https://doi.org/10.56093/ijas.v90i3.101461

Indian Journal of Agricultural Sciences **90** (3): 519–23, March 2020/Article

Growth, yield, water use efficiency of wheat (*Triticum aestivum*) under different sowing dates, planting methods and irrigation treatments

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Received: 27 July 2018; Accepted: 31 July 2019

ABSTRACT

Field experiments were conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana during *rabi* seasons of 2014–15 and 2015–16. Wheat (*Triticum aestivum* L.) variety WH-1105 was sown on 10th and 30th November under two planting methods (flat and bed) with three irrigation treatments (I_1- three post-sowing irrigations at crown root initiation (20-25 days after sowing), flag leaf emergence (70-80 days after sowing) and soft dough stages (115-120 days after sowing), I_2- I_{1+} fourth irrigation during last week of March (Hard dough stage) and I_3- Recommended four post-sowing irrigations (crown root initiation, tillering, jointing/booting and milking) in sub-sub plots replicated four times. The experiment was planned to study the effect of sowing dates, planting methods and irrigation treatments on growth, yield and water use efficiency of wheat. Dry matter accumulation and leaf area index showed significant differences between different dates of sowing and planting methods during entire growing period however significant differences among irrigation treatments were observed at 120 DAS during both the seasons. The grain yield and water use efficiency was higher in 10th November sowing as compared to 30th November as well as under bed planting compared to flat planting. However by giving one extra irrigation during end of March under I_2, the increase in grain yield was up to 6-13% over I_3 and I_1 treatments.

Key words: Bed planting, Dry matter accumulation, Leaf area index, Water use efficiency, Wheat

Wheat (*Triticum aestivum* L.) is an important and remunerative *rabi* crop of North India. High temperature can cause a delay in seedling growth. Rainfall during harvesting of wheat is harmful, ultimately leading to a situation of food insecurity in the country (Janjua *et al.* 2010). Due to climate change the water shortage will be one of the limiting factors in future especially under Punjab conditions. So improving water use efficiency (WUE) through irrigation management is a viable approach to mitigate the water shortage problem. Several practices such as water-saving irrigation, planting crop on raised beds and furrows, irrigation application etc. are gaining importance in water-saving agriculture for improving WUE (Singh *et al.* 2010).

Bed planting in rice-wheat system is a viable technique for improving resource use efficiency, and increasing yield and saving resources like water, nutrients and labour etc. The crop is planting on raised beds, and the furrows are used for irrigation (Anonymous 2016). It provides better water management and reduces the seed rate than conventional flat planting (Jat *et al.* 2005).

Along with modification in planting methods, irrigation scheduling at critical stages can also be used to maximize crop yield and water productivity. During grain filling stage, plants are subjected to some unfavourable conditions such as high temperature, low winter rainfall, shortage of water for irrigation, the need to withholding irrigation for saving water and early land evacuation for cultivation of following crop. Lot of work has already been reported on water saving practices but still there is a need to evaluate these practices under Punjab conditions. In view of this, the experiments were planned to study the growth, yield and water use efficiency of wheat under different sowing dates, planting methods and irrigation treatments so that viable management strategies could be identified to improve water use efficiency of wheat without any significant reductions in grain yield.

MATERIALS AND METHODS

The experiment was conducted during *rabi* seasons of 2014–15 and 2015–16 at the Research Farm, Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana, located at 30°54'N latitude 75°48'E longitude and at an altitude of 247 m amsl. This area is characterized by subtropical type of climate with hot summers during May-June and cold winters during December-January. The wheat variety WH-1105 was sown on two dates of sowing (10th November and 30th November) under two planting methods (flat planting and bed planting) with three irrigation treatments (I_1- three post-sowing irrigation at CRI, flag leaf emergence and soft dough stages, I_2- I_{1+} fourth irrigation during last week of March (Hard dough

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stage) and I_3- recommended four post-sowing irrigations, crown root initiation (20-25 days after sowing), tillering (40-45 days after sowing), Jointing/booting (60-70 days after sowing) and milking (100-105 days after sowing) with four replications. The soil of the experimental field was sandy loam in texture. The data collected on growth and yield parameters were statistically analyzed by using Split- split Plot Design in statistical package CPCS-1. The recommended PAU Package and Practices were followed for raising crop. The periodic leaf area index was recorded with Canopy Analyzer. The water use efficiency was calculated using the following formulae (Zhang *et al.* 2007).

$$\text{Water use efficiency (kg/ha/mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Water use (mm)}}$$

RESULTS AND DISCUSSION

Dry matter accumulation: The D_1 produced significantly higher total above dry matter as compared to D_2 during 2014–15 and 2015–16, respectively. The reduction in dry matter (DM) production in delayed sowing was due to reduction in vegetative growth duration as a result of rise in temperature February onwards that caused the crop to mature early. Similar results were also reported by Suleiman *et al.* (2014). Significantly higher amount of dry matter was produced in bed planting (M_2) as compared to flat planting (M_1) during 2014-15 and 2015-16 respectively, which might be due to production of higher number of tillers in M_2 which positively influenced the DM production during both the years. Moreover in M_2 method wheat intercepted more solar radiation and produced higher DM as compared to M_1 method. Khatri *et al.* (2002) also observed higher leaf area index (LAI), dry matter accumulation and grain yield in bed planted crop as compared to flat planted crop. The maximum DM accumulation was obtained after 120 DAS under I_2 followed by I_3 and I_1 during 2014–15 and 2015–16, respectively. The crop experienced high temperature stress at the end of March which ultimately affected the DM production of the crop. So by applying an extra irrigation in March, crop avoided stress period to some extent. These results are in accordance with those of Aslam *et al.* (2003).

Leaf area index: Maximum LAI was observed at 90 days after sowing and started decreasing gradually as the older leaves reached senescence (Table 1). Significantly higher LAI was recorded in D_1 as compared to D_2 during 2014–15 and 2015–16. It might be due to better crop vigour and growth in early sown crop. Dar *et al.* (2018) also reported that 15th October sown wheat crop recorded higher leaf area index than 15th November sown crop. The maximum leaf area index was recorded in M_2 as compared to M_1 during

Table 1 Dry matter accumulation and leaf area index under different date of sowings, planting methods and irrigation treatments during *rabi* 2014–15 and 2015–16

Treatment	Dry matter accumulation (q/ha)									
	30 DAS		60 DAS		90 DAS		120 DAS		At physiological maturity	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
D_1	18.1	15.7	62.2	53.1	154.3	144.7	174.8	160.5	182.6	172.1
D_2	15.2	12.9	54.0	45.7	142.6	129.3	159.1	142.7	169.5	157.4
CD (P=0.05)	2.2	1.1	4.6	3.1	3.8	5.5	11.4	9.1	11.0	10.2
M_1	15.9	13.4	55.1	46.2	146.5	133.0	163.9	146.3	171.2	156.6
M_2	17.4	15.2	61.0	52.6	150.3	141.0	170.0	156.9	180.9	172.9
CD (P=0.05)	1.1	1.4	3.6	3.8	3.6	6.4	4.5	9.6	6.7	8.9
I_1	16.7	14.0	57.2	48.8	146.0	134.4	159.7	146.2	170.3	158.3
I_2	16.9	14.5	59.3	50.2	149.5	139.3	173.0	158.3	183.7	173.3
I_3	16.3	14.5	57.8	49.2	149.7	137.3	168.1	150.3	174.1	162.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS	9.8	5.9	8.9	10.8
	Leaf area index									
D_1	2.0	1.6	3.75	3.1	4.7	4.6	4.3	4.0	2.6	2.2
D_2	1.8	1.4	3.27	2.6	4.2	4.1	3.7	3.5	2.4	1.8
CD (P=0.05)	NS	NS	0.47	0.4	0.3	0.5	0.3	0.2	0.1	0.3
M_1	1.9	1.5	3.32	2.6	4.2	4.2	3.7	3.6	2.3	1.9
M_2	1.9	1.5	3.71	3.1	4.7	4.5	4.2	3.9	2.6	2.1
CD (P=0.05)	NS	NS	0.31	0.3	0.3	0.3	0.5	0.2	0.2	0.1
I_1	1.8	1.5	3.47	2.8	4.4	4.3	3.8	3.7	2.4	1.9
I_2	1.9	1.5	3.59	2.9	4.5	4.4	4.2	3.9	2.7	2.2
I_3	1.9	1.5	3.48	2.8	4.4	4.3	3.0	3.8	2.4	2.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.30	0.2	0.2	0.2

rabi 2014–15 and 2015–16, respectively, because crop stand as well as tiller production was higher in M_2 method. The maximum LAI was recorded at 90 DAS during both the crop seasons and decreased afterwards.

Significantly higher LAI was obtained under I_2 followed by I_3 and I_1 during both the years. The effect of irrigation scheduling was non-significant up to 90 days and afterwards significant differences were observed. The decrease in LAI due to moisture stress might be due to reduction in rate of cell division and cell elongation and lower rate of photosynthesis. These were in agreement with the results of Hamid *et al.* (2012).

Yield and yield attributing characteristics

Number of effective tillers: Significantly higher number of effective tillers were produced when sowing was done on 10th November as compared to 30th November sowing (Table 2). The delayed sowing of the crop reduced the number of effective tillers. The reduction in effective tillers with delayed sowing was also reported by Qasim *et al.* (2008). Maximum number of effective tillers/m^2 was observed in M_2 as compared to M_1 method. Kaur and Dhaliwal (2015) also reported higher number of effective tillers under bed planted crop as compared to flat planted crop. The I_2 recorded significantly higher number of effective tillers as compared to the other treatments (I_3 and I_1). The I_1 irrigation treatment resulted in minimum number of effective tillers. Sarwar *et al.* (2010) also concluded that more number of effective tillers were produced by increasing irrigations.

Ear length: The ear length was significantly influenced by sowing time, planting methods and irrigation schedules. The maximum ear length (10.4 cm) was recorded in D_1 followed by D_2 (9.73 cm) during *rabi* 2014–15. During *rabi* 2015–16, maximum ear length (10.1 cm) was recorded at harvesting in 10th November sown crop followed by 30th November (9.43 cm) significantly lower ears were recorded in D_1 than D_2. The longer ears in early sowing might be due to more dry matter accumulation and long duration of different phenophases. The similar effect of delayed sowing on ear length in wheat was reported by Kumar *et al.* (2005). Significantly higher ear length was recorded in M_2 than M_1 method during both the crop seasons which might be better crop stand, higher LAI and DM accumulation and more productive tillers which collectively contributed longer ears in bed planting crop as compared to flat planted crop. Similar trend was also observed by Kaur *et al.* (2001). The application of extra irrigation to the crop significantly influenced the ear length under I_2 treatment followed by I_3 treatment and I_1 treatment during both the crop seasons. Brahma *et al.* (2007) also reported that plant height, total DM production, ear length and 1000-grain weight were higher in frequently irrigated treatments.

Number of grains per ear: The number of grains per ear was directly proportional to ear length. Significantly higher number of grains per ear was recorded in D_1 than D_2 during both the seasons which might be due to higher ear length in early sowing. The high temperature stress at reproductive phase of crop results in poor yield due to reduced number of grains per spike and shriveled grain with poor quality (Kaur and Pannu 2008). In M_2 method, higher number of grains per ear was observed as compared to M_1 during *rabi* 2014–15 and 2015–16, respectively. Ear length was maximum in bed planting crop which contributed towards the highest number of grains per ear. Zhongming and Fahong (2005) also reported similar results. Significantly higher number of grains per ear was obtained under I_2 followed by I_3 and I_1 during both the crop seasons. Idnani and Kumar (2012) also observed the similar results.

1000-grain weight: The highest 1000-grain weight was recorded in D_1 which may be due to low temperature essential for the reproductive growth. Fayed *et al.* (2015) reported that significantly higher 1000-grain weight was obtained under early sowing date (October 15). Planting method also influenced the 1000-grain weight significantly. The highest 1000-grain weight was recorded in M_2 method during both the crop seasons. Meisner *et al.* (2005) and

Table 2 Yield attributing characteristics under different dates of sowing, planting methods and irrigation treatments during *rabi* 2014-15 and 2015-16

Treatment	Yield attributing characteristics								Grain yield (q/ha)		Water use efficiency (kg/ha/mm)	
	Number of effective tillers/m^2		Ear length per ear (cm)		Number of grains per ear		1000 grain weight (g)					
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
D1	485.7	439.8	10.4	10.1	55.5	52.3	37.1	35.3	50.0	47.0	13.2	12.1
D2	425.9	403.2	9.7	9.4	49.2	45.4	34.9	33.2	45.0	43.0	11.2	10.1
CD (P=0.05)	41.9	34.8	0.5	0.6	4.1	2.2	1.8	1.1	3.7	3.8	1.7	1.7
M1	435.2	381.2	9.9	9.5	50.0	46.5	35.3	33.4	45.5	44.2	11.1	9.9
M2	476.6	461.7	10.3	10.0	54.1	51.1	36.6	35.1	49.5	45.7	13.2	12.3
CD (P=0.05)	36.4	49.8	0.4	0.4	3.9	4.5	0.9	1.3	3.7	NS	1.9	1.0
I1	431.7	377.1	9.4	9.3	49.6	45.2	34.7	32.9	45.9	42.4	13.1	12.1
I2	480.1	469.8	10.6	10.2	55.9	51.1	37.1	35.5	49.5	48.8	11.4	9.9
I3	455.7	397.5	10.3	9.8	50.7	50.1	36.9	34.4	47.5	46.1	12.0	11.2
CD (P=0.05)	32.3	42.8	0.7	0.5	4.4	3.4	1.6	1.91	NS	3.5	1.3	0.9

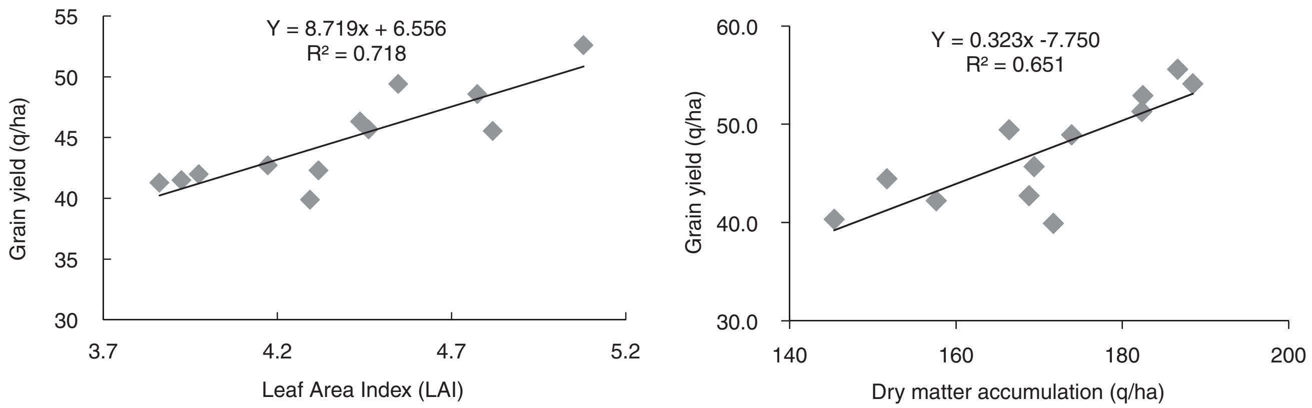

Fig 1 Relationship between grain yield and leaf area index and dry matter accumulation (2 years pooled data).

Hossain *et al.* (2006) also revealed that bed planting produced more grain weight due to significantly higher effective tillers, ear length and number of grains were observed in bed planted crop, which produced higher grain weight during both the crop seasons. In I_2 maximum grain weight was observed followed by I_3 and I_1 treatments. Naresh *et al.* (2013) also reported that adequate and prolonged supply of water increased productive tillers, number of grains per ear and 1000 grain weight.

Grain yield: The data showed that the highest grain yield was produced in D_1 (50.0 and 47.0 q/ha in 2014–15 and 2015–16, respectively) as compared to D_2 (45.0 and 43.0 q/ha in 2014–15 and 2015–16, respectively). Kaur and Dhaliwal (2015) also reported that grain yield was higher in 1st November sown crop (51.3 q/ha) as compared to 15th November and 30th November sown crops. Bed planting produced significantly higher grain yield during 2014–15 but no significant differences were observed during 2015–16 although numerically higher grain yield was obtained under bed planted crop. Similar yield increase under bed planting in wheat was also reported by Hossain *et al.* (2004). Maximum grain yield was obtained under I_2 as compared to I_3 and I_1 during both the crop seasons. However, the differences among the irrigation treatments during 2014–15 were non-significant as good amount of rainfall (219.6 mm) was received during entire crop season, whereas only 72.3 mm rainfall was received during 2015–16. Grain yield of wheat was significantly increased with an increase in irrigation frequency. Similarly, Kang *et al.* (2002) also reported the similar results.

Water use efficiency: Sowing time, planting methods and irrigation treatments significantly affected the water use efficiency (WUE) of wheat during both the seasons (Table 2). D_1 exhibited more WUE as compared to D_2. In early sown crop higher WUE was also observed by Meena *et al.* (2015). The highest WUE (up to 15.5 % in 2014-15 and 19.0 %) in 2015–16 was recorded under M_2 method as compared to M_1 method which might be due to increase in grain yield and less amount of water applied per irrigation than M_1 method (Buttar *et al.* 2006). The WUE was higher (up to 13.0 % during 2014–15 and up to 18.1 % during 2015–16) in I_1 as compared to I_3 and I_2 treatments. The higher value of consumptive water use lead to decrease in WUE under unstressed treatments. Zaman *et al.* (2017) also reported that an increase in water supply lead to reduction in water use efficiency.

Regression analysis: The regression analysis of grain yield with LAI and dry matter accumulation was conducted (Fig 1). A positive and linear relationship of grain yield with LAI and DM accumulation was observed. Similarly, a positive and linear relationship between grain yield and water use efficiency (Fig 2) was also observed with R^2value of 0.74.

In view of declining groundwater level in Punjab, management of natural resources needs more attention. Therefore to have sustainable food production in future, resource conservation technologies like bed planting and irrigation management can play crucial role. Because of

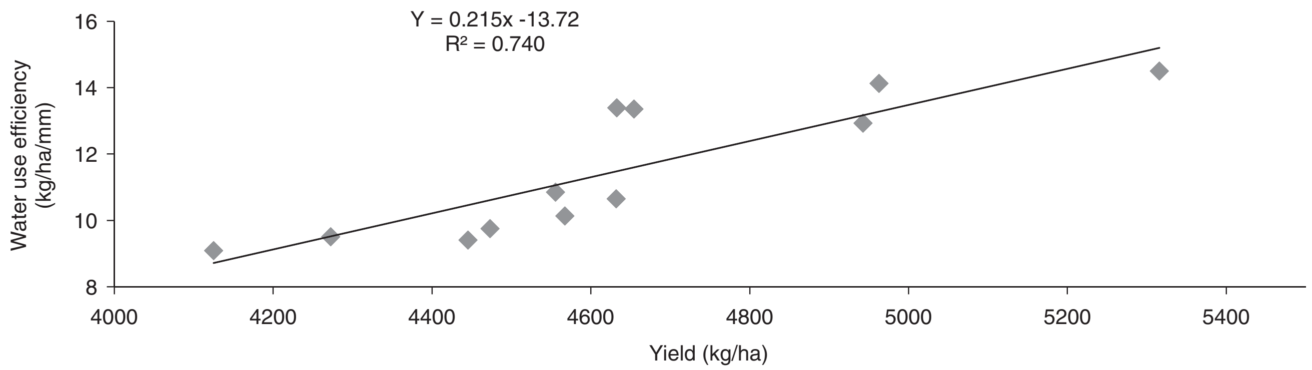

Fig 2 Relationship between grain yield with water use efficiency (2 years pooled data).

water scarcity and limitation of arable land, future increase in production will have to come mainly by growing more food on existing land and water. Hence better management practices needs to be validated often and this study serves as one.

ACKNOWLEDGEMENTS

The authors are thankful to the Department of Science and Technology (DST), New Delhi for funding the adhoc project under which the present investigation was carried out.

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