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RESEARCH PAPER

Effect of thermal stress management strategies on yield and yield attributes of wheat (*Triticum aestivum* L.) under late sown conditions

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Abstract : Field experiment was conducted at research farm, Department of Agricultural Meteorology, CCS HAU, Hisar located at 29° 10' N latitude, 75° 46' E longitude and 215.2 m altitude during *Rabi* season of 2007-08 and 2008-09 (Last week of December) to study the effect of thermal stress management strategies on yield and yield attributes of wheat under late sown conditions. The grain, straw and biological yields were maximum in T_5 (3803, 5829 and 9632 kg ha^{-1}, respectively) and these were lower in T_1 (3504, 5617 and 9121 kg ha^{-1}, respectively) during 2007-08. During 2008-09, the grain, straw and biological yields were maximum in T_5 (3713, 5814 and 9527 kg ha^{-1}, respectively) and these were lowest in T_1 (3417, 5598 and 9016 kg ha^{-1}, respectively). The harvest and attraction index were maximum in T_3 (39.6 and 65.5%, respectively) and these were minimum in T_1 (38.4 and 62.4%, respectively) during 2007-08. During 2008-09, harvest and attraction index were maximum in T_3 (39.1 and 64.1%, respectively) and minimum in T_1 (37.9 and 61.0%, respectively). Among post anthesis strategies, the highest grain and biological (3758 and 9659 kg ha^{-1} in 2007-08) and (3666 and 9551 kg ha^{-1} in 2008-09) was observed in S_3. The harvest and attraction index were statistically at par among all the treatments during both the crop seasons. The pooled LAI (r = 0.94), LAD (r = 0.96), CGR (r = 0.98) at vegetative and the pooled LAI (r = 0.92), LAD (r = 0.98), CGR (r = 0.78) at reproductive phase have shown highly significant and positive correlation with grain yield.

Key Words : Thermal stress management strategies, Yield and yield attributes, Correlation, Wheat

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important food crop of world and is grown under different soil and climatic conditions. In India it is second most important food crop, cultivated extensively in North-Western and Central zones. Wheat is a photo-insensitive and thermo-sensitive long day plant. Temperature plays dominant role to wheat adaptation in India. Cool weather during vegetative growth and warm weather at maturity is deemed ideal for this crop. However, conditions of photoperiod, radiation, temperature, rainfall and humidity vary greatly among the wheat growing regions.

The crop under late sowing suffers due to sub-optimal temperature at sowing, which causes delayed germination by slowing down the rate of physiological activities related to germination namely absorption of water, hydrolysis of nutrient inside the embryo, slow growth, development and low yield. The delayed sowing further causes supra-optimal thermal stress at reproductive phase, which results in forced maturity (Gupta *et al.*, 2002). This high temperature stress at reproductive phase of crop results in poor yield due to reduced number of grains per spike and shriveled grain with poor quality (Sharma *et al.*, 2007). Delay in wheat sowing 20 and 40 days from the normal sowing date (15th November) reduced grain yield by 23 kg $ha^{-1}day^{-1}$ and 30 kg $ha^{-1}day^{-1}$, respectively (Kaur and Pannu, 2008) . Therefore, it becomes imperative to

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develop suitable production practices for obtaining higher yield under late sown conditions. So the dry sowing of wheat saves the time of sowing and this makes possible for farmers to sow wheat within the least consumed time period and it saves the pre-sowing irrigation (Ashfaq and Zahid, 2004). Low germination in dry sowing method can be compensated by 25 per cent higher seed rate than the normal seed rate. Another technique of overnight seed soaking in water and different salt solutions followed by surface drying and then sowing improves the stand establishment and early vigour of wheat. Keeping this in mind, an attempt has been made to study the effect of thermal stress management strategies on yield and yield attributes of wheat under late sown conditions.

MATERIALS AND METHODS

Field experiment was conducted at research farm, Department of Agricultural Meteorology, CCS HAU, Hisar located at 29° 10' N latitude, 75° 46' E longitude and 215.2 m altitude during *Rabi* season of 2007-08 and 2008-09 (Last week of December). The experiment was put in a Split Plot Design and comprised of six pre-sowing strategies in main plots namely (T_1)-Normal seeding (Control), (T_2)-Sowing in dry seed bed followed by irrigation, (T_3)-Sowing with 25% higher seed rate in dry seed bed followed by irrigation, (T_4)-Overnight soaked seed sowing, (T_5)-Overnight soaked seed sowing with 25 per cent higher seed rate in dry bed followed by irrigation and (T_6)-NAA (200 ppm solution) primed seed sowing and three post anthesis trategies *viz.,* (S_1)-Normal without spray, (S_2)-Urea (2.5%) spray followed by light and frequent irrigation at weekly interval anthesis onwards and (S_3)-Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis in sub-plots with three replications. The recommended dose of nitrogen (150 kg N ha^{-1}), phosphorus (60 kg P_2O_5 ha^{-1}) and zinc sulphate (25 kg ha^{-1}) were applied. Full dose of phosphorus and zinc and half dose of nitrogen were applied before sowing and remaining ½ N was top dressed after first irrigation. The source of nitrogen and phosphorus were urea and single super phosphate. Irrigation was applied at crown root initiation (CRI) and flag leaf to all treatments whereas, at milking and dough irrigation was applied to S_2 only during both the crop season. Each irrigation was about 7 cm and other operations were carried out as per recommendation in the package of practices for wheat crop.

The observations on yield and yield attributing characters were taken from each plot at the time of harvest. Five plants were selected randomly and tagged from each plot and used for recording numbers of effective tillers per plant, number of spikelets per spike, number of grains per spike, grain yield per plant, biological yield per plant. Grains were separated with a mini-plot thresher from biological yield obtained from each plot. The grain yield from net plot was weighed on top pan balance and converted into kg ha^{-1}. After harvesting, the wheat crop was sun dried up to one week and then weight of net harvested area of wheat in each plot was recorded with spring balance which was converted into kg ha^{-1}. Straw yield from net plot was computed by subtracting the grain yield from the total produce harvested (biological yield) and later on converted into kg ha^{-1}. After threshing and weighing, a random sample of grains was taken from each plot. From these sample one-thousand grains were counted at random with the help of mechanical seed counter and the weight (g) was taken with electronic balance for recording of test weight. The harvest index for each plot was calculated by dividing the total grain yield by the total dry matter (grain + straw yield) of the same net plot and multiplied by 100 as given below:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \text{ x } 100$$

The attraction rate is referred as a ratio of grain yield and straw yield and is expressed in percentage. This was calculated by using the following formula:

$$\text{AI (\%)} = \frac{\text{Grain yield}}{\text{Straw yield}} \text{ x } 100$$

Critical difference (CD) at 5 per cent was worked out using statistical technique as described by Gomez and Gomez (1984) for yield and yield attributes. Correlations of pooled value of crop growth parameters like leaf area index (LAI), leaf area duration (LAD), specific leaf area (SLA), crop grow rate (CGR) and dry matter accumulation with yield and yield attributes were computed at vegetative and reproductive phase.

RESULTS AND DISCUSSION

Results indicate that among pre-sowing strategies, the number of effective tillers per plant, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain yield per plant and biomass yield per plant were significantly higher in T_5 and these were lower in T1 during both the crop seasons (Table 1). This might be due to the fact that T_5 produced higher leaf area index, leaf area duration and higher crop growth rate, stayed green for longer time in T_1 as compared to other treatments. Similar variations in yield attributes due to various seeding treatments have also been reported by Gupta *et al.* (2006), Kant *et al.* (2003), Nazir *et al.* (2000) and Chahal *et al.* (1994). All the yield attributes were higher during 2007-08 than 2008-09. Among post anthesis strategies, number of effective tillers per plant, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain yield per plant, biomass yield per plant, grain and biological yield were higher in S_3 over S_1 during both crop seasons.

In general, the grain, straw and biological yields were higher in treatments with soaked or primed seeds as compared to treatments which were dry seeded (Table 2). Among pre-sowing strategies, the perusal of data on grain, straw and biological yield of wheat were higher in T_5 and these were

Table 1: Effect of thermal stress management strategies on yield attributes of wheat under late sown conditions

Treatments	2007-08						2008-09					
	No. of effective tillers plant^{-1}	No. of spikelets spike^{-1}	No. of grains spike^{-1}	1000-grain weight (g)	Grain yield plant^{-1} (g)	Biomass yield plant^{-1} (g)	No. of effective tillers plant^{-1}	No. of spikelets spike^{-1}	No. of grains spike^{-1}	1000-grain weight (g)	Grain yield plant^{-1} (g)	Biomass yield plant^{-1} (g)
Pre-sowing strategies to enhance early germination (Main-plot)												
T_1	3.3	18.7	49.9	40.1	4.6	9.7	3.0	17.1	47.8	39.6	4.5	9.5
T_2	3.5	18.7	49.9	41.2	4.7	9.8	3.1	17.3	47.9	39.6	4.5	9.6
T_3	4.0	19.3	51.4	41.8	5.0	10.2	3.7	17.8	49.7	40.8	4.9	10.1
T_4	3.9	19.0	50.7	41.7	5.0	10.2	3.5	17.7	49.3	40.0	4.9	10.0
T_5	4.2	19.7	52.4	42.1	5.2	10.9	4.0	18.0	50.3	41.4	5.0	10.6
T_6	3.7	18.9	50.3	41.3	4.8	10.1	3.3	17.5	48.3	39.7	4.7	9.8
S.E.±	0.1	0.4	1.2	0.9	0.1	0.2	0.1	0.4	1.1	0.9	0.1	0.2
C.D. (P=0.05)	0.3	NS	NS	NS	0.4	0.7	0.2	NS	NS	NS	0.3	0.7
Post anthesis strategies (Sub-plot)												
S_1	3.6	18.3	48.7	39.7	4.7	9.7	3.3	16.9	46.9	38.6	4.6	9.5
S_2	3.7	18.9	50.3	41.0	4.8	10.1	3.4	17.4	48.4	39.8	4.7	9.9
S_3	4.0	20.0	53.3	43.4	5.1	10.7	3.6	18.4	51.3	42.2	5.0	10.5
S.E.±	0.1	0.3	0.7	0.6	0.1	0.1	0.04	0.2	0.7	0.6	0.1	0.1
C.D. (P=0.05)	0.2	0.8	2.0	1.7	0.2	0.4	0.14	0.7	2.0	1.6	0.2	0.4

NS = Treatment difference not significant, T_1: Normal seeding (Control), T_2: Sowing in dry bed followed by irrigation, T_3: Sowing with 25% higher seed rate in dry bed followed by irrigation, T_4: Overnight soaked seed sowing, T_5: Overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation, T_6: NAA (200 ppm solution) primed seed sowing, S_1: Normal without spray, S_2: Urea (2.5%) followed by light and frequent irrigation at weekly interval anthesis onwards, S_3: Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis

Table 2: Effect of thermal stress management strategies on yield of wheat under late sown conditions

Treatments	2007-08					2008-09				
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Attraction index (%)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Attraction index (%)
Pre-sowing strategies to enhance early germination (Main plot)										
T_1	3504	5617	9121	38.4	62.4	3417	5598	9016	37.9	61.0
T_2	3542	5630	9171	38.6	62.9	3453	5613	9066	38.1	61.5
T_3	3761	5742	9503	39.6	65.5	3672	5726	9398	39.1	64.1
T_4	3665	5835	9499	38.6	62.8	3575	5820	9394	38.1	61.4
T_5	3803	5829	9632	39.5	65.2	3713	5814	9527	39.0	63.9
T_6	3637	5759	9396	38.7	63.1	3546	5744	9290	38.2	61.7
S.E.±	84	131	214	0.9	1.5	82	130	211	0.9	1.4
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Post anthesis strategies (Sub plot)										
S_1	3561	5592	9152	38.9	63.7	3474	5576	9050	38.4	62.3
S_2	3637	5712	9350	38.9	63.7	3548	5696	9245	38.4	62.3
S_3	3758	5902	9659	38.9	63.7	3666	5885	9551	38.4	62.3
S.E.±	50	79	129	0.5	0.9	49	78	127	0.5	0.9
C.D.(P=0.05)	147	230	377	NS	NS	143	229	372	NS	NS

NS = Treatment difference not significant, T_1**:** Normal seeding (Control), T_2**:** Sowing in dry bed followed by irrigation, T_3**:** Sowing with 25% higher seed rate in dry bed followed by irrigation, T_4**:** Overnight soaked seed sowing, T_5**:** Overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation, T_6**:** NAA (200 ppm solution) primed seed sowing, S_1**:** Normal without spray, S_2: Urea (2.5%) followed by light and frequent irrigation at weekly interval anthesis onwards, S_3**:** Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis lower in T_1 during both crop seasons. The grain, straw and biological yields were maximum in T_5 (3803, 5829 and 9632 kg ha^{-1}, respectively) and these were lower in T_1 (3504, 5617 and 9121 kg ha^{-1}, respectively) during 2007-08. The increased yield in T_5 attributed to early emergence, taller plants, higher LAI (12.4% at 70 days after sowing), LAD (12.3% during 71-90 days after sowing), CGR (12.9% during 71-90 days after sowing) and more number of effective tillers (4.2) in T_5 than T_1 during 2007-08. During 2008-09, the grain, straw and biological yields were maximum in T_5 (3713, 5814 and 9527 kg ha^{-1}, respectively) and these were lowest in T_1 (3417, 5598 and 9016 kg ha^{-1}, respectively). This might be due to early emergence, higher LAI (12.7% at 70 days after sowing), LAD (12.8% during 71-90 days after sowing) and CGR (13.5% during 71-90 days after sowing) in T_5 than T_1 during 2008-09. However, harvest and attraction index were maximum in T_3 (39.6 and 65.5%, respectively) and these were minimum in T_1 (38.4 and 62.4%, respectively) during 2007-08. During 2008-09, harvest and attraction index were maximum in T_3 (39.1 and 64.1%, respectively) and minimum in T_1 (37.9 and 61.0%, respectively). The harvest and attraction index (%) were statistically at par among pre-sowing strategies during both crop seasons.

The lower grain and biological (3504 and 9121 kg ha^{-1} in 2007-08) and (3417 and 9016 kg ha^{-1} in 2008-09) was observed in T_1. The probable reason for low productivity in T_1 are delayed emergence, less number of effective tillers, poor LAI, LAD, CGR and dry matter accumulation at different stages. The soaking of seed with water and 25 per cent higher seed rate resulted in increase of 8.5 per cent in 2007-08 and 8.7 per cent in 2008-09 grain yield in T_5 than T_1. The seed soaking enhanced the rate of germination and early seedling emergence than dry seed. The early emergence resulted to enhance the crop growth and development and increased grain yield. The increase in grain and biological yield by water soaking treatment under late-sown conditions in wheat had also been reported by Suryakant *et al.* (2001), Kahlon *et al.* (1992), Singh and Singh (1991) and Mahajan *et al.* (1991).

Among post anthesis strategies, the grain, straw and biological yields were significantly higher in S_3 and lowest in S_1 during both the crop seasons. The harvest and attraction index were statistically at par among all the treatments during both the crop seasons. The highest grain and biological (3758 and 9659 kg ha^{-1} in 2007-08) and (3666 and 9551 kg ha^{-1} in 2008-09) was observed in S_3. The grain yield increased in S_3 over S_1 by 5.4 per cent and 5.6 per cent during 2007-08 and 2008-09, respectively. The high productivity in S_3 might be due to spray of 2.5 per cent urea and 0.5 per cent $ZnSO_4$ at anthesis which resulted in higher grain yield during both crop seasons. The spray of urea and $ZnSO_4$ may have helped in slow senescence as reflected by chlorophyll content and increased crop duration by two days. The increased photosynthesis rate and longer reproduction period may have increased grain number per spike and test weight.

Among the growth parameters SLA had negative significant association with yield and yield attributes at vegetative and reproductive phase (Table 3). The pooled LAI (r = 0.94), LAD (r = 0.96), CGR (r = 0.98) at vegetative and the pooled LAI (r = 0.92), LAD (r = 0.98), CGR (r = 0.78) at reproductive phase have shown highly significant and positive correlation with grain yield. This suggests greater significance of leaf area and dry matter accumulation during vegetative and active reproductive phase of crop. The significant positive correlation among mean LAI, LAD, CGR,

Table 3: Correlation coefficient of growth parameters with yield and yield attributes at vegetative and reproductive phase in late sown wheat

Growth parameters \ Yield attributes	No. of spikelet $spike^{-1}$	No. of grain $spike^{-1}$	1000-grain weight	Grain yield $plant^{-1}$	Grain yield	Biological yield $plant^{-1}$	Biological yield	Straw yield
Vegetative phase								
LAI	0.87*	0.83*	0.77*	0.89*	0.94*	0.82*	0.84*	0.68*
LAD	0.74*	0.78*	0.73*	0.92*	0.96*	0.85*	0.87*	0.71*
SLA	-0.46*	-0.61*	-0.68*	-0.37*	-0.27	-0.47*	-0.46*	-0.61*
CGR	0.82*	0.89*	0.87*	0.96*	0.98*	0.93*	0.97*	0.88*
DM	0.87*	0.66*	0.59*	0.53*	0.60*	0.48*	0.49*	0.34*
Reproductive phase								
LAI	0.83*	0.80*	0.78*	0.86*	0.92*	0.81*	0.83*	0.68*
LAD	0.75*	0.87*	0.85*	0.98*	0.98*	0.93*	0.97*	0.88*
SLA	-0.76*	-0.83*	-0.86*	-0.56*	-0.54*	-0.66*	-0.64*	-0.68*
CGR	0.96*	0.82*	0.76*	0.73*	0.78*	0.69*	0.69*	0.54*
DM	0.99*	0.95*	0.92*	0.82*	0.83*	0.80*	0.82*	0.75*

*Significance at P = 0.05 (r = 0.3298, N = 6x3x2 = 36)
LAI = Leaf area index, LAD = Leaf area duration, SLA = Specific leaf area, CGR = Crop growth rate, DM = Dry matter

yield attributes and grain yield have also been reported by Tyagi (1997).

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