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Research Paper

Response of wheat cultivers under varied irrigation regimes, temporal adjustments and locations in Punjab

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ABSTRACT

Wheat is a predominant food crop of Punjab, contributing significantly towards state's agricultural economy. However, the diverse agro-climatic zones of the state, ranging from the sub-montane regions to the plains and arid regions, exploring exclusive challenges for wheat cultivation in Punjab. To identify different varieties suitable for particular region as well as to optimize crop management practices, the comprehensive field trials were conducted aiming towards analysing the data and contributing towards the development of sustainable wheat production system in Punjab. A field experiment was conducted over two consecutive *rabi* seasons (2017–18 and 2018–19) at three different locations in Punjab (Ludhiana, Faridkot, and Ballowal Saunkhri). The experiment followed a factorial split plot design with three dates of sowing (D_1, 25th October; D_2, 15th November; D_3, 5th December) and three wheat cultivars (V_1, WH1105, V_2, UNNAT PBW 550, V_3, PBW 590) in the main plots, whereas two irrigation treatments (I_1: Recommended, I_2: Recommended ± weather forecast based) in the subplots. Across both seasons, the crop sown on 15th November consistently exhibited the highest tiller count (per/m^2) and dry matter at harvest (g/m^2) i.e. 120.0 and 388.4, 115.2 and 378.0 and 90 and 262.2 for Ludhiana, Faridkot and Ballowal Saunkhri respectively. At Ludhiana, Faridkot and Ballowal Saunkhri, the grain yield was 4.8 t/ha, 4.6 t/ha and 3.7 t/ha respectively for D_2 which was significantly higher than D_3 (4.2 t/ha, 3.8 t/ha and 3.0 t/ha) and at par with D_1 (4.6 t/ha, 4.4 t/ha and 3.6 t/ha) for Ludhiana, Faridkot and Ballowal Saunkhri respectively). Among the cultivars, UNNAT PBW550 produced significantly more yield (4.8, 4.7 and 3.9 t/ha) than PBW 590 (4.0, 3.6 and 3.0 t/ha) for Ludhiana, Faridkot and Ballowal Saunkhri respectively. Ballowal Saunkhri recorded lowest grain yield among the different locations. Analysis indicated non-significant differences in yield under different irrigation schedules across the three sowing dates. it has been observed from the study that reduction in yield is caused with delay in sowing time of wheat, whereas scheduling irrigation based on weather forecast can be helpful in saving irrigation water and other resources.

***Key words*:** Agroclimatic zones, Irrigation schedules, Sowing dates, Varieties, Wheat

Wheat (*Triticum aestivum* L.) is a predominant cereal crop which is widely cultivated under 34.57 lakh ha in Indo-Gangetic plains, India. All of India's states cultivate wheat, with the exception of the southern and northern ones. The top producers, Haryana, Punjab, Rajasthan, and Uttar Pradesh, produce 80% of the nation's wheat. With a production of 165.67 lakh tonnes and it occupied over 35.17 lakh hectares in Punjab (Anonymous 2024-25). A major factor in raising wheat production was the introduction of dwarf wheat cultivars, which were supported by better cultural practices and protection techniques. It is a temperate-region cereal crop that is grown in India from November to April. Wheat is a long-day crop plant that is extremely thermosensitive and photo-insensitive, and it needs a cool environment to flourish in its early stages. Temperature increases may have an impact on crop productivity (Wu *et al*., 2016). It typically needs a temperature range of 10 to 15°C for sowing and 21 to 26°C for ripening, along with 50 to 100 cm of seasonal rainfall on average. Since greenhouse gas emissions over the past few decades have caused the global temperature to rise by 1°C above its pre-industrial level, global warming is a grave problem on a global scale (IPCC, 2014).

In Punjab, there are mainly five agro-climatic zones. Each zone has a distinct cropping system. For example, maize-wheat system in Foot-hill (*Kandi*) zone, rice-wheat

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in Central zone and cotton-wheat in South Western zone. In South-Western zone & Kandi zone, productivity of wheat is relatively lower than the Central zone because of its soil type, topography, sowing window, irrigation, etc. The timely irrigation saves the wheat crop from low temperature during the growth period and also minimizes the effect of forced maturity during the hot month of March and April. But in South Western zone, the availability of good quality of irrigation water is insufficient. The water supply from the canals is erratic and the ground water is of poor quality. In *kandi* zone, most of the area is rainfed and crop is totally dependent on rains. Thus, there is a need to analyze the performance of wheat in different agroclimatic regions under different environments (Buttar *et al.,*2006).

In addition to use of high-yielding cultivars, better agronomic techniques, and favorable weather in India's wheat-growing regions have contributed to the current state of wheat production. Wheat is primarily grown in the winter, with sowing starting in November and harvesting taking place in April or May. Rainfall has little effect on crop growth and yield in Punjab because 95% of the cropped area is irrigated for the wheat harvest.

As groundwater is depleting day by day, applying irrigation in view of weather forecast can significantly contributed towards water conservation and can reduce the harmful effects of aberrant weather conditions.

At the moment, the wheat crop is sown from the fourth week of October to the middle of December. In Punjab state, however, the entire month of November is seen to be the best time to plant wheat. Shifting sowing time of a crop is one of the most easily adaptable strategies to the changing climate. However, whether to sow early or late to adapt to climate change at a given site would depend on the current climatic conditions and future changes in climate. A simulation study showed that shifting of sowing date for wheat from normal sowing date to 24th November in Punjab will be the most suitable measure to nullify the impact of climate change for three climatic zones of the state but in one agroclimatic zone for higher yield the optimized sowing date (24th November) needs to be supplemented with higher N doses (Kaur *et al.,* 2023). The main idea behind this was that wheat cultivars revealed different levels of performance in different agroclimatic regions of Punjab. Early maturing varieties will be more suitable for areas having shorter growing seasons and risk of late season stresses. The varieties will be identified for good disease resistance and heat tolerance in different regions. The optimal sowing time, irrigation, and fertilization practices will significantly influence wheat yield and quality. Therefore, the present study was conducted to evaluate the effect of different dates of sowing and irrigation scheduling on wheat productivity in different agroclimatic zones under changing climate scenarios.

MATERIALS AND METHODS

The present study was carried out in Punjab, India, during two consecutive *rabi* seasons (2017–18 and 2018–19) at three different locations *i.e*, Ludhiana, Faridkot and Ballowal Saunkhri, representing three agroclimatic zones of Punjab. Ludhiana, lies in Central plain zone having longitude 75°56'E and 30°54'N, Research Station Faridkot lies in South western zone having longitude 74°73' and latitude 30°67' and Ballowal Saunkhri lies in sub mountainous Punjab having longitude 75°48' and 31°40' latitude Fig. 1.

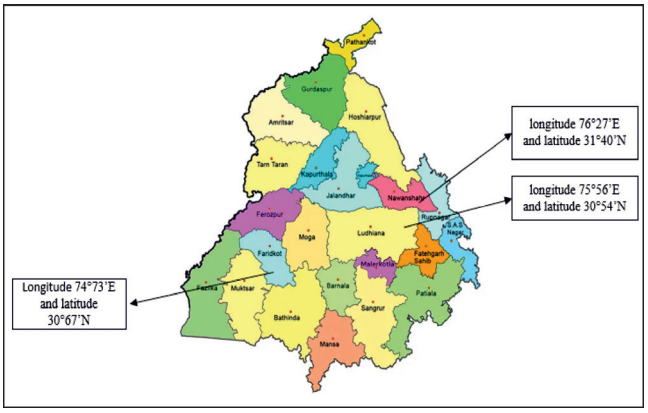

Fig. 1. Map of Ludhiana, Faridkot and Ballowal Saukhri stations

Weather at different locations

In Punjab, higher productivity can be expected if maximum temperature remains within 15-22 & 21-28°C and minimum temperature remains within 4-11 & 7-13°C during vegetative & grain development stages, respectively (Anonymus 2022). The average annual rainfall is 755, 400 and 1051 mm, for Ludhiana, Faridkot and Ballowal Saunkhri, respectively. Approximately 80 per cent of which is received during south-west monsoon season (June to September).

The meteorological data of observatories installed at different stations showed that the total rainfall received was highest in Ballowal Saunkhri i.e 114.8 and 337.2 mm during rabi seasons of 2017-18 and 2018-19, respectively. The total rainfall recorded at Ludhiana was 86.4 and 213.2 mm during *rabi* seasons of 2017-18and 2018-19, respectively. The rainfall received during both the years (2017-18 and 2018-19) was comparatively less at Faridkot i.e 41.6 and 65.3mm, respectively (Fig. 2).

Soil properties

The soil texture of Ballowal Saunkhri station is sandy loam, the soil pH is 7.8 and EC is 0.21 dS m^{-1} and organic carbon is 4.8 g kg^{-1}, at Ludhiana station soil pH is 7.6. EC

is 0.19 dS m^{-1} and organic carbon is 3.6 g kg^{-1}, for Faridkot station soil pH is 7.8, EC is 0.32 dS m^{-1} and organic carbon is 5.5 g kg^{-1}.

The field experiment was conducted in factorial split plot design with three replicates, three dates of sowing (25th October, 15th November and 5th December), three wheat varieties (WH_1105, UNNAT PBW 550 and PBW 590) as main plots and two irrigations levels (recommended and forecast based) as a sub-plot. Wheat crop was sown at row to row spacing of 22.5 cm, using 100 kg/ha seed rate for two cultivars (WH1105 and PBW 590) and 112.5 kg/ha for Unnat PBW 550 as recommended by the PAU, Ludhiana. Seed treatment was also done with 4 ml of Dursban 20 EC per kg seed, dried the seed in shade and then treated the seed with Vitavex @ 2 g/kg seed. Recommended dose of Nitrogen was applied in the form of urea @ 125 kg N/ha in three splits i.e. half at sowing time and the second half at CRI stage with first irrigation and third irrigation. Phosphorus @ 62.5 kg P_2O_5 /ha was applied at sowing time at all three locations for all dates of sowing. The crop data recorded during 2017-18 and 2018-19 was pooled for analysis.

The first irrigation was applied after 21 days after sowing and after that irrigations were given as per recommended in package of practices. The depth of each irrigation was kept at 7.5 cm for all the plots. Weeds were controlled by applying Stomp 30 EC @ 2500 ml/ha mixed in 500 litres of water, and applied at two days after sowing. The data pertaining to 1000 grain weight and number of grains per ear were recorded at maturity from randomly selected five plants and number of tillers from one meter row length from each plot. The dry weight of plant was taken after drying at 65 °C till constant weight was achieved. The weight of grains was calculated by weighing the grains obtained from five randomly selected ears and the average weight was expressed at 12 percent grains moisture content. The grain yield was expressed in $kgha^{-1}$ at 12 percent moisture content. The harvest index was calculated by dividing the seed yield with biological yield and was taken as percentage (Nichiporovich, 1995).

Table 1. Effective tillers, dry matter and tillers of wheat as influenced by dates of sowing and irrigation levels at Ludhiana during *rabi* season

Treatments	Ludhiana			Faridkot			Ballowal Saukhri		
	Plant Height at harvest (cm)	Tillers/m^2	Dry-matter (g/m^2)	Plant Height at harvest (cm)	Tillers/m^2	Dry matter (g/m^2)	Plant Height at harvest (cm)	Tillers (per $meter^2$)	Dry matter (g/m^2)
Dates of sowing									
5-Oct	89.9	107.3	320.3	85.9	105.4	288.1	83.5	87.3	227.5
15-Nov	91.5	120.0	388.4	87.4	115.2	378.0	85.3	90.0	262.2
5- Dec	83.2	90.8	266.2	82.6	89.8	259.9	79.3	66.9	205.8
CD (0.05)	3.3	12.6	19.4	2.9	13.4	15.0	2.4	7.3	10.5
SEm	1.1	4.1	6.6	0.9	4.2	4.9	0.8	2.4	3.2
Varieties									
WH1105	92.7	119.9	319.1	89.2	108.5	304.1	86.3	86.4	232.9
Unnat PBW550	88.4	116.2	352.1	84.4	111.1	323.0	82.7	87.6	243.0
PBW590	83.6	91.0	303.7	82.3	90.8	298.9	79.1	73.0	218.4
CD (0.05)	3.3	12.6	19.4	2.9	13.4	15.0	2.4	7.3	10.5
SEm	1.1	4.1	6.6	0.9	4.2	4.9	0.8	2.4	3.2
Irrigation Levels									
Recommended(I1)	88.6	107.2	326.0	85.2	104.6	312.1	83.0	82.1	233.5
Recommended±Forecast based(I2)	87.9	104.8	322.5	85.6	102.4	305.2	82.4	80.7	230.1
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

RESULTS AND DISCUSSION

Weather conditions at different agroclimatic regions of Punjab

Among the years 2017-18 and 2018-19, higher yield was observed during 2018-19, the difference in yield between the two seasons may be due to favourable weather conditions during the second year of study. Hundal and Kaur (2007) reported a significant decrease in yield with rise in temperature by 4°C. During March 2018 the average maximum temperature at Ludhiana, Faridkot and Ballowal Saunkhri were 29.3, 29.6 and 29.4°C, respectively, which was about 2.6, 3.7 and 1.3°C, respectively above normal. During 2019, average maximum temperature at Ludhiana, Faridkot and Ballowal Saunkhri was 25.3, 25.4 and 25.1, respectively, which was 1, 0.5, 3 °C below the normal, respectively (Fig 2).

Maximum temperature of January month during 2017-18 and 218-19, at Ludhiana and Faridkot was higher by (0.5 °C and 1.8 °C) and (0.5°C and 0.3°C), respectively. During 2017-18, Maximum temperature for February at Ballowal Saunkhri, Ludhiana and Faridkot was higher than the normal (0.6°C, 1.7°C, 2.1°C) as compared to 2018-19, respectively (Fig. 2). During 2017-18 maximum temperature of April was also higher from the normal at Ludhiana and Faridkot by 1^{0}C and 0.7 ^{0}C as compared to 2018-19, where it was also increased by 0.3 °C at both the locations. So yield was higher during 2018-19 as compared to 2017-18.

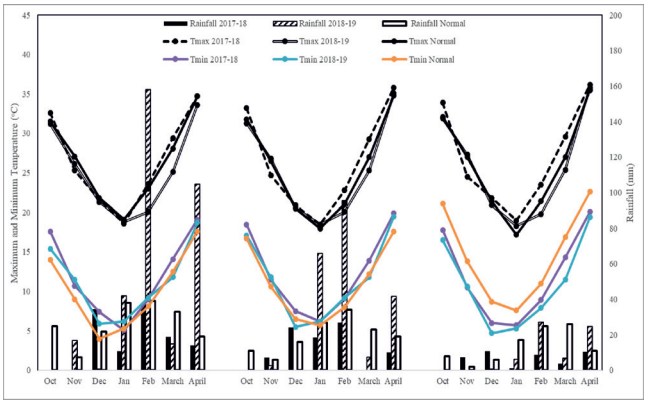

Fig. 2. Maximum temperature, minimum temperature and rainfall at Ballowal Saunkhri, Ludhiana and Faridkot during *rabi* season 2017-18 and 2018-19

During 2017-18, Minimum temperature at Ballowal Saunkhri and Ludhiana for March was also higher from normal by 1.6°C, and 1.7°C, respectively. Whereas, during 2018-19, it was lower by 0.4°C and 0.7 °C, respectively. During 2017-18 minimum temperature of April was also higher from the normal at Ballowal and Ludhiana by 1.5^{0}C and 2.3 ^{0}C as compare to 2018-19, where it was also increased by 1.1°C and 1.9°C, respectively (Fig. 2).

Among the different locations, maximum temperature during February and March months were higher from the normal at Faridkot followed by Ludhiana and Ballowal Saunkhri. The highest rainfall was received at Ballowal Saunkhri followed by Faridkot and Ludhiana. The lowest yield was observed at Ballowal Saunkhri This may be due to the highest rainfall and light soil, as the highest yield was observed in Ludhiana followed by Faridkot, where the maximum temperatures were 1.7^{0}C and 2.1^{0}C, respectively.

As per rainfall amount received during 2017-18 and 2018-19, it has been observed that the rainfall received during 2018-19 was higher than the 2017-18 at all the stations. Mainly during the month of January, February and April higher rainfall was received from normal at all the three locations during 2018-19 except Faridkot station, where it was highest during February month only. During 2017-18 and 2018-19 total seasonal rainfall was also higher at Ballowal Saunkhri (114.8 mm and 337.2 mm) followed by Ludhiana (86.4mm and 213.2 mm) and Faridkot (41.6mm and 65.3mm), respectively (Fig. 2). Percent change from normal was higher during 2018-19 as compared to 2017-18. During 2018-19 Deviation from normal was 83.9 percent at Ballowal Saunkhri, 56.7 percent at Ludhiana and -31.2 percent at Faridkot. In South Western zone & Kandi zone, productivity of wheat is relatively lower than the Central zone because of its sowing windows and irrigation pattern. But in South Western zone, the quality of irrigation water is poor whereas canal water supply is erratic.

Growth parameters of wheat at different locations: The data pertaining to plant height, number of tillers and dry matter for three different locations is given below:

At Ludhiana

The significantly higher plant height, number of tillers and dry matter were produced in second sowing date (91.5, 120.0 and 388.4 m^2) followed by first sowing date (89.9, 107.3 and 320.3) and third sowing date (83.2, 90.8 and 266.2) at Ludhiana, respectively (Table 1). It has been observed that 15th November sowing produced more plant height, tillers and dry matter by 10%, 32% and 46% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher plant height (88.4), tillers (116.2) and dry matter (352.1) as compared to WH 1105 and PBW 590. The plant height, tillers and dry matter were higher by 6%, 28 % and 16 %, respectively from PBW 590. However, all the irrigation levels produced similar results except plant height, tillers and dry matter in recommended irrigation treatment. Shivani *et al.* (2003) and Gupta *et al.* (2010) also reported

that early sowing of wheat produced significantly more number of tillers as compared to the delayed sowing.

At Faridkot

The sowing dates showed a significant effect on the plant height, tillers and dry matter production. The plant height, numbers of tillers and dry matter were significantly higher in crop sown on 15th November (87.4, 115.2 and 378) as compared to the crop sown on 5th December (82.6, 89.8 and 259.9) and were statistically at par with the crop sown on 25th October (85.9, 105.4 and 288.1) (Table 1). It has been observed that 15th Nov. sowing produced more plant height, tillers and dry matter by 5.8%, 28% and 45 % higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 performed better as compared to other two varieties. It produced significantly higher plant height (84.4), tillers (111.1) and dry matter (323.0) as compared to other two varieties, which was higher by 2.5%, 22.3% and 8%, respectively from PBW 590. However, a non-significant difference has been found in the irrigation levels while recommended irrigation produced higher plant height, tillers and dry matter.

At Ballowal Saunkhri

The growth parameters like plant height, tillers and dry matter observed higher in 15th November sowing crop. Plant height, numbers of tillers and dry matter were significantly higher in crop sown on 15th November (85.3, 90.0 and 262.2) followed by 25th October (83.5, 87.3 and 227.5) and 5th December (79.3, 66.9 and 205.8) (Table 1). It has been observed that 15th Nov. sowing produced more plant height, tillers and dry matter by 7.6%, 34.5% and 27% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 performed better as compared to other two varieties. It produced significantly higher plant height (82.7), tillers (87.6) and dry matter (243.0) as compared to other two varieties, which was higher by 4.5%, 20% and 11.3%, respectively from PBW 590. However, a non-significant difference has been found in the irrigation levels while recommended irrigation produced higher plant height, tillers and dry matter. Ludhiana has the highest growth parameters, followed by Ballowal Saunkhri and Faridkot. The varying meteorological conditions of three location could be the contributing factors of this. The lowest yield at Ballowal Saunkhri can also be attributed to the sandy loam nature of the soil there.

Yield attributes of wheat at different locations:

At Ludhiana

Significantly higher ear length, no. of grains, 1000 grain weight and effective tillers were produced in second sowing date (11.5, 60.3, 48.6 and 109.1) followed by first sowing date (11.2, 58.8, 45.5 and 104.6) and third sowing date (9.9, 50.5, 35.5 and 80.8), respectively (Table 2). It has been observed that 15th November sowing produced more ear length, no. of grains per ear, 1000 grain weight and effective tillers by 16.2%, 19.3%, 36.9 and 33.8% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher ear length (11.0), no. of grains (59.3) 1000 grain weight (47.0) and effective tillers (109.6) as compared to WH 1105 and PBW 590. The ear length, no. of grains, 1000 grain weight and effective tillers were higher by 11.7%, 18%, 14.8 and 24%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher ear length, number of grains, 1000 grain weight and effective tillers in recommended irrigation treatment.

At Faridkot

Significantly higher ear length, no. of grains, 1000 grain weight and effective tillers were produced in second sowing date (10.8, 51.3, 45.5 and 107.3 respectively) followed by first sowing date (10.5, 48.9, 43.6 and 98.7 respectively) and third sowing date (9.7, 41.7, 38.3 and 81.3 respectively). (Table 2). It has been observed that 15th November Sown crop produced more ear length, no. of grains per ear, 1000 grain weight and effective tillers by 11.4%, 23%, 18.8 and 5.8% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher ear length (10.1), number. of grains (49.8) 1000 grain weight (45.5) and effective tillers (104.2) as compared to WH 1105 and PBW 590. The ear length, no. of grains, 1000 grain weight and effective tillers were higher by 4.1%, 15.3%, 19.3 and 2.6%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher ear length, no. of grains, 1000 grain weight and effective tillers in recommended irrigation treatment.

At Ballowal Saunkhri

Significantly higher ear length, no. of grains, 1000 grain weight and effective tillers were produced in second sowing date (10.2, 41.0, 40.7 and 85.3 respectively) followed by first sowing date (9.5, 39.4, 39.9 and 83.5 respectively) and third sowing date (8.8, 35.4, 37.2 and 79.3 respectively) (Table 2). It has been observed that 15th November sown crop produced more ear length, no. of grains per ear, 1000 grain weight and effective tillers which were 16.6%, 16.0%, 9.3%, and 7.5% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher ear length (9.6), no. of grains (41.4) 1000 grain weight (41.7) and effective tillers (82.7) as compared to WH 1105 and PBW 590. The ear length,

Table 2. Yield attributes of wheat under different treatments during *rabi* season at Ludhiana, Faridkot and Ballowal Saukhri

Treatments	Ludhiana				Faridkot				Ballowal Saukhri			
	Ear length (cm)	No. of grains per ear	1000 grain weight (g)	Effective tillers	Ear length (cm)	No. of grains per ear	1000 grain weight (g)	Effective tillers	Ear length (cm)	No. of grains per ear	1000 grain weight (g)	Effective tillers
Dates of sowing												
5-Oct	11.2	58.8	45.5	104.6	10.5	48.9	43.6	98.3	9.5	39.4	39.9	83.5
15-Nov	11.5	60.3	48.6	109.1	10.8	51.3	45.5	107.3	10.2	41.0	40.7	85.3
5- Dec	9.9	50.5	35.5	80.8	9.7	41.7	38.3	81.3	8.8	35.4	37.2	79.3
CD (0.05)	0.9	5.4	3.1	5.3	0.7	3.7	2.5	6.8	0.4	4.3	2.8	5.0
SEm	0.3	1.8	1.0	1.8	0.2	1.2	0.8	2.3	0.1	1.4	0.9	1.7
Varieties												
WH1105	11.6	60.2	45.8	107.3	10.2	48.9	43.8	98.9	10.0	41.1	39.5	86.3
Unnat PBW550	11.0	59.3	47.0	109.6	10.1	49.8	45.5	104.2	9.6	41.4	41.7	82.7
PBW590	9.9	50.3	40.9	91.4	9.7	43.2	38.1	84.5	9.2	33.4	37.1	79.1
CD (0.05)	1.2	5.7	3.6	5.3	0.7	3.7	2.5	6.8	0.4	4.3	2.8	2.4
SEm	0.3	1.8	1.0	1.8	0.2	1.2	0.8	2.3	0.1	1.4	0.9	1.7
Irrigation Levels												
Recommended(I1)	10.8	57.5	45.4	103.8	10.1	48.0	42.9	97.9	9.5	38.9	39.6	83.0
Recommended±Forecast based(I2)	10.8	55.6	43.9	101.8	10.2	46.6	42.0	93.8	9.6	38.4	39.3	82.4
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

no. of grains, 1000 grain weight and effective tillers were higher by 4.9%, 23.8%, 12.6 and 4.6%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher ear length, number of grains, 1000 grain weight and effective tillers in recommended irrigation treatment. The geographical locations of these three locations may be the reason behind the changes in these parameters.

Yield and harvest index of wheat at different locations:

At Ludhiana

Significantly higher biological yield (t/ha), straw yield(t/ha), grain yield (t/ha) and harvest index (%), were recorded in second sowing date (13.6, 8.7, 4.8 and 35.6 respectively) followed by first sowing date (13.1, 8.5, 4.6 and 35.8 respectively) and third sowing date (11.8, 7.6 4.2 and 35.0 respectively) (Table 3). It has been observed that 15th November sown crop produced more biological yield, straw yield and grain yield by 15.2%, 14.5% and 14.3% higher than 5th December sowing, respectively (Sardana *et al.*, 2002). Among the varieties, Unnat PBW 550 produced significantly higher biological yield (13.5), straw yield (8.6), grain yield (4.8) and harvest index (36.1) as compared to WH 1105 and PBW 590. The biological yield, straw yield and grain yield were higher by 13.5%, 10.2%, 20% and 5.9%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher biological yield, straw yield and grain yield in recommended irrigation treatment. The interaction effect between the sowing dates and varieties showed that yield of all the varieties was higher in the second sowing date and reduced with further delay in sowing (Table 3).

At Faridkot

Significantly higher biological yield (t/ha), straw yield(t/ha), grain yield (t/ha) and harvest index (%), were recorded in second sowing date (12.9, 8.2, 4.6 and 36.3) followed by first sowing date (12.6, 8.1, 4.4 and 35.6) and third sowing date (11.6, 7.8, 3.8 and 33.1), respectively (Table 3). It has been observed that 15th November sowing produced more biological yield, straw yield and grain yield by 11.2%

Table 3. Yield attribute of wheat under different treatments during *rabi* season at Ludhiana. Faridkot and Ballowal Saunkhri

Treatments	Ludhiana				Faridkot				Ballowal Saukhri			
	Biological yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index (%)	Biological yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index (%)	Biological yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index (%)
Dates of sowing												
5-Oct	13.1	8.5	4.6	35.0	12.6	8.1	4.4	35.6	10.4	6.7	3.6	35.1
15-Nov	13.6	8.7	4.8	35.6	12.9	8.2	4.6	36.3	10.9	7.2	3.7	34.6
5- Dec	11.8	7.6	4.2	35.8	11.6	7.8	3.8	33.1	9.1	6.0	3.0	33.4
CD (0.05)	0.6	0.6	0.2	NS	0.5	NS	0.2	NS	0.6	0.8	0.3	NS
SEm	0.2	0.2	0.08	1.1	0.1	0.2	0.09	1.1	0.2	0.2	0.1	1.4
Varieties												
WH1105	13.2	8.5	4.7	36.0	12.4	7.7	4.6	37.4	10.4	6.8	3.5	34
Unnat PBW550	13.5	8.6	4.8	36.1	12.9	8.2	4.7	36.7	10.7	6.7	3.9	37
PBW590	11.9	7.8	4.0	34.1	11.8	8.1	3.6	30.7	9.4	6.4	3.0	31.9
CD (0.05)	0.6	0.6	0.2	NS	0.5	NS	0.2	3.5	0.6	0.8	0.3	NS
SEm	0.2	0.2	0.08	1.1	0.1	0.2	0.09	11	0.2	0.2	0.1	1.4
Irrigation Levels												
Recommended(I1)	12.8	8.2	4.6	36.0	12.5	8.2	4.3	34.6	10.2	6.6	3.5	34.5
Recommended± Forecast based(I2)	12.9	8.3	4.5	34.9	12.3	8.1	4.3	35.3	10.1	6.6	3.4	34.3
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

5.1% and 21.0% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher biological yield (12.9), straw yield (8.2), grain yield (4.7) and harvest index (36.7) as compared to WH 1105 and PBW 590. The biological yield, straw yield, grain yield and harvest index were higher by 9.3%, 1.2%, 30.5% and 19.5%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher biological yield, straw yield and grain yield in recommended irrigation treatment. The interaction effect between the sowing dates and varieties showed that yield of WH1105 and Unnat PBW 550 varieties was higher when sown on 15th November and reduced with further delayed sowing in December (Table 4). The V3 PBW 590 variety produced higher yield when its sowing was done on 5th December. It means for late sowing V3 PBW 590 variety can be preferred over the WH1105 and Unnat PBW 550.

At Ballowal Saunkhri

Significantly higher biological yield (t/ha), straw yield (t/ha), grain yield (t/ha) and harvest index (%), were recorded in second sowing date (10.9, 7.2, 3.7 and 34.6) followed by first sowing date (10.4, 6.7, 3.6 and 35.1) and third sowing date (9.1, 6.0, 3.0 and 33.4), respectively (Table 3). It has been observed that 15th November sowing produced more biological yield, straw yield, grain yield and harvest index by 19.8%, 20.0%, 23.3% and 3.5% higher than 5th December sowing, respectively. Among the varieties, Unnat PBW 550 produced significantly higher biological yield (10.7), straw yield (6.7), grain yield (3.9) and harvest index (37) as compared to WH 1105 and PBW 590. The biological yield, straw yield and grain yield were higher by 13.8%, 4.7%, 30% and 15.9%, respectively from PBW 590. However, the irrigation levels were found non-significant but produced higher biological yield, straw yield and grain yield in recommended irrigation treatment. The results showed that grain yield was decreased with delay in sowing. However, more decreased was notice under crop sown

Table 4. Interactive effect of sowing dates and varieties on grain yield (kg/ha) of wheat at different locations (pooled data of 2017-18 and 2018-19)

Sowing date/varieties	WH1105	UNNAT PBW 550	PBW 590	Mean
Ludhiana				
05 Oct	5,020.7	4,891.7	3,974.1	4,628.9
15 Nov	5,023.1	5,186.5	4,343.2	4,850.9
05 Dec	4,301.3	4,585.0	3,923.3	4,269.8
Mean	4,781.7	4,887.8	4,080.2	
Faridkot				
05 Oct	5,248.4	4,997.0	3,214.7	4,486.7
15 Nov	5,329.1	5,383.7	3,369.3	4,694.1
05 Dec	3,370.2	3,909.1	4,317.7	3,865.7
Mean	4,649.2	4,763.3	3,633.9	
Ballowal Saukhri				
05 Oct	4,145.8	4,015.9	2,834.0	3,665.2
15 Nov	4,003.4	4,389.5	2,990.9	3,794.6
05 Dec	2,515.2	3,506.2	3,193.7	3,071.7
Mean	3,554.8	3,970.6	3,006.2	

in 5th December during the pooled data of 2017-18 ad 2018-19. Among the varieties early sown varieties are performed well under normal dates of sowing but the late sown variety perform statistically better under 5th December sown crop. At Ballowal Saunkhri station, late sown variety i.e PBW 590 is perform well under 5th December sown crop as compared to other varieties (Table 4).

Regression and correlation relationships wheat yield with weather parameters at different stages

Correlation and regression relationships between different wheat stages and weather parameters were carried out during 2017-18 & 2018-19 for different locations of Punjab (Table 5 to 8). Both the maximum and minimum temperatures showed negative and significant regression relationships during jointing and booting stages. Maximum temperature showed negative relationship at booting stage ($R^2 = 0.28$) during 2018-19 at Ludhiana. Similarly, at Ballowal Saunkhri a negative relationship during 2017-18 at jointing stage (0.54) and at booting stage (0.26) has been observed while during 2018-19 only booting stage showed significant relationship (0.29). However, no significant relationship has been found at Faridkot. Correlation studies were also worked out for different stages at different locations during both the years of study. It has been found that maximum temperature was negatively correlated at booting stage at all the locations i.e. -0.42 and -0.53 at Ludhiana; -0.51 and 0.52 at Ballowal Saunkhri during both the years of study except at Faridkot (-0.38) during 2017-18 only. During 2018-19, maximum Temperature at Ballowal Saukhri showed negative correlation at heading (-0.37) and anthesis (0.38) stage (Table 5).

Similarly, minimum temperature showed negative relationship at booting stage ($R^2 = 0.25$) during 2017-18 at Ballowal Saunkhri but no significant relationship has been observed at any other stage and location. Correlation

Table 5. Correlation of grain yield with maximum temperature at different stages of wheat crop

Stages	Correlation coefficient					
	Ludhiana		Faridkot		Ballowal Saukhri	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Jointing	0.06	0.17	-0.17	-0.29	-0.73**	-0.15
Booting	-0.42**	-0.53**	-0.38*	-0.28	-0.51**	-0.52**
Heading	-0.06	-0.09	-0.05	0.15	-0.28	-0.37*
Anthesis	-0.12	-0.28	-0.22	-0.24	-0.14	-0.38*
Milking	0.14	-0.31	0.08	-0.24	-0.20	-0.20
PM	-0.13	-0.17	-0.32*	0.06	0.13	0.03

Correlation **Significant at 0.05 level of probability, *Significant at 0.10 level of probability

Table 6. Correlation of grain yield with minimum temperature at different stages of wheat crop

Stages	Correlation coefficient					
	Ludhiana		Faridkot		Ballowal Saukhri	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Jointing	-0.27	-0.21	-0.14	-0.32*	-0.45**	-0.35**
Booting	-0.22	-0.21	-0.34*	0.11	-0.50**	-0.30
Heading	-0.22	-0.27	-0.15	-0.39*	-0.25	-0.22
Anthesis	0.12	-0.01	-0.17	-0.17	-0.08	-0.20
Milking	0.24	-0.01	0.11	-0.33*	-0.09	-0.40**
PM	0.04	-0.34	-0.04	0.06	-0.19	0.004

Correlation **Significant at 0.05 level of probability, *Significant at 0.10 level of probability

Table 7. Regression relationship of grain yield with maximum temperature at different growth stages of wheat crop

Stages	Regression relationship between yield and maximum temperature at different growth stages of wheat					
	Ludhiana		Faridkot		Ballowal Saukhri	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Jointing	Y = 0.003X+ 19.1 R^2 = 0.003	Y = 0.02X + 18.3 R^2 = 0.03	Y = -0.02X + 20.8 R^2 = 0.03	Y = -0.01X + 19.8 R^2 = 0.0885	Y = -0.05X + 21.5 R^2 = 0.54**	Y = -1.5X + 67.4 R^2 = 0.02
Booting	YY = -1.8X + 84.4 R^2 = 0.18	Y = -0.06X + 48.5 R^2 = 0.28**	Y = -1.7X + 78.4 R^2 = 0.10	Y = -0.09X + 22.8 R^2 = 0.08	Y = -1.8X + 74.5 R^2 = 0.26**	Y = -0.06X + 21.8 R^2 = 0.29**
Heading	Y = -0.03X + 23.8 R^2 = 0.003	Y = -0.24X + 51.6 R^2 = 0.009	Y = -0.09X + 44.6 R^2 = 0.002	Y = -0.07X + 24.0 R^2 = 0.11	Y = -0.14X + 28.7 R^2 = 0.07	Y = -1.0X + 58.4 R^2 = 0.13
Anthesis	Y = -0.03X + 27.4 R^2 = 0.013	Y = -0.61X + 59.9 R^2 = 0.07	Y = -0.62X + 58.1 R^2 = 0.05	Y = -0.08X + 26.6 R^2 = 0.05	Y = -0.34X + 42.8 R^2 = 0.01	Y = -0.83X + 55.6 R^2 = 0.14
Milking	Y = 0.05X + 25.1 R^2 = 0.02	Y = -0.40X + 56.3 R^2 = 0.09	Y = 0.21X + 36.7 R^2 = 0.007	Y = -0.09X + 30.0 R^2 = 0.06	Y = -0.56X + 49.9 R^2 = 0.04	Y = -0.3X + 45.4 R^2 = 0.04
PM	Y = -0.08X + 25.3 R^2 = 0.01	Y = -0.11X + 35.9 R^2 = 0.03	Y = -0.01X + 30.8 R^2 = 0.001	Y = 0.02X + 29.9 R^2 = 0.004	Y = 0.46X + 19.0 R^2 = 0.01	Y = 0.01X + 30.1 R^2 = 0.001

Regression-**Significant at 0.05 level of probability, *Significant at 0.10 level of probability

studies showed significant relationship at Faridkot and Ballowal Saunkhri but a non-significant relationship has been found at Ludhiana (Table 5 & 6). It has been found that minimum temperature was negatively correlated at jointing (-0.32), booting (-0.39) and milking stage (-0.33) at Faridkot during 2018-19 while at booting (-0.34) during 2017-18. Similarly, at Ballowal Saunkhri three stages i.e. jointing (-0.45, -0.35 during 2017-18 & 2-18-19, respectively), booting (-0.50 during 2017-18) and milking (-0.40 during 2018-19) were significantly correlated.

The study conducted on different sowing dates, irrigation levels and cultivars of shows that Variations in temperature have a significant impact on wheat yield, resulting in lower production. Specifically, the weather conditions in 2018-19 proved to be more favourable for wheat production compared to 2017-18, contributing to higher yields during the former period. Planting of the cultivars recommended for the late sown conditions can be useful to overcome the yield reduction in December sown crop. It will be essential to develop heat-tolerant cultivars under changing temperature conditions and use effective irrigation techniques focusing on weather-based irrigation due to Punjab's declining water table.

Table 8. Regression relationship of grain yield with minimum temperature at different growth stages of wheat crop

Stages	Regression relationship between yield and minimum temperature at different growth stages of wheat					
	Ludhiana		Faridkot		Ballowal Saukhri	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Jointing	Y = -0.03X + 7.8 R^2 = 0.07	Y = -0.07X + 9.4 R^2 = 0.04	Y = -0.009X + 6.3 R^2 = 0.02	Y = -0.02X + 6.4 R^2 = 0.10	Y = -0.05X + 7.6 R^2 = 0.20	Y = -2.76X + 53.5 R^2 = 0.12
Booting	Y = -0.85X + 51.2 R^2 = 0.05	Y = -0.67X + 51.4 R^2 = 0.07	Y = -1.75X + 54.0 R^2 = 0.11	Y = 0.01X + 6.4 R^2 = 0.01	Y = -1.64X + 45.4 R^2 = 0.25*	Y = -0.07X + 10.8 R^2 = 0.09
Heading	Y = -0.56X + 50.4 R^2 = 0.05	Y = -0.05X + 47.1 R^2 = 0.0003	Y = -0.05X + 11.7 R^2 = 0.02	Y = -0.06X + 11.5 R^2 = 0.15	Y = -0.47X + 38.5 R^2 = 0.06	Y = -0.06X + 11.4 R^2 = 0.05
Anthesis	Y = 0.3X + 41.5 R^2 = 0.01	Y = -0.06X + 47.2 R^2 = 0.0002	Y = -0.07X + 14.2 R^2 = 0.03	Y = -0.03X + 11.1 R^2 = 0.02	Y = -0.21X + 36.3 R^2 = 0.006	Y = -0.05X + 12.8 R^2 = 0.04
Milking	Y = 0.06X + 9.9 R^2 = 0.06	Y = -0.13X + 17.5 R^2 = 0.11	Y = 0.04X + 10.3 R^2 = 0.01	Y = -0.08X + 15.9 R^2 = 0.10	Y = -0.34X + 38.6 R^2 = 0.009	Y = -0.15X + 18.3 R^2 = 0.16
PM	Y = 0.01X + 15.1 R^2 = 0.001	Y = -0.12X + 21.3 R^2 = 0.04	Y = -0.01X + 15.6 R^2 = 0.002	Y = 0.017X + 14.9 R^2 = 0.003	Y = -0.64X + 44.7 R^2 = 0.03	Y = 0.001X + 16.2 R^2 = 2E-05

Regression **Significant at 0.05 level of probability, *Significant at 0.10 level of probability

REFERENCES

Anonymous. 2025-25. *Package of practices for rabi crops of Punjab.* Punjab Agricultural University, Ludhiana, Punjab.

Buttar G.S., Jalota, S.K., Mahey R.K. and Aggarwal, N. 2006. Early Prediction of Wheat Yield in South-Western Punjab Sown by Different Planting Methods, Irrigation Schedule and Water Quality Using the CERES Model. *Journal of Agricultural Physics* **6**: 46–50.

Gupta A., Gupta M. and Bazaya B.R. 2010. Effect of sowing dates and genotypes on growth and yield of durum wheat (*Triticum durum* L.) *SKUAST Journal of Research* **9**: 164–68.

Gupta A., Gupta M. and Singh P. 2007. Production potential of wheat (*Triticum aestivum*) cultivars under late and very late sown conditions in Jammu.*Environmental Economics* **25**: 1198–200.

Hundal, S.S. and Kaur P. 2007. Climatic variability and its impact on cereal productivity in Indian Punjab. *Current Science* **92**: 506–512.

IPCC (2014) Climate change 2014. Impacts, adaptation, and vulnerability. Working group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Technical Report. Cambridge University Press, Cambridge, UK/New York, USA.

Kaur Prabhjyot, Sandhu S.S., Kothiyal Shivani and Kaur Jatinder. 2023. An assessment of adaptation measures to enhance wheat productivity under climate change during early, mid and end of 21st century in Indian Punjab. *The Journal of Agricultural Science* **61**: 477–87.

Sardana V, Sharma S.K., Randhawa A.S. 2002. Performance of wheat varieties under different sowing dates and nitrogen levels in sub montane region of Punjab. *Indian Journal of agronomy* **47**(3): 372–377.

Shirpurkar G.N., Kashid N.V. and Pisal A.A. 2007. Effect of different sowing dates and varieties on yield and yield attributes of wheat. *Agricultural Science Digest* **27**: 68–70

Shivani, Verma U.N., Kumar S., Pal S.K. and Thakur R. 2003. Growth analysis of wheat (*Triticum aestivum* L.) cultivars under different seeding dates and irrigation levels in Jharkhand. *Indian Journal of Agronomy* **48**: 282–86.

Wu D. R., Yu Q., Lua C. H. and Hengsdijk H. 2006. Quantifying production potentials of winter wheat in the North China Plain. *European Journal of Agronomy* **24**: 226–35.