Indian Journal of Agronomy **61** (3): 366–371 (September 2016)

Research Paper

Effect of sowing methods, paddy straw mulch and irrigation schedules on crop performance, water productivity and monetary returns of barley (*Hordeum vulgare*)

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Received : January 2016; Revised accepted : June 2016

ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2013–14 and 2014–15 at Ludhiana, Punjab, to study the impact of sowing methods, mulch levels and irrigation schedules on crop performance and monetary returns of barley (*Hordeum vulgare* L.). The sowing methods, i.e. bed and conventional flat sowing, did not influence significantly the growth, yield, water productivity and gross and net returns. Application of paddy straw mulch @ 6 t/ha increased the growth, dry-matter accumulation (5.3 and 11.5%), yield-attributing characters, yield (5.0 and 10.8%), water productivity (7.8 and 19.4%) and gross (4.9 and 10.8%) and net returns (2.0 and 4.2%) than 3 t/ha mulch and no-mulch application respectively. Irrigation schedule of irrigation water : cumulative pan evaporation (IW : CPE) ratio of 1.0 exhibited the maximum dry-matter accumulation at harvesting, yield-attributing characters, 3.7 and 5.8% higher grain yield and gross and net returns and 5.4 and 7.9% higher benefit: cost ratio than IW : CPE ratio of 0.8 and 0.6 respectively. However, water productivity was the maximum at an IW: CPE ratio of 0.6, being comparable to an IW : CPE of 0.8 and 9.7% higher than an IW : CPE of 1.0.

Key words : Barley, Crop production, IW : CPE ratio, Mulch, Net returns, Sowing method

Now-a-days, barley has become a viable and useful crop in winters owing to release of improved varieties and upcoming of improved industries in India, especially in Punjab, Haryana and Rajasthan. As an important cereal crop, barley is cultivated successfully in a wider range of climate all over the world. It is a dual-purpose crop, i.e. food and feed for human beings and animals, and a valuable input for malt industry. It is the fourth important cereal crop after wheat, rice and maize in the world. Barley occupied 0.673 million ha area in India, with 1.83 million tonnes of production and 2,718 kg/ha of average productivity during 2013–14 (www.indiastat.com, 2015). In Punjab, it is cultivated on an area of 0.012 million ha with total production of 0.046 million tones, having an average productivity of 3,833 kg/ha in 2013–14 (www.indiastat.com, 2015). Although a minor crop, barley can play an important role in enhancing the food security of the country. But the productivity of this crop in India is very low as compared to that of many other countries, mainly due to use of low inputs and improper agronomic practices. Besides, high temperatures, uncertain rainfall and declining groundwater table has also lead to decline in crop productivity under changing climatic scenario. So, raising grain yield is one of the major objectives of national food security mission. Compared with conventional flat sowing method, furrow-irrigated raised-bed planting system (FIRBS) has several important advantages, viz. improved water distribution and efficiency, nutrient-use efficiency, mechanical weed control, reduced lodging and appreciable reduction in seed rates, have been reported by Hobbs *et al.* (1998) and Dhillon *et al.* (2004) in wheat crop. In Punjab, paddy straw is burnt by farmers in large quantities which lead to air pollution, in addition to loss of nutrients, i.e all of carbon, 90% of nitrogen, 60% of sulphur and 20–25% of phosphorus and potassium (Dobermann and Fairhurst, 2002). Mulch application may be an effective method to increase productivity by conserving moisture through reduction in soil evaporation, in addition to moderation of soil temperature, modification of crop microclimate, suppression of weed growth, improving soil physical, chemical and biological properties, preventing the soil salinity from flowing back to surface and checking the direct beating action of rains, thus lead-

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ing to control of soil erosion, etc (Gupta *et al.,* 1990; Bu *et al.,* 2002). So, use of paddy straw as mulch can be a good option to increase productivity. Another possible solution can be optimum scheduling of irrigation. Application of water according to the crop need helps in increasing crop productivity. Sharma and Verma (2010), Hossain and Akhtar (2014) and Almarshadi and Ismail (2014) reported significant effect of irrigation on growth, yield-attributing characters and grain yield. Since some knowledge gaps have been identified regarding feasibility of mulching under bed and flat sowing and irrigation scheduling under mulching of barley crop, the present investigation was conducted to study the effect of sowing methods, mulch levels and irrigation schedules on growth behaviour, productivity and profitability in barley crop.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2013–14 and 2014–15 at the Punjab Agricultural University, Ludhiana, situated (30°54' N and 75°48' E, 247 m above mean sea-level) in the central plain region of Punjab state under Trans-Gangetic agro-climatic zone of India. The soil was loamy sand, normal in reaction *p*H 7.4 and electrical conductivity 0.12 dS/m, low in organic carbon (0.21%) and available nitrogen (182.2 kg/ha) and medium in available phosphorus (20.0 kg/ha) and potassium (213.6 kg/ha). The average bulk density of soil was 1.60 g/cm^3 and the field capacity (–0.3 bar) and permanent wilting point (–15 bar) of 0–180 cm soil profile were 38.29 and 12.71 cm, respectively, and the available water in the 0–180 cm soil profile was 25.58 cm. The treatments comprised combination of 2 sowing methods, i.e. bed sowing and conventional flat sowing, and 3 mulch levels, viz. no mulch, paddy straw mulch @ 3 t/ha and 6 t/ha, in main plots and 3 irrigation schedules, viz. Irrigation water: cumulative pan evaporation (IW : CPE) of 0.6, 0.8 and 1.0 in subplots. The experiment was conducted in split-plot design with 3 replications. In case of bed sowing, sowing was done with tractor-operated bed planter, which makes 37.5 cm wide bed and 30 cm wide and 15 cm deep furrow between 2 beds and sow 2 rows of barley, 20 cm apart, on top of bed. In case of flat sowing, sowing was done with tractor-mounted seed-cum-fertilizer drill with row-to-row spacing of 20 cm, by using recommended seed rate (87.5 kg/ha) of variety ‘PL 807’. However, under bed sowing, seed rate was reduced by 25%. The sowing was done on 12 and 8 November during 2013–14 and 2014–15, respectively. A basal dose of 62.5 kg N and 30 kg P_2O_5/ha was applied through urea (46% N) and diammonium phosphate (DAP) (18% N and 46% P_2O_5) as per recommendation. The loose paddy straw was applied immediately after sowing of crop as per treatments. The depth of each irrigation was measured with Parshall flume i.e. 50 mm for bed sown plots and 75 mm for flat-sown plots. The gross size of experimental plot was 5.0 m × 2.7 m. Each plot was surrounded by a buffer of 0.75 m width. The first irrigation was given commonly at crop-establishment stage, i.e. on 12 and 9 December during 2013 and 2014 respectively. The subsequent irrigations were given based on IW : CPE ratio as per treatments. Under bed sowing, in case of 1.0 IW : CPE ratio, only 1 irrigation was given, i.e. on 12 and 27 March during 2013–14 and 2014–15, respectively, in case of 0.8 IW : CPE ratio, only 1 irrigation was applied, i.e. on 16 March during 2013–14 and no irrigation came out during 2014–15; and in case of 0.6 IW : CPE ratios, no irrigation came out during 2013–14 and 2014–15. Under flat sowing, in case of 1.0 IW : CPE ratio, only 1 irrigation was applied, i.e. on 23 March during 2013–14 and no irrigation came out during 2014–15; however, in case of 0.8 and 0.6 IW : CPE ratios, no irrigation came out during both the years. The crop received 142.8 and 195.4 mm total rainfall during 2013–14 and 2014–15 respectively. The crop was harvested on 11 and 10 April during 2013–14 and 2014–15 respectively.

The emergence count per square metre was recorded 15 days after sowing (DAS). The plant height and dry-matter accumulation were recorded at harvesting. However, total tillers/m^2 were recorded at 120 DAS and effective tillers/m^2 were recorded at harvesting. The yield attributes, viz. number of spikes/m^2 (effective tillers), spike length, grains/spike; grain weight/spike and 1,000-grain weight were recorded at time of harvesting. Biological and grain yields were recorded from the net plot size and then expressed as t/ha. The straw yield was calculated by subtracting the grain yield from biological yield. Harvest index was calculated by dividing the grain yield with biological yield (grain + straw) and grain : straw ratio by dividing the grain yield with straw yield. Water productivity (kg/m^3) was calculated dividing the grain yield (kg/ha) by the total water expense (m^3/ha). Gross returns, net returns and benefit: cost ratio were calculated as per standard methods. Statistical analysis was done as per split plot design (Gomez and Gomez, 1984) and treatment means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

On the basis of pooled data, emergence count/m^2 (Fig. 1) was significantly higher in conventional flat-sowing method than bed sowing method. This might be owing to less seed used in bed-sowing method than flat sowing. The results confirm the findings of Singh *et al.* (2013). Plant height and dry-matter accumulation at harvesting and total tillers/m^2 at 120 DAS were not affected significantly by sowing methods (Fig. 1). Saini and Walia (2010) also reported insignificant effect of sowing methods on growth characters in wheat crop. Mulch application @ 6 t/ha significantly decreased the emergence count than that at 3 t/ha and no mulch application being statistically at par with each other. This might be due to straw load to emerging seedlings. Ram *et al.* (2013) also reported lesser emergence under mulching in wheat crop. The plant height was significantly higher where mulch was applied @ 6 t/ha than no-mulch application, but statistically at par with 3 t/ha mulch (Fig. 2). The total tillers/m^2 and dry-matter accumulation were significantly higher under mulch application of 6 t/ha than 3 t/ha mulch and no mulch application. Improvement in growth parameters, viz. plant height, tiller count and dry-matter production, with mulch application might be owing to better hydrothermal conditions provided by mulch application. The results are in line with those of Dadhwal (2011) in wheat crop. Further, it was observed that different irrigation schedules did not affect the emergence of seedlings significantly, as there was no differential irrigation application up to the emergence stage (Fig 3). The plant height was significantly more under an IW : CPE ratio of 1.0 than IW : CPE ratio of 0.6 but statistically at par with that of IW : CPE ratio of 0.8. Mollah and Paul (2011) also reported higher plant height where 40 mm irrigation water was applied than 20 mm and no irrigation. The total tiller count/m^2 at 120 DAS was not affected significantly by different irrigation schedules, as the differential irrigation was provided after this growth stage as per irrigation treatments. However, dry-matter accumulation at harvesting was significantly higher under irrigation schedule of IW : CPE ratio of 1.0 than IW : CPE ratio of 0.8 and 0.6. Significantly higher plant height and dry-matter production at harvesting might be owing to better moisture regime under IW: CPE ratio of 1.0. The

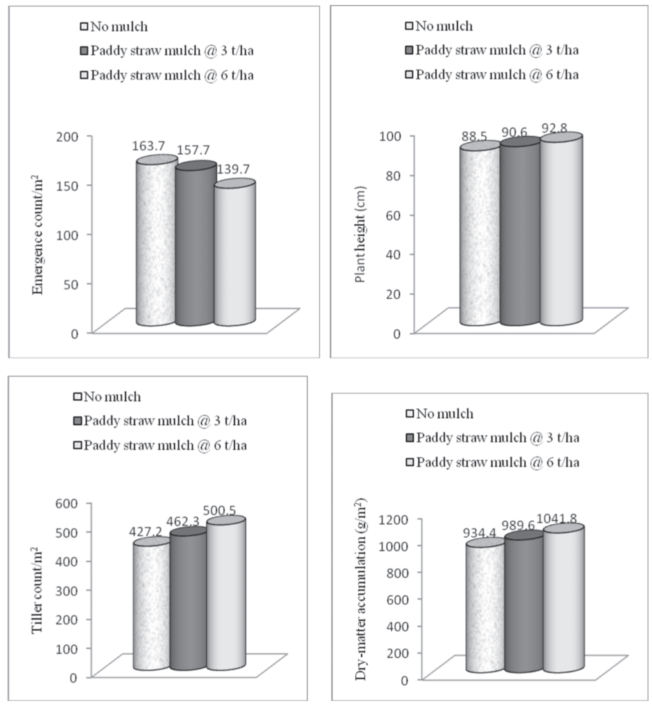

Fig. 2. Effect of mulch levels on emergence count, plant height at harvesting, tiller count at 120 DAS and dry-matter accumulation at harvesting of barley.

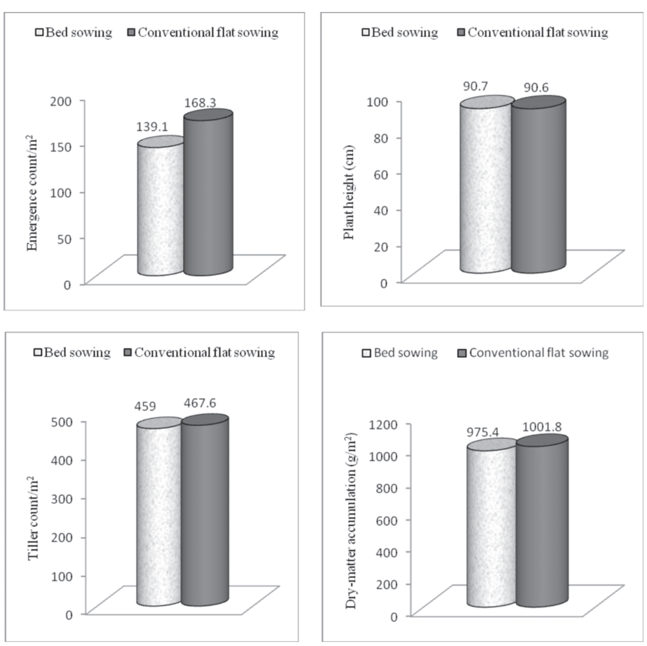

Fig. 1. Effect of sowing methods on emergence count, plant height at harvesting, tiller count at 120 DAS and dry-matter accumulation at harvesting of barley.

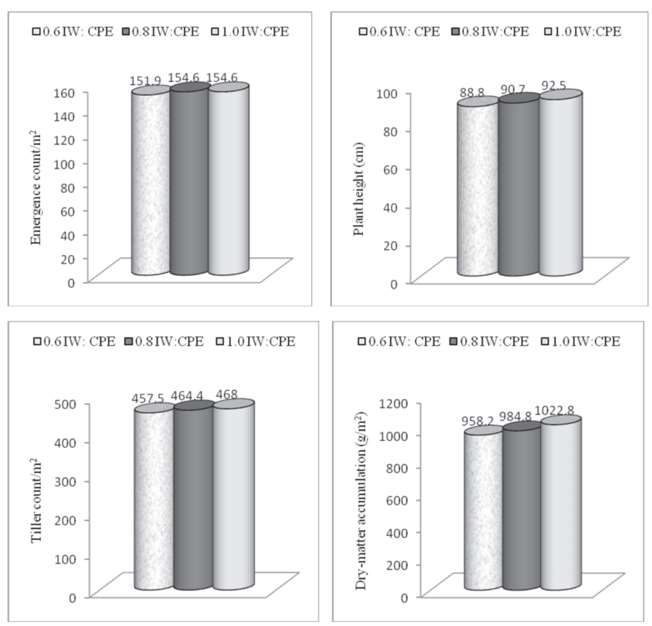

Fig. 3. Effect of irrigation schedules on emergence count, plant height at harvesting, tillers count at 120 DAS and dry-matter accumulation at harvesting of barley.

results support the findings of Singh *et al.* (2012).

Yield-attributing characters

The pooled data showed that all the yield attributes, viz. spikes/m^2, spike length, grains/spike, grain weight/spike and 1,000-grain weight, were not affected significantly by both the sowing methods (Table 1). Singh *et al.* (2013) also reported similar results. Mulch application @ 6 t/ha resulted in significantly more spikes, grains/spike and grain weight/spike, being statistically at par with 3 t/ha mulch application over no mulch application. This might be owing to better growth under mulching. However, mulch levels did not affect significantly the spike length, grains/spike and 1,000-grain weight. These results confirm the findings of Dadhwal (2011). Among the different irrigation schedules, grains/spike, grain weight/spike and 1,000-grain weight were significantly higher under irrigation schedule of IW : CPE ratio of 1.0 compared to IW : CPE ratio of 0.6 but statistically at par with IW : CPE ratio of 0.8. Our results confirm the findings of Sandhu (2006), Sharma and Verma (2010) and Singh *et al.* (2012). However, spikes/m^2 and spike length were not affected significantly by different irrigation schedules. This might be due the application of irrigation (as per the treatments) very late in the crop-growth period.

Yield

The pooled data showed that both the sowing methods did not influence significantly the biological, grain and straw yields, harvest index and grain : straw ratio (Table 2), confirming the findings of Singh *et al.* (2012). Mulch application @ 6 t/ha resulted in significantly higher biological and grain yield than 3 t/ha mulch and no-mulch application, respectively, whereas harvest index and grain : straw ratio were not significantly affected by different mulch levels. The higher biological and grain yields with mulch application might be owing to better growth and yield-attributing characters as compared to no-mulch application. Sarkar and Singh (2007) and Dadhwal (2011) also reported higher grain yield with mulch application. Further, irrigation schedule of IW : CPE ratio of 1.0 resulted significantly higher grain yield, being statistically at par with 0.8 IW : CPE ratio than 0.6 IW : CPE ratio. This might be attributed to higher growth and yield-attributing characters under irrigation schedule of 1.0 IW : CPE ratio. However, biological yield, straw yield, harvest index and grain : straw ratio were not affected significantly by irrigation schedules. Sharma and Verma (2010), Singh *et al.,* (2012) and Hossain and Akhtar (2014) reported higher grain yield with more number of irrigations in many studies.

Water productivity

The pooled data showed that water productivity (WP) was not affected significantly by different sowing methods. Numerically, WP was more under bed sowing than conventional flat sowing method. The higher WP under bed sowing might be attributed to less total water expense than flat-sowing method. Singh *et al.* (2012) also reported similar results. However, non-significant results might be due to less number of irrigation applied because of occurrence of uniform rainfall during both the crop seasons.

Table 1. Effect of sowing methods, mulch levels and irrigation schedules on yield attributes of barley (pooled data of 2 years)

Treatment	Spikes/m^2	Spike length (cm)	Grains/spike	Grain weight/ spike (g)	1,000-grain weight (g)
Sowing method					
Bed	378.0	7.94	49.6	1.71	35.4
Flat	390.3	7.89	48.9	1.69	34.8
SEm±	4.37	0.07	0.49	0.02	0.73
CD (P=0.05)	NS	NS	NS	NS	NS
Mulch level (t/ha)					
0	363.7	7.81	47.6	1.63	34.3
3	385.2	7.94	49.6	1.70	35.2
6	403.5	8.01	50.5	1.76	35.9
SEm±	5.35	0.08	0.60	0.03	0.90
CD (P=0.05)	19.1	NS	2.14	0.09	NS
Irrigation schedule (IW : CPE)					
0.6	378.1	7.83	48.1	1.64	33.9
0.8	382.3	7.91	49.1	1.70	34.9
1.0	392.1	8.02	50.5	1.75	36.6
SEm±	6.92	0.10	0.47	0.03	0.65
CD (P=0.05)	NS	NS	1.61	0.08	1.89

Table 2. Effect of sowing methods, mulch levels and irrigation schedules on yield, water productivity and economics of barley (pooled data of 2 years)

Treatment	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Grain: straw ratio	Water productivity (kg/m^3)	Cost of cultivation (×10^3₹/ha)	Gross returns (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: cost ratio
Sowing method										
Bed	11.1	4.37	6.69	0.40	0.66	1.54	23.9	64.2	40.2	1.69
Flat	11.3	4.42	6.87	0.39	0.65	1.51	24.2	65.1	41.0	1.56
SEm±	0.11	0.03	0.08	0.002	0.006	0.011	-	0.50	0.50	0.022
CD (P=0.05)	NS	NS	NS	NS	NS	NS	-	NS	NS	NS
Mulch level (t/ha)										
0	10.6	4.17	6.43	0.39	0.65	1.39	21.6	61.3	39.7	1.84
3	11.2	4.40	6.79	0.39	0.65	1.54	24.1	64.7	40.6	1.69
6	11.7	4.62	7.12	0.39	0.65	1.66	26.6	67.9	41.4	1.56
SEm±	0.13	0.04	0.10	0.003	0.008	0.014	-	0.62	0.61	0.03
CD (P=0.05)	0.46	0.16	0.36	NS	NS	0.043	-	1.95	NS	0.10
Irrigation schedule (IW: CPE)										
0.6	10.9	4.28	6.65	0.39	0.65	1.58	24.0	63.1	39.1	1.64
0.8	11.1	4.37	6.71	0.40	0.65	1.57	24.0	64.3	40.2	1.68
1.0	11.5	4.53	6.97	0.40	0.65	1.44	24.2	66.6	42.5	1.77
SEm±	0.16	0.06	0.11	0.003	0.007	0.021	-	0.92	0.92	0.04
CD (P=0.05)	NS	0.17	NS	NS	NS	0.062	-	2.69	2.69	0.10

Price of grain, ₹11,000/t (2013–14) and ₹11,500/t (2014–15); price of straw, ₹2,000/t (2013–14) and ₹2,500/t (2014–15)

The WP was affected significantly by different mulch levels. Maximum WP was recorded under 6 t/ha mulch which was significantly more than where 3 t/ha and no mulch was applied. Mulch application @ 6 t/ha increased the WP by 7.8 and 19.4% over 3 t/ha mulch and with no-mulch application respectively. This might be owing to more grain yield and less total water expense where mulch was applied as compared to no mulch. Sarkar and Singh (2007) also reported higher water productivity in crop where mulch was applied as compared with no mulch. Among the different irrigation schedules, irrigation schedule of IW: CPE ratio of 0.6 resulted in significantly higher WP than 1.0 but statistically at par with 0.8. The higher WP under irrigation schedule of 0.6 IW : CPE ratio might be due to less total water expense. The results are in line with those of Mollah and Paul (2011) and Singh *et al.* (2012).

Economics

The gross and net returns and benefit: cost ratio were not affected significantly by both the sowing methods (Table 2), as there was no significant difference in grain and straw yields and cost of cultivation between the 2 sowing methods. Among the different mulch levels, the cost of cultivation was the maximum where mulch was applied @ 6 t/ha than that at 3 t/ha mulch and no-mulch application due to cost of mulch application. Mulch application @ 6 t/ha increased the gross returns significantly than 3 t/ha mulch and no-mulch application. This might be owing to higher grain and straw yields under mulching. Dadhwal (2011) also reported higher economic returns with mulching. The net returns were not affected significantly by different mulch levels. Benefit: cost ratio was significantly higher with no-mulch application than mulch application of 3 t/ha and 6 t/ha. Among the irrigation schedules, irrigation schedule of 1.0 IW : CPE ratio registered significantly higher gross and net returns and benefit: cost ratio as compared to 0.6 IW : CPE ratio, but statistically at par with 0.8 IW : CPE ratio. Higher economic returns under irrigation schedule of IW : CPE ratio of 1.0 and 0.8 than 0.6 might be owing to more grain and straw yields.

Thus, it can be concluded that bed sowing of barley can be recommended for improved water productivity without sacrificing grain yield and among the mulch levels and irrigation schedules, mulch application @ 6 t/ha and irrigation schedule of 0.8 IW: CPE ratio can be used for better grain yield, water productivity and economic returns of barley crop.

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