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Effect of temperature on the growth and yield of wheat (*Triticum aestivum* L.) cultivars

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Abstract
The field experiment was conducted during *rabi* sesone 2015-16 to generate the ground truth data of wheat crop. The experiment was conducted in Split Plot Design and replicated four times. The treatment comprised of three dates of sowing viz. 25th November (D1), 10th December (D2) and 25th December (D3) kept as a main plot with three varieties viz. PBW-343 (V1), PWB-502 (V2) and LOKE-1 (V3) kept as a subplot. The crop weather condition overestimated the plant height, total dry matter (g/m^2), leaf area index, days taken to 50% flowering, days taken to maturity, RGR, CGR, number of effective tillers per spike, grain yield (kg ha^{-1}), 1000 grains weight (g), number of grains spike-1, days taken to maturity, grain yield and harvest index of wheat crop grown in region. The lowest error percent was recorded in a timely sown crop of wheat (November 25th) with PBW-343 variety (D_1V_1) and error percent increased with delay in sowing. The crop growth in wheat crop depicted well the variation in yield due varying crop growth environment based on different dates of sowing. The grain yield events were close to observed values in a timely sown crop suggested that the yield was well within the accepted limits, therefore the predicting wheat yield events in the regions of Uttar Pradesh, where the experiment was conducted.

Keywords: Wheat, Temperature, Growth, Yield

1. Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop, which plays an important role in food and nutritional security. About 40 percent of the total food grain reserves of the country is contributed by wheat crop. In India, three species of wheat are cultivated, 87 percent of cultivated wheat belongs to *Triticum aestivum* (bread wheat), 12 percent of cultivated wheat belongs to *Triticum durum* (macaroni wheat) and 1 percent of cultivated wheat belongs to *Triticum dicoccum* (emmer wheat). The global area of the wheat is 275.4 mha and production is 674.9 mt in 2015. In India, the total area under wheat is 31.34 mha, with the production of 95.91 mt and the productivity of wheat in India is 3.06 tonne ha^{-1}. In India, the highest area under wheat cultivation is in Uttar Pradesh. Uttar Pradesh also ranks first in terms of production and Haryana ranks first in productivity. In Haryana, an area under wheat is 2.49 m ha and the production of wheat is 11.6 mt and the productivity is 4.72 tonne ha-1. The wheat production in the country is highly variable due to its wide adaptability in different climatic regions. In the present scenario of climatic change of "global warming", there is a great challenge of sustainable wheat production in the country. It is projected by IPCC that 3-4 ^{0}C average temp. will be increased by 2080 A.D. and winter will be warmer as compared to the monsoon period etc, hence winter production will be adversely affected due to high temperature. Therefore adaptability and the impact of climate change on wheat production through varietals management and agronomic practices are required. In series, a prediction model or mathematical or planning, the farm operations to reduce the losses caused by aberrant weather. The damage of wheat by 2020 has been projected to be between 105 to 109 million tonnes with a shortfall of 32-38 million tonnes in comparison to present production. As the crop area is mostly oscillating between 24 to 27 million ha in the last fifteen years and there is very little scope for expansion of the area in the future, therefore production is to be increased exponentially. An agro-climatic approach and proposed a model for the yearly crop growth warning. This relates to crop growth, development and crop yield. Wheat production is limited primarily by environmental stresses. It is very difficult to find 'stress-free' areas where crops may approach their potential yields. Abiotic environmental factors are considered to be the main source (71%) of yields reductions. Drought is one of the most common environmental stresses that affect the growth and development of plants through alterations in metabolism and gene expression.

2. Materials and Methods

A field experiment was conducted during *rabi* season 2015-16 at the Agro Meteorological research farm, N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) at a distance of about 42 km away from Faizabad district headquarter on Faizabad Raibarelly road and geographical situation of experimental site lies at latitudes 260 47' North and longitude 820 12′ East and altitude of 113 meters from main sea level in the Indo genetic alluvium of eastern (U.P). The Faizabad district falls in a semi-arid zone, receiving a mean annual rainfall of amount 1100 mm. out of which about 90 Percent of the total rainfall received during south-west monsoon (from June to Sep.); with 7 percent in the winter season (Tripathi *et al*., 1998). Fertilizers were applied as per the recommended dose for the wheat crop by the university (i.e. 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}). As per recommendation, we have applied nitrogen through Urea, phosphorus through diammonium phosphate and potassium through muriate of potash were applied to wheat. Half dose of N and a full dose of P_2O_5, and K_2O were applied as basal application as per treatment, 1/4th portion of N was applied during a tillering stage and rest 1/4th at ear head stage of the crop. The experiments consist of 9 treatment combinations which comprised 3 dates of sowing and three varieties. The experiment was conducted in split-plot design (SPD) and replicated four times. The crop was sown with three different dates on 25th November 2015, 10th December 2015, and 25th December 2015. Sowing was done in row 20 cm apart and plant spacing made 5 cm. a seed rate of 100 kg ha^{-1} was used. Planking was done to cover the seeds just after the sowing. The treatment comprised of three dates of sowing viz. 25th November (D_1), 10th December ($_{D2}$) and 25th December (D_3) kept as a main plot with three varieties viz. PBW-343 (V_1), PWB-502 (V_2) and LOKE-1 (V_3) kept as a subplot. The crop weather condition overestimated the plant height, total dry matter (g/m^2), leaf area index, days taken to 50% flowering, days taken to maturity, RGR, CGR, number of effective tillers per spike, grain yield (kg ha^{-1}), 1000 grains weight (g), number of grains $spike^{-1}$, days taken to maturity, grain yield and harvest index of wheat crop grown in region.

3. Result and Discussion

3.1 Plant height (cm)

Plant height of Indian Wheat recorded at various growth stages as affected by growing environments and cultivars have been presented in Table-1. Plant height increased successively with the age of the crop. It is evident from the data that growing environments and cultivars influenced plant height significantly at all the growth stages except 30 DAS. Taller plants were obtained at the growing environment of 25th, November which was significant over the rest both of the growing environments. Shorter plants were recorded under wider growing environments 25th, December sowing. Cultivars had a significant variation on Plant height at all the stages except 30 DAS. It is quite evident from the data that higher plant height was obtained in PBW-343 which was at par with PBW-502 at all the stages while significantly superior over Lok-1 variety. Data also showed that Lok-1 variety recorded smaller height of Plant at all the stages. Laghari *et al.* (2012) [6]

Table 1: Plant height (cm) of Wheat as affected by growing environments and cultvars

Treatments	Plant Height (cm)		
	30 DAS	60 DAS	90 DAS
Growing environment			
25, November	22.37	78.61	90.79
10, December	21.20	70.76	81.72
25, December	20.12	63.63	73.49
SEm±	0.23	1.75	1.92
CD at 5%	0.64	5.53	6.05
Cultivars			
PBW-343	21.88	74.43	85.96
PBW-502	17.95	71.04	82.04
LOK-1	15.17	67.53	78.00
SEm±	0.40	1.02	1.32
CD at 5%	1.18	2.40	2.85

3.2 Leaf area index

Leaf area index as affected by growing environments have been presented in Table-2. LAI increased successively till 75 DAS and thereafter declined. It is quite obvious from the data that the LAI was significantly affected due to growing environments at all stages. Significantly higher leaf area index was obtained at growing environment 25th, November compared to sowing done on 10th, December growing environment, and 25th, December growing environment proved lowest LAI at all the stages of crop. Leaf area index was affected significantly at all the stages due to cultivars. The highest leaf area index (4.8) was recorded in variety. Data also reveal that Lok-1 variety recorded the lowest (3.9) leaf area index at all the growth stages. Pandey *et al.* (2014) [8]

Table 2: Leaf area index of Wheat as affected by growing environments and cultivars

Treatments	Leaf Area Index					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Growing environment						
25, Nov.	1.44	3.91	4.64	4.87	4.72	2.83
10, Dec.	1.35	3.45	4.17	4.38	4.23	2.54
25, Dec.	1.28	3.16	3.75	3.92	3.58	2.28
SEm ±	0.03	0.09	0.12	0.14	0.12	0.06
CD at 5%	0.9	0.26	0.32	0.37	0.31	0.21
Cultivars						
PBW-343	1.54	3.66	4.39	4.62	4.45	2.67
PBW-502	1.39	3.51	4.19	4.38	4.25	2.55
LOK-1	1.30	3.35	3.98	4.17	4.05	2.43
SEm ±	0.02	0.07	0.09	0.09	0.09	0.05
CD at 5%	0.07	0.16	0.20	0.23	0.17	0.13

3.3 Total Dry matter (g/m^2)

Dry matter accumulation as influenced by growing environments and cultivars has been presented in Table – 3. It is quite obvious from the data that dry matter accumulation varied significantly due to growing environments at all the stages of wheat. It was recorded higher under the treatment when Wheat was sown on 25th, November which was at while significantly superior over rest both of the growing environments. Wider growing environment recorded the lowest dry matter at all the stages. Dry matter accumulation was affected significantly at all the stages due to varieties.

The highest dry matter accumulated was recorded in PBW-343 variety which was at par with PBW-502 while significant over Lok-1 at all the stages of Indian wheat. Data also reveal that Lok-1 variety recorded lowest dry matter accumulated at all the growth stages. Rahman *et al.* (2009) [9]

Table 3: D.M. accumulated (g/m^2) of wheat as affected by growing environments & cultivars

Treatments	Total Dry matter		
	30 DAS	60 DAS	90 DAS
Growing environment			
25, Nov.	50.13	506.42	844.00
10, Dec.	48.13	449.57	749.30
25, Dec.	46.72	429.63	716.00
SEm±	0.98	8.34	12.53
CD at 5%	1.45	22.04	38.71
Cultivars			
PBW-343	49.63	479.70	799.43
PBW-502	48.65	462.57	770.93
LOKE-1	46.70	443.35	738.93
SEm±	0. 75	3.15	9.16
CD at 5%	1.23	8.72	24.26

3.4 Days taken to 50% flowering
Days taken to 50% flowering of wheat as affected by the date of sowing and varieties have been presented in Table – 4. A critical examination over data obviously reveals that among the different date of sowing 25th November recorded a higher value of days taken to 50% flowering followed by 10th December sowing. Among the varieties, PBW-343 recorded a significantly higher value of days taken to 50% flowering followed by PBW-502 and Lok-1.

Table 4: Days taken to 50% flowering as influenced by different date of sowing wheat cultivars

Treatments	Days taken to 50% flowering
Date of sowing	
25th November	97
10th December	87
25th December	80
SEm±	02
CD (P = 0.05)	09
Varieties	
PBW-343	89
PBW-502	88
Lok-1	86
SEm±	1
CD (P = 0.05)	5

3.5 Days taken to maturity (DAS)
Days to maturity as affected by growing environments and cultivars have been presented in Table-5. A perusal of data showed that different growing environments influenced significantly to flower initiation. Maximum days taken to maturity (127) were recorded when the crop sown on 25th, November growing environment which was superior over 10th, December and 25th, December growing environment. The minimum day taken to maturity was recorded (113) at 25th, December growing environment. Days to maturity were affected by different varieties. The maximum days taken to maturity were recorded with PBW-343 (122 Days) variety followed by PBW-502 (120) and then Lok-1 (118 Days). Liangzhi *et al.* (2009) [7]

Table 5: Effect of growing environments on Days taken to maturity of wheat cultivars

Treatments	Days taken to maturity
Growing environments	
25th, November	127
10th, December	120
25th, December	113
Cultivars	
PBW-343	122
PBW-502	120
Lok-1	118

3.5 Crop Growth Rate (CGR)
Crop Growth Rate as affected by growing environments and cultivars have been presented in Table- 6. A perusal of data showed that different growing environments influenced significantly to Growth rate. Maximum Crop growth rate (15.2) were recorded when crop was sown on 25th, November growing environment which was superior over 10th December and 25th, December growing environment. The minimum Crop growth rate was recorded (12.7) at 25th, December growing environment. Crop growth rate were affected by different varieties. The Crop growth were recorded with PBW-343 (14.3) variety followed by PBW-502 (13.8) and then Lok-1 (13.2). Bobade, P. (2010) [4]

Table 6: Effect of growing environments on crop growth rate (CGR) of wheat cultivars

Treatments	Crop Growth Rate	
	30-60 DAS	60-90 DAS
Growing environment		
25, November	15.21	11.25
10, December	13.38	9.99
25, December	12.76	9.55
SEm ±	3.92	0.27
CD at 5%	N S	0.85
Cultivars		
PBW-343	14.3	10.66
PBW-502	13.8	10.28
LOK-1	13.2	9.85
SEm ±	0.27	0.19
CD at 5%	0.79	0.56

3.7 Relative Growth Rate (RGR)
Relative Growth Rate as affected by growing environments and cultivars have been presented in Table-7. A perusal of data showed that different growing environments influenced significantly to the Growth rate. Maximum Relative growth rate (0.01) was recorded when the crop was sown on 25th, November growing environment which was superior over 10th, December and 25th, December growing environment. The minimum Relative growth rate was recorded (0.01) at 25th, December growing environment. Relative growth rate was affected by different varieties. The Crop growth was recorded with PBW-343 (0.01) variety followed by PBW-502 (0.01) and then Lok-1 (0.01).

Table 7: Effect of growing environments on crop growth rate (RGR) of wheat cultivers

Treatments	Relative Growth Rate	
	30-60 DAS	60-90 DAS
Growing environment		
25, November	0.18	0.77
10, December	0.17	0.74
25, December	0.15	0.73
SEm ±	0.000	0.002
CD at 5%	0.002	0.006
Cultivars		
PBW-343	0.017	0.075
PBW-502	0.017	0.075
LOK-1	0.017	0.074
SEm ±	0.000	0.001
CD at 5%	0.002	0.004

3.8 Test weight (1000 grain weight)

The data showing the influence of different growing environments on test weight of wheat varieties are shown in Table-8. Results revealed that different growing environments had a significant influence on test weight of wheat varieties and the maximum test weight of grains was observed in D1 (25 November) closely followed by the sowing date (10 December) and late growing environment (25 December). On average the higher test weight of grains was observed in PBW-343 (40.82g) While lower test weight of wheat grains was observed in LOK-1 (52.03g). Akintunde, O K. (2013) and Branka *et al*. (2014) [1, 5].

Table 8: Effect of Growing environments on Test weight of wheat cultivars

Treatment	Test weight (g)
Growing environment	
25, Nov.	40.82
10, Dec.	36.83
25, Dec.	32.03
SEm±	0.77
CD at 5%	N S
Cultivars	
PBW-343	40.1
PBW-502	35.6
LOK-1	32.68
SEm±	0.45
CD at 5%	N S

3.9 Number of spikes/m^2

The data showing the influence of the growing environment on a number of spikes / m^2 of different wheat varieties are shown in Table-9. It was observed from the table that there was a significant influence of different growing environments and weather and on the average maximum number of spikes/ m^2 was observed in variety V_1 (365) followed by V_2 (347) whereas, Minimum number. of ear heads /m^2 was recorded in variety V_3(310). Higher no. of ear heads /m^2 (365) was observed in early sown condition as compared to 10 December and 25 December sowing (347 and 310, respectively) but significantly at par with that with 10 December sowing 347). Spikes/m^2 decreased sharply when sowing was done on D_3. Zhang *et al*. (2009) [11].

Table 9: Effect of Growing environments on number of spikes/m^2 of wheat cultivars

Treatment	No. of spikes/m^2
Growing environment	
25, Nov.	365.70
10, Dec.	347.41
25, Dec.	310.84
SEm±	8.01
CD at 5%	21.25
Cultivars	
PBW-343	353.31
PBW-502	337.95
LOK-1	332.69
SEm±	3.76

3.10 Number of grains/spike

The data showing the influence of different environments on the number of grains/spike of wheat varieties are presented in Table-10. It can be seen from the table that there was a significant influence of different growing environments on a number of grains/spike and maximum numbers of grains/spike (45) were observed in early sowing D1 and decreased when the sowing was delayed. A number of grain/spike was highest in D1 but that was no significant difference among growing environments. Among different varieties, PBW-1 produced a significantly higher number of grains/spike closely followed by LOKE-1 and PBW-502 produce significantly (41) which a number of grains favorable at conducted to LOK-1. Wajid, D. (2004) [10].

Table 10: Effect of Growing environments on number of grains/spike of wheat cultivers

Treatment	No. of grains/Spike
Growing environment	
25, Nov.	45.57
10, Dec.	41.52
25, Dec.	37.93
SEm±	0.97
CD at 5%	3.06
Cultivars	
PBW-343	43.13
PBW-502	41.80
LOK-1	40.08
SEm±	0.56
CD at 5%	1.09

3.11 Number of effective tillers/m^2

A number of ear bearing tillers were counted from four places in each plot at harvest using 20cm × 20cm quadrate. Averaged out these values and finally expressed in a number of effective tillers / m^2.

Table 11: Effect of Growing environments on number of effective tillers/m^2 of wheat cultivers

Treatment	No. of effective tillers/m^2
Growing environment	
25, Nov.	392.8
10, Dec.	365.9
25, Dec.	321.9
SEm±	5.07
CD at 5%	14.8
Cultivars	
PBW-343	398.9
PBW-502	370.3
LOK-1	332.5
SEm±	3.5
CD at 5%	8.10

3.12 Grain yield (q/ ha)

The data pertaining to the influence of different growing environments on grain yield of different wheat varieties are given in Table-12. It was observed from the table that maximum grain yield 41.82 q/ha was obtained in the early growing environment (D_1) which is significantly higher as compared to the other two growing environments. A number of grains and number of spikes on higher in the wheat crop which is favoring grain yield. The lowest grain yield was recorded with the sowing of wheat on 25 December. On average, significantly higher grain yield was obtained in variety PBW-343 (40.82 q/ha) followed by PBW-502 whereas, the lower grain yield was recorded in variety LOK-1 (34.07 q/ha) being at par to each other. The interaction effect of sowing dates and varieties was found significant and it was found that under 25 November and 25 December sowing variety PBW-343 produced a comparatively higher yield. Akula, B. (2005) and Amrawat, T. *et al*. (2013) [2, 3].

Table 12: Effect of Growing environments on grain yield q/ha of wheat cultivars

Treatment	Grain yield/ha
Growing environment	
25, Nov.	40.8
10, Dec.	37.9
25, Dec.	32.3
SEm±	0.8
CD at 5%	2.6
Cultivars	
PBW-343	41.3
PBW-502	38.2
LOK-1	34.7
SEm±	0.52
CD at 5%	1.5

3.13 Harvest index

The recovery of grain in total dry matter was considered as harvest index which was expressed in percentage and calculated by using the following formula.

$$HI = \frac{\text{Economic yield (grain)}}{\text{Biological yield (grain + straw)}} \times 100$$

Table 13: Effect of Growing environments on harvest index of wheat cultivars

Treatment	Harvest index
Growing environment	
25, Nov.	42.1
10, Dec.	40.7
25, Dec.	39.9
SEm±	0.9
CD at 5%	2.4
Cultivars	
PBW-343	41.4
PBW-502	40.7
LOK-1	40.1
SEm±	0.6
CD at 5%	NS

4. Conclusion

It can be seen that maximum temperature is negatively correlated with grain yield at two stages (50% flowering and milking stages). The higher maximum temperature on these stages is giving to adversely affect the final grain yield. One interesting observation from the present study was that the maximum temperature has a positive effect on the yield of PBW-343 variety in the initial stage of crop growth (CRI, tillering stage). It means that the PBW-343 variety is responding well to the higher value of maximum temperature which is finally contributing to grain yield and rainfall influenced the grain yield both positively and negatively. The highest significant effect of rainfall was observed during the 50% flowering. Crop sensitivity to the maximum temperature and rainfall in PBW-343 cultivar, 50% flowering and milking stage was identified as the critical stage for abiotic stresses. In addition to its 50% flowering, stage rainfall was identified as a critical parameter. The yield all parameters conditions, pooled over cultivars, also showed 50% flowering to be the most sensitive phonological stage for both maximum temperature and rainfall with absolute t-values -4.54 ($P< 0.05$) and 2.51 ($P< 0.05$), respectively, closely followed by milking stage in maximum temperature.

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