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QUANTIFICATION OF TEMPERATURE AND ITS EFFECT ON WHEAT YIELD IN JHARKHAND REGION

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ABSTRACT

Wheat was grown under field conditions from 2006-07 to 2010-11 under fifteen sets of environmental condition by sowing the crops on different dates. Grain yield was found negatively related with the temperature rise. The wheat crop stage anthesis-milking was found to be the most sensitive to temperature rise, the minimum temperature rise being more detrimental than rise in maximum temperature. Wheat grain yield was found to decline by 45% with an increase of 3-5°C in maximum and minimum temperatures. Correlation study between temperature rise and wheat yield exhibited that exposure to higher minimum temperature was more detrimental (r= -0.82**) than exposure to higher maximum temperature (r= -0.71**). Cardinal temperature ranges, for important crop stages, have been worked out for producing higher (> 4 t/ha), medium (3-4 t/ha) and lowest (>3 t/ha) yield levels. Quantified relations obtained between wheat yield and temperature regimes would be of immense help in rendering appropriate advisories to the farmers.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's leading cereal crop cultivated over an area of about 651 million tons making it the third most-produced cereal after maize and rice. India achieved remarkable progress in wheat production during the last four decades and is the second largest wheat producer in the world with the production touching a record level of 93.90 mt an area of around 28.40 m ha during 2011-12, production has increased tremendously but is still far below the potential yield (11.2 tonnes/ha).Although, India is well placed in meeting its needs for food grains the major objective of food and nutritional secretary for its entire population has not been achieved. The demand for food grains is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development. Wheat grains are comparatively better source of protein consumed in India. About 10-12% protein requirement is met by wheat (Meena *et al.,* 2013). Quantification of weather and its effect on growth, development and productivity of crops is pre-requisite for developing a sustainable production module in any given agroclimatic region. High-temperature episodes are known to be detrimental to wheat yields (Farooq *et al.,* 2011; Sikder and Paul, 2010; Ugarte *et al.,* 2007). Above average temperatures can cause accelerated plant growth development, reduced grain filling period (Sharma *et al.,* 2008), and consequently reduced yields (Anwar *et al.,* 2007). Above average temperatures may also lead to increased maintenance respiration resulting in decreased carbon assimilation and reduced yields (Reynolds *et al.,* 2001; Chauhan *et al.,* 2011). The reproductive stage of most Australian winter grown wheat varieties currently occurs in the August–September time frame. The reproductive stage is considered the weakest link in the susceptibility of wheat to high temperatures (Zinn *et al.,* 2010; Porter and Semenov, 2005).Wheat crop has been found sensitive to high temperature regimes. However, the magnitude of damage depends on the variety of crop and on the stage of development getting coincided with the higher temperature and. High temperatures severely limit wheat yield by accelerating plant development and specifically affecting the floral organs, fruit formation and the functioning of the photosynthetic apparatus. Experimental results, with spring wheat, by Mahi *et al.* (1991), Mc Master and Wilhelm (1998) revealed that the effect of temperature on growth and grain yield of cereal depends on the stage of development of crop. Any deviation in maximum and minimum temperature from optimum value during its critical phenological stages adversely affects the yield. It is, therefore, essential to have knowledge of exact optimal temperature range for the growth and development of a genotype to predict its maturity, adaptation and yield in a particular environment and also to adjust the showing windows so as to have least adverse impact of higher temperature regimes on the performance and final yield of the crop.

Wheat cultivation in Jharkhand has gained popularity in recent years and area under this crop is gradually expanding with the adoption of rainwater harvesting and re-uses technique for increasing the irrigation potential in the state of Jharkhand. The variety K- 9107 is a promising variety of Jharkhand region due to its high yielding ability with bold grains. Sudden rise in temperature during second fortnight of February has been frequently reported for the region and found that wheat crop sown on arround 20th November with an average seasonal air temperature of 17.5 ºC produced highest grain yield whereas every delay in sowings, by a fortnight or so, caused reduction in yield by 16 to 22 percent as crop plants were exposed to an increased average seasonal air temperature of 18-20ºC (Kumari *et al.,* 2009). Impact of temperature variability, temperature extremes and changes in its average values, in consideration with the critical stages of wheat crop has not yet been quantified in Jharkhand state. In the present paper attempt has been made to establish the relationship of wheat yield (K- 9107) with the maximum, minimum and optimum temperature range for different stages and duration of exposure of higher temperature in plateau and hill region of Jharkhand.

MATERIALS AND METHODS

In order to quantify the impact of temperature variations on wheat cultivar, the crop (var. K-9107) was exposed to fifteen sets of environmental conditions by sowing the crop on different dates in five consecutive years (2006-07 to 2010-11) in the research farm of Birsa Agricultural University during *Rabi* seasons under "crop weather relationship" experiment of AICRPAM. The soil is sandy loam with water retentive capacity of 9 % at PWP and 22 % at FC. Crop was grown under irrigated condition with spacing of 20 cm (row to row) following the recommended package of practices. Weather parameters were recorded at the agro meteorological observatory located 300 meters away from experimental field. Average values of maximum, minimum and mean temperatures at vegetative, flowering, milking and maturity stages were worked out for each date of sowing. Correlation between these three temperatures values with observed yields were established. Cardinal temperature ranges (maximum, minimum and optimum) for important crop stage, producing the highest (> 4 tons/ha), medium (4-3 tons/ha) and the lowest (< 3 tons/ha) yields were calculated from the given sets of observations. Duration of exposure of higher temperature (over optimum value) at most critical stage and its effect on yield were also quantified

RESULTS AND DISCUSSION

Relationship of temperature parameters (maximum, minimum and mean) with wheat yield, at different crop stages, is presented in Table 1. Correlation coefficient (r) values showed that grain yield was adversely affected by these three temperature parameters at all the considered crop stages. The maximum temperature, during vegetative stage, registered significant negative association (r =0.56) with yield while minimum and mean temperature, during this period, did not influence the yield significantly. However, the stage anthesis-milking was found to be the most vulnerable to temperature rise, both maximum (r = -0.71*) as well as minimum (r = -0.82*). Ferris *et al*.(1998) and Waiker and Arun (2015) has reported substantial reduction in wheat grain yield under the warmer and more variable temperature conditions during anthesis stage.

Regression equation developed between yield and temperature (minimum, maximum and mean) revealed (fig.1) that the quantum of reduction in yield with unit increase in minimum temperature during anthesis-milking stage was higher (218 kg/ha) than the reduction due to increase in maximum (145 kg/ha) and mean (186 kg/ha) temperatures.

Based on the pooled analyses of temperature vs. yield (K-9107 as a test variety) the optimum ranges of maximum and minimum temperatures, at different stages, for getting wheat grain yields of more than 4 t/ha, 4-3 t/ha and less than 3 t/ha

Table 1: Correlation Coefficients between temperature and wheat yield at different stages with wheat yields.

Parameters/Stages	Vegetative	Boot - Anthesis	Anthesis-Milking	Milking -Maturity
T. Max	-0.56*	-0.61*	-0.71**	-0.56*
T. Min	-0.38	-0.80**	-0.82**	-0.72**
T. Mean	- 0.51	-0.76**	-0.78**	-0.68**

Table 2: Cardinal temperature ranges during different stages of Wheat (var. K-9107)

Temperature	Vegetative	Anthesis	Milking	Maturity
Yield >4.0t/ha				
Maximum	22.5-24.5 (23.5)	21-27.5(25.2)	23.5-29.5(26.3)	30-32.5(31.2)
Minimum	7.0-8.0(7.1)	7.5-11.5(9.1)	7.0-10.0(8.6)	11.5-13.5(12.3)
Yield 4-3t/ha				
Maximum	23.0-24.0(23.5)	23.5-32.0(27.2)	24.0-33.0(30.2)	26.5-37.0(33.5)
Minimum	6.8-8.5(7.5)	10.0-13.1(11.6)	10.0-15.0(13.4)	13.0-18.0(16.4)
Yield <3t/ha				
Maximum	24.0-26.0(25.1)	30.0-32.0(30.9)	33.0-35.0(34.2)	33.0-35.5(34.3)
Minimum	8.1-9.6(8.9)	12-14.5(13.3)	14.5-16.0(15.4)	15.5-20.5(17.9)

(Optimal values in parentheses)

Table 3: Temperature rise at Anthesis-Milking stage and % fall in productivity of Wheat (var K-9107)

Increase in temperature from	Maximum temperature		Minimum temperature		
optimum by (ºC)	2-3	3.1-5	3	4	5
% fall in productivity (yield/ha)	27-40(14-21q/ha)	44-45(22-23q/ha)	15-39(8-20 q/ha)	27-40(20-23 q/ha)	44-45(22-23q/ha)

Table 4: Exposure to higher temperatures at Anthesis-Milking stage and Yield of Wheat (K-9107)

Year	Duration ofMaximum Temp(>2deg C)	Duration ofMinimum Temp(>2deg C)	Yield (q/ha)	% fall in productivity over highest yield (51.5q/ha)
2006-07	0	14	37.6	27
2007-08	1	2	43.6	15
2008-09	3	4	40.7	21
2009-10	1	1	45.5	12

Table 5: Long term analysis of temperature vs. yield with current year (VarK- 9107)

Stages	T Max (°C)			Optimum range(Yield > 4t/ha)
	20th Nov	5th Dec	20th Dec	
Vegetative	21.7	21.9	22.3	22.5 - 24.5
Boot-Anthesis	25.9	28.8	27.3	21 - 27.5
Anthesis-Milk	27.4	26.8	29.4	23.5 - 29.5
Milk-maturity	29.0	31.2	32.3	30 - 32.5
	T Min (°C)			
Vegetative	5.9	7.0	8.3	7- 8
Boot-Anthesis	11.9	14.8	15.8	7.5 - 11.5
Anthesis-Milk	14.3	16.5	15.6	7 - 10.0
Milk-maturity	15.9	17.8	19.2	11.5 - 13.5
Yield (t/ha)	3.9	3.5	3.4	

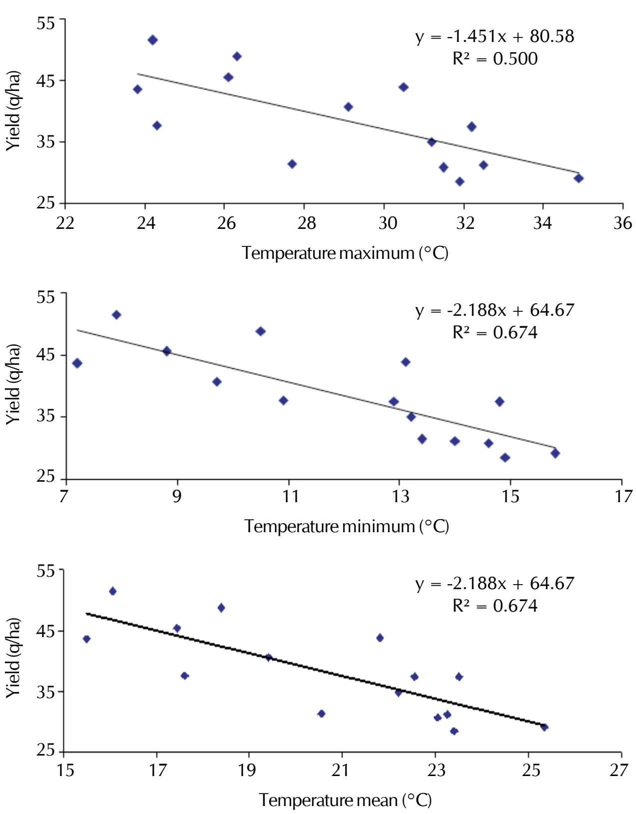

Figure 1: Effect of maximum, minimum and mean temperature during Anthesis- Milking stage on wheat yield.

have been identified (Table.2). Long term analysis of temperature effect on wheat yield showed that relatively lower maximum as well as minimum temperature are required during vegetative stage than required at reproductive stage (anthesis to maturity). Maximum temperature in the range of 22.5-24.5 °C with an average of 23.5°C and minimum temperature in the range of 7–8 °C with an average of 7.1°C during vegetative stage were found to be optimum temperature limits. For obtaining higher wheat yield (>4t/ha) upper limits of maximum and minimum temperature during anthesis (the most thermal sensitive stage) should not be more than 27.5 and 11.5°C, respectively. Further rise in maximum and minimum temperature, above the cardinal range, identified for different stages, has been found to reduce the wheat yield considerably, to the extent of medium (4-3t/ha) to lowest (< 3t/ha) levels.

Prevailing temperature regimes during vegetative stage, with respect to maximum and minimum temperatures, producing the highest (51.49 q/ha) as well as the lowest (28.50 q/ha) yields under the long term crop weather relationship experiment also showed the similar trend. Differences were higher during reproductive stage with highest variation in average maximum and minimum temperature of approximately 10°C at anthesis stage (Fig.2).

Based on the above findings anthesis-milking stage could be regarded as the most susceptible to temperature rise. On an average 2-3 °C rise in maximum temperature has been found to cause 27-40% fall in wheat yield and 44-45 % fall due to an increase of 3-5°C (Table 3). Similarly, 3°C, 4°C and 5°C rise in minimum temperature caused 15-39%, 27-40% and 44- 45% reduction in wheat yield, respectively.

The effects of short periods of exposure to high temperature (above 31°C) on wheat yields are thought to be equivalent to a 2-3°C warming in seasonal mean temperature. Wheat crops sown on normal date (20th Nov) showed a large variation in yield as they exposed to higher temperature episodes for different durations (Table 4). Also, up to 27% reduction in grain yield has been observed due to 14 days exposure to higher minimum temperature at anthesis-milking stage. Exposure to higher minimum temperature was found to be more detrimental to wheat yield as compared to higher

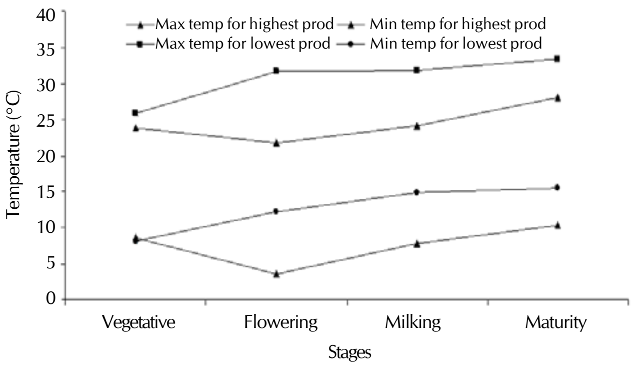

Figure 2: Comparison of temperature ranges for highest and lowest yield

maximum temperature.

Comparison between long term analysis of temperature and yield of K 9107 with 2014-15 wheat crops performance (Table 5) sown under three different environmental sets *i*.e. normal (20th Nov), mod. normal (5th Dec) and late (20 Dec) condition showed that wheat crops experienced optimum range of maximum temperature but all were exposed to higher minimum temperature as compared to their optimum minimum temperature ranges during each reproductive stage *i*.e. from anthesis to maturity stage and yielded less than 4t/ha. Minimum temperature was 2.4 to 6.5°C higher over optimum range during reproductive stage and maximum differences were found during anthesis to milking stage (4.3 to 6.5°C) for all the three sowing dates crops resulted into decrease in yield of K -9107 by 11-13%.

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