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Variation in radiation use efficiency of wheat (*Triticum aestivum* L.) as influenced by thermal stress management strategies 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 (2007-08 and 2008-09) to study the variation in heat and radiation use efficiency of wheat as influenced by thermal stress management strategies under late sown conditions. The grain, straw and biological yields in pre-sowing treatment were maximum when overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation. Under post anthesis treatments, the highest grain and biological yields were observed in treatment of Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis. The highest radiation use efficiency (RUE) was recorded in pre-sowing treatment when overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation at milking. Under post anthesis strategies, the maximum RUE was observed in treatment of Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis.

Key words: *Thermal stress management strategies, radiation use efficiency, yields and wheat*

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. This crop has contributed immensely to the advent and flourishment of green revolution, increasing production by six times in comparison to that of 1960's. 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). A variation from the optimum temperature, during its vegetative or reproductive growth, adversely affects the onset and duration of phenophasic development and yield of crop. Keeping in view the importance above factors, the present investigation was carried out to study variation in heat and radiation use efficiency of wheat as influenced by thermal stress management strategies 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. The cultivar PBW-502 was grown during *rabi* season of 2007-08 and 2008-09. The experiment was put in a split plot design comprised of six pre-sowing strategies in main plots and three post anthesis strategies in sub-plots with three replications.

Pre-sowing strategies

T1-Normal seeding (Control)

T2-Sowing in dry seed bed followed by irrigation

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T3-Sowing with 25% higher seed rate in dry seed bed followed by irrigation

T4-Overnight soaked seed sowing

T5-Overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation

T6-NAA (200 ppm solution) primed seed sowing

Post anthesis strategies

S1-Normal without spray

S2-Urea (2.5%) spray followed by light and frequent irrigation at weekly interval anthesis onwards

S3-Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis

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 CRI and flag leaf to all treatments whereas, at milking and dough irrigation was applied to S2 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 various phenological stages of the crop, *viz*., emergence, tillering initiation, flag leaf, anthesis, milking, dough and physiological maturity (PM) were identified visually on randomly selected plants. The daily values of weather parameters prevailed during *rabi* season (2007-08 and 2008-09) were recorded at Agromet Observatory, CCS HAU, Hisar situated at a distance of 5m from the experimental site at morning 0727 and evening 1427 hour.

A Line quantum sensor (Model L1-190SB) was used to measure the photosynthetically active radiation (PAR 400-700nm) at canopy level at tillering, flag leaf, milking, dough and physiological maturity stages. The reflected radiation was obtained by keeping the sensor downward inverted and it was also kept on the ground across the rows diagonally to get transmitted radiation at the ground. To get the reflected PAR from the ground the sensor was held in the inverse position at 0.05 m above the ground. The IPAR was determined using the following relationship:

IPAR of the whole canopy = (Incident radiation on canopy – Transmitted radiation at bottom)

The above measurements were taken at different phenophases on clear days between 11.00 and 12.00 hours IST when disturbances due to leaf shading and leaf curling and solar zenith angle were minimum. Data were recorded at three points in each plot and averaged. The extra terrestrial radiation for daily periods was calculated following Allen *et al*. (1998). The mean daily values of incoming solar radiation were estimated using Angstrom's formula. The photosynthetically active radiation (PAR) was calculated by multiplying it with 0.48 following Monteith (1972). The biomass produced per unit amount of intercepted photosynthetically active radiation (IPAR) expressed as gram of dry matter produced per 1 MJ of PAR is termed as radiation use efficiency (RUE). The values of RUE (g MJ^{-1}) for different phonological stages were computed by using the following formula:

RUE = [{Biomass yield or dry matter (g m^{-2})} / {Accumulated intercepted PAR (MJ m^{-2})}]

Grain, straw and biological yields were recorded from each plot at the time of crop harvest.

RESULTS AND DISCUSSION

Yield

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 1). Among pre-sowing strategies, the perusal of data on grain, straw and biological yield of wheat were higher in T5 and these were lower in T1 during both crop seasons. The grain, straw and biological yields were maximum in T5 (3803, 5829 and 9632 kg ha^{-1}, respectively) and these were lower in T1 (3504, 5617 and 9121 kg ha^{-1}, respectively) during 2007-08. During 2008-09, the grain, straw and biological yields were maximum in T5 (3713, 5814 and 9527 kg ha^{-1}, respectively) and these were lowest in T1 (3417, 5598 and 9016 kg ha^{-1}, respectively). 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). The increased yield in T5 attributed to early emergence, taller plants, higher leaf area index (12.4% at 70 days after sowing), leaf area duration (12.3% during 71-90 days after sowing), crop growth rate (12.9% during 71-90 days after

Table 1: 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})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Pre-sowing strategies to enhance early germination (Main plot)						
T1	3504	5617	9121	3417	5598	9016
T2	3542	5630	9171	3453	5613	9066
T3	3761	5742	9503	3672	5726	9398
T4	3665	5835	9499	3575	5820	9394
T5	3803	5829	9632	3713	5814	9527
T6	3637	5759	9396	3546	5744	9290
SEm±	84	131	214	82	130	211
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Post anthesis strategies (Sub plot)						
S1	3561	5592	9152	3474	5576	9050
S2	3637	5712	9350	3548	5696	9245
S3	3758	5902	9659	3666	5885	9551
SEm±	50	79	129	49	78	127
CD (P=0.05)	147	230	377	143	229	372

NS = Treatment difference not significant

T1: Normal seeding (Control), **T2:** Sowing in dry bed followed by irrigation, **T3:** Sowing with 25% higher seed rate in dry bed followed by irrigation, **T4:** Overnight soaked seed sowing, **T5:** Overnight soaked seed sowing with 25% higher seed rate in dry bed followed by irrigation, **T6:** NAA (200 ppm solution) primed seed sowing, **S1:** Normal without spray, **S2:** Urea (2.5%) followed by light and frequent irrigation at weekly interval anthesis onwards, **S3:** Urea (2.5%) + $ZnSO_4$ (0.5%) spray at anthesis

sowing) and more number of effective tillers (4.2) than T1 during 2007-08. However, the highest grain (3713 kg ha^{-1}) and biological (9527 kg ha^{-1}) yields were observed in T5 and lowest in T1 among all pre-sowing strategies in 2008-09. This might be due to early emergence, higher leaf area index (12.7% at 70 days after sowing), leaf area duration (12.8% during 71-90 days after sowing) and crop growth rate (13.5% during 71-90 days after sowing) than T1 during 2008-09.

Among post anthesis strategies, the grain, straw and biological yields were significantly higher in S3 and lowest in S1 during both the crop seasons. The highest grain and biological yields (3758 and 9659 kg ha^{-1} in 2007-08) and (3666 and 9551 kg ha^{-1} in 2008-09) was observed in S3. The grain yield increased in S3 over S1 by 5.4% and 5.6% during 2007-08 and 2008-09, respectively. The high productivity in S3 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.

Radiation use efficiency (RUE, g MJ^{-1})

The radiation use efficiency (RUE) increased gradually till milking and then decreased upto physiological maturity among all treatments during both the crop seasons (Table 2). The highest RUE was recorded in T5 (2.11and 1.96 g MJ^{-1} in 2007-08 and 2008-09, respectively) at milking. The maximum RUE was observed in S3 and lowest in S1 in post anthesis strategies at all phenophases during both the crop seasons. Radiation use efficiency varied significantly among different treatments. It increased with crop growth and its peak values at milking in all treatments thereafter decreased at successive growth stages. The reason for this decline in RUE might be due to less intercepted photosynthetically active radiation by the crop resulting from decreased

Table 2 : Effect of thermal stress management strategies on radiation use efficiency (RUE, g MJ^{-1}) in wheat under late sown conditions

Treatments	Phenophases 2007-08					Phenophases 2008-09				
	Tillering	Flag leaf	Milking	Dough	PM	Tillering	Flag leaf	Milking	Dough	PM
Pre-sowing strategies to enhance early germination (Main-plot)										
T1	0.87	1.52	1.96	1.86	1.39	0.79	1.50	1.87	1.77	1.15
T2	0.89	1.57	1.99	1.89	1.41	0.81	1.53	1.89	1.78	1.16
T3	0.95	1.67	2.07	1.98	1.45	0.88	1.64	1.94	1.86	1.23
T4	0.93	1.62	2.03	1.94	1.44	0.86	1.58	1.92	1.82	1.20
T5	0.98	1.72	2.11	2.01	1.47	0.91	1.69	1.96	1.89	1.25
T6	0.92	1.58	2.01	1.93	1.44	0.83	1.55	1.92	1.80	1.19
SEm±	0.02	0.04	0.05	0.04	0.03	0.02	0.04	0.04	0.04	0.03
CD (P=0.05)	0.07	0.11	NS	NS	NS	0.06	0.11	NS	NS	NS
Post anthesis strategies (Sub-plot)										
S1	0.91	1.58	1.98	1.89	1.41	0.83	1.55	1.87	1.78	1.17
S2	0.92	1.61	2.03	1.93	1.43	0.85	1.58	1.92	1.82	1.20
S3	0.94	1.65	2.08	1.99	1.46	0.86	1.61	1.97	1.87	1.22
SEm±	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.03	0.03	0.02
CD (P=0.05)	NS	NS	0.08	0.08	NS	NS	NS	0.09	0.07	NS

chlorophyll content in the matured leaves in addition to the slower rate of increase in biomass during this period because of high temperature stress and leaf senescence and only translocation of biomass was happening from source to sink. This result was conformity by Sharma *et al.* (2000). The maximum value of RUE was recorded with T5 and S3 and minimum with T1 and S1 among all the treatments during both crop seasons. The less RUE was obtained in T1 and S1 due to less dry matter accumulation at different growth stages.

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