Optimizing sowing windows for wheat (*Triticum aestivum* L.) in the sub-temperate climate of the North-Western Himalayas

ABSTRACT

A field investigation was carried out at theResearch farm of theDepartment of Agronomy, CSKHPKV, Palampur during the winter season to evaluate the suitability of variable owing windows under limited irrigation regimes with two wheat cultivars. The five sowing windows 15th, 30th October, 15th, 30th November and 15th December along with two wheat cultivars i.e., HPW-349 and HPW-155 were investigated under a factorial randomized block design with three replications for each treatment. The timely sown crop on 15th October resulted in significantly higher values for growth attributes such as plant height, leaf area index, number of tillers per meter square and yield attributes such as spike length, number of grains per spike and test weight. The grain yield consequently was recorded to be the highest for the timely sown crop i.e., the15th October sown crop. The timely sown crop sown on 15th October resulted in a21.6% higher grain yield as compared to the15th December sown crop.Furthermore, delaying the sowing date by one month from 15th October to 15th November, the wheat grain yield declined by 12%, similarly, delaying the sowing date from 15th November to 15th December resulted in yield reduction by 7%. The highest gross, net returns and benefit-cost ratio were also recorded to be the higher for the timely sown crop i.e., 15th October.

Keywords: Crop phenology, sowing windows, varieties, and wheat.

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the important cereal crops in the world with wider production and consumption across the globe. Wheat has been cultivated in an area of 219 million hectares and 808.4 million tons globally, whereas in India it is cultivated in an area of 30.4 million hectares with a production of around 107.7 million tons (FAOSTAT, 2024). With a significant production of wheat on aglobal level, India is 2nd largest producer of wheat and still possesses a significant potential to improveits wheat production under the influence of modern improved agro-practices (Jat *et al.,* 2024).In Himachal Pradesh, this crop is presently being cultivated on 319.476 thousand hectares with a production of 609.31 thousand tones and productivity of 1.90 metric tonnes per hectare (Department of Agriculture, 2022-23).

Changing climatic conditions like increasing temperatures and declining rainfall have been considered significant reasons for declining wheat productivity especially due to shortened grain filling period leading to reduced grain size for wheat (Farhad *et al.,* 2023). The study on climatic trends in HP also revealed decreasing trends of rainfall and on the contrary increase in maximum and minimum temperatures in themountain state Himachal Pradesh affecting crop yield (Rana *et al*., 2012). Altering the planting schedules has proved to be a critical practice to increase the resilience of wheat to changing climate (Pathania *et al.,* 2018; Pathania *et al.,* 2019) in North Western Himalayas conditions. The studies carried out in this region also indicated that the application of rainfall and temperature forecasts proved to be beneficial in saving considerable irrigation water in crops(Rana *et al.,* 2013)

Exposing the crop to variable environments with optimized sowing window can help in understanding the phenological as well as biomass production response to differing weather elements such as temperature, relative humidity, precipitation, sunshine hours etc (Mangani *et al.,* 2023; Pareek *et al.,* 2023). Besides, altering sowing windows, considering the significantly higher productivity potential of wheat cultivars as well as the ability to respond with wider adaptations such as improved photosynthetic efficiency under changing climates can play a vital role in improving wheat productivity (Sattar *et al.,* 2023). Therefore, considering the need to investigate the influence of variable sowing windows as well as wheat cultivars on theproductivity and profitability of wheat under the conditions of North-Western Himalayas. The objectives of the study were to study the effect of variable sowing windows and wheat cultivars on wheat growth, productivity, agro-meteorological indices and profitability of wheat.

2. MATERIAL AND METHODS

Site and soil

The field investigation was conducted during the winter season of at theResearch farm of theDepartment of Agronomy, CSKHPKV, Palampur. The experimental field was at an average above-mean sea level of 1290.8 m with agro-climatic conditions defined as sub-temperate and sub-humid with high rainfall, severe low temperatures during winters and moderate temperatures during mild summers. During the crop season, the weekly maximum and minimum temperature varied from 10 to 34^{0}C and 0.5 to 25.5^{0}C with total seasonal rainfall of 370.8 mm. The highest maximum temperature of 34^{0}C was observed during the 19th meteorological week whereas the highest value for minimum temperature (34^{0}C) was observed in 16th meteorological week. The lowest value for the minimum temperature was 0.5^{0}C which was observed in 2nd meteorological week similarly the lowest value for the maximum temperature (10^{0}C) was observed in 2nd metrological week.The highest average weekly rainfall (78.6 mm) was recorded during the 4th meteorological week whereas in the case of evapotranspiration, the corresponding highest (50.5 mm) and lowest values (9.3 mm) were recorded during the 16th and 4th meteorological week. The maximum average weekly relative humidity (89%) was recorded during the 3rd meteorological week whereas the lowest relative humidity (48%) was recorded in the 19th meteorological week. The soil at the experimental field was silty clay loam in texture, with acidic soil reaction (pH = 5.7), medium content of available nitrogen (316 kg/ha), phosphorus (16.7 kg/ha) and organic carbon (0.8%) whereas available potassium (298 kg/ha) was high in the field soil.

Experimental detail

The field investigation was carried out in a randomized block design with factorial arrangement. The treatments consisted of five wheat sowing dates (15th October, 30th October, 15th November, 30th November and 15th December) and 2 wheat cultivars (HPW-349 and HPW-155) which were replicated thrice. The gross plot size for each treatment was 16.8 m^2 whereas the net plot size was 13 m^2. The field was prepared using 1-2 ploughings followed by levelling and breaking of clods. The seed rate was 100 kg/ha whereas the row spacing was kept at 22 cm. The primary nutrients i.e., nitrogen, phosphorus and potassium were applied at the rate of 120, 60 and 30 kg/ha. Half of the nitrogen, full dose of phosphorus and potassium were applied as basal dose whereas the rest of the nitrogen was applied at crown root initiation stage as top dressing. Hand weeding was practised along with Isoproturon application at the rate of 1.25 kg/ha to keep the weed population below threshold levels. The phenological and yield attributes were recorded from the net plot for the randomly selected five wheat plants (Rana and Kumar, 2014).The harvesting was carried out manually using sickles. The crop was threshed to separate the grains from the straw(Rana *et al.,* 2014).

Data analysis

The data was analyzed using prescribed procedures for factorial randomized block design (FRBD) as per Gomez and Gomez (1984). The variations among treatment means were assessed ata5% level of significance using the least significance difference.

3. RESULTS AND DISCUSSION

Phenological studies

Crop phenological development serves as a critical biological indicator of climate change and the effects of rising temperatures. Studying crop phenology is essential for understanding how crops respond and adapt to changing climate conditions. In the present field investigation, the alteration of sowing dates, significantly impacted the days to complete the crop emergence, crown root initiation, tillering, ear emergence and physiological maturity. The wheat crop sown on 15th October attained the emergence (10 days) and crown root initiation (28 days) in the shortest span whereas the following late sown crops on 15th (12, 30 days, respectively), 30th November (12, 30 days, respectively) and 15th December (14, 32 days, respectively) took comparatively greater days to attain emergence and crown root initiation (Table 1). Contrary to this, moving ahead for the tillering (68 days), ear emergence (131 days) and physiological maturity (167 days), 15th October sown crop took greater number of days whereas the crop sown on 15th (62, 125 and 156 days, respectively), 30th November (61, 122 and 148 days, respectively) and 15th December (58, 119 and 138 days, respectively) completed the tillering, ear emergence and physiological maturity in a comparatively shorter period. Wheat cultivars, however, did not differ significantly in terms of days required to attain different phenological stages such as emergence, crown root initiation, tillering, ear emergence and physiological maturity. The results observed in the present investigation were consistent with the findings revealed by Sattar and his co-workers in 2023 wherein they reported that delaying the sowing of wheat crops resulted in extended period of vegetative phases whereas shortened period of reproductive stages. Such a response was recorded due to lower temperaturesin the winter season for the late sown crop whereas exposure to higher temperatures during reproductive phases therefore resulting in shortened reproductive stages (Sattar *et al.,* 2023).

Table 1. Effect of varieties and date of sowing on thenumber of days taken to different phenologicalstages

Treatments	Days to Emergence	Days to CRI	Days to tillering	Days to ear emergence	Physiological maturity
Varieties					
HPW-349	11	30	64	126	156
HPW-155	12	29	63	125	154
LSD (P=0.05)	NS	NS	NS	NS	NS
Sowing window					
15th October	10	28	68	131	167
30th October	11	28	68	128	165
15th November	12	30	62	125	156
30th November	12	30	61	122	148
15th December	14	32	58	119	138
LSD (P=0.05)	1.4	1.5	3.6	2.8	4.7

Effect of varieties and date of sowing on growth and yield attributes on wheat crop

Growth attributes

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Plant height is a vital growth attribute of cereal crops, especially wheat. In the present field investigation, wheat cultivars did not respond significantly differently in terms of plant height, however, a significant response was recorded in terms of plant height for the crop with variable dates of sowing. The crop sown in October whether 15th (114.8 cm) or 30th October (114.2 cm) resulted in significantly tallerplants whereas the crop sown late on the 15th (104.9 cm), 30th November (99.5 cm) and 15th December (94 cm) observed comparatively shorter plants (Table 2). Leaf area index was recorded to be responding differently for the crop sown at varying dates of sowing however the wheat cultivars did not show any significant response in terms of leaf area index. The highest leaf area index was recorded for the crop sown on 15th October (3.24), and parallelly crop sown on 30th October (3.17) resulted in a similar leaf area index for the wheat crop (Table 2). The crop sown late such as on 15th (2.99), 30th November (2.81) and 15th December (2.92) resulted in considerably lower leaf area index for the wheat crop. The number of tillers per meter square was observed to be significantly responding to the variable dates of sowing with crop sown on 15th (294) and 30thof October (291) resulting in the highest number of tillers per meter square for the wheat crop. Contrary to this, crop sown late on dates such as 15th (280), 30th (270) November and 15th (259) December resulted in a substantially lower number of tillers per meter square for the wheat crop. However, the wheat cultivars did not respond differently in terms of several tillers per meter square. Reduction in values of growth attributes such as plant height, leaf area index and number tillers per meter square in the present investigation for delayed sowing conditions can be attributed to exposure of crop to lower temperature during winter season which may have slowed down the metabolic activities leading to curtailed growth. However, timely sown crop may have attained the optimum growth before getting exposed to peak winter season (Jha *et al.,* 2023; Sattar *et al.,* 2023). The findings in the present field study reported on reduction in number of tillers per meter square corroborate with the findings reported by Poudel and his co-workers in his field study reported in 2020.

Yield attributes

The variable dates of sowing produced significant effects over wheat spike length. Spike length was recorded to be significantly higher for the sowing dates of 15th (10.5 cm) and 30th October (10.5 cm). However, late sown wheat crop sown on 15th (9.7 cm), 30th November (9.3 cm) and 15th December (9.0 cm) responded with considerable reduction in spike length (Table 2). Wheat cultivars again did not produce any significant effects over spike length of wheat. Number of grains per spike were found to be significantly influenced under the impact of variable dates of sowing. The timely sown crop on 15th (55) and 30th October (52) resulted in considerably higher number of grains per plant whereas delay in sowing date i.e., 15th (47), 30th November (44) and 15th December (42) resulted in considerably loss in terms of number of grains per plant. The wheat cultivars, however, did not produce any significant effect over number of grains per plant. The test weight of wheat crop was significantly influenced under the impact of variable dates of sowing. The timely sown crop especially on 15th October (48.48 g) resulted in significantly higher tests weight for the crop whereas further delay in sowing date such as 15th (45.48 g), 30th November (43.72 g) and 15th December (41.6 g) resulted in reduction in test weight of the crop (Table 2).

In the present investigation, optimized growth under the favourable temperature regime for the timely sown crop might have improved the formation of yield attributes ata better rate, whereas reduced growth for the crop sown late have resulted in poor performance in terms of yield attributes. Significantly higher values for yield attributes such as spike length, number of grains per spike and test weight for the timely sown crop i.e., 15th October can further be attributed to exposure of crop to optimum temperature during period of flowering as well as grain formation and filling whereas in case of late sown crop or delayed sowing of the crop might have exposed to higher temperatures leading to heat stress and ultimately reduced values for yield attributing characters (Jha *et al.,* 2023). Furthermore, for delayed sowing with increasing temperature during reproductive stages there have been grain shrinkage due to production ofROS (reactive oxygen species) as well as grain abortion

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(Sattar *et al.,* 2023). Jha and his co-workers and Sattar and his co-workers in different studies based on variable dates of sowing for wheat crop observed similar impact over yield attributes (Jha *et al.,* 2023; Sattar *et al.,* 2023).

Crop yield

The dates of sowing considerably influenced the grain yield of wheat crop. The timely sown crop sown on 15th October resulted in 21.6% higher grain yield as compared to 15th December sown crop i.e., as the sowing date was delayed from 15th October to 15th December the grain yield declined from 40.1 to 33 q/ha (Table 2). Furthermore, delaying the sowing date by one month from 15th October to 15th November, the wheat grain yield declined by 12%, similarly, delaying the sowing date from 15th November to 15th December resulted in yield reduction by 7%. The cultivars however did not produce significantly different grain yield for the wheat crop. Straw yield was significantly influenced by the impact of various sowing dates. The timely sown crop of 15th October produced 11.7% higher straw yield compared to 15th December sown crop i.e., 15th October sown crop produced 64 q/ha straw whereas 15th December sown crop produced 57.3 q/ha straw yield. Similarly, delaying crop sowing by one month from 15th October to 15th November and 15th November to 15th December resulted in a 5% loss in straw yield. The cultivars did not respond significantly in terms of straw yield of wheat crop.

The lower yield levels in the present filed investigation for the delayed sowing conditions can be attributed to reduced growth as well as reduction in the sink size. Sink size in the present study can be attributed to lower test weight, spike length and number of grains per spike. The delayed sown wheat crop was exposed to critical day length for flowering in a shorter duration i.e., lesser number of days available during maximum vegetative stage or tillering and subsequently the maturity was also attained in a shorter number of days due to higher prevailing atmospheric temperatures (Aslam *et al.,* 2017).Furthermore, to shortened reproductive period i.e., ear emergence and physiological maturity for the wheat crop may result in shrinkage of sink size and ultimately reduce the wheat yield (Poudel *et al.,* 2021). The findings of the present field investigation were found to be consistent with the study results reported by Dubey and his coworkers in 2019 in terms of reduction in wheat yield due to exposure of crop to elevated temperatures. However, timely sown crop provides the crop with an opportunity to accumulate optimum amount of photosynthates for better sink size and ultimately the economic yield (Dar Eajaz *et al.,* 2018). Poudel and his coworkers reported grain yield reduction to even an extent of 47% with exposure of crop to heat stress, especially for late-sowncrops(Poudel *et al.,* 2021). Reduction in grain yield of wheat with exposure of crop to heat stress was also reported by Poudel and his co-workers in 2020. Also, lower aerosol values andhigher net radiant energy during the COVID-19 pandemic lockdown period improved crop productivity as represented by the higher NDVI during the lockdown period in in agricultural ecosystems in the Himalayan foothills (Pokhariyal *et al.,* 2021)

Parallel to grain yield, straw yield was reduced considerably in the present study owing to reduced values for growth attributes such as plant height, leaf area index and number of tillers per meter square. Sattar and his co-workers in 2020 reported a similar impact onwheat straw yield for delayed sowing of wheat crops with exposure to elevated temperatures. The results of the present study corroborate with findings reported by Sattar and Srivastava in 2021 over wheat straw yield with late sown wheat crop.

Table 2. Effect of varieties and date of sowing on growth and yield attributes on wheat crop

Treatment	Plant height (cm)	LAI	No. of tillers/ m^2	Spike length (cm)	No. of grains	1000-grain weight	Grain yield (q/ha)	Straw yield (q/ha)
Varieties								
V1 (HPW-349)	106.4	3.06	280	9.9	48	45.65	36.25	61.21
V2 (HPW-155)	104.6	2.99	278	9.7	47	44.98	35.83	60.09
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Sowing window								
15th October	114.8	3.24	294	10.5	55	48.48	40.14	64.00
30th October	114.2	3.17	291	10.5	52	47.32	38.38	63.04
15th November	104.9	2.99	280	9.7	47	45.48	35.32	60.62
30th November	99.5	2.81	270	9.3	44	43.72	33.37	58.25
15th December	94	2.92	259	9.0	42	41.6	33.01	57.32
LSD (P=0.05)	5.0	0.2	10.8	0.8	3.5	2.5	1.4	3.7

Crop profitability

Gross returns were not significantly influenced by different wheat cultivars. However, sowing of the crop at different dates have resulted in significant effects over gross returns for wheat cultivation. Crop sown on 15th October generated 21.6% greater gross returns i.e., crop sown on 15th December was responsible for 53640 INR gross returns whereas crop sown on 15th October resulted in 65222 INR gross returns (Table 3). The highest gross returns for the timely sown crop can be attributed to substantially higher grain yield recorded for the treatment.Similarly, Thakur et al. 2024 reported considerably higher gross returns for the timely transplanted rice crop in comparison to the late transplanted rice crop(Thakur *et al.,* 2024).

Wheat cultivars were not able to exert any significant influence over net returns from wheat cultivation, however, sowing of the crop at different dates resulted in asignificant impact on the net returns generated from the wheat cultivation. The crop sown on the 15thof October resulted in significantlyhigher net returns for wheat cultivation i.e., 40.7% higher than the crop sown on the 15thof December. The Crop sown on 15th October was able to generate 40012 INR net returns whereas the crop sown on 15th December was only able to generate net returns of 28430 INR. The net returns for the timely sown crop on 15th October can be attributed to significantly higher grain yield as well as considerably higher gross returns for the respective treatment.The net returns were also observed to be considerably higher for timely sown crop in comparison to late sown crops in rice by Thakur et al. 2024 ((Thakur *et al.,* 2024).

Benefit cost ratio was not significantly influenced by the impact of different wheat cultivars. Variable dates of sowing resulted in significant influence over the benefit-cost ratio. Sowing of the crop on 15th October (1.59) resulted in asignificantly higher benefit-cost ratio whereas the lowest benefit cost ratio was recorded for the crop sown on 15th December (1.13) (Table 3). A significant higher benefit-cost ratio for the 15th October sown crop can be attributed to considerably higher gross returns for the corresponding crop.A similar, effect of changed sowing or transplanted dates on the benefit-cost ratio was observed by Thakur et al. 2024 in

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rice crops wherein they observed that delaying the translating from 15th June to 25th July resulted in a considerably lower benefit-cost ratio for rice crops (Thakur *et al.,* 2024).

Table 3. Effect of varieties and date of sowing on growth and yield attributes on wheat crop

Varieties	**Gross return**	**Net return**	**B:C ratio**
V1 (HPW-349)	58914	33704	1.34
V2 (HPW-155)	58228	33018	1.31
LSD (P=0.05)	NS	NS	NS
Sowing window			
15th October	65222	40012	1.59
30th October	62367	37157	1.47
15th November	57402	32192	1.28
30th November	54223	29013	1.15
15th December	53640	28430	1.13
LSD (P=0.05)	3827	3827	0.15

4. CONCLUSION

In the present investigation crop growth, yield attributes, yield and profitability were not significantly influenced by wheat cultivars whereas a significant influence of sowing dates was observed. The present investigation has concluded sowing of wheat crops in October whether 15th (1st fortnight) or 30th October (2nd fortnight) is optimum for considerably higher grain yield of wheat. Delaying sowing by each month i.e., 15th October to 15th November and from 15th November to 15th December reduced the grain yield by 12 and 7%, respectively. Similarly, substantially higher growth and yield character attributes such as plant height, leaf index, number of tillers per meter square and spike length, number of grains per spike, and test weight were recorded for the timely sown crop i.e., 15th October sown crop. Consequently, the highest gross, net returns and benefit-cost ratio wererecorded for the 15th October sown crop.

ETHICAL APPROVAL (WHEREEVER APPLICABLE)

The present investigation did not involve any studies on human or animal participants.

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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