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Effect of thermal stress on wheat productivity in West Bengal

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ABSTRACT

An experiment was carried out during winter seasons of 2005-06, 2006-07 and 2007-08 at the Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India with five wheat varieties (PBW 343, HD2733, HW 2045, PBW533 and K9107) on three dates of sowing (18th November, 3rd December and 18th December) in a split plot design, keeping dates of sowing in the main plot and varieties in the subplot with the objective to find out the effect of temperature change on the duration of different phenophases of wheat crop and its productivity. The phenophases (CRI, tillering, flowering and milk) were delineated and the duration of exposure of the crop to higher maximum and minimum temperature than the normal and extent of high temperature were worked out. The 18th November sown crop had to tolerate a higher maximum and minimum temperature than their normal to the tune of 2° and 3.5°C respectively. When the sowing was delayed the crop was exposed to more maximum and minimum temperature than the earlier sown crops. On second date, the crop had to tolerate a 3.9 and 5.3°C more maximum and minimum temperatures than their normal values. The December sown crop was also exposed to higher maximum and minimum temperature than the normal values. Ear weight at the milk stage could be significantly explained through the variation in cumulative maximum as well as minimum temperatures at the flowering stage. The cumulative maximum temperature (as predictor) explained 20% variation in ear weight at the milk stage whereas 15% variation was explained through the cumulative minimum temperature for the same phenophase. The cumulative minimum temperature at the flowering stage explained 20% variation in LAI significantly.

***Key words**:* Minimum and maximum temperature, phenophase, leaf area index, ear weight, wheat

Climate change, particularly, the temperature change, emanating from the human activities has raised a hue and cry in the planet Earth (Das and Lohar, 2005; Sivakumar, 2006). The change in temperature has not only altered the different natural phenomena viz. shifting of monsoon, frequent occurrence of cyclones etc. but also has created a change in the agricultural productivity of a particular area. Out of the 300 domesticated plants, used for human food and cultivated in agricultural field, wheat is the most sensitive crop in relation to temperature (Singha *et al.*, 2006; Hundal and Kaur, 2007 and Pandey *et al.*, 2007). The growth and development of wheat in Eastern India, having short and mild winter, spanning from October to March, are extremely subjected to this temperature change but no systematic study on this aspect is available at present.

With an aim to delineate the effect of temperature change on the duration of different phenophases of wheat crop and its productivity, a three year experiment was carried out (2005-06, 2006-07 and 2007-08) on five varieties (PBW 343, HD 2733, HW 2045, PBW 533 and K9107) which were sown on three different dates (18th November, 3rd December and 18th December). The information generated from this experiment may be helpful for growing wheat in the Eastern-Gangetic plains of India particularly in the state of West Bengal.

MATERIALS AND METHODS

The experiment was carried out during rabi seasons of 2005-06, 06-07 and 07-08 at Jaguli Students' Instructional Farm (New Alluvial Zone), Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India ($22^0 56^/$ N latitude, $88^0 32^/$ E longitude and an altitude of 9.75 m above mean sea level) having tropical humid climate with short and mild winter (average annual rainfall ! 1457 mm, 85% of which is received during June to September, mean monthly temperature range 10°C – 37°C). Experimental soil is sandy loam (order – Entisol, Great Group –Fluvaquents) and neutral in reaction (pH – 6.90) having 0.077% total N, 57.25 kg ha^{-1} available P_2O_5, 221.51 kg ha^{-1} available K_2O and 0.78% organic carbon.

The land was prepared by ploughing and cross-ploughing with tractor followed by laddering. Irrigation and drainage channels were suitably laid out. Total experimental site was divided into 3 blocks. Five varieties of wheat (PBW 343, HD 2733, HW 2045, PBW 533 and K9107) were sown on three dates (18th November, 3rd December and 18th December) in each block, keeping dates of sowing in the main plot and varieties in the subplot in a split plot design having the plot size of 15 m^2. The crop was fertilized with 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} where N was given in 3 splits ($^1/_3$ rd as basal, $^1/_3$ rd at 20-25 DAS and the rest on 45 DAS). One presowing irrigation was given for uniform germination,

Table 1: Duration of different phenophases of wheat varieties exposed to higher maximum and minimum temperature than the normal under 3 dates of sowing (pooled over years)

Variety	Duration of phenophase (days)			Duration exposed to higher maximum temperature (days)			Extent of high temperature (°C)			Duration exposed to higher minimum temperature (days)			Extent of high temperature (°C)		
	CRI – Tillering	Tillering - Flowering	Flowering – Milking	CRI – Tillering	Tillering - Flowering	Flowering – Milking	CRI – Tillering	Tillering - Flowering	Flowering – Milking	CRI – Tillering	Tillering - Flowering	Flowering – Milking	CRI – Tillering	Tillering - Flowering	Flowering – Milking
D1 (18th November) Sowing															
PBW343	25	34	15	10	16	6	2.0	4.1	2.7	7	11	10	3.5	6.4	6.5
HD2733	25	32	15	10	16	8	2.0	4.1	3.2	7	9	10	3.4	5.3	6.5
HW2045	25	23	14	10	9	5	2.0	4.3	2.7	7	6	6	3.5	4.3	5.2
PBW533	25	27	16	10	11	9	2.0	4.1	3.2	7	7	8	3.6	4.3	5.2
K9107	25	27	16	11	11	9	2.0	4.1	3.2	7	7	8	3.33	4.3	5.2
D2 (3rd December) Sowing															
PBW343	27	24	11	10	12	5	3.9	3.2	1.8	6	12	6	5.3	6.1	3.8
HD2733	27	24	11	10	12	5	3.9	3.2	1.8	6	12	6	5.3	6.1	3.8
HW2045	23	14	16	10	4	9	2.16	2.2	3.2	5	4	8	5.3	3.3	5.5
PBW533	27	24	11	10	12	5	3.9	3.2	1.8	6	12	6	5.3	6.1	3.8
K9107	27	24	11	10	12	5	3.9	3.2	1.8	6	12	6	5.3	6.1	3.8
D3 (18th December) Sowing															
PBW343	27	20	13	9	14	3	4.2	3.3	0.7	7	14	3	4.5	6.5	2.5
HD2733	27	20	13	9	14	3	4.23	3.3	0.7	7	14	3	4.5	6.5	2.5
HW2045	27	15	11	9	9	5	4.2	3.2	1.7	7	10	6	4.5	6.2	3.8
PBW533	27	20	13	9	14	3	4.2	3.3	0.7	7	14	3	4.5	6.5	2.5
K9107	27	20	13	9	14	3	4.2	3.3	0.7	7	14	3	4.5	6.5	2.5

whereas subsequent irrigations were given as per demand of the crop.

The daily maximum and minimum temperatures and 30 years normal values were collected from the adjacent meteorological observatory of the department of Agricultural Meteorology. The duration of each phenophase (CRI, tillering, flowering and milk) were delineated and the duration of exposure of the crop to higher maximum and minimum temperature and extent of high temperature were worked out.

RESULTS AND DISCUSSION

Effect of higher maximum temperature

First date of sowing (18th November)

Duration of phenophases of different varieties (mean of 3 years) has been presented in Table 1. It was observed that the duration of CRI to tillering for all the varieties was 25 days. This indicated that the vegetative phase for all the wheat varieties, grown under West Bengal condition did not vary. The vegetative phase builds the capacity factor of the crop; shorter duration in the vegetative phase in any variety may invite reduced growth and development having an adverse effect on yield. The duration of tillering to flowering for different varieties ranged from 23 to 34 days, the maximum and the minimum duration were recorded in PBW343 and HW2045 (Table 1) respectively. The result indicated that the duration for tillering to flowering was not homogeneous like the previous phenophase. Shorter duration observed in HW2045, might have an adverse impact on the growth and yield of this variety.

Duration of flowering to milk for different varieties ranged from 14-16 days; PBW343 and HD 2733 had 15 days duration, PBW533 and K9107 had 16 days and the HW 2045 had only 14 days.

The four out of five varieties (except K9107) were exposed to higher maximum temperature than the normal for a duration of 10 days out of 25 days during CRI to tillering stage. The K9107 was exposed to higher maximum temperature for 11 days out of 25 days. The CRI to tillering stage is not so crucial for the productivity of wheat. During this phenophases, all the varieties were subjected to a high maximum temperature to an extent of 2^0C.

The variety PBW343, out of 34 days duration for tillering to flowering stage, was exposed to higher maximum temperature than normal for 16 days. This variety experienced 4.07^0C higher temperature than the normal value during this phenophase. The variety HD 2733 experienced higher maximum temperature for 16 days out of 32 days duration

Table 2: PPrincipal component regression analysis results (Stepwise) keeping principal component score of cumulative maximum and minimum temperature as predictor and ear weight and LAI at milking as dependent variables.

Variables	Unstandardized Co-eff.		Standardized Co-eff.	t value	Sig	R	R^2	Adjusted R^2	S.E. (est)
	B	SE	Beta						
(Constant)	214.521	23.348		9.188	0.000	0.469	0.220	0.202	67.406
Cumulative maximum temperature (Flowering)	0.191	0.055	0.469	3.479	0.001				
Dependent variable : Ear weight at milking.									
(Constant)	224.795	23.336		9.633	0.000	0.418	0.174	0.155	69.335
Cumulative minimum temperature (Flowering)	0.307	0.102	0.418	3.014	0.004				
Dependent variable : Ear weight at milking.									
(Constant)	4.214	0.230		18.288	0.000	0.453	0.205	0.186	0.685
Cumulative minimum temperature (Flowering)	3.342E-03	0.001	0.453	3.328	0.002				
Dependent variable : LAI at milking.									

during tillering to flowering stage. The variety HW 2045 experienced a higher temperature of 4.27°C than the normal value during tillering to flowering stage. This exposure to the higher temperature might be critical for this variety during this phenophase.

During flowering to milk stage, the varieties experienced a higher temperature to an extent of 2.67°C to 3.17°C than the normal value. Out of total 14-16 days duration, 5-9 days had higher maximum temperature (Table 1).

Second date of sowing (3rd December)

When the crop was sown on 3rd December, the duration of CRI to tillering stage was higher for all the varieties (except HW 2045) in comparison to D_1 sowing (Table 1). All the varieties had to tolerate a higher maximum temperature to the tune of 3.9°C (except HW 2045) for 10 days out of 27 days duration.

During tillering to flowering, the duration of HW 2045 was drastically reduced to 14 days in comparison to other varieties (24 days). The four out of five varieties experienced 3.16°C higher temperature for 12 days duration during this phenophase. The duration of flowering to milk stage was drastically reduced in four out of five varieties; more or less 50% of the duration was exposed to higher maximum temperature than the normal values and the extent of high temperature was 1.76°C in four out of five varieties. In case of HW 2045, a duration of 9 days out of 16 days was exposed to higher maximum temperature than the normal value and the crop experienced 3.16°C higher temperature than the normal value.

Third date of sowing (18th December)

When the crop was sown on 18th December, the observed pattern was similar, CRI to tillering stage experienced a high temperature to the tune of 4.23°C whereas the flowering to milk stage experienced 0.67°C higher than the normal value (except HW 2045). The variety HW 2045 recorded a lower durations for tillering to flowering and flowering to milk stages in comparison to other four varieties (Table 1).

Effect of higher minimum temperature

First date of sowing (18th November)

During CRI to tillering, out of 25 days duration, all the varieties were exposed to higher minimum temperature than the normal for 7 days and this 7 days duration experienced a high temperature of 3.5°C on an average; the K9107 experienced 3.3°C, whereas PBW 533 experienced 3.6°C higher minimum temperature than the normal value. Heterogeneity appeared during tillering to flowering stages in respect of the duration as well as the duration exposed to the higher minimum temperature than the normal value. The varieties PBW 343, HD 2733, HW 2045, PBW 533 and K9107 were exposed to higher minimum temperature for a duration of 11, 9, 6, 7 and 7 days respectively. During this period, PBW343 and HD2733 were subjected to a high temperature of 6.4 and 5.3°C and the rest 3 varieties experienced 4.3°C higher minimum temperature than the normal value (Table 1). Heterogeneity existed in case of duration of flowering to milk stage, where HW2045 recorded the minimum duration of 6 days exposed to higher minimum temperature than the normal value (Table 1).

Second date of sowing (3rd December)

When crop was sown on 3rd December, homogeneity appeared in the duration of different phenophases as well as duration exposed to higher minimum temperature than the normal, except HW2045 (Table 1). During CRI to tillering, all the varieties experienced 5.3°C higher minimum temperature and this minimum temperature was quite higher than the D_1 sown crops. Similarly, the tillering to flowering stage also experienced a very high minimum temperature than the normal value and the extent of temperature difference from the normal was 6.1°C in all the varieties except HW2045. The HW2045 experienced higher minimum temperature during flowering to milk stage and the duration also was higher (8 days) in comparison to other varieties. The extent of high minimum temperature during flowering to milk stage for this variety was 5.5°C almost double the value obtained in case of other varieties.

Third date of sowing (18th December)

In case of D_3 sowing (18th December) HW2045 had a longer duration exposed to higher minimum temperature during flowering to milk stage than the other four varieties. This variety experienced a high minimum temperature of 3.8°C than the normal which was the highest during flowering to milk stage experienced by the different wheat varieties.

Principal component analysis

Principal component regression analysis (PCRA) showed that the ear weight at the milk stage could be significantly explained with the variation in cumulative maximum as well as minimum temperatures at the flowering stage. The cumulative maximum temperature (as predictor) explained 20% variation in ear weight at the milk stage whereas 15% variation was explained through the cumulative minimum temperature for the same phenophase (Table 2). Although photosynthetic contribution of ear is non-significant in case of wheat but increased maximum and minimum temperature may increase the ear respiration resulting in low apparent rates of ear photosynthesis (Evans and Rawson, 1970). The cumulative minimum temperature at the flowering stage explained 20% variation in LAI significantly (Table 2).

CONCLUSION

Changes in maximum and minimum temperatures in the Gangetic plain zones of Eastern India had shortened the duration of different phenophases and adversely affected the growth processes of wheat varieties growing in the zone. There is a possibility of drastic reduction in wheat yield due to change in maximum and minimum temperature.

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