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Research Paper

Productivity and quality of malt barley (*Hordeum vulgare*) as affected by sowing date, rate and stage of nitrogen application

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ABSTRACT

A field experiment was carried out during *rabi* season of 2006-07 and 2007-08 with a objective to find out optimum time of sowing, rate and proper stage for application of nitrogen to get good quality of malt barley (*Hordeum vulgare* L.) for higher malt and grain yield. The experiment was laid out in split plot design with three dates of sowing (20, 30 October and 10 November) and three levels of nitrogen as 62.5, 78.5 and 93.75 kg N/ha (100, 125 and 150 per cent of recommended N, respectively) in main plots and three stages of nitrogen application {whole of nitrogen before pre sowing irrigation (S_1), half of nitrogen before pre sowing irrigation + half at(45 days) maximum tillering stage (S_2) and half of nitrogen before pre sowing irrigation + 1/4 at (25 days) tillering stage + 1/4 at (65 days) boot stage (S_3)}in sub plots. The results of mean of two years revealed that 10 November sowing gave the significantly higher grain yield, effective tillers, number of grain ear, harvest index and malt yield than 20 October and 30 October due to minimum lodging. Barley crop responded significantly up to 78.5 kg N/ha. Application of nitrogen in three split (S_3) increased significantly plant height, dry matter accumulation, effective tillers, ear length, number of grains/ear, grain, straw and malt yield as compared to two splits (S_2) and single application (S_1). It can be concluded that barley crop for higher malt recovery, malt and grain yield, can be sown on 10 November with the application of 78.5 kg N/ha in three splits (half nitrogen before pre sowing irrigation, 1/4 at tillering stage and 1/4 at boot stage).

Key word : Date of sowing, Grain yield, Malt barley, Malt quality parameters, Nitrogen scheduling,

Barley is a hardy crop which is grown throughout the temperate and tropical regions of the world. In production, it ranks fourth after rice, maize and wheat and is usually used as food for human beings and feed for animals and poultry. It is also a valuable input for industries for extracting malt to be utilized in brewing, distillation, baby foods, cocoa malt drinks and aryuvedic medicines. Each 100 g of barley grain comprise 10.6 g protein, 2.1 g fat, 64 g carbohydrate, 50 mg calcium, 6.0 mg iron, 31 mg vitamin $B_{1,}$ 0.10 mg vitamin B_2 and 50 μg folate (Vaughan *et al.*, 2006). During 2007-08, in Punjab, this crop was grown over 12 thousand hectares and recorded a production of 44 thousand metric tonnes with an average yield of 3652 kg/ha (Anonymous, 2012-13).

Nitrogen is the main constituent of amino acids which are precursor to protein. So, malt barley grain yield, grain protein and kernel plumpness are the characteristics strongly related to available nitrogen (Grant, 2000). Lauer and Partridge (1990) observed that grain yield and protein content increased significantly with increase in nitrogen levels. Time of nitrogen application is an important cultural practice for realizing potential yield of any crop. Application of full dose of nitrogen at sowing may not be able to meet the nutritional requirements of the crop up to maturity and may result in lower grain yield and low nitrogen content. While split application of nitrogen may increase protein content of grain, its higher rates can result in translocation of excessive amount of nitrogen from vegetative organs to grains thereby resulting in poor malt quality. So, improper rates as well as time of nitrogen application may reduce grain yield and quality below the acceptable levels. Keeping the above in consideration, the present study was taken to find out optimum time of sowing, nitrogen and proper stage for application of nitrogen to get good quality of malt barley for higher malt and grain yield.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2006-07 and 2007-08 at Department of Agronomy, Punjab Agricultural University, Ludhiana. The soil was

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loamy sand in texture having pH 7.9, low in available N, medium in available P and K were 193, 20.5 and 218.5 kg/ha, respectively. The experiment on barley was conducted in split-plot design with three replications. The main plot consisted of three dates of sowing (20 and 30 October and 10 November) and three levels of nitrogen as 62.5, 78.5 and 93.75 kg/ha (100, 125 and 150 per cent of recommended nitrogen, respectively) and three stages of nitrogen application (S_1 - Full before pre sowing irrigation, S_2- 50 per cent before pre sowing irrigation + 50 per cent at maximum tillering stages (45 DAS) and S_3 - 50 per cent before pre sowing irrigation + 25 per cent at tillering stages (25 DAS) + 25 per cent at boot stage (65 DAS) in the form of urea (46% N) were in sub plots. Field was ploughed twice with a tractor drawn disc harrow and twice with a cultivator followed by planking when it came to optimum moisture condition. The two row malt barley variety VJM-201 was sown using seed rate of 87.5 kg/ha at 22.5 cm apart by placing seed at a depth of 5cm. The barley crop was sown at three dates of sowing as per treatments. Nitrogen was applied at 62.5, 78.5 and 93.75 kg/ha at different stages as per treatments. Protein and starch content were analyzed using automatic whole grain analyzer Infratech-1241 supplied by FOSS analytical AB, Sweden. The instrument measures the light transmitted through the grain in the range of 850-1050 nm. The instrument used five sub samples of whole grains. The value of the constituent was displayed directly as per the software provided in the equipment.

Malting of barley grains were carried out as per the method suggested by Singh and Sosulski (1985). Properly cleaned, weighed samples of barley grains were steeped in water at 15°C in an incubator for a period of 60 hours. Water was changed every 8-10 hours and an air rest of 1 hr was given after 24 hours during steeping. Then steeped samples taken in a muslin cloth were placed in a wooden box with wire mesh bottom for germination in an incubator at 15°C and relative humidity of more than 90 per cent. They were allowed to germinate for a period of 5 days. Then the green malt was kilned in an oven at 45° C for the first 20 hours and then at 85°C for 4 hours. Roots from the kilned malt were removed. Weight of malt and roots was recorded separately to calculate malt yield.

$$\text{Malt yield (\%)} = \frac{\text{Malt weight}}{\text{Sample weight}} \times 100$$

Diastatic power of malt was analyzed as per the procedures suggested by AOAC (1990). Five grams of ground sample and 1 tea spoon ignited quartz sand was taken into 100-125 ml flask and mixed by rotating flask then added 46 ml buffer solution at 30^o C and again mixed by rotating flask until all flour in suspension after that placed in constant temperature on water bath at 30^o C and maintained at this temperature. Exactly after 1 hour, flask was shaken by rotation every 15 minutes. At the end of 1 hour added 2 ml 3.58 N H_2SO_4 and mixed thoroughly, added immediately 2 ml sodium tungstate solution and again mixed thoroughly and stand for 2 minutes and filtered it discarded first 8-10 drops of filtrate. Mix filtrate; remove 5 ml aliquot after that maltose was determined by pipette out 5 ml extract into 125 ml titration flask. Added exactly 10 ml alkaline ferricyanide with pipette (reagent 4), mixed and immersed flask in vigorously boiling water bath so that surface of liquid in flask is 3-4 cm below the surface of boiling water. Delay between filtering of the extract and treatment in boiling water bath should not exceed 15-20 minutes. Further delay may cause error due to sucrose hydrolysis in acid solution. Exactly 20 minutes after immersion, samples were removed from water bath and cooled under running water. Added 25 ml acetic acid salt solution, mixed well by rotation, titrated with 0.1 N thiosulphate to complete disappearance of blue colour. To calculate ml ferricyaninde reduced by subtracting ml thiosulphate required from thiosulphate equivalent of ferricyanide reagent. Report as mg maltose produced by 10 g flour in hr at 30^o C.

Diastatic power (DP) = ml of Sodium thiosulphate used for (sample-blank) × 23

$$\text{DP on dry basis} = \frac{^{o}\text{L} \times 1000}{100\text{–moisture contents}}$$

Maltose equivalent (mg maltose per 10^{-1} g) = ml of Sodium thiosulphate used for (sample-blank) x 92

Analyze α-amylase activity was determined as per the procedure given by Perten (1966). Alpha amylase activity is the activity of enzyme to degrade the starch. It is determined by stirring number. This method is based on the unique ability of the alpha amylase to liquefy a starch gel. Strength of the enzyme is measured by stirring number as times in seconds require stirring and allowing stirrer to fall a measured distance through a hot aqueous flour gel undergoing liquefaction.

Stirring number value was estimated by using RVA (Rapid Visco Analyzer) Starch master, Newport Scientific, Australia using following procedure. Switched on the instrument and allowed it to warm up for 30 minutes, weighed 4.0 g malt in a consister and added 25.0 ml of distilled water into the consister and vigorously jogged the blade through the sample up and down 10 minutes or until it mixed uniformly. Ideal temperature for determination of stirring number value is 95±1^{o}C, time for completion of test is 3 minutes and time between readings should be 1 second. Initiated the measurement cycle by depressing the motor tower of the instrument then removed the consister on the completion of the test and discard. Recorded the stirring number value displayed at the end of the test.

Barley grain, malt, rootlets and grain moisture content can be weighed with high precision and accurately. Malting losses and yields may be determined rather exactly, provided that no grains are lost at any stage in the malting programme (Briggs 1998). The relationships are:

Malt yield (% d b) = [malt (d b) × 100] ÷ barley (d b)

Malting loss (% d b) = [barley (d b) – malt (d b) × 100 ÷ barley (d b)

Rootlets (% d b) = [rootlets (d b) × 100] ÷ barley (d b)

Therefore, malting loss (%) - rootlets (%) = respiration (%) + steeping loss (%)

Muslin cloth bags with 100 g of cleaned barley seeds were placed for the malting process. After kilning, the samples were weighed and polished with a vortex cleaner, which removed rootlets. Malting losses (%) were calculated using the difference in weight divided by the initial weight, multiplied by 100.

$$\text{Malting loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Initial weight of sample (before malting)

W_2 =Weight of malt sample without roots (after malting)

Weight of roots was recorded separately to calculate root losses.

$$\text{Root loss (\%)} = \frac{W_2}{W_1} \times 100$$

Where,

W_1 = Initial weight of sample (before malting)

W_2 = Weight of roots (after malting)

Muslin cloth bags with 100 g of cleaned barley seeds were placed for the steeping process. After steeping, steeped grains were dried at initial sample moisture content and weighed. Steeping losses (%) were calculated using the difference in weight divided by the initial weight, multiplied by 100.

Steeping losses (%) =

Where,

W_1 = Initial weight of sample (before steeping)

W_2 =Weight of steeped grains (after steeping)

Respiration losses are determined by the following equation:

Malting loss (%) - rootlets (%) = respiration + steeping loss (%)

Malting loss (%) - rootlets (%) = A

Respiration losses (%) = A - steeping loss (%)

RESULTS AND DISCUSSION

Growth characters

Plant height and dry matter accumulation were significantly affected with dates of sowing, levels and time of nitrogen application (Table 1). At the harvest, highest plant height and dry matter accumulation was observed with 20 October sowing which was significantly higher than 30 October and 10 November sown crop (Table 1). The crop sown on 30 October and 10 November had statistically same plant height. However, dry matter accumulation in wheat at harvest was reduced significantly with the delay in sowing from 20 October to 10 November. Decrease in plant height and dry matter accumulation in late sowing was due to shorter growing period. These results are in conformity with those of Patel *et al.* (2004) that late sowing of barley (15 December) gave lower plant height as compared to (15 November) sown crop.

At harvest, maximum plant height and dry matter accumulation of barley was recorded with 93.75 kg N/ha, which was significantly more than 78.5 and 62.5 kg N/ha (Table 1). The significantly lower plant height and dry matter accumulation was observed with 62.5 kg N/ha than higher levels of nitrogen. These results are in conformity with the findings of Meena *et al.* (2012) found that plant height and dry matter increased significantly with each successive increase in N level up to 90 kg N/ha. The increase in dry matter accumulation was due to taller plants and increased nitrogen application.

The highest plant height at harvesting stage was observed (Table 1) when half nitrogen was applied before pre sowing irrigation, 1/4 at tillering stage and 1/4 at boot stage, (three splits) which was significantly higher than application of nitrogen in two equal splits, i.e. before pre sowing irrigation and at maximum tillering stage and whole nitrogen before pre sowing irrigation (single application). The highest dry matter was accumulated at harvest with three splits which was statistically at par with two equal splits and significantly higher than single application of nitrogen. Similar results were reported by Singh *et al.*, (2006) and reported highest plant height and dry matter accumulation with three equal splits. These results indicate the benefit of nitrogen application at boot stage in barley as compared to tillering stage.

Yield attributes and yield

The yield attributing characters of malt barley viz. effective tillers, number of grains per ear and 1000-grain weight was exhibited significant differences with different dates of sowing, levels and time of nitrogen application (Table 1). Highest number of effective tillers, number of grains per ear and 1000-grain weight was significantly more with 10 November sowing, which was significantly higher than 30 and 20 October sowing dates. The significantly lowest number of effective tillers was recorded in the early sown crop on 20 October. However, the lowest number of grains per ear was recorded from the crop sown on 20 October and was at par in 30 October sown crop. The ear length was not varied significantly with the dates of sowing. However, the ear length increased with the delay in sowing from 20 October to 10 November. But the differences were non-significant. These results were in conformity with those of Lauer and Partridge (1990), reported that delayed planting of spring barley reduces tiller numbers per plant but increases the proportion of effective tillers that survive. Late sowing of barley (15 December) showed ear head, grains/ear, and 1000-grain weight as compared to 15 November sown crop (Patel *et al.* 2004).

Increasing levels of nitrogen showed significant impact on yield attributing characters of barley viz. effective tillers, ear length, number of grain per/ear and 1000-grain weight (Table 1). The effective tillers, ear length and number of grains per ear significantly increased with the each increment of nitrogen. The highest number of ear bearing tillers, the maximum ear length, number of grain per/ear were obtained with application of 93.75 kg N/ha and which were significantly higher than that obtained with 78.5 and 62.5 kg N/ha. The 1000-grain weight increased with the each level of nitrogen but it was significantly similar of the crop received 78.5 and 93.75 kg N/ha. However, the application of 93.75 kg N/ha had the significantly more than 62.5 kg N/ha. Singh and Singh (2005) at Varanasi, reported significant increase in ears m^{-2}, grains/ear and 1000-grain weight were increased with the increase in nitrogen up to the highest level tried.

Time of nitrogen application showed significant differences at different stages on yield attributing characters of barley viz. effective tillers, ear length and number of grains per ear (Table 1). The highest effective tillers, the longest ear and number of grain per/ear were recorded when nitrogen was applied in three splits (half before pre sowing irrigation, 1/4 at tillering stage and 1/4 at boot stage), which were significantly higher than those with the application of nitrogen in two equal splits and single application. The grain weight did not vary with time of nitrogen application. The longest ears in case of three splits and two splits might be attributed to better development of vegetative infrastructure as plant height and dry matter accumulation during the growth owing to better partitioning of assimilates towards the reproductive parts. Similar findings were reported by Roy and Singh (2006), reported that three splits applications of nitrogen produce longest ear length as compared to two splits and single application. 1000-grain weight did not vary significantly with the nitrogen applied at different stages; however the maximum

Table 1. Effect of sowing dates, dose and time of nitrogen on growth, yield attributes and grain yield of malt barley (Mean of 2 years)

Treatment	Plant height at harvest (cm)	Dry matter accumulation at harvest (g/m^2)	Effective tillers/m^2	Ear length (cm)	Grains/ ear	1,000-grain weight (g)	Lodging (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Date of sowing										
20 October	101.9	1064.8	481.9	9.5	27.6	43.6	49.8	3.92	6.99	35.2
30 October	97.9	1023.3	527.2	9.7	27.9	45.8	19.4	4.29	6.71	39.1
10 November	96.0	997.3	582.2	10.0	29.0	46.1	8.5	4.73	6.07	44.0
SEm±	1.5	11.4	14.1	0.07	0.18	00.54	0.7	0.12	0.23	1.3
CD (P=0.05)	3.3	28.5	35.2	NS	0.50	1.45	1.5	0.29	0.50	2.8
Nitrogen level (kg N/ha)										
62.5	90.0	917.2	478.4	9.1	26.6	44.5	18.5	3.89	5.42	41.9
78.5	100.8	1068.1	537.1	9.6	28.5	45.5	25.1	4.43	6.73	39.8
93.75	105.0	1101.8	576.4	10.2	29.8	45.9	34.1	4.61	7.87	36.9
SEm±	1.5	11.4	14.1	0.16	0.38	0.54	0.7	0.12	0.23	0.5
CD (P=0.05)	3.3	28.5	35.2	0.40	0.85	1.25	1.5	0.29	050	1.2
Stage of N application										
Full before pre sowing Irrigation	92.8	995.8	457.9	9.3	25.3	44.7	33.1	3.69	5.92	38.5
50% before pre sowing irrigation + 50% at 45DAS	98.5	1038.6	539.9	9.7	29.1	45.2	22.2	4.45	6.77	39.8
50% before pre sowing irrigation + 25% at 25 DAS + 25% at 65 DAS	104.4	1057.0	593.9	10.0	30.5	46.0	17.4	4.79	7.33	39.5
SEm±	1.2	14.5	9.5	0.06	0.31	1.09	0.6	0.08	0.19	0.5
CD (P=0.05)	2.6	36.2	23.4	0.15	0.75	NS	1.4	0.19	0.44	1.2

1000-grain weight was observed under the three splits of nitrogen as compared to two equal splits and whole nitrogen at sowing. These findings were in line with those of Munir and Shatanawi (2001), reported that application of nitrogen in three splits increased the spike number. The higher number of fertile tillers with split application of nitrogen might be due to easy availability of nitrogen during the growth period. However, Roy and Singh (2006) reported that three splits applications of nitrogen gave highest number of ears, ear length, number of grains and test weight as compared to one or two splits.

The grain yield of malt barley significantly enhanced as the sowing was delayed from 20 October to 10 November. However, the maximum grain yield was recorded from 10th November sown crop, which was significantly higher than 30 October and 20 October sown crop (Table 1). The lowest grain yield in early sown crop might be due to severe lodging during reproductive stage. These results are in conformity with those of Porwal *et al.*, (1991), reported that 31 October sown crop gave less grain yield as compared to 15 November sown crop. Late sowing of barley (15 December) gave lower yield as compared to 15 November sown crop due to the lower ear head, plant height, number of grains/ear, 1000-grain (Patel *et al.*, 2004). The maximum lodging was recorded when crop was sown on 20 October, which was significantly higher than 30 October and 10 November sown crop. The grain yield of 10 November sown crop was higher due to higher number of effective tillers, number of grains and grains weight. The maximum straw yield obtained from 20 October sown crop, which was statistically at par with 30 October sown crop and significantly higher than 10 November sown crop.

The grain yield, lodging percentage and straw yield significantly differed with different levels of nitrogen. The maximum grain yield was obtained with 93.75 kg N/ha, which was statistically at par with 78.5 kg N/ha and significantly higher than 62.5 kg N/ha (Table 1). The highest straw yield was obtained with 93.75 kg N/ha, which was significantly higher than 78.5 and 62.5 kg N/ha. The similar results were reported by Singh *et al.* (2001), reported that the increasing levels of nitrogen significantly increased growth, yield attributes and yield of malt barley up to the highest level of 90 kg/ha. The maximum grain and straw yield was obtained with nitrogen applied in three splits, which was significantly higher than two equal splits and single application (Table 1). This might be ascribed to better growth and development of barley crop in three and two splits than whole of nitrogen application before pre sowing irrigation. Elmobarak *et al.* (2007) reported that split application of N gave the higher grain yield. However, Roy and Singh (2006) reported that three splits applications of nitrogen gave significantly higher grain yield and straw yield as compared to one or two splits.

The interaction effects of nitrogen levels and time of application were significant. The application of 93.75 kg N/ha in three splits (S_3) gave significantly higher grain yield, which was statistically at par with 93.75 kg N/ha applied in two splits and 78.5 kg N/ha applied in three splits (S_3) and significantly higher than all other treatments (Table 2).

The harvest index of malt barley was significantly influenced by sowing the crop at different dates. The maximum harvest index was recorded in 10 November sown crop, which was significantly higher than 20 October and 30 October sown crop (Table 1). The harvest index varied significantly with different doses of N. The highest harvest index was obtained with 62.5 kg N/ha, which was signifi-

Table 2. Interaction effect of nitrogen levels and time of application on grain yield and malt yield (t/ha) of barley (Mean of 2 years)

Treatment	kg N/ha			Mean
	62.5	78.5	93.75	
Stage of N application		*Grain yield (t/ha)*		
Full before pre sowing irrigation	3.42	3.83	3.82	3.69
50 % before pre sowing irrigation + 50 % at 45 DAS	3.93	4.47	4.95	4.45
50% before pre sowing irrigation + 25% at 25 DAS +25% at 65 DAS	4.30	5.00	5.07	4.79
Mean	3.89	4.43	4.61	-
SEm±		0.13		
CD (P=0.05)		0.32		
Stage of N application		*Malt yield (t/ha)*		
Full before pre sowing irrigation	2.91	3.08	3.01	3.00
50 % before pre sowing irrigation + 50 % at 45 DAS	3.31	3.66	4.01	3.66
50% before pre sowing irrigation + 25% at 25 DAS +25% at 65 DAS	3.55	4.21	4.16	3.97
Mean	3.26	3.64	3.73	-
SEm±		0.13		
CD (P=0.05)		0.33		

cantly higher than 78.5 and 93.75 kg N/ha. However, it was also differed significantly with nitrogen application at different stages. Whereas, the higher harvest index was obtained with nitrogen application in three splits, which was significantly higher than two splits and single. The higher grain and straw yield of barley was due to higher yield attributes with the application of 93.75 kg N/ha in three splits due to the advantage of nitrogen application at boot stage as compared to tillering stage.

The maximum lodging was recorded when crop sown on 20 October, which was significantly higher than 30 October and 10 November sown crop. Similar findings were reported that sowing too early will increase the potential for disease problems and lodging by Barr (2002). The lodging increased with increment of each nitrogen dose. The maximum lodging was recorded with the application of 93.75 kg N/ha, which was significantly higher than 78.5 and 62.5 kg N/ha (Table 1). Nitrogen application at different stages influenced lodging in barley. Single application of nitrogen recorded the maximum lodging, which was significantly higher than nitrogen applied in two and three splits. Thompson *et al*. (2004) reported that additions of N fertilizer may cause lodging and increase grain protein above desirable levels.

Quality of grain

The grain hardiness and husk content were not varied but kernel plumpness, protein and starch were differed statistically with the dates of sowing. The highest kernel plumpness and starch content were recorded in the late sown crop on 10 November which was significantly higher than the crop sown on 20 October (Table 3). However, the values were similar under October sown crop. The lowest kernel plumpness in October sown crop was mainly due to severe lodging. The protein content in the grains was highest and significantly higher on 20 October than crop sown on 10 November but the crop sown on 30 October and 10 November had the similar protein content. The maximum grain hardiness and husk content were recorded in the early sown crop on 20 October as compared to late sown crop.

The grain hardness, husk content, protein and starch content varied with the nitrogen levels. The maximum grain hardness, husk content and protein content was observed with 93.75 kg N/ha, which was statistically at par with 78.5 kg N/ha and significantly higher than 62.5 kg N/ha (Table 3). Nitrogen level did not show significant impact on kernel plumpness. However, highest kernel plumpness was recorded with 62.5 kg N/ha followed by 78.5 and 93.75 kg N/ha. Clancy *et al.* (1991) reported that higher N level of 90 kg N/ha increased the grain protein and reduced percentage of plump kernels by 4%. The starch content decreased with each increment of nitrogen dose. The maximum starch content was obtained with 62.5 kg N/ha, which was significantly higher than 78.5 and 93.75 kg N/ha.

Nitrogen application at different stages showed significant differences in the grain hardness, husk content, protein and starch content (Table 3). The grain hardness, husk content and protein content were decreased with the split

Table 3. Effect of sowing dates, dose and time of nitrogen on quality characters of malt barley (Mean of 2 years)

Treatment	Grain hardness (kg)	Husk content (%)	Kernel plumpness (weight basis %)	Protein (%)	Starch (%)
Date of sowing					
20 October	13.3	10.8	83.4	11.2	61.2
30 October	13.1	10.7	84.1	10.6	62.2
10 November	13.1	10.6	86.0	10.3	63
SEm±	0.06	0.05	0.98	0.15	0.55
CD (P=0.05)	NS	NS	2.15	0.35	1.21
Nitrogen level (kg N/ha)					
62.5	12.9	10.5	84.8	10.2	63.8
78.5	13.2	10.7	84.6	10.8	62.3
93.75	13.9	10.9	84.1	11.2	60.2
SEm±	0.14	0,11	1.97	0.15	0.55
CD (P=0.05)	0.31	0.25	NS	0.35	1.20
Stage of N application					
Full before pre sowing irrigation	13.9	11.3	84.4	11.3	59.2
50 % before pre sowing irrigation + 50% at 45DAS	13.1	10.7	84.7	10.8	62.7
50% before pre sowing irrigation + 25% at 25 DAS + 25 % at 65 DAS	12.5	10.1	84.9	10.1	64.6
SEm±	0.16	0.15	1.99	0.09	0.78
CD (P=0.05)	0.35	0.35	NS	0.20	1.71

application of nitrogen. The highest protein content with single application of nitrogen might be due to severe lodging resulted in less plant height and dry matter accumulation. Similar findings were also reported by Singh *et al.* (2006). The highest these parameters were obtained with single application of nitrogen which was significantly higher than two and three splits. However, starch content was obtained highest with three splits which were significantly higher than two splits and single application. Whereas, the kernel plumpness did not vary with the nitrogen application at different stages in splits but slightly higher with three splits than two and single split.

Malt quality parameters and yield

Significant differences in diastatic power, a-amylase activity, malt recovery and malt yield were exhibited with different dates of sowing (Table 4). Maximum stirring number i.e. minimum α-amylase activity and diastatic power of grain was recorded highest from the crop sown on 20 October, which was significantly higher than 30 October and 10 November sown crop and the values under the later dates of sowing also differed significantly. Similar trend was observed in diastatic power as well as in malt yield of barley. The reverse trend was observed in case of malt recovery. The lowest malt recovery was recorded in the early sown crop of 20 October, which was significantly lower than 30 October and 10 November sown crop; however the malt recovery was at par in 30 October and 10 November sown crop. It was due to higher protein content in the grains in the early sown crop on 20 October than the crop sown on 30 October and 10 November had the similar protein content. It shows negative relationship with the protein content.

Nitrogen doses significantly influenced the a-amylase activity, diastatic power and malt yield of barley (Table 4). The a-amylase activity and malt yield significantly increased with 93.75 kg N/ha, was at with 78.5 kg N/ha and significantly higher than 62.5 kg N/ha. This might be due to better growth, improved yield attributing characters and higher grain yield of barley. Clancy *et al*. (1991) reported that higher N level of 90 kg/ha significantly increased a-amylase by 25 % and diastatic power by 15%, while malt extract was unaffected. The highest diastatic power was obtained with 93.75 kg N/ha which was statistically more than that obtained with 78.5 and 62.5 kg N/ha. However, kernel plumpness did not vary with nitrogen levels. Verma *et al.* (2003) reported that increase in the nitrogen levels increased the diastatic power at 90 kg N/ha. However, the reversed trend was observed in malt recovery, the highest malt recovery was recorded with 62.5 kg N/ha, was at par with 78.5 kg N/ha and significantly higher than 93.75 kg N/ha. It shows negative relation with the application of N.

Table 4. Effect of sowing dates, dose and time of nitrogen on malt quality parameters, malt recovery and malt yield (Mean of 2 years)

Treatment	α-amylase activity (SN)	Diastatic power (mg maltose per 10g)	Malt recovery (%)	Malt yield (t/ha)	Steeping losses (%)	Respiration losses (%)	Root losses (%)
Date of sowing							
20 October	33.9	445.9	78.6	3.09	0.99	16.05	3.74
30 October	32.6	408.3	83.3	3.57	0.98	11.81	3.89
10 November	31.1	385.4	84.2	3.97	0.95	10.72	4.12
SEm±	0.41	4.5	0.9	0.11	0.009	0.88	0.08
CD(P=0.05)	0.95	10.4	2.0	0.26	NS	1.93	0.17
Nitrogen level (kg N/ha)							
62.5	31.6	399.8	83.8	3.26	0.94	11.10	4.10
78.5	32.5	413.6	81.8	3.64	0.97	13.24	3.88
93.75	33.4	426.1	80.4	3.73	1.0	14.83	3.76
SEm±	0.41	4.5	0.9	0.11	0.02	0.87	0.08
CD(P=0.05)	0.95	10.4	2.0	0.26	0.04	1.91	0.17
Stage of N application							
Full before pre sowing irrigation	37.3	480.9	81.2	3.00	1.02	14.20	3.51
50% before pre sowing irrigation + 50% at 45 DAS	33.4	425.5	82.1	3.66	0.98	12.96	3.95
50% before pre sowing irrigation + 25% at 25 DAS + 25 % at 65 DAS	26.8	333.1	82.8	3.97	0.89	12.02	4.28
SEm±	0.65	2.2	0.48	0.06	0.011	0.57	0.07
CD(P=0.05)	1.5	4.9	1.05	0.15	0.025	1.25	0.16

SN-Higher the stirring number (SN) lower the α-amylase activity

The interaction effects of nitrogen levels and time of application were significant. The significantly higher malt yield was recorded with the application of 93.75 kg N/ha in three splits (S_3) which was statistically at par with 93.75 kg N/ha applied in two splits and 78.5 kg N/ha applied in three splits (S_3) and significantly higher than all other treatments (Table 2).

The nitrogen application at different stages in barley, however, evinced the impact on α-amylase activity, diastatic power, malt recovery and malt yield (Table 4). The highest diastatic power and α-amylase activity was obtained with single application, which was significantly higher than two splits and three splits. However, kernel plumpness did not vary with split nitrogen. This might be ascribed to better growth and development of crop with split application of nitrogen. These results were in conformity with those of Singh *et al* (2006). The maximum malt recovery received with the three splits which was at par with two splits and significantly higher than single split. The lower malt recovery of barley with single application of nitrogen was due to higher protein content and severe lodging of crop. The malt yield obtained with three splits, which was statistically higher than two splits and single application. The higher yield of malt with split application of nitrogen might be ascribed to better growth, lesser lodging, lesser protein content, improved yield attributing characters and higher grain yield of barley.

Steeping losses during malting were not varied due to dates of sowing. But the respiration and root losses were significantly affected by the dates of sowing (Table 4). Maximum respiration losses during malting were observed under the 20 October sown crop which was significantly higher than that 30 October and 10 November sown crop and the differences in respiration losses among the 30 October and 10 November sown crop were non-significant. The reversed trend was observed in root losses. The maximum root losses were recorded in the crop sown on 10 November, which was significantly higher than the October sown crop and the values of root losses were similar under October sown crop. The steeping and respiration losses increased with each increment of nitrogen dose. The highest steeping and respiration losses were obtained with 93.75 kg N/ha, which were statistically at par with 78.5 kg N/ha and significantly higher than 62.5 kg N/ha. The maximum root losses were obtained with 62.5 kg N/ha, which were significantly higher than 78.5 and 93.75 kg N/ha. The maximum steeping and respiration losses were observed with single application, which were significantly higher than two and three splits. The maximum root losses were recorded with three splits, which were significantly higher than two splits and single application. Singh *et al.* (1974) reported that application of full dose of nitrogen at the time of sowing keeps the nitrogen content and all other malting parameters within the desirable limit. They further reported that split application though improved the grain yield to some extent but detrimental to malting quality.

It can be concluded that for higher malt yield and recovery, malt and grain yield, barley crop can be sown on 10 November with the application of 78.5 kg N/ha in three splits-half nitrogen before pre sowing irrigation, 1/4 at tillering stage and 1/4 at boot stage.

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