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Research Paper

Effect of sowing methods, nitrogen levels and irrigation scheduling on yield and quality of malt barley (*Hordeum vulgare* L.)

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ABSTRACT

A field experiment was conducted during *rabi,* 2006-07 and 2007-08 to study the effect of methods of sowing, nitrogen levels and irrigation scheduling on production and quality of malt barley (*Hordeum vulgare* L.). The study revealed that plant height, dry matter accumulation, effective tillers, grains/ear, 1,000-grains weight and grain and straw yields were statistically at par with different method of sowing. Similar trend was also observed for grain quality, malt quality, recovery and yield of malt. Grain, straw and malt yields increased significantly with an increase in N level from 75 to 125% of recommended dose as a result of increase in plant height, dry matter accumulation, effectives tillers, grains/ear and 1,000-grains weight. The highest grain (5.0 t/ha) and malt yield (3.98 t/ha) were obtained with 125% of recommended N, which was statistically at par with 100% of recommended N and significantly higher than 75% of recommended N. Irrigation at 1.00 IW/CPE ratio significantly increased plant height, dry matter accumulation, effective tillers, grains/ear, 1,000-grains weight, grain yield (5.3 t/ha) and straw yield (7.35 t/ha) as compared to 0.75 and 0.50 IW/CPE ratio. Similar trend was also observed for recovery and yield of malt. N, P and K uptake was also not-significantly affected by methods of sowing, while increase in N levels and IW/CPE ratio significantly increased NPK uptake by malt barley.

Key words : Irrigation schedule, Malt barley, Nitrogen levels, Protein, Sowing methods, Starch

Barley is a hardy crop, which is grown throughout the temperate, tropical and sub tropical regions of the world. It 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 for brewing, baby foods, coca malt drinks and ayurvedic medicines. It is preferred over other cereals for malting purpose because of its glumes and hulls are firmly cemented to the kernel and remain attached to the grain after threshing. The hull protects the coleoptile from damage during processing, as it grows and elongates under the hull. The hull also acts as a filter for separation of soluble materials. Processing of barley grain for malting largely depends upon several quality parameter like protein and starch content in grain, time taken for germination, uniformity in grain size, husk content, 1,000 kernel weight and kernel plumpness. Agronomic practices influence the yield, protein content and other quality parameters of barley grain which have direct bearing on the malt quality. The agronomic practices for malt grade barley are different from its grain crop. Methods of sowing, nitrogen levels and irrigation greatly affect the yield and malt quality of barley. Tillage methods have a major influence on aeration, moisture and temperature of soil which in turn affect the yield and quality of crop. The barley sown by different methods (flat, bed and FIRBS) had no significance effect on grain yield of malt barley (AICW&BIP 2004), but beneficial effects have been reported in wheat (Singh *et al* 2009). Nitrogen is the most important element for realising potential yield of crops, but it increases protein content in grain which is undesirable for brewing (Verma *et al.* 2003). Thus, optimum application of nitrogen is a pre-request for production of malt barley. Soil moisture is another factor which influences the yield and quality of barley. For example in a study protein content in barley decreased with increase in moisture level (Grant *et al.*, 1991). In another study malting quality of barley was reduced due to water stress at grain filling stage (Smith and Gyles 1988). Keeping in view the above facts, a study on effect of methods of sowing, nitrogen levels and irrigation scheduling on yield and quality of malt barley was conducted under Punjab conditions.

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MATERIALS AND METHODS

The field experiments were carried out at Student's farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* season of 2006-07 and 2007-08. Ludhiana is situated at 30^o 56' N latitude, 75^o 52' E longitude and altitude of 247 m above mean sea level (amsl). The soil of experiment field was loamy sand in texture with normal soil reaction and electrical conductivity, low in organic carbon and available nitrogen, medium in available phosphorus and potassium. Treatments comprised of three sowing methods [furrow irrigation raised bed (FIRB), flat bed zero tillage (FBZT) and flat bed conventional tillage (FBCT)], three nitrogen levels (75, 100, and 125% of recommendation)and three irrigation schedules (0.50, 0.75 and 1.00 IW/CPE). The recommended dose of nitrogen is 62.5 kg/ha. Experiment was laid out in split-plot design with three replications. A uniform basal dose of 30 kg P_2O_5/ha in the form of super phosphate and 15 kg K_2O/ha in the form of murate of potash were applied before sowing. Nitrogen was applied at the time of sowing as per treatment in the form of urea. The field was ploughed twice with a tractor drawn disc harrow and twice with a cultivator followed by planking except in zero till plots. In zero and conventional tillage plots sowing were done with single row cotton drill at a row spacing of 22.5cm. Barley was sown on 23rd October in 2006-07 and 25th October in 2007-08. In bed planting method sowing were done with tractor operated wheat bed planter which enables sowing of two barley rows 22.5 cm apart on each bed. Irrigations were given as per treatment of IW/CPE schedules. Growth parameters (plant height and dry matter) were recorded at the interval of 30 days. Average plant height of 10 tagged plants in the plot was recorded in cm. Dry matter accumulation in the above ground parts was recorded from one meter row length and then converted into g/m^2.Crop was harvested on 24 and 28 March respectively during 2006-07 and 2007-08 and threshed with the help of a thresher. The grain and straw yield of net plot was converted into tonnes/ha. The yield attributes (effective tillers per m^2, grains/ear and 1,000-grains weight) were recorded at harvest. The harvest index was calculated on the basis of economic and biological yield. Plumpness of barley kernels was determined by the method suggested by ASBC (1992). One kg of grains was taken and sieved through 1.9 × 0.24 mm sieve. The grains retained on the sieve were weighed and expressed as per cent plumpness (w/w). The grains hardness was measured using the hardness tester supplied by Kiya Seisakusho Ltd., Japan. Ten grains at random from the lot were crushed individually on the instrument and the average force required to crack the grains was recorded in kgs. The test weight was measured using the test weight apparatus designed by Directorate of Wheat Research, Karnal. The instrument uses 100 ml volume of the grain. Weighing of measured quantity of grains gives the value in kilogram/ hectoliter (kg/hl) (DWR 1998). Protein and starch content were analyzed using automatic whole grain analyzer (Infratech-1241) manufacture 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. Malt quality parameters such as diastatic power and α-amylase activity were analyzed as per the procedure suggested by AOAC (1990) and Perten (1966), respectively. Malting of barley grains were carried out as per the method suggested by Singh and Sosulski (1985). N, P and K (kg/ha) uptake by grain and straw of barley were estimated at harvest stage. The husk content (%) was determined by using following formulae:

$$\text{Husk content (\%)} \quad \frac{\text{Dry weight of husked barley - Dry weight of dehusked barley}}{\text{Dry weight of husked barley}}$$

RESULTS AND DISCUSSION

Growth characters

Plant height and dry matter accumulation is an important index for assessment of crop performance. The increase in plant height and dry matter accumulation was slow up to 60 days after sowing (DAS) and thereafter it increased tremendously from 60 to 120 DAS and thereafter there was negligible accretion in these growth parameters until harvest. The methods of sowing did not influence the plant height and dry matter accumulation of barley at harvest stage (Table 1). Legere *et al.* (1997) reported statistically similar plant height and dry matter accumulation of spring barley under different tillage methods. Plant height and dry matter accumulation of barley increased with each increment of nitrogen level from 75 to 125% of recommendation. At harvest maximum plant height and dry matter accumulation were recorded with 125% of recommended N as compared to 75 and 100% of recommended N. Moreno *et al.* (2003) reported maximum plant height and dry matter accumulation of barley with 120 kg N/ha as compared to lower doses. Irrigation schedules influenced the plant height and dry matter accumulation of barley. At harvest, irrigation scheduling with 1.00 IW/CPE ratio produced significantly taller plants and more dry matter accumulation than other irrigation schedules. Increase in plant height and dry mater accumulation at 1.00 IW/CPE ratio was mainly due to frequent irrigations and more availability of water throughout the crop season and thus no water stress occurred. Elmobarak *et al.* (2007) reported that application of irrigation every 10 days gave significantly higher plant height and dry matter accumulation than irrigation applied every 20 days.

Yield attributes and yield

Methods of sowing did not significant affect effective tillers, grains per ear and 1000 grains weight in malt barley (Table 1). The nitrogen levels in barley manifested significant impact on number of effective tillers, number of grains/ear and 1,000-grains weight. Highest number of ear bearing tillers and grains/ear were obtained with application of 125% of recommended N, which were significantly higher than 100 and 75% of recommended N. Highest 1,000-grains weight was obtained with application of 125% of recommended N, which was statistically at par with 100% of recommended N and significantly higher than 75% of recommended N. Singh and Singh (2005) at Varanasi also reported a significant increase in effective tillers, 1,000-grains weight and grains/ear with an increase in doses of nitrogen from 20 to 80 kg /ha. Irrigation schedules showed significant impact on number of effective tillers, number of grains/ear and 1,000-grains weight. The highest number of effective tillers and number of grains/ear were recorded with 1.00 IW/CPE ratio, which was significantly higher than 0.75 and 0.50 IW/CPE ratio. Highest 1,000-grains weight was obtained with 1.00 IW/CPE ratio, which was statistically at par with 0.75 IW/CPE ratio and significantly higher than 0.50 IW/CPE ratio. At 1.00 IW/CPE ratio more plant height and dry mater accumulation was observed which ultimately increased effective tillers, number of grains/ear and 1,000-grains weight.

Methods of sowing failed to show any significant affect on the grain yield of barley. The highest grain yield was recorded with FBZT followed by FBCT and FIRB planted crop (Table 1). The maximum lodging was found in FIRB planted crop followed FBCT and lowest in FBZT crop. Due to which maximum effective tillers, grains/ear and 1,000-grains weight was found in FBZT crop, which ultimately result in higher yield than FIRB and conventional tillage FBCT crop. The grain yield increased with each increment of nitrogen dose. The highest grain yield was obtained with 125% of recommended N which was statistically at par with 100% of recommended N and significantly higher than 75% of recommended N. The increased grain yield with 125% of recommended N was mainly due to more dry matter accumulation, effective tillers, grains/ear and 1,000-grains weight of malt barley. These results are in conformity with those of Moreno *et al* (2003) and Liben *et al* (2011). Irrigation schedules significantly affected the grain yield of malt barley. Highest grain yield was obtained with 1.00 IW/CPE ratio, which was significantly higher than 0.75 and 0.50 IW/CPE. This might be due to better growth and development of barley crop under 1.00 IW/CPE ratio. Sowing methods failed to affect the straw yield significantly. The highest straw yield was

Table 1. Effect of methods of sowing, nitrogen levels and irrigation scheduling on growth parameters, yield attributing characters, harvest index, grain and straw yield of malt barley (data pooled over 2 years)

Treatment	Plant height (cm) At harvest	Dry matter (g/m^2) At harvest	Effective tillers (No/m^2)	Grains/ear	1,000-grains weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Sowing methods								
FIRB	88.9	867.5	453.7	27.1	45.2	4.3	5.8	42.3
FBZT	91.2	919.1	487.4	28.2	47.3	4.6	6.1	43.1
FBCT	95.1	954.6	468.3	27.4	46.2	4.4	6.4	40.8
SEm±	1.4	12.5	6.15	0.4	0.5	0.05	0.16	0.55
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (% of RDF)*								
75	86.2	855.4	411.0	24.3	44.6	3.8	5.2	42.5
100	91.6	918.1	475.5	28.2	46.6	4.5	6.2	42.1
125	97.4	967.6	519.0	30.3	47.6	5.0	6.9	42.8
SEm±	2.0	14.1	7.8	0.45	0.9	0.09	0.23	0.35
CD (P=0.05)	5.1	42.0	25.3	1.25	2.2	0.3	0.6	NS
Irrigation scheduling (IW/CPE ratio)								
0.50	85.1	833.1	371.2	21.8	45.0	3.6	4.6	43.1
0.75	92.0	929.0	467.8	27.9	46.2	4.4	6.2	41.3
1.00	98.2	979.1	566.4	33.1	47.6	5.3	7.4	42.0
SEm±	1.0	12.8	6.9	0.35	0.85	0.06	0.20	0.65
CD (P=0.05)	3.4	35.8	18.75	1.13	1.95	0.2	0.45	NS

RDF-Recommended dose of fertilizer; *62.5 kg/ha; FIRB-furrow irrigated raised bed; FBZT- flat bed zero tillage; FBCT- flat bed conventional tillage obtained from FBCT, which was significantly higher than FBZT and FIRB planted crop. The highest straw yield in FBCT sown crop was due to more plant height and dry matter accumulation. The straw yield increased with each increment of nitrogen dose during both the years. The highest straw yield was obtained with 125% of recommended N, which was significantly higher than 100 and 75% of recommended N. The highest straw yield with 125% of recommended N was due to more plant height and dry matter accumulation. These findings were in conformity with those of Singh and Singh (2005). Irrigation schedules significantly affected the straw yield. The highest straw yield was obtained with 1.00 IW/CPE ratio which was significantly higher than 0.75 and 0.50 IW/CPE ratio. The highest harvest index was observed in FBZT followed by FIRB and FBCT crop. The highest harvest index with FBZT plot followed by FIRB and FBCT was due to more grain yield. The variable nitrogen levels and irrigation schedules did not significantly influence harvest index of malt barley.

Grain quality characters

Methods of sowing failed to influence significantly the test weight, kernel plumpness, grain hardness, protein and husk content of malt barley grain. Nevertheless the highest test weight and kernel plumpness were obtained with FBZT sowing (Table 2). This was mainly due to less lodging in FBZT sown crop as compared to other methods of sowing. The hardness, protein and husk content of grain were the highest in FIRB planted crop followed by FBCT and FBCT sowing. Methods of sowing significantly influenced the starch content in barley. The highest starch content was observed in FBZT followed by FBCT and FIRB planted crop. Abiotic stress due to more lodging increased protein content while it decreased starch content (Wallwork *et al* 1998). The grain hardness, husk content, protein content and test weight increased with each increment of nitrogen dose. The highest grain hardness and husk content were observed with 125% of recommended N; statistically at par with 100% of recommended N and significantly higher than 75% of recommended N. The highest protein content and test weight were obtained with 125% of recommended N; significantly higher than 100 and 75% of recommended N. The increased grain hardness with higher levels of nitrogen has been reported by Weston *et al.* 1993. Nitrogen levels did not show significant impact on kernel plumpness and starch content. Although highest kernel plumpness and starch was found with 75% of recommended N followed by 100 and 125% of recommended N. These findings are in conformity with those of Weston *et al* (1993). Irrigation scheduling significantly influenced the grain hardness and husk and protein content. The highest grain hardness and husk and protein content were observed with 0.50 IW/CPE ratio, which was

Table 2. Effect of methods of sowing, nitrogen levels and irrigation scheduling on quality characters of grain, malt quality parameters, recovery and malt yield of malt barley(data pooled over 2 years)

Treatment	Grain hardness (kgs)	Test weight (kg/hl)	Husk content (%)	Kernel plumpness (%)	Protein (%)	Starch (%)	α-amylase activity (SN)	Diastatic power (mg maltose/10 g)	Malt recovery (%)	Malt yield (t/ha)
Sowing methods										
FIRB	12.7	60.5	10.9	83.9	10.5	60.7	34.5	419.4	80.6	3.48
FBZT	12.5	61.2	10.7	85.2	10.1	61.2	33.7	409.2	82.6	3.78
FBCT	12.5	60.6	10.7	84.1	10.4	61.0	34.0	417.6	81.8	3.62
SEm±	0.06	0.25	0.07	0.2	0.05	0.02	0.19	4.0	0.4	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (% RDF)*										
75	12.3	59.4	10.6	85.3	9.9	62.0	33.2	403.1	83.4	3.24
100	12.6	61.1	10.8	84.4	10.3	61.1	34.2	413.4	81.3	3.68
125	13.0	61.6	11.0	83.5	10.8	59.8	35.2	429.8	80.1	3.98
SEm±	0.03	0.08	0.08	0.02	0.05	0.06	0.2	3.8	1.0	0.10
CD (P=0.05)	NS	0.1	0.2	NS	0.3	NS	1.5	11.6	NS	0.20
Irrigation scheduling (IW/CPE ratio)										
0.50	13.5	59.1	11.5	83.4	11.2	59.3	28.4	348.1	78.6	2.76
0.75	12.5	60.5	10.7	84.4	10.2	61.3	35.3	426.4	82.4	3.67
1.00	11.8	62.6	10.1	85.4	9.6	62.3	38.4	471.7	83.9	4.44
SEm±	0.2	0.4	0.06	0.05	0.05	0.4	0.6	5.2	0.2	0.03
CD (P=0.05)	0.5	1.9	0.3	0.4	0.2	1.7	1.7	15.4	1.0	0.16

RDF- Recommended dose of fertilizer; *62.5 kg/ha; FIRB-furrow irrigated raised bed; FBZT- flat bed zero tillage; FBCT- flat bed conventional tillage; SN-Stirring number significantly higher than 0.75 and 1.00 IW/CPE ratio. The highest protein content and grain hardness with 0.50 IW/CPE ratio might be due to moisture stress at grain filling stage. Irrigation schedules in barley significantly influenced the test weight, kernel plumpness and starch content in malt barley grains. The highest test weight and kernel plumpness were obtained with 1.00 IW/CPE ratio, which were significantly higher than 0.75 and 0.50 IW/CPE ratio. Irrigation schedules significantly influenced the starch content in malt barley grain. The highest kernel plumpness and starch content were obtained with 1.00 IW/CPE ratio, which was statistically at par with 0.75 IW/CPE ratio and significantly higher than 0.50 IW/CPE ratio. Verma *et al* (2003) also documented the improvements in grain quality with more irrigation.

Malt quality parameters

Method of sowing had no significant affect on α-amylase activity and diastatic power of barley malt. Nevertheless highest α-amylase activity and diastatic power were obtained with FIRB planted crop followed by FBCT and FBZT crop (Table 2). Methods of sowing had no significant influence on recovery and yield of malt. Nevertheless the highest malt recovery and yield was obtained with FBZT crop followed by FBCT and FIRB planted crop. Nitrogen doses significantly influenced the α-amylase activity and diastatic power of barley malt. The highest α-amylase activity was obtained with 125% of recommended N, which was statistically at par with 100% of recommended N and significantly higher than 75% of recommended N. The highest diastatic power was obtained with 125% of recommended N which was significantly higher than 100 and 75% of recommended N. The malt recovery decreased with each increment of nitrogen dose. The highest malt recovery was obtained with 75% of recommended N which was significantly higher than with 100 and 125% of recommended N. The higher nitrogen levels produced higher protein content in grain which is undesirable for malt recovery as malt extract is inversely related to grain protein content (Verma *et al* 2003). However, the malt yield increased with each increment of nitrogen dose. The highest malt yield was obtained with 125% of recommended N which was significantly higher than with 100 and 75% of recommended N. This was mainly due to higher grain yield which compensated the lower malt recovery with 125% of recommended N. Irrigation schedules in barley significantly influenced the α-amylase activity, diastatic power, recovery and yield of malt. The highest α-amylase activity, diastatic power, recovery and yield of malt were obtained with 1.00 IW/CPE ratio, which were significantly higher than 0.75 and 0.50 IW/CPE ratio. The lower malt recovery in 0.50 IW/CPE ratio resulted from higher protein content due to water stress. Verma *et al* (2003) reported improvements in malting quality and production with irrigation.

Table 3. Effect of methods of sowing, nitrogen levels and irrigation scheduling on nutrients uptake (kg/ha) by grain and straw of malt barley (data pooled over 2 years)

Treatment	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
Sowing methods						
FIRB	71.8	19.8	7.8	11.8	22.6	87.3
FBZT	73.0	20.0	7.9	12.4	23.4	90.0
FBCT	73.1	21.6	8.0	13.7	22.2	95.7
SEm±	0.8	0.5	0.01	0.4	0.35	3.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nitrogen levels (% RDF)*						
75	60.6	16.5	6.3	10.8	19.2	74.4
100	73.2	20.8	8.3	13.1	23.1	92.2
125	84.1	23.6	9.3	13.7	26.0	106.1
SEm±	2.1	0.7	0.3	0.3	0.3	3.6
CD (P=0.05)	6.2	2.2	1.0	1.0	1.4	10.3
Irrigation scheduling(IW/CPE ratio)						
0.50	63.1	16.6	6.6	9.5	19.6	75.3
0.75	72.9	21.3	7.7	12.8	22.5	92.0
1.00	81.9	23.6	9.2	15.5	26.3	105.7
SEm±	1.3	0.5	0.3	0.3	0.5	3.2
CD (P=0.05)	3.8	1.6	1.0	0.7	1.4	8.0

RDF-Recommended dose of fertilizer; *62.5 kg/ha; FIRB-furrow irrigated raised bed; FBZT- flat bed zero tillage; FBCT- flat bed conventional tillage

Nutrients uptake

Nutrients uptake (N, P and K) by malt barley (grain and straw) was not significantly affected by different methods of sowing (Table 3). Nitrogen and potassium uptake by grain and straw of malt barley were significantly increased with increase in nitrogen levels. The highest nitrogen and potassium uptake by grain and straw of malt barley were observed with 125% of recommended N; were significantly higher than that obtained with 100 and 75% of recommended N. Phosphorus and potasium uptake by grain and straw was increased significantly with increase in nitrogen levels. Nitrogen, phosphorus and potassium uptake by grain and straw of malt barley were significantly influenced by irrigation schedules. The highest uptake of nitrogen, phosphorus and potassium by grain and straw of malt barley was observed with 1.00 IW/CPE ratio, which was significantly higher than 0.75 and 0.50 IW/CPE ratio irrigation schedules.

Thus it is concluded that methods of sowing did not influence yield and quality, while increased nitrogen levels and irrigation ratio improved productivity and quality of malt barley.

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