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Biochemical and yield responses of wheat genotypes to normal and heat stress condition

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Abstract
The investigation was undertaken in the research field of wheat research unit, Dr. PDKV, Akola (M.S), during the *Rabi* season of 2014-15 and 2015-16. In order to study the biochemical and yield responses of wheat (*Triticum aestivum* and *Triticum durum*) at different dates of sowing, an experiment laid out in factorial randomized block design replicated thrice. The experiment comprised of two dates of sowing i.e. 17^{th} November and 11^{th} December with seven wheat genotypes namely AKAW-4627, AKDW-4021, AKAW-3722, AKW-1071, NIDW-295, AKAW-3997 and AKAW-4210-6. Among biochemical traits studied, Starch content in leaves was significantly reduced under late sown condition (2.93%) in comparison to normal sown condition (3.73%) at 60 DAS, The reduction in starch content was up to 21.46% due late sown condition at heading stage. Proline (µg g^{-1}) at flag leaf stage was significantly increased under late sown condition (36.94) in comparison to normal sown condition (34.31). The per cent increase in proline content was up to 7.76% due late sown condition at flag leaf stage. There was reduction (5.78%) in MSI caused due to late sowing in wheat at anthesis stage. Among yield traits, reduction caused due to heat stress i.e. productive $tillers^{-1}$ m^2 (21.10%), Grain yield (g) $spike^{-1}$ (10.07%) and Grain yield ha^{-1} (21.12%). Among wheat Genotypes AKAW-4210-6 proved superiority in yield i.e. 42.45 and 37.81 qt ha^{-1} respectively, under normal and heat stress condition. On the basis of yield stability index genotypes AKAW-4627 (0.90) found superior followed by AKAW-4210-6 (0.89) and AKAW-3722 (0.87).

Keywords: wheat, phonology, yield and heat stress

Introduction
High temperature stress starting from anthesis mainly affects the several traits like, cell membrane injury, proline content, starch content, assimilate availability, translocation of photosynthates to the grain, influence grain development hence lower grain weight $spike^{-1}$, reduced number of productive tillers $plant^{-1}$, reduced numbers of grains $spike^{-1}$ and induced forced maturity resulting in lower grain yield. Selecting heat tolerant genotypes based upon their biochemical traits and higher yield is important. However, no single trait fully explains why some wheat genotypes are able to yield satisfactorily even under stress conditions. Based on better biochemical and yield and yield attributing traits high yielding and stress tolerant genotypes could be identified and will be used in crop improvement programme under heat stress environment.
High temperatures causing heat stress in wheat are expected to increase in frequency across the globe. Heat stress substantially affects grain setting, duration and rate, and ultimately grain yield. Nonetheless the timing, duration and intensity of heat stress determine its impact on grain yield. The adversities of heat stress can be minimized by developing tolerant genotypes and agronomic strategies. Even though in wheat, mechanisms of heat tolerance on a physiological basis are relatively well-understood, research into assimilate partitioning and phenotypic flexibility are needed in future.

Materials and Methods
The field experiment was conducted during the *Rabi* season of 2014-15 and 2015-16 at Wheat Research Unit, Dr. PDKV, Akola (M.S) is situated in the subtropical zone at the latitude of 20^0 42' North and longitude of 77^0 02' East. Altitude of the place is 307.41 m above the mean sea level, India; to assess the performance of wheat genotypes under different sowing dates. The experiment was laid out in Factorial Randomized Block Design replicated three times. Sowing was done in 1.5 m x 5 m^2 plots with plant spacing 20 cm x 2 cm. The treatment comprised of two dates of sowing i.e. 17^{th} November and 11^{th} December as a factor A and seven wheat genotypes namely AKAW-4627, AKDW-4021, AKAW-3722, AKW-1071, NIDW-295, AKAW-3997 and AKAW-4210-6 as factor B. Yield stability index was calculated as per the formula given by Bouslama and Schapaugh (1984) [4]. The observations on phenological and

yield contributing traits were recorded as randomly selected five plants from each plot. The pooled data of two seasons were analyzed as per Panse and Sukhatme (1967) [10].

Variation in growth environment and heat stress was induced by manipulation of the sowing dates i.e. timely and late sowing; Weather condition during the first season of research trail daily temperature showed the notable variation within the maximum and minimum temperature at the anthesis stage of crop i.e. 1 to 7 meteorological weeks of 2015. The maximum temperature in timely sowing ranged within 29.8 to 24.0 ^{0}C and minimum temperature ranged in 17.02 to 6.5 ^{0}C. At late sowing maximum and minimum temperature ranged within 27.2 to 32.8 ^{0}C and 7.5 to 16.3 ^{0}C, respectively. During the second season of research trail maximum and minimum temperature at the anthesis stage of crop showed the notable variation also at the second season, i.e. 1 to 7 meteorological weeks of 2016. The maximum temperature at timely sowing ranged within 29.9 to 34.2 ^{0}C and minimum temperature ranged in 9 to 9.17 ^{0}C. At late sown condition the maximum and minimum temperature ranged within 31.0 to 36.0 ^{0}C and 9.5 to 18.4 ^{0}C, respectively.

Results and Discussion

Effect sowing windows on biochemical and yield traits

Due to the variation of sowing date the ambient temperature vary widely which affects the of crop growth. Table 1 and 2 shows that, Date of sowing significantly influenced the biochemical and yield traits *viz*. starch content in leaves, proline content at flag leaf stage, membrane stability index, Productive tillers^{-1} m^2, Grain yield (g) spike^{-1} and Grain yield ha^{-1}.

Mean starch content (%) in leaves decreased from 3.73 to 2.93 due high temperature stress induced by delayed sowing. The rate of decrease in starch content (%) in leaves was 21.46%. Genotypic differences were observed for mean starch content in leaves ranging from 3.09 to 3.71%. The significantly highest starch was found in AKAW-3997 (3.71%), followed by NIDW-295 (3.54%), AKAW-3722 (3.36%) and AKAW-4627 (3.28%). Lowest starch content (%) in leaves was observed in AKAW-4210-6 (3.09%); In interaction effect of sowing dates and genotypes showed significant differences, genotype AKDW-4021 (4.07%) under timely sowing exhibited significantly highest starch content and it was followed by genotypes AKAW-3997 (4.02%) and NIDW-295 (3.93%) under timely sowing. Genotype AKAW-3997 (3.41%) followed by AKAW-4627 (3.22%), NIDW-295 (3.14%) and AKAW-3722 (2.97%) exhibited high values for starch content under delayed sowing by one month. In present investigation relatively lower values of starch than the mean of all genotypes were found in high yielding genotypes at 60 days after sowing. It may be due to remobilization of starch from leaves to the just formed grain (sink) in these early genotypes.

It was evident that, mean proline (µg g^{-1}) significantly increased under late sown condition (36.94 µg g^{-1}) in comparison to timely sown condition (34.31 µg g^{-1}). Flag leaf proline (µ g g^{-1}) increased by 7.66% due to high temperature stress induced by late sowing; Among the wheat genotypes, mean flag leaf proline (micro g g^{-1}) was found to be significantly highest in genotype AKAW-4627 (40.69 µg g^{-1}) over all the genotypes. It was followed by AKAW-4210-6 (38.67 micro g g^{-1}), AKAW-3722 (37.50 µg g^{-1}) over the general mean (35.63 µg g^{-1}). However, it was least in genotype AKDW-4021 (31.24 µg g^{-1}); In interaction effect of sowing dates and genotypes showed significant differences, genotype AKAW-4627 (38.70 µg g^{-1}) under timely sowing exhibited significantly highest flag leaf proline (µg g^{-1}) and it was followed by genotypes AKAW-4210-6 (36.95 µg g^{-1}) and AKAW-3722 (35.60 µg g^{-1}) under timely sowing. Genotype AKAW-4627 (42.67 µg g^{-1}) followed by AKAW-4210-6 (40.40 µg g^{-1}), AKAW-3722 (39.40 micro g g^{-1}) and AKAW-3997 (35.25 µg g^{-1}) exhibited high values for flag leaf proline (µg g^{-1}) under late sown condition. Similar findings were reported by several authors, Ahmed and Farooq (2013) revealed that accumulation of proline contents at flag leaf stage differed significantly among varieties for various planting times. The late sowing had accumulated the highest proline content (36.94 µg g^{-1}) which can be related to sharp rise in temperature at flag leaf stage. In this situation, plant accumulated the osmolytes such as proline that may lead towards the increase in proline content.

Significantly maximum mean membrane thermostability index was found under timely sown condition (72.20%) as compared to late sown condition (68.02%). There was 5.78% reduction in MSI caused due to late sowing in wheat at 60 DAS (anthesis stage). The genotypes showed significant variations for mean MSI ranging from 62.58% to 77.63%. The genotypes *viz*., AKAW-3997 (77.63%), AKAW-4210-6 (73.48) and AKAW-3722 (72.20) showed significantly higher MSI than the general mean (70.11%). The lowest MSI was found in genotype NIDW-295 (62.30%). The interaction between sowing dates and genotypes in respect of membrane thermostability index was found to be non significant. Resistance to high temperature involved several complex tolerance and avoidance mechanism, and membrane thermostability can explain the heat tolerance potential in plants at the cellular level since the cell membrane is thought to be a site of primary physiological injury by high temperature (Blum, 1988, Hall, 1992) [3, 6]. Since membrane thermostability is reasonability heritable (Fokar *et al.*, 1998) [5] and show high genetic correction with yield. The thermostability can be considered important for the determinant of heat tolerance.

It was revealed that, significantly higher number of mean productive tillers m^{-2} (359.41) were recorded in timely sowing (crop sown on 17th November) as compared to late sowing (crop sown on 11th December) i.e., 283.56. High temperature stress induced by late sowing caused 21.10% reduction in number of productive tillers m^{-2}. Among different genotypes, the maximum mean number of productive tillers m^{-2} recorded in AKAW-4210-6 (401.35) followed by AKAW-4627 (344.56) and AKAW 3997 (324.26) were significantly higher than the mean of all genotypes (321.49). However, genotype AKAW-4210-6 and AKAW-4627 were found significantly superior over each other and also rest of the genotypes. In respect of interaction effects, Genotype AKAW-4210-6 when sown under timely condition exhibited significantly the highest number of productive tillers m^{-2} (424.46) over all the combinations followed by AKAW-3997 (388.18) and AKAW-4627 (362.75) under the same condition and lowest in NIDW-295 (206.87) when sown under late sown condition. The reduced number of productive tillers m^{-2} was due to increased mortality of productive tillers occurring because of intense competition for the limited resources under high temperature stress. The tillers have to compete for the resources (assimilates and nitrogen) from elongating stem in the background of shorter crop growth duration under late sown condition. Similar results were also reported by Khan *et al*. (2007) [8], Bahar *et al*. (2008) [2], Kalita *et al*. (2009) [7], Mukherjee (2012) [9].

The grain weight spike^{-1} (g) was found significantly maximum under timely sown condition (1.72 g) relative to late sown condition (1.55 g) in wheat. The reduction in grain weight spike^{-1} to the extent of 10.07% was caused due to late sowing. Among the wheat genotypes tested, top ranking genotype AKAW-4210-6 in grain yield (kg ha^{-1}) has recorded significantly highest mean grain weight spike^{-1} of 1.85 g over all the genotypes, and it was followed by AKAW-4627 (1.67 g), AKDW-4021 (1.65 g), AKAW-3997 (1.63 g) and AKAW-3722 (1.61 g). However, least (1.51 g) grain weight spike^{-1} was recorded in NIDW-295. The interaction effects, Genotype AKAW-4210-6 recorded highest grain weight spike^{-1} of 1.96 and 1.75 g under timely and late sown conditions respectively. Genotypes *viz*., AKDW-4021 (1.83 g) and AKAW-4627 (1.70) also recorded significantly higher grain weight spike^{-1} next to AKAW-4210-6 under timely sown condition. Whereas, genotypes *viz*., AKAW-4627 (1.64 g) and AKAW-3997 (1.60 g) were next to AKAW-4210-6 under late sown condition. When genotype AKW-1071 (1.60 g) sown under timely condition exhibited lowest grain weight, while, genotype NIDW-295 exhibited lowest (1.35 g) under delayed sown condition. In the present investigation, All wheat genotypes showed decreasing trend in grain weight spike^{-1} under delayed sowing, decrease in grain weight spike^{-1} under late sown condition (high temperature stress of 2.87ºC) and some genotypes was mainly due to reduction in grain number earhead^{-1} as well shriveled grain because of competition for assimilate between grains of the same ear head has been much prominent and they could not get sufficient assimilate (source limitation of grain development).

The data pertaining to grain yield ha.$^{-1}$ evident that, crop sown on 17th November (timely sowing) recorded the significantly higher grain yield of 35.94 qt ha^{-1} as compared to the crop sown on 11th December (late sowing) i.e., 28.35 qt ha^{-1} mean grain yield ranged from 31.38 to 42.45 qt ha^{-1} under timely sowing and 20.67 to 37.81 qt ha^{-1} under late sowing in present investigation. The 21.12% reduction in grain yield under late sown condition caused due to high temperature stress of 2.87^{0}C occurred at post anthesis stage. The significant genotypic differences were found for grain yield, among the genotypes; early duration genotype AKAW-4210-6 recorded the significantly highest grain yield of 40.13 qt ha^{-1} than all the wheat genotypes. The another early duration genotype AKAW-4627 recorded the significantly higher grain yield of 34.47 qt ha^{-1} than all the wheat genotypes except AKAW-4210-6 and it was followed by genotype AKAW-3997 (32.43 qt ha^{-1}), AKAW-3722 (31.76 qt ha^{-1}), AKDW-4021 and (28.85 qt ha^{-1}). Genotypic differences in grain yield might be due to genetic potential of different varieties to express in terms yield attributing traits in differential environmental condition.

Table 1: Biochemical traits in wheat genotypes as influenced by sowing dates, genotypes and their interactions (pooled data for 2014-15 and 2015-16)

Particulars	Starch content (%) in leaves at 60 DAS			Proline (µg g-1) at flag leaf stage			Membrane thermostability (%) at 75 DAS		
Treatment	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**
G_1 (AKAW-4627)	3.34	3.22	3.28	38.70	42.67	40.69	72.26	65.70	68.98
G_2 (AKDW-4021)	4.07	2.31	3.19	30.33	32.15	31.24	71.71	67.91	69.81
G_3 (AKAW-3722)	3.75	2.97	3.36	35.60	39.40	37.50	73.52	70.88	72.20
G_4 (AKW-1071)	3.58	2.74	3.16	32.01	33.80	32.90	67.68	64.47	66.08
G_5 (NIDW-295)	3.93	3.14	3.54	33.78	34.93	34.35	66.09	59.08	62.58
G_6 (AKAW-3997)	4.02	3.41	3.71	32.84	35.25	34.04	78.84	76.43	77.63
G_7 (AKAW-4210-6)	3.44	2.74	3.09	36.95	40.40	38.67	75.28	71.68	73.48
Mean	3.73	2.93	3.33	34.31	36.94	35.63	72.20	68.02	70.11
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	SE (m) ±	**CD at 5%**		**SE (m) ±**	**CD at 5%**		**SE (m) ±**		**CD at 5%**
Sowing Date (D)	0.02	0.07		0.15	0.42		0.65		1.89
Genotype (G)	0.04	0.12		0.27	0.79		1.22		3.53
Interaction (D x G)	0.06	0.17		0.38	1.12		1.72		NS

Table 2: Yield traits in wheat genotypes as influenced by sowing dates, genotypes and their interactions (pooled data for 2014-15 and 2015-16)

Particulars	Productive tillers^{-1} m^2			Grain weight (g) spike^{-1}			Grain yield (q) ha^{-1}			yield stability index (YSI)
Treatment	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	**(D_1) Timely sowing**	**(D_2) Late sowing**	**Mean**	
G_1 (AKAW-4627)	362.75	326.37	344.56	1.70	1.64	1.67	36.31	32.64	34.47	0.90
G_2 (AKDW-4021)	332.95	244.16	288.55	1.83	1.47	1.65	33.29	24.40	28.85	0.73
G_3 (AKAW-3722)	339.72	295.53	317.63	1.66	1.56	1.61	33.96	29.55	31.76	0.87
G_4 (AKW-1071)	354.03	273.40	313.71	1.60	1.49	1.55	35.40	27.36	31.38	0.77
G_5 (NIDW-295)	313.81	206.87	260.34	1.67	1.35	1.51	31.38	20.67	26.03	0.66
G_6 (AKAW-3997)	388.18	260.34	324.26	1.66	1.60	1.63	38.82	26.04	32.43	0.67
G_7 (AKAW-4210-6)	424.46	378.25	401.35	1.96	1.75	1.85	42.45	37.81	40.13	0.89
Mean	359.41	283.56	321.49	1.72	1.55	1.64	35.94	28.35	32.15	0.79
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	SE (m) ±	**CD at 5%**		**SE (m) ±**	**CD at 5%**		**SE (m) ±**	**CD at 5%**		-
Sowing Date (D)	3.23	9.39		0.01	0.04		0.29	0.86		-
Genotype (G)	6.04	17.57		0.03	0.07		0.55	1.60		-
Interaction (D x G)	8.55	24.84		0.04	0.10		0.78	2.27		-

Conclusion

In the present investigation, biochemical and yield indices like starch content in leaves, flag leaf proline content, membrane thermostability index at anthesis stage, Productive tillers^{-1} m^2, Grain weight (g) spike^{-1} and Grain yield ha^{-1}, were identified as powerful tools for selection of wheat genotypes under both timely and heat stress conditions. It is concluded that biochemical and yield traits of wheat were significantly influenced by heat stress created by delayed sowing. In regards to grain yield as the final product of different physiological and biochemical processes, and also in regard to values of proline content, yield stability index, and yield contributing traits, AKAW-4210-6 and AKAW-4627 were identified as superior genotypes. These genotypes can be utilized in further breeding programs for development of heat stress tolerant wheat genotypes for delayed sown condition.

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