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Influence of paddy straw mulch on crop productivity and economics of bed and flat sown wheat (*Triticum aestivum*) under different irrigation schedules

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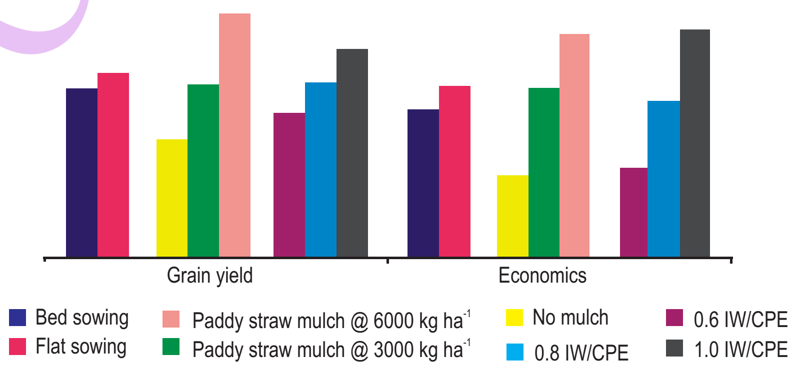
Abstract

Aim: Extensive cultivation of paddy and burning of paddy straw by farmers in north-western India has led to a serious problem of decreased underground water table along with degradation of soil health and environmental pollution. The utilization of paddy straw as mulch in wheat crop can be a good option to solve these problems. So, a field experiment was conducted with the objective to study the influence of paddy straw mulch on productivity and economics of bed and flat sown wheat crop under different irrigation schedules.

Methodology: Treatments comprised of combination of two sowing methods i.e., bed sowing and conventional flat sowing and three mulch levels viz., no mulch, paddy straw mulch @ 3000 kg ha^{-1} and paddy straw mulch @ 6000 kg ha^{-1} in main plots and three irrigation schedules viz., 0.6, 0.8 and 1.0 irrigation water/cumulative pan evaporation (IW/CPE) in sub-plots and conducted in split-plot design with three replications at Punjab Agricultural University, Ludhiana during winter season of 2013-14 and 2014-15. The growth parameters were recorded periodically at 30 day interval and yield attributes and yield were recorded at harvest. The net returns were calculated by subtracting the total variable cost from gross returns.

Results: Both the sowing methods did not significantly influence the growth, yield attributes, yield and gross and net returns. Mulch application @ 6000 kg ha^{-1} significantly increased the plant height (88.3 cm), number of spikes (358.7 m^{-2}) and spike length (10.1 cm) and as a result achieved highest biological (12800 kg ha^{-1}) and grain yield (5380 kg ha^{-1}) and net returns (₹ 62763.5 ha^{-1}) than mulch @ 3000 kg ha^{-1} and no mulch. Among the irrigation schedules, significantly higher biological (12480 kg ha^{-1}) and grain yield (5250 kg ha^{-1}) was registered under irrigation schedule of 1.0 IW/CPE ratio, might be due to significantly more number of spikes (347.0 m^{-2}), grains spike^{-1} (49.4), grain weight spike^{-1} (1.85 g) and 1000-grain weight (38.5 g) which led to significantly higher net returns (₹ 62817.0 ha^{-1}) as compared with 0.8 and 0.6 IW/CPE ratio.

Interpretation: Productivity and economics were found to be higher under mulch application @ 6000 kg ha^{-1} and irrigation schedule of 1.0 IW/CPE ratio in wheat crop.



Introduction

Wheat (*Triticum aestivum*) is the second most important cereal crop in India, after rice and is a dominant crop of Punjab. World trade in wheat is greater even if all other crops are combined (Curtis *et al*., 2002). It has higher protein content than other major cereals i.e., maize and rice. It is the major source of proteins and calories which are almost 72 % in an average diet (Heyne, 1987). This crop contributes substantially to the national food security by providing more than 50 % of the calories to the people who mainly depend on it. Currently, India is the second largest wheat producer in the world, next to China. Punjab state contributes approximately 11 % share in area (3.51 million hectares) and 19 % share in production (17.62 million tonnes) with highest productivity (5017 kg ha^{-1}) of wheat as compared to country's area of 31.19 million ha, 94.48 million tonnes of production and 3030 kg ha^{-1} of productivity, in the year 2013-14 (FAO, 2015). With growing population, world food demand will grow by 70–90 % by 2050. It is estimated that India will require 109 million tonnes of wheat to feed the population of about 1.25 billion by the year 2020 i.e., the desired growth rate of production by 2020 will be 2.2 % as compared to the actual growth rate of 1 %. Also, India's per capita wheat production is 67 kg against per capita consumption of 73 kg, which is on the rise. In addition, water scarcity and climate change has increased the pressure due to decline in crop productivity.

Various agronomic practices have been developed to ensure high crop productivity per unit of water. Furrow irrigated raised bed planting system (FIRBS) has been found very effective for improving water productivity (Tanwar *et al.,* 2014) along with several other advantages viz., improved nutrient use efficiency, mechanical weed control, relay intercropping and reduction in seed rates (Sayre and Hobbs, 2004). Evaporation from soil surface results in a considerable loss of moisture and has a direct impact on wheat yield. In wheat production, soil evaporation is usually 30–60 % of total evapotranspiration (Gregory *et al.,* 1992; Yanusa *et al.,* 1993). Mulching has proved to be useful in conserving moisture and increasing productivity in wheat (Ahmed *et al.,* 2007; Chakraborty *et al.,* 2008; Ram *et al.,* 2013). So rice straw can be used as mulch to conserve soil moisture as in Punjab, rice straw is burnt by farmers in large quantities which lead to air pollution in addition to loss of nutrients particularly N, P and S. Another possible solution can be irrigation scheduling. As water scarcity is increasingly serious, there is a need for adopting optimum irrigation scheduling. Irrigation scheduling has been described as a primary tool to improve water use efficiency, crop yield and availability of water resources for other uses. Keeping these points in mind, the present investigation was conducted to study the effect of sowing methods, mulch levels and irrigation schedules on crop productivity and economics in wheat.

Materials and Methods

A field experiment was conducted during winter seasons of 2013-14 and 2014-15 at Punjab Agricultural University, Ludhiana, situated at 30° 54' N latitude and 75° 48' E longitude at an altitude of 247 m amsl in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India. Soil of the experimental site was loamy sand in texture, normal in pH (7.4) and electrical conductivity (0.12 dS m^{-1}), low in organic carbon (0.21%) and available nitrogen (182.15 kg ha^{-1}) and medium in available phosphorus (19.96 kg ha^{-1}) and potassium (213.56 kg ha^{-1}). The experiment was conducted in a split-plot design with three replications. The treatments comprised of combination of two sowing methods i.e., bed sowing and conventional flat sowing and three mulch levels viz., no mulch, paddy straw mulch @ 3000 kg ha^{-1} and paddy straw mulch @ 6000 kg ha^{-1} in main plots and three irrigation schedules viz. IW/CPE ratio of 0.6, 0.8 and 1.0 in sub-plots. The 'HD 2967' variety of wheat was used at recommended seed rate i.e., 100 kg ha^{-1} in case of conventional flat sowing and 75 kg ha^{-1} in case of bed sowing. Sowing was done in the first fortnight of November during both the years. The recommended dose of nutrients i.e., 125 kg N and 62.5 kg P_2O_5 per hectare was applied. Loose paddy straw was applied immediately after sowing of crop as per treatment. The plant height (cm) and tiller count (No. m^{-2}) were recorded at 30 day interval and at harvest and are presented in the form of graphs. The yield attributes viz., number of spikes (m^{-2}), spike length, grains per spike (No.), grain weight per spike (g) and 1000-grain weight were recorded at harvest. Biological (bundle weight) and grain yield was recorded from the net plot size and expressed as kg ha^{-1}. 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 was calculated by dividing the grain yield with straw yield. The gross returns were calculated by multiplying the price of grain and straw with their respective yields, net returns were calculated by subtracting total variable cost from gross returns and benefit cost ratio was calculated by dividing the net returns with total variable cost under the respective treatment. 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

The plant growth parameters i.e., plant height and tiller count per square metre were not significantly affected by both the sowing methods at all the crop growth stages during both the years (Fig. 1 and Fig. 2). Saini and Walia (2010) also reported insignificant differences in plant height and tiller count between bed and flat sowing methods. However, at 30 days after sowing (DAS), conventional flat sowing produced significantly more number of tillers (197.0 and 202.3 m^{-2}) than bed sowing method (180.1 and 185.2 m^{-2}) during 2013-14 and 2014-15, respectively. This might be due to lesser plant population on beds as compared

Table 1 : Effect of sowing methods, mulch levels and irrigation schedules on yield attributes of wheat

Treatment	No. of spikes (m^{-2})			Spike length (cm)			No. of grains per spike			Grain weight per spike (g)			1000-grain weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Sowing methods															
Bed	336.8	335.1	336.0	9.38	10.4	9.90	48.6	48.5	48.5	1.91	1.69	1.79	39.6	34.9	37.2
Flat	343.2	345.4	344.3	9.24	10.3	9.78	47.7	47.0	47.3	1.89	1.67	1.79	39.0	34.6	36.8
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mulch levels (kg ha^{-1})															
0	313.0	325.5	319.3	9.14	10.2	9.68	47.1	46.7	46.9	1.87	1.65	1.76	38.4	34.2	36.3
3000	342.9	341.9	342.4	9.27	10.3	9.80	48.3	47.8	48.1	1.89	1.68	1.78	39.4	34.7	37.1
6000	364.1	353.0	358.7	9.52	10.6	10.10	49.1	48.7	48.9	1.93	1.71	1.82	40.0	35.3	37.6
CD (p = 0.05)	17.8	19.1	8.3	NS	NS	0.27	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation schedules (IW/CPE)															
0.6	326.6	336.4	332.0	9.19	10.3	9.73	45.6	47.2	46.4	1.84	1.63	1.73	37.7	33.2	35.4
0.8	342.4	340.4	341.4	9.32	10.4	9.86	48.1	47.7	47.9	1.90	1.68	1.79	39.4	34.9	37.1
1.0	351.0	344.0	347.0	9.41	10.5	9.95	50.7	48.2	49.4	1.96	1.74	1.85	40.8	36.1	38.5
CD (p = 0.05)	13.0	NS	9.9	NS	NS	NS	2.7	NS	1.7	0.07	0.08	0.05	1.8	1.7	1.2

NS = Non- significant

to flat plots due to lower seed rate used in bed sowing (Ram *et al*., 2013a; Singh *et al*., 2008). The yield attributes were not significantly affected by different sowing methods (Table 1). Being statistically at par, conventionally flat sown wheat gave 1.9 and 3.1 % more spikes per square metre over bed sown wheat during 2013-14 and 2014-15, respectively and other yield attributes viz., spike length, number of grains per spike, grain weight per spike and 1000-grain weight were numerically more in bed sown crop than conventional flat sown crop. Similar results were reported by Dhillon *et al.* (2005). Both the sowing methods did not influence significantly the biological, grain and straw yields, harvest index and grain straw ratio. Insignificant effect of both the sowing methods on growth and yield attributes resulted in similar yields. Ram *et al.* (2013a); Saini and Walia (2010) and Dhillon *et al.* (2005) also reported similar grain yield under bed and flat sowing mehods. Similar trend was observed in pooled data. The cost of cultivation, gross and net returns and benefit cost ratio were also insignificantly affected by both the sowing methods.

Different mulch levels influenced the plant height significantly at 30, 60, 90, 120 DAS and at maturity (Fig. 1). The plant height was significantly higher where mulch was applied @ 6000 kg ha^{-1} than 3000 kg ha^{-1} mulch and no mulch application at all the crop growth stages except at maturity at which application of 6000 kg ha^{-1} mulch gave significantly more plant height than no mulch but was statistically at par with 3000 kg ha^{-1} mulch during 2013-14, however during 2014-15, there was insignificant effect on plant height. The data (Fig. 2) revealed that tiller count per square metre was significantly more under mulch application of 6000 kg ha^{-1} than 3000 kg ha^{-1} and no mulch application and 3000 kg ha^{-1} mulch also produced significantly more number of tillers than no mulch application at all the growth stages of crop, except at 30 DAS during both the years. At 30 DAS, there was insignificant difference in tiller number among the mulch levels due to lesser emergence count under mulch level of 6000 kg ha^{-1} as compared to 3000 kg ha^{-1} and no mulch application. Ram *et al.* (2013) also reported lesser plant population initially under 6000 kg ha^{-1} mulch due to straw load on emerging seedlings but later on, crop compensated for lower emergence by producing more tillers. Higher plant height and tiller production under mulching might be due to better hydrothermal conditions provided by mulch. These findings are confirmed by the results of Ahmed *et al.* (2007); Shafiq *et al.* (1994) who reported significantly higher plant height and tiller count under all the mulch levels than no mulch due to higher soil moisture contents under mulch.

The yield attributes viz, spike length, number of grains per spike, grain weight per spike and 1000-grain weight were not significantly affected by different mulch levels (Table 1). However, number of spikes (m^{-2}) was significantly higher where mulch was applied @ 6000 kg ha^{-1} than 3000 kg ha^{-1} mulch and no mulch application during 2013-14, however during 2014-15, application of 6000 kg ha^{-1} mulch gave significantly more number of spikes than no mulch, but statistically at par with 3000 kg ha^{-1} mulch application. Similar trend was observed in pooled data. Ahmed *et al.* (2007); Chaudhary and Iqbal (2013) reported higher number of spikes m^{-2} in mulch treated plots than no mulch control. Further, the pooled data showed that significantly more spike length (10.1 cm) was recorded with 6000 kg ha^{-1} mulch application than with 3000 kg ha^{-1} mulch (9.80 cm) and with no mulch (9.68 cm). Higher

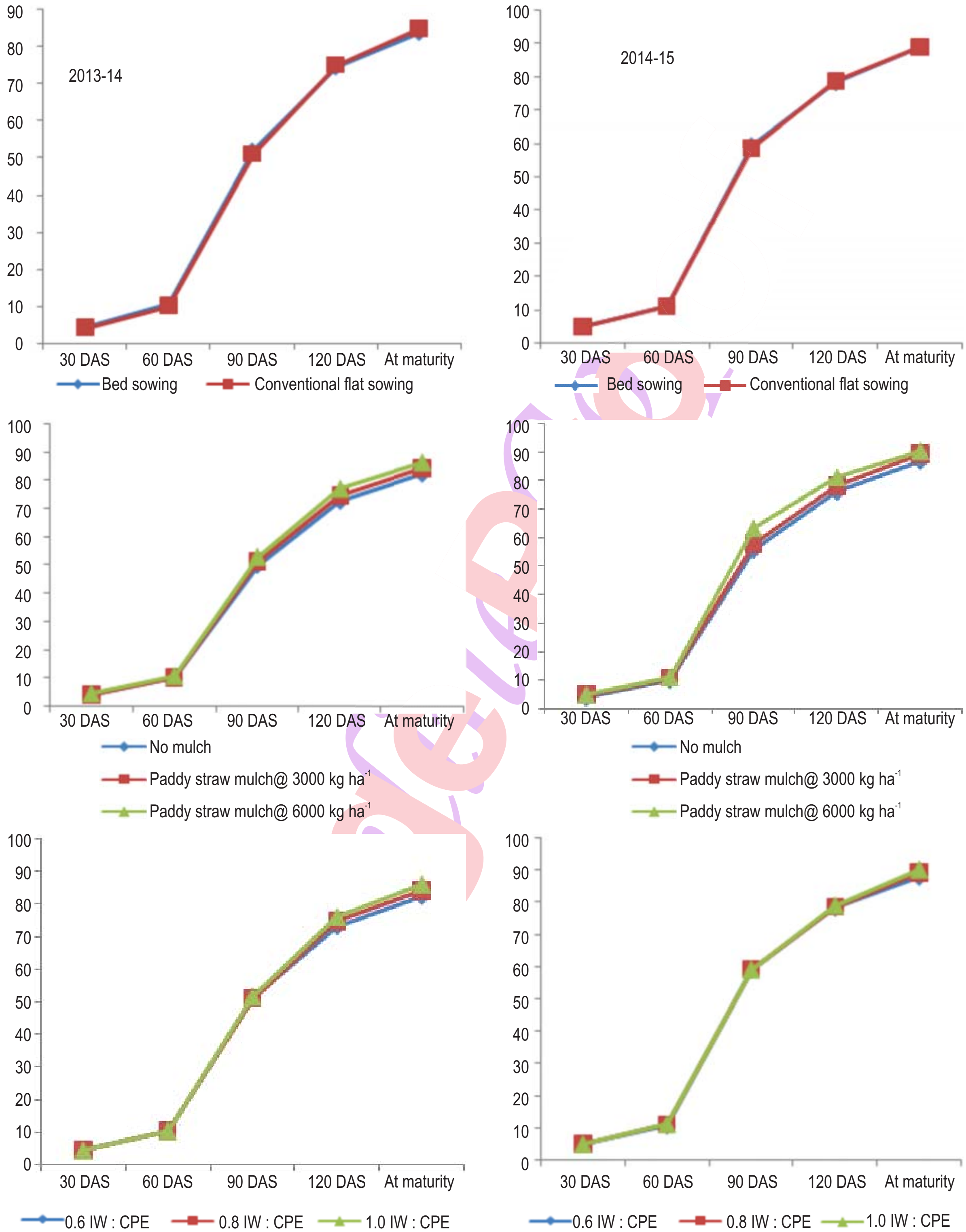


Fig. 1 : Periodic plant height (cm) as influenced by different sowing methods, mulch levels and irrigation schedules

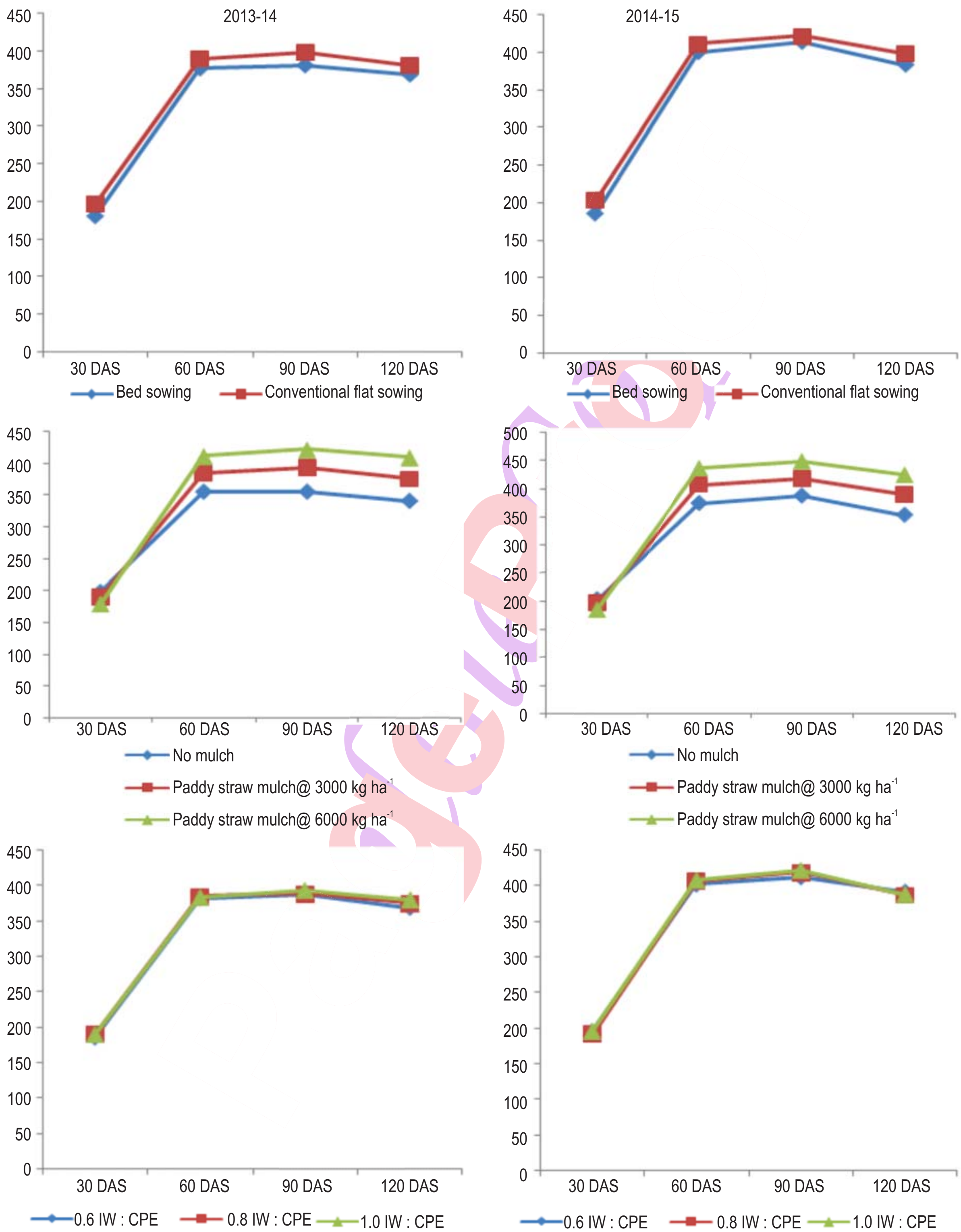


Fig. 2 : Periodic tiller count (m^{-2}) as influenced by different sowing methods, mulch levels and irrigation schedules

Table 2 : Effect of sowing methods, mulch levels and irrigation schedules on biological, grain and straw yield, harvest index and grain straw ratio of wheat

Treatment	Biological yield (kg ha^{-1})			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index			Grain straw ratio		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Sowing methods															
Bed	12410	11470	11940	5380	4640	5010	7030	6830	6930	0.434	0.405	0.420	0.77	0.68	0.73
Flat	12620	11750	12190	5470	4740	5110	7150	7010	7080	0.433	0.404	0.419	0.75	0.68	0.72
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mulch levels (kg ha^{-1})															
0	11610	10870	11240	5010	4410	4710	6600	6460	6530	0.432	0.407	0.419	0.75	0.69	0.72
3000	12660	11640	12150	5480	4680	5080	7180	6960	7070	0.433	0.403	0.418	0.76	0.68	0.72
6000	13260	12340	12800	5780	4990	5380	7480	7350	7410	0.436	0.405	0.420	0.77	0.68	0.73
CD (p = 0.05)	560	530	350	180	200	120	200	450	250	NS	NS	NS	NS	NS	NS
Irrigation schedules (IW/CPE)															
0.6	12140	11150	11650	5240	4510	4870	6900	6640	6770	0.432	0.405	0.418	0.77	0.68	0.73
0.8	12540	11570	12060	5430	4670	5050	7110	6900	7010	0.433	0.404	0.419	0.75	0.68	0.72
1.0	12850	12120	12480	5600	4900	5250	7250	7220	7230	0.436	0.405	0.421	0.76	0.69	0.72
CD (p = 0.05)	550	760	460	200	290	170	270	NS	320	NS	NS	NS	NS	NS	NS

NS = Non- significant

Table 3 : Effect of sowing methods, mulch levels and irrigation schedules on gross returns, net returns and benefit cost ratio of wheat

Treatment	Cost of cultivation (₹ ha^{-1})		Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		Benefit cost ratio	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Sowing methods								
Bed	29987	31008	91129	87827	61142	56819	2.04	1.83
Flat	30514	31602	92604	89829	62090	58227	2.04	1.85
CD (p = 0.05)	-	-	NS	NS	NS	NS	NS	NS
Mulch levels (kg ha^{-1})								
0	27857	28710	85022	83390	57165	54680	2.05	1.90
3000	30251	31305	92834	88767	62583	57462	2.07	1.84
6000	32645	33900	97744	94326	65100	60427	1.99	1.78
CD (p = 0.05)	-	-	2667	3453	2667	3453	NS	NS
Irrigation schedules (IW/CPE)								
0.6	30151	31173	88823	85326	58673	54153	1.95	1.74
0.8	30301	31284	92061	88480	61761	57197	2.04	1.83
1.0	30301	31459	94715	92677	64415	61219	2.13	1.95
CD (p = 0.05)	-	-	3155	5163	3155	5163	0.10	NS

NS = Non- significant; Price of grain- ₹ 14 kg^{-1} (2013-14) and ₹ 14.50 kg^{-1} (2014-15); Price of straw- ₹ 2.25 kg^{-1} (2013-14) and ₹ 3.00 kg^{-1} (2014-15)

spike length with mulching was also reported by Khan *et al.* (2014); Mishra (1996). The biological, grain and straw yields were significantly higher where mulch was applied @ 6000 kg ha^{-1} than 3000 kg ha^{-1} mulch and no mulch application, however, harvest index and grain straw ratio were insignificantly affected by different mulch levels (Table 2). The pooled data showed that mulch application @ 6000 kg ha^{-1} produced 5.9 and 14.2 % higher grain yield than where 3000 kg ha^{-1} and no mulch was applied, respectively. This might be due to better growth and yield attributing characters where mulch was applied in comparison to no mulch application. Higher grain yield under mulch application was also reported in other studies (Khan *et al.,* 2014; Chaudhary and Iqbal, 2013; Singh *et al*., 2011; Acharya *et al*., 1998). Hegan *et al.* (2015) reported 29.3 to 30.63 % increase in yield due to film mulching over without mulching in cotton crop. The cost of cultivation was maximum where mulch was applied @ 6000 kg ha^{-1} than 3000 kg ha^{-1} mulch and no mulch application due to the cost of mulch application (Table 3). The gross returns were significantly higher (₹ 97744 ha^{-1}) where mulch was applied @ 6000 kg ha^{-1} than 3000 kg ha^{-1} mulch (₹ 92834 ha^{-1}) and no mulch application (₹ 85022 ha^{-1}) during 2013-14 and trend was similar during 2014-15. Higher gross returns in mulch treatments might be due to higher grain yield than no mulch. The net returns were significantly higher under mulch application of 6000 kg ha^{-1} than no mulch, but statistically at par with 3000 kg ha^{-1} mulch application. However, benefit cost ratio was insignificantly affected by different mulch levels during both the years. Brahma *et al*. (2007) also reported higher gross and net returns where mulch was applied due to higher grain yield under straw mulch application as compared to no mulch.

The data revealed that the differences in plant height and tiller count were insignificant due to irrigation schedules at all the stages of crop growth up to 120 DAS during both the years because differential irrigation treatments were started only after 120 DAS due to uniform distribution of rainfall throughout the crop growing period (Fig. 1 and 2). However, at maturity during 2013-14, significantly higher plant height was observed under irrigation schedule of IW/CPE ratio of 1.0 than 0.6 which was statistically at par with irrigation schedule of 0.8, however, irrigation schedule of IW/CPE ratio of 0.6 and 0.8 were found to be statistically at par with each other. Among the yield attributing characters, the pooled data (Table 1) showed that number of spikes (m^{-2}) and number of grains per spike were significantly higher under irrigation schedule of IW/CPE ratio of 1.0 as compared to IW/CPE ratio of 0.6, but statistically at par with IW/CPE ratio of 0.8. However, grain weight per spike and 1000-grain weight were significantly higher under irrigation schedule of IW/CPE ratio of 1.0 as compared to IW/CPE ratio of 0.8 and 0.6. The results are confirmed by the findings of Aslam *et al.* (2014) who reported more number of effective tillers with more number of irrigations. The biological, grain and straw yields were significantly higher under irrigation schedule of IW/CPE ratio of 1.0 as compared to IW/CPE ratio of 0.6, but statistically at par with IW/CPE ratio of 0.8 during both the years (Table 2). However, during 2014-15, there was insignificant effect on straw yield. Harvest index and grain straw ratio were insignificantly affected by irrigation schedules during both the years. Irrigation schedule of IW/CPE ratio of 1.0 produced significantly more biological yield (12850 kg ha^{-1}) as compared to irrigation schedule of IW/CPE ratio of 0.6 (12140 kg ha^{-1}), but statistically at par with irrigation schedule of IW/CPE ratio of 0.8 (12540 kg ha^{-1}) during 2013-14. Irrigation schedules of IW/CPE ratio of 0.8 and 0.6 were also statistically at par with each other. Similar trend was observed during second year. Aslam *et al.* (2014) also observed higher biological yield where more number of irrigations were applied. However, the pooled data revealed that biological and straw yields were significantly higher under irrigation schedule of IW/CPE ratio of 1.0 being statistically at par with 0.8 as compared to 0.6, whereas grain yield was significantly higher (4.0 and 7.8 %) under irrigation schedule of IW/CPE ratio of 1.0 than IW/CPE ratio of 0.8 and 0.6. Cost of cultivation increased with increase in number of irrigations during both years (Table 3). The gross and net returns and benefit cost ratio were significantly higher under irrigation schedule of IW/CPE ratio of 1.0 as compared to IW/CPE ratio of 0.6, but statistically at par with IW/CPE ratio of 0.8 during both the years, however, during 2014-15, benefit cost ratio was not significantly affected by different irrigation schedules.

Different sowing methods did not influence significantly the growth, yield attributing characters, yield and economics. Among mulch levels and irrigation schedules, mulch application @ 6000 kg ha^{-1} and irrigation schedule of 1.0 IW/CPE ratio can be used for better growth, grain yield and economic returns of wheat crop.

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References

Acharya, C.L., O.C. Kapur and S.P. Dixit: Moisture conservation for rainfed wheat production with alternative mulches and conservation tillage in the hills of north-west India. *Soil Till. Res.*, **46**, 153-163 (1998).

Ahmed, Z.I., M. Ansar, M. Iqbal and N.M. Minhas: Effect of planting geometry and mulching on moisture conservation, weed control and wheat growth under rainfed conditions. *Pak. J. Bot.,* **39,** 1189-1195 (2007).

Aslam, H., M.A. Ansari, S.K. Baloch, S.U. Baloch and A.S. Baloch: Effect of irrigation scheduling on the growth and harvest index of wheat (*Triticum aestivum* L.) varieties. *Persian Gulf Crop. Prot.,* **3,** 15-29 (2014).

Brahma, R., A.D. Janawade and Y.B. Palled: Effect of irrigation schedules, mulch and antitranspiratnt on growth, yield and economics of wheat (cv. DWD-1006). *Karnataka J. Agric. Sci.*, **20**, 6-9 (2007).

Chakraborty, D., S. Nagarajan, S. Aggarwal, V.K. Gupta, R.K. Tomar, R.N. Garg, R.N. Sahoo, A. Sarkar, U.K. Chopra, K.S.S. Sarma and N. Kalra: Effect of mulching on soil and plant water status, and the growth and yield of wheat (*Triticum aestivum* L.) in a semi-arid environment. *Agric. Water Manage.,* **95,** 1323–1334 (2008).

Chaudhary, S. and J. Iqbal: Weed control and nutrient promotion in zero-tillage wheat through rice straw mulch. *Pak. J. Weed Sci. Res.,* **19,** 465-474 (2013).

Curtis, B.C., S. Rajaram and H.G. MacPherson: Bread Wheat. Food and Agriculture Organization of the United Nations (2002).

Dhillon, S.S., A. Prasher and S. Thaman: Comparative studies on the effect of weed management practices on *Phalaris minor* in bed and conventionally planted wheat (*Triticum aestivum* L.). *Ind. J. Ecol.,* **32,** 72-75 (2005).

FAO: FAOSTAT Agricultural Production Database, Food and Agriculture Organization of the United Nations, FAO, Rome (2015).

Gomez, K.A. and A.A. Gomez: Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons, New York (1984).

Gregory, P.J., D. Tennant and R.K. Belford: Root and shoot growth, and water and light use efficiency of barley and wheat crops growth on shallow duplex soil in a Mediterranean-type environment. *Aust. J. Agric. Res.,* **43,** 555–573 (1992).

Hegan, D., L. Tong, H. Zhiquan, S. Qinming and L. Ru: Determining time limits of continuous film mulching and examining rersidual effects on cotton yield and soil properties. *J. Environ. Biol.,* **36**, 677-684 (2015).

Heyne, E.G.: Wheat and Wheat Improvement. 2nd Edn., Madison, Wiscon, USA (1987).

Khan, R.H., A. Khalid and M.R. Sajjad: Effect of different types of mulches on grain yield and yield components of wheat (*Triticum aestivum*) under rainfed condition. *J. Biol. Agric. Hlth.,* **4,** 85-91 (2014).

Mishra, O. R.: Influence of mulching and antitranspirants on water conservation yield contributing characters of different rainfed wheat varieties. *Crop Res.,* **11,** 1-8 (1996).

Ram, H., V. Dadhwal, K.K. Vashist and H. Kaur: Grain yield and water use efficiency of wheat (*Triticum aestivum* L.) in relation to irrigation levels and rice straw mulching in northwest India. *Agric. Water Manage.,* **128,** 92-101 (2013).

Ram, H., Y. Singh, K.S. Saini, D.S. Kler and J. Timsina: Tillage and planting methods effects on yield, water use efficiency and profitability of soybean-wheat system on a loamy sand soil. *Expl. Agric.,* **49,** 524-542 (2013a).

Sayre, K.D. and P.R. Hobbs: The raised-bed system of cultivation for irrigated production conditions. In: Sustainable Agriculture and the International Rice-Wheat System (Eds.: R. Lal, P.R. Hobbs, N. Uphoff and D.O. Hansen). Marcel Dekker, Inc., New York, USA, pp. 337-355 (2004).

Saini, M.K. and U.S. Walia: Effect of planting patterns and weed control treatments on *Phalaris minor* growth and productivity of wheat (*Triticum aestivum*). *Ind. J. Agron.,* **55**, 110-113 (2010).

Shafiq, M., M.R. Amin, M.Z. Ikram and G.R. Sandhu: Effect of fertilizer and mulches on wheat growth and yield under rainfed conditions. *J. Agric. Res.,* **32,** 165-171 (1994).

Singh, B., E. Humphreys, P.L. Eberbach, A. Katupitiya, Y. Singh and S.S. Kukal: Growth, yield and water productivity of zero-till wheat as affected by rice straw mulch and irrigation schedule. *Field Crops Res.,* **121,** 209–225 (2011).

Singh, Y., E. Humphreys, S.S. Kukal, S.S. Dhillon, S.S. Singh, B. Kaur, S. Thaman, A. Prashar, S. Yadav, N. Kaur, D. J. Smith, J. Timsina and P.R. Gajri: Crop performance in a permanent raised bed rice-wheat cropping system in Punjab, India. *Field Crops Res.,* **111**, 1-20 (2008).

Tanwar, S.P.S., S.S. Rao, P.L. Regar, S. Datt, Praveen-Kumar, B.S. Jodha, P. Santra, R. Kumar and R. Ram: Improving water and land use efficiency of fallow-wheat system in shallow Lithic Calciorthid soils of arid region: Introduction of bed planting and rainy season sorghum–legume intercropping. *Soil Till. Res.,* **138,** 44-55 (2014).

Yanusa, J.A.M., R.K. Belford, D. Tennant and R.H. Sedgley: Row spacing fails to modify soil evaporation and grain yield in spring wheat in a dry Mediterranean environment. *Aust. J. Agric. Res.,* **44,** 661–676 (1993).