 1/3 at planting and 2/3 at tillering and all at planting. Source of nitrogen fertilizer was urea. Randomized complete block design with split plot arrangement of treatments with three replications was used. Malt barley variety Ebon was used for this experiment.

2.3. Agronomic and yield data collection

The collected growth parameters, yield and yield components and seed quality were biological yield, grain yield, harvest index, hectoliter weight, thousand kernel weight, seeds per spike, plant height, spike per 50cm and spike length.

2.4. Statistical analysis

The collected data was subjected to analysis of variance (ANOVA) using SAS software version 9.0(SAS Institute Inc.2004). Significant difference among treatment means were assessed using the least significant difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

2.5. Experimental Procedures

The field was ploughed by disc plough and harrowed using tractor before planting. Then it was leveled manually using hand tools. Recommended seed rate of malt barley (150kgha^{-1}) was used. The crop was planted in row in which the inter row spacing was 20cm.

3. Results and discussion

3.1. Agronomic parameters and yield

Biological yield of malt barley did not indicate significant effect to both nitrogen rate and time of nitrogen application in all cropping seasons and over all data. Relatively highest biological yield of malt barley was recorded at the application of 92 kg/ha of nitrogen which is 11983 kg/ha in 2009/10 cropping season. From time of nitrogen application treatments the highest biological yield (1441 kg/ha) was recorded at all at planting of nitrogen in2009/10 cropping season. The highest biological yield of malt barley (25631 kg/ha) was recorded at the application of 92 kg/ha of nitrogen in 2010/11 cropping season. From time of nitrogen application the highest biological yield (23977kg/ha) was recorded at ½ at planting and ½ at tillering of nitrogen in2010/11 cropping season. The combined data indicated that the highest biological yield (25624 kg/ha) of malt barley was recorded at the highest nitrogen rate (92 kg/ha) application (table 1).This is the reason that nitrogen plays a great roll in vegetative development of plants. Similar to this finding fasil and demelash (2021) reported that increasing nitrogen ratelinearly increased straw yield. In agreement with this report, Derebe *et al.* (2018) reported that N rate significantly enhanced the straw yield of malt barley, since N usually promotes the vegetative growth of a plant. Amsal *et al*. (2000) also reported that increasing nitrogen rate has increased wheat biological yield.

Table 1.Effect of rate and timing of nitrogen fertilizer on biological yield (kg/ha) on malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	9454	21791	35260	22169
46	9533	23851	38972	24119
69	9724	23453	31982	21719
92	11983	25631	39258	25624
LSD	2529.1	3318	9309.8	3180.9
T of N				
T1	9481	23977	36521	23326
T2	9598	23453	37839	23630
T3	11441	23614	34744	23267
LSD	2190.3	2873.4	8062.5	2754.7
CV	25.42	14.33	26.1	14.0

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Data analysis indicated that grain yield of malt barley was highly significantly affected by nitrogen application rate only in 2009/10 cropping season. The highest grain yield of malt barley (4495.2kg/ha) was

recorded at 23 kg/ha of nitrogen rate in this cropping season. The combined data of the three years of grain yield indicated that nitrogen rate and time of nitrogen application did not significantly affected grain yield of malt barley. The highest grain yield of malt barley (7293.7 kg/ha) was obtained at ½ at planting and ½ at tillering of nitrogen application. This implies that malt barley requires nitrogen fertilizer equally at planting and at tillering for optimum yield. From nitrogen application rate the highest grain yield (7316.0 kg/ha**)** was obtained at 46kg/ha of nitrogen (table 2).When nitrogen rate exceeds this rate grain yield declines. This might be due to higher nitrogen rate increases biological yield than grain yield. This in line with Sakatu *et al*. (2020) who reported that the highest grain yield of malt barley was recorded at 46kg/ha of nitrogen application and declines as nitrogen fertilizer rate increases. However, this result disagree with the report of Zeleke *et al*. (2020) who reported that as nitrogen rate increases, malt barley grain yield linearly increased up to 92kg/ha of nitrogen fertilizer.

Table 2.Effect of rate and timing of nitrogen fertilizer application on grain yield (kg/ha) on malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	4495.2[a]	8859.3	8347.8	7234.1
46	3870.8[ab]	9239.8	8837.2	7316.0
69	3463.1[bc]	9153.2	7517.7	6711.3
92	3179.4[c]	9227.3	7842.1	6749.6
LSD	682.8	810	1357.1	545.4
T of N				
T1	4015.9	9493.7	8371.6	7293.7
T2	3620.6	8948.7	7790.4	6786.6
T3	3619.9	8917.3	8246.6	6927.9
LSD	591.32	701.4	1175.2	472.3
CV	18.61	9.08	17.0	8.0

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Harvest index of malt barley was significantly affected by nitrogen application rate in 2010/11 cropping season. The combined data indicated that nitrogen application rate significantly affected harvest index. The highest harvest index of malt barley 36.7 and 36.8 were obtained at 23 kg/ha of nitrogen application and at ½ at planting and ½ at tillering application time of nitrogen, respectively. As nitrogen rate increased harvest index of malt barley decreased. This result is in line with the finding of Derebe *et al*. (2018) who reported that as applied nitrogen increased harvest index of malt barley decreased. This could be accounted for the enhanced above ground biomass yield in response to the incremental rates of N in contrast to grain yield during the growing season (table 3).

Table 3.Effect of rate and timing of nitrogen fertilizer application on harvest index of malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	41.3	40.8[a]	28.1	36.7[a]
46	40.9	38.8[ab]	25.3	35.0[a]
69	37.5	39.3[a]	29.1	35.3[a]
92	31.1	36.3b	26.0	31.1[b]
LSD	8.98	2.80	10.67	3.7
T of N				
T1	41.5	39.7	29.3	36.8
T2	36.6	38.5	23.8	33.0
T3	34.9	38.2	28.2	33.7
LSD	7.78	2.43	9.24	3.2
CV	24.37	7.40	40.2	11.2

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Thousand kernel weight was not significantly affected by both nitrogen fertilizer rate and time of nitrogen application in all cropping seasons and over all. Among fertilizer rate treatments 23 kg/ha of nitrogen gave the highest thousand kernel weight (44.0g). This might be due to lower seeds per spike at lower nitrogen rate. However this result disagrees with the report of Derebe *et al*. (2018) who reported that nitrogen fertilizer rate has not significantly affected thousand kernel weight of malt barley. In time of nitrogen application the highest thousand kernel weight (43.66g) was obtained at½ at planting and ½ at tillering of nitrogen application. This means malt barley requires nitrogen fertilizer equally at planting and at tillering for good seed size (table 4).

Table 4.Effect of rate and timing of nitrogen fertilizer on thousand kernel weight of malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	41.3	41.2	49.4	44.0
46	40.4	41.2	45.0	42.2
69	40.1	41.4	47.4	43.0
92	39.9	42.1	48.1	43.4
LSD	1.27	1.18	4.50	1.5
T of N				
T1	40.6	41.5	48.7	43.66
T2	40.0	41.0	45.6	42.2
T3	40.6	42.0	48.1	43.61
LSD	1.10	1.03	3.90	1.3
CV	3.22	2.92	9.7	3.8

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Seeds per spike of malt barley didn't show significant effect to both nitrogen fertilizer rate and time of nitrogen application in 2009/10, 2010/11 cropping seasons and combined data. Nitrogen fertilizer rate showed significant difference to nitrogen fertilizer rate in 2011/12 cropping season (table 5).

Table 5.Effect of rate and timing of nitrogen fertilizer on seeds per spike

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	26.4	24.4	24.4^{b}	25.0
46	25.5	25.2	29.3^{a}	26.6
69	25.3	24.7	25.9^{ab}	25.3
92	25.7	26.0	27.6^{ab}	26.4
LSD	1.41	1.34	4.86	1.6
T of N				
T1	26.1	25.1	26.1	25.8
T2	25.7	24.9	26.1	25.5
T3	25.4	25.2	28.3	26.3
LSD	1.22	1.16	4.2	1.4
CV	5.62	5.49	18.5	6.5

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Plant height of malt barley showed significant difference to nitrogen rate in 2009/10 cropping season. The combined data of plant height showed highly significant difference and significance difference to nitrogen rate and timing of nitrogen application, respectively. The highest plant height (97.2cm) was recorded at 69 kg/ha of nitrogen at combined data which is almost equal with 96.8cm that was recorded at 92kg/ha of nitrogen. Fasil and Demelash (2021) also indicated that plant height of malt barley increased as nitrogen fertilizer increased. This indicates that nitrogen increases plant height because it plays great role in vegetative development of plant. Out of timing of nitrogen application treatments, all at planting gave the highest plant height of malt barley which is 96.7cm (table 6).

Table 6.Effect of rate and timing of nitrogen fertilizer on plant height of malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	92.7^{c}	95.6	88.6	92.3^{b}
46	93.7^{bc}	95.0	92.2	93.6^{b}
69	99.0^{ab}	98.4	94.3	97.2^{a}
92	100.8^{a}	96.3	93.3	96.8^{a}
LSD	5.56	2.77	5.51	2.3
T of N				
T1	95.6	95.3	90.8	93.9^{b}
T2	95.0	95.9	92.3	94.4^{b}
T3	95.8	97.8	93.2	96.7^{a}
LSD	4.81	2.40	4.7	2.0
CV	5.89	2.94	6.1	2.5

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

In this study spike per 50cm showed significant difference to nitrogen fertilizer rate only in 2009/10 cropping season and combined data. Highest spike per 50cm of malt barley was recorded at 69 kg/ha N (table 7).

Table 7.Effect of rate and timing of nitrogen fertilizer on spike per 50cm

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	41.8[b]	72.3	63.8	59.3[bc]
46	37.5[b]	73.0	64.7	58.4[c]
69	43.8[ab]	85.0	63.8	64.2[a]
92	50.3[a]	78.6	61.3	63.4[ab]
LSD	7.41	13.19	5.87	4.7
T of N				
T1	44.5	76.5	63.0	61.3
T2	42.5	82.5	61.7	62.2
T3	43.0	72.6	65.5	60.4
LSD	6.41	11.42	5.09	4.1
CV	17.47	17.46	9.4	7.9

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

Spike length was not significantly affected by nitrogen fertilizer rate but only significantly affected by timing in2010/11 and 2011/12 cropping seasons (table 8).

Table 8.Effect of rate and timing of nitrogen fertilizer on spike length of malt barley

N rate(kg/ha)	2009/10	2010/11	2011/12	combined
23	7.3	7.4	7.9	7.6
46	7.5	7.4	8.0	7.6
69	7.4	7.7	8.1	7.8
92	7.7	7.8	7.9	7.8
LSD	0.50	0.61	0.44	0.2
T of N				
T1	7.5	8.0	7.7	7.7
T2	7.5	7.5	8.0	7.7
T3	7.5	7.4	8.2	7.7
LSD	0.43	0.52	0.38	0.2
CV	6.83	8.19	5.7	3.4

T1=½ at planting and ½ at tillering, T2=1/3 at planting and 2/3 at tillering T3=all at planting

4. COCLUSION

The result of this study indicated that, even though there was no significant difference for biological yield and grain yield to both nitrogen fertilizer rate and time of nitrogen application the highest biological yield (25624 kg/ha) and grain yield (7316.0kg/ha) of malt barley were recorded at 92kg/ha and 46kg/ha of nitrogen fertilizer rate, respectively. But harvest index of malt barley was significantly affected by nitrogen application rate. The highest harvest index of malt barley 36.7 and 36.8 were obtained at 23 kg/ha of nitrogen application and at ½ at planting and ½ at tillering application time of nitrogen, respectively. The combined data of plant height showed highly significant difference and significance difference to nitrogen rate and timing of nitrogen application, respectively. The highest plant height (97.2cm) was recorded at 69 kg/ha of nitrogen. From timing of nitrogen application treatments, all at planting gave the highest plant height of malt barley which is 96.7cm. Spike per 50cm showed significant difference to nitrogen fertilizer rate. Highest spike per 50cm of malt barley was recorded at 69 kg/ha. Generally, we can recommend 46kg/ha of nitrogen fertilizer and ½ at planting and ½ at tillering application time of nitrogen for improving yield of malt barley at Kofele district.

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