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Combating the harm effects of weather change on wheat using climate smart technologies in eastern Uttar Pradesh

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Abstract
Influence of weather change on wheat yield, productivity, crop phenology, accumulation of growing degree days (GDD), biomass and heat use efficiency (HUE) studied under field condition through the accumulated heat unit system. An on farm trial in farmer participatory mode were conducted at 5 location of each districts namely Basti, Gorakhpur and Siddharthnagar by selecting cooperator and well equipped farmers in these districts. Trials were conducted under irrigated ecosystem during Rabi season 2014-2015 and 2015-2016. The treatment comprises four sowing dates (3 November, 18 November, 3 December and 18 December) and 3 tillage practices (zero tillage, conventional tillage and reduced tillage). Highest accumulation of GDD (1904 & 1907), lowest phenol thermal index (PTI) (10.0 and 9.2) and highest grain yield was recorded with early sowing (3 November.) of wheat in both the years but highest HUE (2.52 and 2.48 kg grain/ha/GDD) was recorded with 18th November sowing of wheat in both the years. Among the tillage practices highest accumulated GDD and HUE with low PTI was recorded with zero till sowing of wheat. Yield reduction after 3rd November sown crop varied with tillage practices. Calculated for delays after the optimum date, grain yield decreased at the rate of 29.1, 35.3 and 44.8 kg /ha/day delayed sowing with ZT, CT and RT sown crop, respectively during 2014-15. While during 2015-16 it was 30.9, 32.3 and 32.3 kg/ha/day. Corresponding values on a relative basis for these tillage practices were 0.60, 0.76 and 0.99 per cent /day during 2014-15 and during 2015-16 it was 0.62, 0.67 and 0.70 per cent /day, respectively. Heading to dough stage, the most thermally sensitive phase, late sown crop was exposed to higher air temperature compared to earlier sown crop. It was also observed that high temperature during heading to milking and milking to dough stage gave forced maturity to the crop by reducing crop duration by 9, 22 and 29 days in 18th November, 3^{rd,} and 18th December sown crop and maximum effect was observed in reduced tillage crop (using one time rotawator).

Keywords: Climate smart, Heat Use Efficiency, Photo thermal index, biomass, wheat

1. Introduction

Wheat (*Triticum aestivum* L.), a major food crop in India, is cultivated on 27.75 M ha with an average productivity of 2.9 t/ha (FAI. 2011) [2]. Climate change is an accepted phenomenon worldwide and it is estimated that by 2030 minimum temperature during Rabi season is increased by 1.85 to 3.07^{o} C, which may reduce irrigated wheat production by about 5 per cent in 2030 and 25 per cent in 2080 (Aggarwal *et al.*, 2010) [1]. Hundal (2004) [4] observed that a 2^{o} C increase in temperature in wheat resulted 15-17 per cent reduction in grain yield but beyond that the decrease was very high. The average productivity of wheat in eastern Uttar Pradesh (EUP) on an average is around 2.7 t/ha. The main reason for low productivity in EUP is sudden rise in temperature at the reproduction phase which reduces the crop period or early maturity. Wheat grain yield generally declines as temperature increases. Temperature stress intensity is severe under late sown condition, causing reduction in duration of later growth phases (Mavi & Tupper 2005) [7]. Ortiz –Monasterio R *et al.* (1994) [5] emphasized the necessity of ensuring that anthesis occurs sufficiently early to permit completion of grain filling before the onset of hot condition. With present trend of increase in cultivation of long duration rice varieties in EUP, wheat sowing is delayed and maturity period is pushed into higher temperature of the summer, thereby exposing most of the grain development period to adverse temperature condition. The major conservation agriculture based technology being adopted is zero tillage wheat in the rice wheat based system of Indo- Gangetic plains (IGP). Malik *et al.* (2011) working at eastern IGP advocated early sowing of wheat for around double productivity that of wheat sown in early December primarily due to avoidance of terminal heat at the end of growing season. Zero tillage technique has the potential to reduce the time for field preparation resulted early sowing. Tomar & Husain (2007) [10] reported more grain /ear all and test weight of wheat in ZT sown wheat than conventional tillage wheat.

Keeping in view the facts mentioned above, present investigation was carried out to assess the impact of different weather environment on growth and yield of wheat.

2. Materials and Methods

On Farm trial in farmer participatory mode were conducted at 5 locations by selecting cooperating and well equipped farmers in Basti, Siddharthnagar and Gorakhpur, (UP) for two years (2014-2015and 2015-16). The treatment comprises of four sowing dates (3rd November, 18th November, 3rd December and 18th December) and 3 tillage practices *viz*: zero tillage, conventional tillage (one deep ploughing+ 2 cross ploughing by cultivator+ planking) and reduced tillage (One rotavator) replicated at 5 locations of each selected district which were treated as 5 replications. The experiment was conducted in split plot design using strip plot technique keeping sowing date in main plot and tillage practice in sub-plot. The soil of the experimental fields was sandy loam or loam, low in nitrogen, phosphorous and medium to low in potash. Sowing was done by using wheat variety HD 2733 with 100 kg seed /ha. Recommended dose of NPK @150:60:40 kg/ha was applied through di-ammonium phosphate, urea and murate of potash. Gorakhpur is situated at 26°43'N latitude, 83°20 E longitude and an altitude of 85 m above mean sea level. The area lies in the North Eastern plain zone under sub-humid sub-tropical climate with an annual rainfall about 1200 mm, out of which 90 percent is received from mid-June to September during SW monsoon. Maximum, minimum temperature and rainfall during crop period of wheat was recorded from meteorological observatory of the Gorakhpur working under IMD Pune. Heat unit concept has been applied to correlate phenological development in crops to predict sowing and maturity dates (Mills 1964). Growing degree day were calculated using base temperature of 5° C from daily mean temperature.

$$GDD = \{(Tmax + Tmin) /2 - T_b$$

Phenothermal index (PTI): The ratio of degree days to the number of days between two phonological stages was calculated as PTI = GDD between two phenological stages/ No. of days taken between two phenophases. Heat use efficiency (HUE) for grain yield was obtained as
HUE= Grain yield/ Accumulated heat unit °C day

3. Result and Discussion

3.1 Growing Degree Days (GDD)

Highest GDD (1904 & 1907) was recorded with 3rd November sowing and decreased as delay in sowing respectively, in both the years (Table 1). Among the tillage practices highest GDD was availed by zero tillage sown wheat followed by conventional tillage (CT) and reduced tillage respectively. GDD decreased with delay in sowing for all the tillage practices in both the years. Decreased GDD requirements with delay in sowing were also reported by Singh *et al*, (2008) [9].

Table 1: Growing degree day (GDD), heat use efficiency of wheat under different growing Environments.

Treatment	GDD (° C Day)		HUE for grain yield (kg/ha/ °C day)	
Sowing date	**2014-15**	**2015-16**	**2014-15**	**2015-16**
3rd November	1904	1907	2.45	2.50
18th November	1793	1782	2.48	2.52
3rd December	1635	1601	2.28	2.52
18th December	1565	1579	1.92	2.11
Tillage practice				
Zero tillage	1776	1742	2.41	2.54
Conventional tillage	1749	1716	2.27	2.42
Reduced tillage	1736	1703	2.12	2.31

3.2 Heat Use Efficiency (HUE)

Heat use efficiency was influenced due to sowing date and tillage practices. The highest HUE for grain yield (2.48 & 2.52 kg/ha/°C day) was recorded in 18th November sowing followed by early sowing (3rd November). Late sown (December sowing) wheat recorded comparatively less heat use efficiency than November sown wheat (Table 2). Higher HUE in 18th November sown wheat might be due to weather condition were more favorable to utilize more heat unit in better way to convert the photosynthates in grain yield. The results supported the findings of Pragyan Kumari *et al*, (2009) [8]. Among the tillage practices zero tillage wheat crop exhibited maximum HUE (2.41 & 2.54 kg/ha °C day) followed by CT wheat & reduced tillage wheat in both the years. Higher HUE in ZT wheat might be due to less effect of heat stress on crop in this treatment. Better HUE recorded in 2nd year of experimentation than 1st year may be due to comparatively low temperature during crop period and rainfall in reproductive phase.

3.3 Phenothermal Index (PTI)

The Phenothermal index ranged from 10.6 to 11.2 during sowing to heading stage in all the date of sowing in both the years. From heading to dough stage, it ranged from 13.2 to 19.6 reflecting an increase in the accumulation of the degree days per growth day between two phonological events and increase in PTI due to delay in sowing at heading to dough stage. Average PTI during crop period was lowest 10.0 and 9.2 in 3rd November sowing and increased subsequently delay in sowing. Findings are in accordance with the findings of Pragyan Kumari *et al*, (2009) [8].

Table 2: Phenothermal index at different crop growth stages of wheat

Sowing date	Sowing to heading		Heading to milking		Milking to dough		Dough to maturity	
	2014-15	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2014-15**
3rd November	11.8	11.9	11.8	10.8	16.2	15.5	20.5	18.8
18th November	11.8	11.2	14.3	13.4	18.5	16.5	20.4	21.7
3rd December	10.9	10.6	15.6	15.3	19.7	17.5	20.2	21.8
18th December	11.2	11.2	18.9	15.3	20.3	21.6	20.3	21.8

Sowing date	Heading to dough		Average PTI during sowing to maturity	
	2014-15	2015-16	2014-15	2015-16
3rd November	9.0	8.2	10.0	9.2
18th November	11.9	9.9	11.2	10.7
3rd December	12.6	11.4	11.6	11.3
18th December	14.6	13.4	13.2	12.5

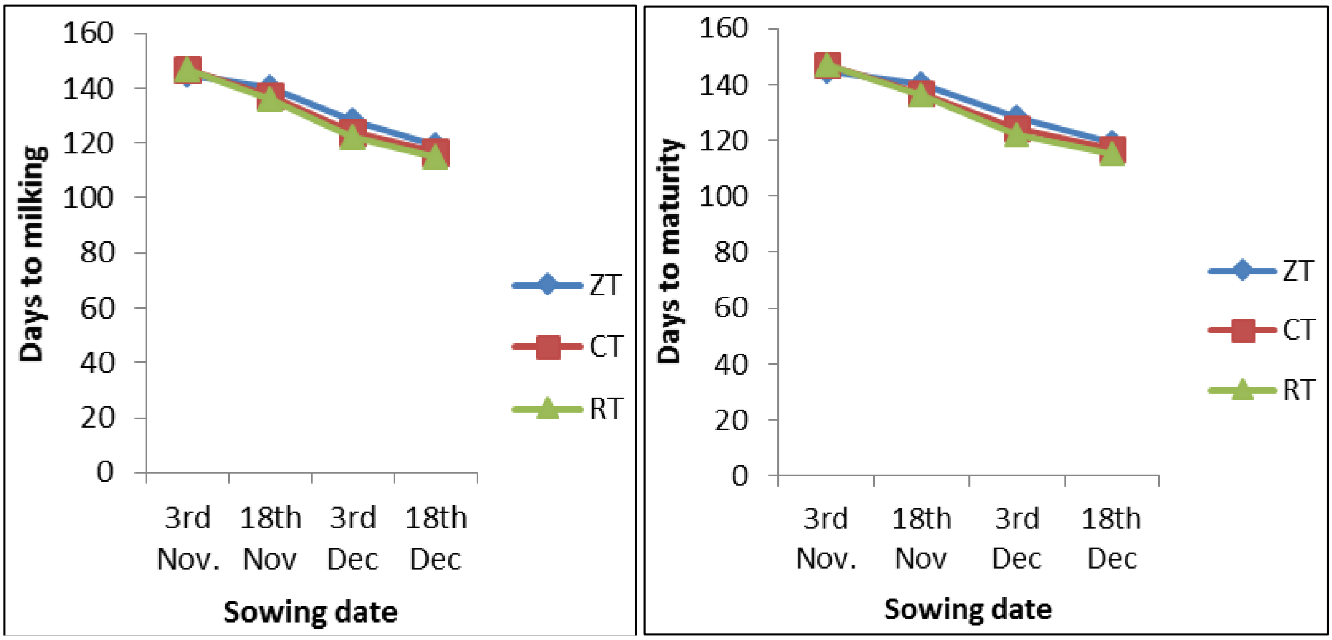
Higher value of PTI from heading to dough stage and sowing to maturity with delay in sowing might be the reason of low yield of wheat in eastern UP.

3.3.1 Temperature
The mean temperatures experienced during different phenophases of wheat are given in table 3. Data showed that during 2015-16 wheat crop experienced low temperature about 1°C compared to 2014-15 on all the sowing dates. It was also observed that late sown crop (3rd December & 18th December) experienced 2 to 3° C higher mean temperature compared to early sowing (November) during crop period in both the years. Data revealed that during 2014-15 3rd and 18th December sown crop experienced 4 and 7 °C higher temperature at heading to milking stage compared to 3rd November sown crop. While in 2015-16 the difference in temperature was 4.5 ° C. Similarly, these two dates also experienced higher mean temperature by 3.5 & 4.1 °C than 3rd November sown crop (21.2 & 20.5 °C) during milking to dough stage in 2014-15, while in 2015-16 it was higher 2°C and 4.1 °C respectively. When heading to dough stage was considered as a single unit, 3rd and 18th December sown crop experienced 3.6 and 5.6 °C higher temperature at this crop stage compared to 3rd November sown crop. While in 2015-16 the difference in temperature was 3.2 and 5.2 °C.

Table 3: Mean temperature during (°C) different phenophases of wheat (mean of three district)

Sowing date	Sowing to heading		Heading to milking		Milking to dough		Dough to maturity	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
3rd November	16.8	16.9	16.8	15.8	21.2	20.5	25.5	23.8
18th November	16.8	16.2	19.3	18.4	23.5	21.5	25.4	26.7
3rd December	15.9	15.6	20.6	20.3	24.7	22.5	25.2	26.8
18th December	16.2	16.2	23.9	20.3	25.3	26.6	25.3	26.8
Sowing date	Heading to dough		Average mean temperature during crop period					
	2014-15	2015-16	2014-15			2015-16		
3rd November	19.0	18.2	20.0			19.2		
18th November	21.9	19.9	21.2			20.7		
3rd December	22.6	21.4	21.6			21.3		
18th December	24.6	23.4	23.2			22.5		

3.4 a. Effect on phenological stage
Early sowing of wheat 3rd and 18th November took the same days for heading but delay in sowing reduced the days to heading. Comparable higher days to maturity of the crop was observed with 3rd November sowing. Subsequent delay in sowing reduced the crop period by 9, 22 and 29 days during 18th November, 3rd and 18th December sowing, respectively. The difference to attain a particular phase was wider after heading and it was clear that heading to maturity was drastically reduced with any delay in sowing after 3rd November for all three tillage practices. However, for late sown zero tillage crop rate of reduction were less than for the other two tillage practices (Fig 3).



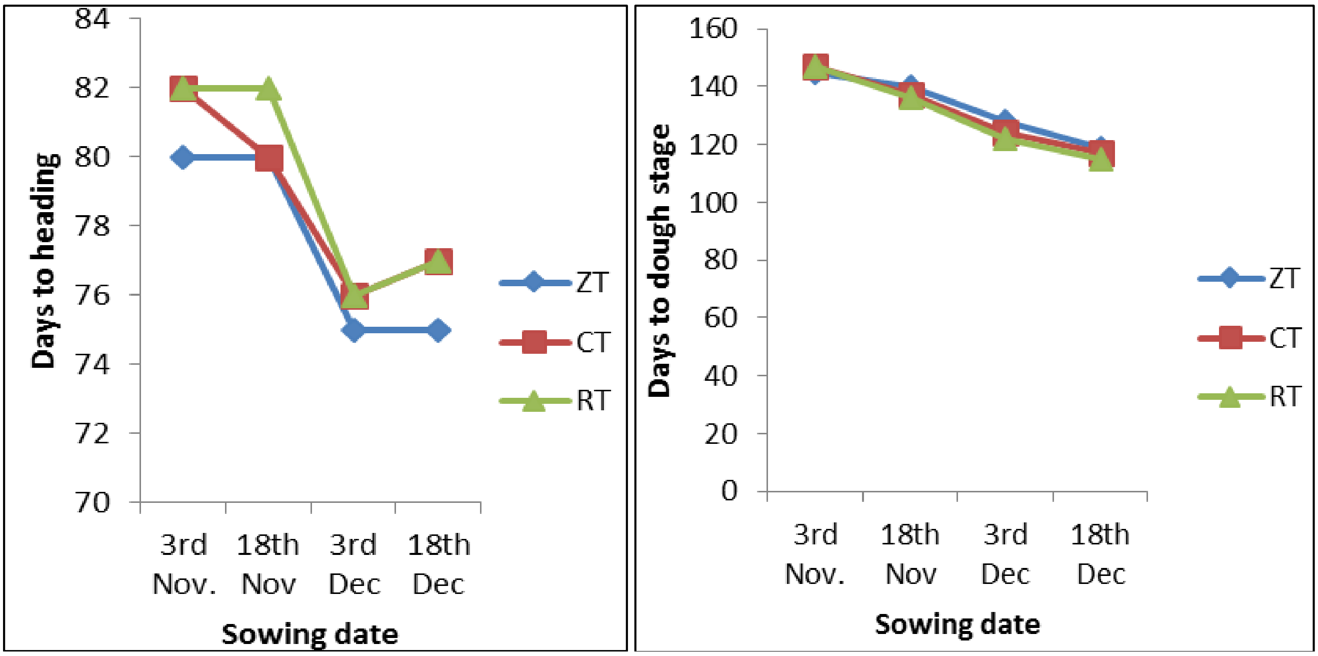


Fig 3: Days taken to different growth stages of wheat in varying growing environments

3.4 b. Absolute and relative losses in grain yield with delayed sowing

Early sowing (3rd and 18th November) crop were at par recorded markedly higher grain yield over 3rd and 18th December sown crop (Table 4) on account of improvement of their yield attributes under these sowing dates, because of the depressing effect of temperature was minimum during the most sensitive, heading to dough stage as these dates availed more duration for this stage. Lowest yield (3010 and 3330kg/ha) was recorded with 18th December sown crop which was significantly lower than 3rd December sown crop. The yield decreased at the rate of 15.9, 28.1 and 37.1kg/ha/day, delayed sowing with 18th November, 3rd December and 18th December 2014-15 while in 2015-16 it was 20, 26 and 45 kg/ha /day. Corresponding values on a relative basis for these sowing dates were 0.34, 0.67 and 0.79 per cent /day during 2014-15 while in 2015-16 it was 0.38, 0.55 and 0.67 per cent /day Higher yield in early sowing of wheat might be due to favorable temperature during crop period helped better development of

Table 4: Effect of sowing date and tillage practices on grain yield (kg/ha) of wheat (mean of three districts)

Sowing date	Tillage practices 2014-15			Mean	Tillage practices 2015-16			Mean
	ZT	CT	RT		ZT	CT	RT	
3rd November	4810	4644	4493	4683	4967	4751	4582	4767
18th November	4560	4482	4290	4444	4963	4505	4491	4491
3rd December	4290	3740	3490	3840	4260	4091	3571	3974
18th December	3500	3055	2475	3010	3570	3300	3129	3333
Mean	4295	3985	3692		4440	4162	3947	
CD for sowing date (P=0.05)	318				324			
CD for Tillage practice (P=0.05)	260				256			
S. date x T. practice (P=0.05)	598				NS			

grain / ear and test weight. Fischer (1975) [3], working under field condition reported that kernel weight is mainly driven by temperature. ZT sown crop recorded significantly higher grain yield (4295 and 4440 kg/ha) over other tillage practices which was 7.7and 16.3 per cent higher during 2014-15over CT wheat and RT wheat. While during2015-16 it was 6.6 and 12.5 per cent higher, respectively.

Yield reduction after 3rd November sown crop varied with tillage practices. Calculated for delays after the optimum date, grain yield decreased at the rate of 29.1, 35.3 and 44.8 kg /ha/day delayed sowing for ZT sown crop, CT and RT sown crop, respectively during 2014-15. While during 2015-16 it was 30.9, 32.3 and 32.3 kg/ha/day. Corresponding values on a relative basis for these tillage practices were 0.60, 0.76 and 0.99 per cent /day during 2014-15 and during 2015-16 it was 0.62, 0.67 and 0.70 per cent /day, respectively. Comparatively less reduction in ZT sown crop might be due to more tolerance of crop against terminal heat stress. Higher number of grain /ear and test weight in this tillage practice over other tillage practice resulted higher grain yield.

3.5 Biomass accumulation: November sown crop (3rd and 18th November) produced similar biomass but comparably higher than December sown crop (Table 5). Lowest biomass was recorded with 18th December sown crop. The reason being less number of fertile tillers, no of grain/ear and test weight with poor crop growth might be due to experience of higher temperature during crop period.

Table 5: Effect of sowing date and tillage practices on yield attributing characters, biomass accumulation and harvest index (mean of three district data)

Treatment	Grain/ear		Test weight (g)		Biomass (kg/ha)		Harvest index (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Sowing date								
3rd November	41	43	40.2	40.7	10853	11086	42.8	42.9
18th November	39	41	38.6	39.2	10590	10890	41.9	42.7
3rd December	36	38	36.6	37.3	9854	9983	38.9	39.7
18th December	36	36	35.0	35.6	8468	8913	35.4	37.3
CD (P=o.o5)	2.7	2.8	1.2	1.4	376	358		
Tillage practice								
Zero tillage	41	42	40.0	40.5	9965	10321	42.9	42.8
Conventional tillage	37	38	37.7	38.3	10062	10242	39.2	40.4
Reduced tillage	36	36	35.5	36.2	9797	10090	37.1	38.8
CD (P=o.o5)	2.7	2.8	1.4	1.3	NS	NS		

3.6 Harvest index: The maximum harvest index (42.8 and 42.9 %) was recorded with 3rd November sown crop during both the years followed by 18th November sown crop. Delaying in sowing reduced the HI drastically. Better HI in early sown crop might be due to better source and sink relationship in this treatment. Higher HI was recorded with ZT sown crop (42.9 and 42.8 %) than CT and RT sown crop. Lowest HI was recorded in RT sown crop might be due to poor development of grain size and number of grain.

4. Conclusion

The optimum sowing date of wheat in EUP for achieving higher yield is 3rd November for all the tillage practices. However, to minimize the yield reduction due to unfavorable weather environment in delayed sowing, zero tillage technique should be adopted.

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