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Research Paper

Yield and quality of malt barley (*Hordeum vulgare*) as influenced by irrigation, nitrogen and methods of sowing

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ABSTRACT

A field experiment was conducted at Ludhiana during *rabi* season of 2006-07 and 2007-08 to find out method of sowing, irrigation and nitrogen for higher malt and grain yield of barley (*Hordeum vulgare* L.). The experiment was carried out in split plot design with three methods of sowing [bed planting (BP), zero tillage (ZT) and conventional tillage (CT)] and three levels of nitrogen (46.9, 62.5 and 78.5 kg N/ha) in main plots and three irrigation schedules (0.50, 0.75 and 1.00 IW:CPE ratio) in sub plots. The results of average of two years revealed that the highest grain yield was recorded from ZT crop followed by CT and BP. Grain yield of ZT crop was 3.4 and 6.0% higher than CT and BP. The highest grain yield was obtained with 78.5 kg N/ha, which was significantly higher than 62.5 and 46.9 kg N/ha. Grain yield with the application 78.5 kg N/ha was 9.8% higher than 62.5 kg N/ha and 28.3% higher than 46.9 kg N/ha. Maximum stirring number i.e. minimum a-amylase activity and diastatic power was obtained under BP crop, 78.5 kg N/ha and 1.0 IW:CPE ratio. The highest malt recovery and yield was obtained with ZT followed by CT and BP. The highest malt recovery and yield was obtained with 46.9 and 62.5 kg N/ha, respectively and both were obtained the highest with 1.00 IW: CPE ratio. The interaction effects showed that irrigation at 1.00 IW: CPE ratio with 78.5 kg N/ha gave significantly more grains and malt yields.

Key words : Grain yield, Irrigation schedule, Malt barley, Methods of sowing, Nitrogen

Barley has the widest ecological range of adaptation among the cereals, which is grown throughout the temperate and tropical regions of the world. It has low cost of production and input requirement, so it is preferred by the resource poor farmers in the country. Barley grains are considered for valuable input for industries for extracting malt to be utilized in brewing, distillation, baby foods, cocoa malt drinks and aryuvedic medicines. Its straw is a good quality fodder for livestock (Meena *et al*., 2012). Barley is preferred over other cereals for malting purpose because its glumes and hulls are firmly cemented to the kernel, which remain attached to the grain after threshing. Hull protects the coleoptile from damage during processing, as coleoptile grows and elongates under the hull. Hull acts as a filter for separation of soluble materials. Kernel texture of steeped barley is also somewhat firmer than that of wheat and rye. Processing of barley grain for malting largely depends upon several factors *viz.* protein content of the grain, time taken for germination, uniformity in grain size, husk content, 1,000 kernel weight and kernel plumpness *etc.* High protein content in grain is undesirable, because malt extract is inversely related to grain protein content (Verma *et al.*, 2003).

Different management practices influence the productivity, protein content and other quality parameters, which have direct bearing on the malt quality of barley grain. The agronomic practices for malt grade barley are altogether different from its grain crop. Amongst these, methods of sowing, irrigation and nitrogen levels greatly affect the yield and malt quality of barley. It is well documented that tillage has a major influence on soil aeration, moisture and temperature. Barley grain yield and 1000-grain weight were higher in zero tillage as compared to conventional tillage (Anonymous 2006). Cantero-Martinez *et al.*, (2003) obtained equal yield under semi-arid conditions, in tilled and no tilled plots. Study conducted at Agra, Durgapur, Hisar and Karnal on flat, bed sowing and FIRBS system showed no difference in grain yield of malt barley (Anonymous 2004). Nitrogen is the most important input for realizing potential yield of any crop as requirement for nitrogen is the highest among all the essential plant nutrients and this nutrient is most limiting under Indian conditions. Nitrogen is the main constituent of amino acids, which are precursor to protein. So, malt barley

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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. So, improper rates of nitrogen application may reduce grain yield and quality below the acceptable levels. Thus, there is need to standardise the methods of sowing, irrigations and nitrogen levels for barley grown for malt. These production factors are location specific as they get largely impacted by the agro-climatic conditions. Not much information is available with regard to different agronomic practices on the yield and quality of malt barley. So, keeping the above facts in view the present investigation on the effect of different agronomic practices on the yield and quality of malt barley (*Hordeum vulgare* L.) have been planned with the objectives to study the effect of method of sowing, irrigation and nitrogen on yield and quality of malt barley.

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, on soil loamy sand in texture having pH 7.9, low in available N, medium in available P and K (193, 20.5 and 218.5 kg/ha, respectively). The treatments of an experiment were evaluated in split-plot design with three replications. The main plots comprised of three methods of sowing (bed planting, zero tillage and conventional tillage) and three levels of nitrogen 46.9, 62.5 and 78.5 kg N/ha, while three irrigation schedules (0.50, 0.75 and 1.00 IW:CPE ratio) 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 for sowing the crop on furrow irrigated raised beds (FIRD) and conventional tillage plots. On beds, crop was sown by bed planter and in conventional tillage with traditional drill. Under zero tillage, crop was sown directly after harvesting the previous crop by giving pre sowing irrigation at optimum moisture. 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 5 cm. The barley crop was sown on 6 and 15 November during 2006-07 and 2007-08, respectively. The nitrogen was applied 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 gram 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 °C and again mixed by rotating flask until all flour in suspension after that placed in constant temperature on water bath at 30 °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° C.

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

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

Maltose equivalent (mg maltose per 10 g) = ml of Sodium thiosulphate used for (sample-blank) × 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°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 consisted 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 yield 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)

Mauslin 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

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

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

RESULTS AND DISCUSSION

Growth characters

The maximum emergence count was recorded with zero-tilled crop, which was statistically at par with conventional tillage but were significantly superior to bed planting (Table 1). However, bed planted crop took significantly more days for initiation and completion of emergence than zero tilled crop but statistically at par with conventional tillage. In bed planting, more number of days to emergence initiation and completion might be due to drying of upper most soil surface resulting from exposure to blowing air. However, delayed in emergence initiation and completion in bed planted barley resulted in less emergence count. Lower time taken for initiation and completion of emergence in zero tilled plots due to the placement of seed at the proper depth and moisture, which resulted in higher emergence count. The nitrogen levels and irrigation schedules showed non-significant impact on the emergence count. It could be due to the non-significant differences in the days taken for initiation and completion of emergence. It shows no beneficial effect of nitrogen and irrigation treatments on initiation and completion of emergence, which resulted in similar emergence count. These results were corroborated the findings of William (2005). Variable nitrogen levels and irrigation schedules did not show any significant impact on count and rate of emergence.

The highest plant height and dry matter accumulation was observed with conventionally tilled crop, which was statistically at par with zero-tilled and significantly higher than bed planted (Table 1). It was happened due to the delayed initiation and completion of emergence in bed planted crop. Ciha (1982) reported statistically similar plant height of spring barley under different tillage systems. Legere *et al.,* (1997) found comparable biomass production per unit area between zero tillage and conventional sowing of spring barley. The highest plant height and dry matter accumulation was recorded with 78.5 kg N/ha, which was significantly higher than 46.9 and 62.5 kg N/ha. It was due to the more availability of nitrogen at higher level as compared to the lower levels of nitrogen. Similar findings were reported by Sandhu (2006). He reported that dry matter accumulation increased significantly with the application of nitrogen up to 78 kg N/ ha. Singh *et al.,* (2001) also reported that the increasing levels of nitrogen significantly increased growth attributes of malt barley up to the highest level of nitrogen.

The highest plant height and dry matter accumulation was recorded with 1.00 IW:CPE, which was significantly higher than 0.75 IW:CPE ratio and 0.50 IW:CPE ratio (Table 1). It was happened due to more frequency of irrigation water which resulted in more availability of soil moisture for longer period. The similar results were recorded by Elmobarak *et al.,* (2007). They revealed that application of irrigation after every 10 days gave the highest plant height and dry weight, which was significantly more than irrigation applied after every 20 days. Singh *et al.,* (2001) also reported similar findings. They reported that application of two irrigations significantly increased the plant height and dry matter accumulation as compared to other treatments of irrigation. Wahab and Singh (1983) found that irrigation had significant favourable influence on dry matter accumulation in barley.

Yield attributing characters

The highest number of effective tillers, ear length, number of grains, grain weight, 1000-grain weight were observed in zero-tilled crop followed by conventionally tilled and bed planted crop (Table 1). It was happened as zero tillage provided the environmental and potential soil quality benefits to the crop (William *et al.* 1999). These results are in conformity with those of Cantero-Martinez *et al.* (2003). They reported that zero tillage achieved slightly, but not significantly greater yield contributing characters than the tilled treatments. Legere *et al.,* (1997) found that barley head density/m^2 and 1,000-grains weight under NT were comparable to those in a tillage system that includes mould board plough in the autumn, followed by spring secondary tillage. The nitrogen levels in barley manifested significant impact on number of effective tillers (Table 1). The highest number of ear bearing tillers, ear length, number of grains and grain weight were obtained with application of 78.5 kg N/ha, which were significantly higher than with 62.5 and 46.9 kg N/ha, However, the highest 1,000-grains weight was obtained with the application of 78.5 kg N/ha, which was statistically at par with 62.5 kg N/ha and significantly higher than 46.9 kg N/ha. Singh *et al.,* (1993) also reported significantly higher ear-bearing tillers with 80 kg N/ha as compared to 60 and 40 kg N/ha. Irrigation

Table 1. Effect of methods of planting, nitrogen levels and irrigation schedules on growth and yield attributes of malt barley (Pooled data of two years)

Treatment	Emergence /m^2	Initiation of emergence (days)	Complete emergence (days)	Plant height (cm)	Dry matter accumulation (g/m^2)	Effective tillers/m^2	Ear length (cm)	Grains/ ear	Grains weight (g/ear)	1,000-grains weight(g)
Methods of sowing										
BP	135.1	5.2	9.9	88.9	867.5	453.8	8.8	27.2	1.15	45.3
ZT	168.7	3.2	6.9	91.3	919.1	487.5	9.2	28.2	1.18	47.3
CT	159.8	4.4	9.5	95.1	954.7	468.3	9.1	27.5	1.16	46.2
SEm±	6.5	0.4	0.3	1.6	15.9	10.6	0.13	0.52	0.015	0.92
CD (P=0.05)	16.2	0.9	0.7	4.1	39.8	NS	NS	NS	NS	NS
Nitrogen (kg/ha)										
46.9	146.3	4.4	9.4	86.2	855.5	411.0	8.4	24.4	1.09	44.6
62.5	153.7	4.3	8.7	91.6	918.1	475.5	9.0	28.2	1.18	46.6
78.5	163.5	4.2	8.1	97.5	967.6	518.9	9.7	30.3	1.24	47.7
SEm±	6.5	0.4	0.3	1.6	15.9	10.6	0.13	0.52	0.015	0.92
CD (P=0.05)	NS	NS	NS	4.1	39.8	25.4	0.3	1.3	0.04	2.2
Irrigation Schedules (IW:CPE)										
0.50	159.0	4.3	8.7	85.1	833.1	371.2	8.6	21.8	1.10	44.9
0.75	151.9	4.4	8.8	91.9	928.0	467.9	9.1	27.9	1.17	46.2
1.00	152.6	4.3	8.7	98.2	979.1	566.4	9.4	33.1	1.23	47.7
SEm±	9.1	0.17	0.13	0.9	14.3	7.8	0.08	0.47	0.019	0.81
CD (P=0.05)	NS	NS	NS	2.3	35.8	18.8	0.2	1.1	0.05	2.0

schedules showed significant impact on number of effective tillers during both the years. The highest number of effective tillers, ear length, number of grains and grain weight was recorded with 1.00 IW:CPE, which were significantly higher than 0.75 IW:CPE and 0.50 IW:CPE. However, the highest 1,000-grains weight was observed with 1.00 IW:CPE, which was statistically at par with 0.75 IW:CPE and significantly higher than 0.50 IW:CPE. Mmmnouie *et al.,* (2006) evaluated five irrigation levels (0, 25, 50, 75 and 100% crop water requirements) and reported that highest number of spikes with 100% crop water requirement compared to lower levels.

Lodging

The data presented revealed that the highest lodging was recorded in bed planted crop, this was significantly higher than conventionally tilled and zero tilled crop (Table 2). However, the significantly lower lodging was recorded in zero tillage. The highest value of lodging in bed planted crop might be due to production of excessive number of total tillers, which were weak and prone to lodging because of higher competition for available resources. The higher lodging of crop was due to heavy and untimely rainfall during the reproductive stage in the first year of the study. Harry (2006) also reported reduction in the number of ears per plant is the yield component most affected by lodging. The lodging increased with each increment of nitrogen dose. The highest lodging was recorded with the application of 78.5 kg N/ha, which was significantly higher than 62.5 and 46.9 kg N/ha. It could be due to more availability of nitrogen, which resulted in better growth and development. The similar findings were reported by Thompson *et al.,* (2004), additions of excessive dose of N fertilizer cause of lodging in barley. Irrigation schedules significantly influenced lodging in barley. The highest lodging was recorded with 1.00 IW: CPE, which was significantly higher than 0.75 IW: CPE and 0.50 IW: CPE. It was due to better growth and development with the application more number of irrigation with 1.00 IW: CPE than the lower IW: CPE.

Yield and harvest index

Methods of sowing failed to show any significant affect on the grain yield of barley (Table 2). The highest grain yield was recorded from zero tilled crop followed by conventionally tilled and bed planted crop. The grain yield of zero tilled crop was 3.4 and 6.0 % higher than conventionally tilled and bed planted crop. Similarly, Cantero-Martinez *et al.,* (2003) also reported that zero tillage achieved slightly, but not significantly higher growth, yield contributing characters and yields than the tilled treatments. On an average, there were 4 and 13% greater yield than minimum tillage (MT) and 9 and 14% greater yield than CT. The grain yield increased with each increment of nitrogen dose (Table 2). The highest grain yield was obtained with 78.5 kg N/ha, which was significantly higher than 62.5 and 46.9 kg N/ha. The grain yield with the application 78.5 kg N/ha was 9.8 % higher than 62.5 kg N/

Table 2. Effect of methods of planting, nitrogen levels and irrigation schedules on yield, yield attributes and quality parameters of malt barley (Pooled data of two years)

Treatment	Lodging (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Grain hardness (kg)	Test weight (kg/hl)	Protein (%)	Starch (%)	Husk content (%)	Kernel plumpness (%)
Methods of sowing										
BP	2.1	4.31	5.87	42.4	12.8	60.5	10.5	60.7	10.9	84.0
ZT	0.5	4.57	6.01	43.2	12.5	61.2	10.1	61.2	10.7	85.2
CT	1.7	4.42	6.40	40.9	12.6	60.6	10.5	61.0	10.8	84.1
SEm±	0.13	0.13	2.6	0.82	0.3	1.1	0.13	1.06	0.13	0.18
CD (P=0.05)	0.3	NS	NS	NS	NS	NS	NS	Ns	NS	NS
Nitrogen (kg/ha)										
46.9	0.3	3.85	5.21	42.6	12.3	59.5	10.0	62.0	10.6	85.3
62.5	1.0	4.50	6.19	42.1	12.7	61.1	10.4	61.1	10.9	84.4
78.5	3.0	4.94	6.89	42.8	13.0	61.7	10.8	59.8	11.0	83.5
SEm±	0.13	0.13	2.6	0.82	0.3	1.1	0.13	1.06	0.13	0.18
CD (P=0.05)	0.3	0.31	6.3	NS	NS	NS	0.3	NS	0.3	NS
Irrigation Schedules (IW:CPE)										
0.50	0.1	3.53	4.65	43.1	13.5	59.1	11.2	59.3	11.6	83.4
0.75	0.8	4.48	6.26	41.4	12.5	60.5	10.2	61.3	10.7	84.4
1.00	3.4	5.28	7.35	42.0	11.8	62.7	9.7	62.4	10.1	85.4
SEm±	0.13	0.08	0.18	0.61	0.21	0.8	0.13	0.75	0.19	0.42
CD (P=0.05)	0.3	0.20	0.43	NS	0.5	2.0	0.3	1.8	0.5	NS

ha and 28.3 % higher than 46.9 kg N/ha. These results are in conformity with those of Sandhu (2006) also reported that grain yield of barley increased significantly with application of nitrogen up to 78 kg N/ha as a result of better plant height, effective tillers, leaf area index, dry matter accumulation, grains/ear, 1000-grain weight and nitrogen uptake as compared to lower doses. However, Singh *et al.*, (2001) and Saini and Thakur (1999) reported that plant height, yield attributes and grain yield increased significantly with each successive increase in N level up to 90 kg N/ha of malt barley

Irrigation schedules significantly affected the grain yield (Table 2). The highest grain yield was obtained with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW:CPE. The grain yield with 1.00 IW:CPE ratio was 17.9 % higher than 0.75 IW:CPE and 49.6 % higher than 0.50 IW:CPE. This might be ascribed to better growth and development of barley crop under 1.00 IW:CPE due to more number of irrigation as compared to lower IW:CPE. These results are in conformity with those of Mmmnouie *et al.*, (2006) and reported that highest number of spikes, number of grains, 1,000-grains weight and grain yield under 100% crop water requirement compared to lower levels. However, Warsi and Lal (1979) reported higher yields of barley with three irrigations applied at tillering (30 to 35 DAS), jointing (60-69 days) and milk stage (90 days). They assessed tillering as the most sensitive stage for irrigation. Garg and Saraswat (1975) found that in the absence of any winter shower, three irrigations at early tillering, flowering and milking stages were needed for getting higher yield of barley. Restricting irrigation at any of these three stages reduced the yield significantly.

The interaction effects of nitrogen levels and irrigation schedules were found to be significant (Table 3). The data revealed that irrigation at 1.00 IW:CPE with 78.5 kg N/ha gave significantly the highest grain yield than all other treatments. It was happened due to more availability of nitrogen at high IW:CPE, which resulted in more growth and yield contributing characters. Singh *et al.,* (1978) revealed that nitrogen and irrigation interaction was significant and 40 kg N with one irrigation gave as high yield (3.01 t/ha) as with 20 kg N and two irrigations (3.08 t/ha). Increased supply of both, nitrogen and irrigation significantly augmented the N uptake in the plant. Kumar (1977) reported significant interaction between soil moisture and nitrogen levels and indicated response of greater magnitude to irrigation under higher levels of nitrogen.

The highest straw yield was obtained from conventionally tilled crop, which was significantly higher than zero-tilled and bed planted crop (Table 2). The straw yield increased with each increment of nitrogen dose. The highest straw yield was obtained with 78.5 kg N/ha, which was significantly higher than 62.5 and 46.9 kg N/ha. Singh and Singh (2005) at Varanasi reported significant increase in grain and straw yields with increased doses of nitrogen from 20 to 80 kg/ha. Irrigation schedules significantly affected the straw yield. The highest straw yield was obtained with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW: CPE. This might be ascribed to better growth and development of barley in 1.00 and 0.75 IW:CPE than 0.50 IW:CPE. Sandhu (2006) revealed that with application of three irrigations straw yield of barley was significantly higher as compared to one or two irrigations. The highest harvest index was observed in zero tilled crop followed by bed planted and conventionally tilled crop (Table 2). The variable nitrogen levels and irrigation schedules failed to show any trend on harvest index.

Table 3. Interaction effect of nitrogen levels and irrigation schedules on grain yield of malt barley (Average of two years)

Treatment	Grain yield (t/ha)			Mean
	Nitrogen (kg/ha)			
	46.9	62.5	78.5	
Irrigation Schedules (IW:CPE)				
0.50	3.12	3.53	3.95	3.53
0.75	3.87	4.50	5.07	4.48
1.00	4.55	5.48	5.81	5.28
Mean	3.85	4.50	4.94	-
SEm±	0.08			
CD (P=0.05)	0.2			
Treatment	Malt yield (t/ha)			Mean
	Nitrogen (kg/ha)			
	46.9	62.5	78.5	
Irrigation Schedules (IW:CPE)				
0.50	2.51	2.75	3.07	2.78
0.75	3.22	3.69	4.16	3.69
1.00	3.95	4.64	4.70	4.43
Mean	3.23	3.70	3.98	
SEm±	0.12			
CD (P=0.05)	0.30			

Grain quality

The highest grain hardness, husk and protein were observed in bed planted crop followed by conventionally tilled and zero tilled crop (Table 2). However, the highest test weight, starch content and kernel plumpness was obtained in zero tilled crop followed by conventionally tilled and bed planted crop. Ciha (1982) also reported similar trend in test weight under the methods of barley sowing. The maximum grain hardness, test weight, husk and grain protein content was observed with 78.5 kg N/ha, but protein and husk content was statistically at par with 62.5 kg

N/ha and significantly higher than 46.9 kg N/ha. However, starch and kernel plumpness was recorded highest with 46.5 kg N/ha as compared to higher levels of nitrogen. These results are in conformity with those of Singh and Singh (2005), observed a higher protein content at 80 kg N/ha as compared with 20, 40, and 60 kg N/ha. However, Thompson *et al.*, (2004) reported that addition of N fertilizer may cause lodging and increase grain protein above desirable levels. The highest grain hardness, husk content and protein content were observed with 0.50 IW:CPE, which was significantly higher than 0.75 and 1.00 IW:CPE. The highest protein content with 0.50 IW:CPE might be due to moisture stress. Grant *et al.*, (1991) and Lauer and Partridge (1990) reported as moisture level increased then starch content concentration increased. The highest test weight, kernel plumpness and starch content were obtained with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW:CPE. Paynter and Young (2004) and Verma *et al.*, (2003) also documented the improvements in grain quality with irrigation. These results are in conformity with those of Petrie *et al.*, (2002) and Weston *et al.*, (1993). This might be ascribed to better growth and development of crop with 1.00 IW:CPE ratio and 0.75 IW:CPE ratio than 0.50 IW:CPE. Paynter and Young (2004) and Verma *et al.*, (2003) also reported improvements in grain plumpness with irrigation.

Malt quality

Maximum stirring number i.e. minimum a-amylase activity and diastatic power was obtained with bed planted crop followed by conventionally tilled and zero tilled crop (Table 4). Maximum stirring number i.e. minimum α-amylase activity and diastatic power was obtained with 78.5 kg N/ha but stirring number was statistically at par with 62.5 kg N/ha and significantly higher than 46.9 kg N/ha, however, diastatic power was significantly higher than 62.5 and 46.9 kg N/ha. Petrie *et al.*, (2002) and Westson *et al.*, (1993) also reported increase in diastatic power of malt with increased nitrogen. The interaction effects were non significant. Maximum stirring number i.e. minimum a-amylase activity and diastatic power was obtained with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW:CPE. Paynter and Young (2004) and Verma *et al*., (2003) reported the improvements in malting quality with irrigation.

Malt recovery and yield

The highest malt recovery and yield was obtained with zero tilled crop followed by conventionally tilled and bed planted crop (Table 4). The malt recovery decreased with each increment of nitrogen dose. The highest malt recovery was obtained with 46.9 kg N/ha, which was significantly higher than 62.5 and 78.5 kg N/ha. However, the highest malt yield was obtained with 78.5 kg N/ha which was significantly higher than 62.5 and 46.9 kg N/ha. Likewise, Petrie *et al.*, (2002) and Weston *et al.*, (1993) also documented statistical parity in malt yield. The highest malt recovery and yield was obtained with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW: CPE. The higher yield of malt with 1.00 and 0.75 IW:CPE

Table 4. Effect of methods of planting, nitrogen levels and irrigation schedules on quality parameters of malt barley (Average of two years)

Treatment	α-amylase activity(SN)	Diastatic power (mg maltose per 10g)	Malt recovery (%)	Malt yield (t/ha)	Steeping losses (%)	Respiration losses (%)	Root losses (%)
Methods of sowing							
BP	34.5	419.5	80.6	3.49	0.98	14.72	3.71
ZT	33.7	409.2	82.7	3.79	0.91	12.56	3.85
CT	34.0	417.6	81.8	3.62	0.93	13.54	3.75
SEm±	0.62	5.9	0.68	0.11	0.01	0.73	0.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Nitrogen (kg/ha)							
46.9	33.2	403.1	83.5	3.23	0.93	11.98	3.90
62.5	34.2	413.5	81.4	3.70	0.94	13.82	3.74
78.5	35.3	429.8	80.2	3.98	0.96	15.03	3.66
SEm±	0.62	5.9	0.68	0.11	0.01	0.73	0.05
CD (P=0.05)	1.6	13.6	NS	0.25	0.03	1.67	0.12
Irrigation Schedules (IW:CPE)							
0.50	28.5	348.1	78.6	2.78	1.02	17.02	3.37
0.75	35.3	426.4	82.5	3.69	0.94	12.92	3.67
1.00	38.5	471.8	84.0	4.43	0.88	10.89	4.27
SEm±	0.76	7.1	0.48	0.07	0.02	0.54	0.05
CD (P=0.05)	1.8	16.3	1.1	0.17	0.05	1.25	0.12

might be ascribed to easy availability of soil moisture resulting from better growth, lesser protein content, improved yield attributing characters and higher grain yield of barley. The lower the malt recovery in 0.50 IW:CPE ratio resulting from higher protein content due to water stress. Verma *et al.* (2003) reported increase in malt recovery with irrigation. The interaction effects of nitrogen levels and irrigation were significant. The data presented revealed that 1.00 IW: CPE ratio with 78.5 kg N/ha gave significantly higher malt yield, which was statistically at par with 1.00 IW: CPE ratio with 62.5 kg N/ha and significantly higher than all other treatments. Increased supply of both, nitrogen and irrigation significantly augmented the N uptake in the plant which resulted in higher malt yield. Kumar (1977) reported significant interaction between soil moisture and nitrogen levels and indicated response of greater magnitude to irrigation under higher levels of nitrogen.

Malt losses

A perusal of data revealed that the methods of sowing in barley did not influence the steeping loss (Table 4). Although the highest steeping loss and respiration loss were obtained with bed planted crop followed by conventionally tilled and zero tilled crop. However, the highest root loss was recorded with zero tilled crops followed by conventionally tilled and bed planted crop. The steeping loss increased with each increment of nitrogen dose. The highest steeping loss was obtained with 78.5 kg N/ha, which was statistically at par with 62.5 kg N/ha and significantly higher than 46.9 kg N/ha. However, highest respiration loss was obtained with 78.5 kg N/ha, which was significantly higher than 62.5 and 46.9 kg N/ha. The highest root losses in malt barley were observed with 46.9 kg N/ha, which were significantly higher than 62.5 and 46.9 kg N/ha. Irrigation schedules significantly influenced the steeping loss in barley. The highest steeping and respiration losses were obtained with 0.50 IW:CPE, which was significantly higher than 0.75 IW:CPE ratio and 1.00 IW:CPE. However, the highest root loss was recorded with 1.00 IW:CPE, which was significantly higher than 0.75 and 0.50 IW:CPE. Novellie (1962) reported that dry matter loss increased because of more respiration loss, which was again depend on more α-amylase activities and diastatic power. He also reported that respiration losses correlated negatively with test weight and starch content, and positively with x-amylase activity. Palmer *et al.*, (1989) reported malting losses of 15-20% in sorghum compared to 7% in barley. Dry matter losses were significantly correlated to respiration loss, root and shoot loss, α-amylase activity, diastatic power, and reduction in paste viscosity. Respiration losses of malted sorghum were higher than losses due to root and shoot growth.

Based on the study, it can conclude that malt barley can be sown with zero tillage, fertilized with 78.5 kg N/ha and applied irrigation at 1.0 IW:CPE ratio for higher malt and grain yield.

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