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Morphological performance of wheat (*Triticum aestivum* L.) genotypes under heat stress condition

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Abstract
An experiment was conducted during *rabi* season of 2016–17 and 2017-18 by using nine wheat genotypes *viz*; AKAW 5023, AKAW 4927, PBN 4905, PBN 4751-02, NIAW 3523, NIAW 2891, AKAW 4210-6 (C), NIAW 34 (C), NIAW 1994 (C) and sowing done at 1-10 December irrigated condition in a randomized block design with three replications to assess the variability of genotypes for morphological traits under heat-stress environment to find out the suitable heat tolerance genotypes for Vidharbha condition. Under late sown conditions morphological traits like, leaf area, LAI, total dry weight plant^{-1}, plant ht. plant^{-1}, number of tillers meter^{-1} row length, 1000 grain weight (g), grain yield plant^{-1}, grain yield plot^{-1}, grain yield/ha (q) were observed. On pooled basis superior performance showed by genotype NIAW 2891 followed by NIAW 3523 over best check AKAW 4210-6 and also higher yield recorded than other genotypes during both the year of sowing and noted as heat tolerance genotypes. These traits can be utilized as selection criteria for improving the grain yield in the warmer wheat growing areas for terminal heat-stress.

Keywords: Wheat, leaf area, LAI, dry weight, plant ht. no. of tillers meter^{-1} row length, yield, terminal heat-stress

Introduction
Wheat is a important cereal second to rice as the main human food crop. In 2018 India production of wheat was 96 Lakh tons (Anonymous, 2018) [2]. Latest figure showed decreases of wheat production due to climate change. Several environmental constraints specially high temperature and water deficit are responsible for serious threat in wheat production. Physiological responses of wheat crop to terminal heat stress have been found to effectively determine genotype resistance or susceptibility (Almeselmani *et al*., 2012) [1]. The terminal heat stress was at anthesis and grain filling stages accelerate maturity and significantly reduce grain size, weight and yield (Mohammadi, 2012) [9]. Plant metabolites in complex biosynthetic pathways are believed to be affected by terminal heat stress. It showed the changes in cell membrane structure thereby plant senescence which leads to shortening of the period of photosynthetic activity (Tewari and Tripathy, 2012). All these impaired physiology of wheat plant under terminal heat stress restrict plant growth and productivity, particularly when it occurs during reproductive stages. There is urgent need for immediate attention to develop heat tolerance wheat genotypes by combining different approaches. The enhanced physiological parameters might be helpful to overcome yield loss under heat stress.

Material and Methods
The study was carried out during 2016-17 and 2017-18 wheat season in the research field of Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola (M.S). Akola is situated in the subtropical zone at the latitude of 200 42' North and longitude of 770 02' East. Altitude of the place is 307.41 m above the mean sea level. Treatments were 9 wheat genotypes (AKAW 5023, AKAW 4927, PBN 4905, PBN 4751-02, NIAW 3523, NIAW 2891, AKAW 4210-6 (C), NIAW 34 (C), NIAW 1994 (C)) sown on late (December 1-10) condition in randomized block design with three replications. For late-sown conditions, management and inputs were same except the seeding date. Each unit plot size was Gross - 6.0 m × 2.16 m (12 rows) and net plot size 6.0 m × 1.80 m (10 Middle rows) length of each. Seeds were sown continuously in 18 cm apart rows at a seed rate of 125 kg ha-1. Recommended fertilizer doses 90:60:40 NPK kg ha^{-1} respectively was applied. Half N and a complete dose of $P_2 O_5$ and $K_2 O$ were given as a basal dose at sowing while the remaining N was applied at 18 days after sowing.
Leaf area measured by scanning the leaves on automatic leaf area meter CI-202, CID (INK), USA. Leaf area was measured at 30, 45, 60 and 75 days after sowing and mean values of leaf

of leaf area (dm^2) $plant^{-1}$ were calculated. LAI calculated by using the formula given by Watson (1947).

$$LAI = \frac{\text{Leaf area plant}^{-1}}{\text{Land area plant}^{-1}}$$

The samples were taken for dry matter study at 30, 45, 60, 75 DAS for both the years recorded on electronic balance. The height of the, plant was measured in centimeter from the base of the plant (ground level) to the tip of the plant and mean values were calculated.

Result and Discussion

Leaf area $plant^{-1}$ (dm^2)

Leaf area $plant^{-1}$ progressively increased with the age of crop up to 60 DAS and subsequently decreased gradually under heat stress conditions. At 75 DAS significant decrease in leaf area $plant^{-1}$ was recorded in second season (1.231 dm^2) as compared to first season (1.269 dm^2). Greater reduction in leaf area $plant^{-1}$ to the extent of 2.83 % was observed in high temperature stress. The significantly highest leaf area $plant^{-1}$ was recorded in genotype NIAW 2891 (1.530 dm^2) however, genotype PBN 4905 (1.275 dm^2) recorded significantly lowest leaf area under heat stress condition. Heat stress affects the sensitivity of pigmentation on photosystem II functions in wheat that in turn lethal impact on deeding growth and leaf development (Karim *et al.* 1999, Mohanty and Mohanty 1988 and Tewari and Tripathy 1998) [5, 8]. Kushwaha *et al.* (2011) [7] reported that late sown wheat crop results in reduced leaf area at anthesis to rise in temperature that adversely affects the photosynthetic activity of the plant.

Leaf area index

There was an increase in mean LAI up to 60 days after sowing. There after it was declined as crop advanced. At 75 DAS, LAI was found to be significantly higher in first season (7.04) than the second season (6.83). The maximum reduction in LAI up to 2.83 % due high temperature stress induced by late sowing was noted. Amongst genotypes, NIAW 2891 (7.77) maintained significantly highest LAI, and genotype PBN 4905 (6.24) had the lowest as compared to other genotypes.

Total dry matter $plant^{-1}$ (g)

Total dry matter production rate $plant^{-1}$ progressively increased from 30 DAS to 75 DAS. At 75 DAS, it was significantly maximum in first season (8.15 g) compared to second season (8.09 g). A marked reduction of 1.85 % was observed under high temperature stress induced by late sowing. Among the genotypes, highest dry matter production $plant^{-1}$ was observed in medium stature genotype NIAW 2891 (10.37 g), while lowest in genotype PBN 4905 (6.63 g). The total dry matter is the result of net photosynthesis in leaves and stem during vegetative phase and mainly due to leaves earhead and stem during reproductive phase. The total dry matter per unit area includes dry matter of leaves, stem and reproductive parts. Differences in genotypes may be the due architecture of genotype and their response to environment. Similar findings were reported by Ihsan *et al.* (2016) [4] they concluded that, dry matter accumulation was decrease 28-57% 01 Dec., 16 Dec. and 01 Jan planting as compared to 16 Nov. planting.

Plant height $plant^{-1}$ (cm)

Lowest plant height $plant^{-1}$ was recorded in genotype PBN 4751-02 (86.89 cm). Whereas, maximum height $plant^{-1}$ was noted in genotype PBN 4905 (108.49 cm) followed by NIAW 2891 (90.66 cm), AKAW 4927 (89.35 cm) at harvest. In *rabi* 2017-18 under heat stress condition resulted in minimum decline in plant height in genotype PBN 4905 (3.57%) next to this, genotypes PBN 4751-02 (6.96%) and AKAW 4927 (7.48%). However, the maximum decline was observed in genotype AKAW 5023 (8.49%), NIAW 2891 (8.32%) and NIAW 3523 (8.02%) when compared with first season of 2016-17. Increasing heat stress environment induced relative reduction in plant height (Khan *et al*. 2007, Sattar *et al.* 2010, Kushwaha *et al*. 2011 and Satyender *et al.* 2013) [6, 12, 7].

Number of tillers $meter^{-1}$

Data regarding number of tillers $meter^{-1}$ row length, significantly all genotypes NIAW 3523 (125), PBN 4751-02 (115.83), NIAW 2891 (113.33), AKAW 5023 (106.66), PBN 4905 (106.16) and AKAW 4927 (106) under study were found *at par* with superior check NIAW 34 (125.16). Reduction in general mean of number of tillers $meter^{-1}$ row length was 2.01% in second year as compared to first year due to heat stress condition.

1000 gain weight (g)

Regarding 1000 grain weight genotype NIAW 2891 and NIAW 3523 recorded significantly higher 1000 grain weight (56.79 and 48.37 g, respectively) as compared to best check AKAW 4210-6 (43.61 g) and rest of the genotypes. Significantly lowest test weigh was recorded in PBN 4905 (39.14 g) in heat stress condition. The high temperature stress induced by late sowing caused 3.43 % reduction in 1000 grain weight in second year over the first year. This happens owing to prevalence of hot and desiccating wind during grain filling period and the lower test weight in late sowing was due to less production of photosynthates due to shorter growing period test weight. The reason for this variability was increasing air temperature with flowering at late sowing in December that decreased amount of all other traits (Khan *et al*., 1990).

Grain yield $plant^{-1}$ (g)

Among wheat genotypes tested, top ranking genotype NIAW 2891 recorded significantly highest mean grain weight $plant^{-1}$ of 5.59 g over a best check AKAW 4210-6 (4.36 g) and rest of the genotypes under studied. However, genotypes NIAW 3523 (5.05 g), AKAW 5023 (4.58 g), PBN 4751-02 (4.05 g) and AKAW 4927 (3.77 g) were found statistically *at par* with best check AKAW 4210-6. Among the genotypes, significantly lowest grain weight $plant^{-1}$ was recorded in PBN 4905 (3.20 g) in heat stress condition. In second season the reduction in grain weight $plant^{-1}$ to extent of 1.41 % over a first season.

Grain yield $plot^{-1}$ (kg)

Significantly superior grain yield $plot^{-1}$ was recorded by genotype NIAW 2891 (3.84 kg) and NIAW 3523 (3.65 kg) when compared with best check AKAW 4210-6 (3.20 kg). Genotypes AKAW 5023 (3.39 kg), PBN 4751-02 (3.06 kg) and AKAW 4927 (2.88 kg) were remained *at par* with best check AKAW 4210-6. Among the genotypes, PBN 4905 (2.42 kg) recorded significantly lowest grain yield $plot^{-1}$ in heat stress condition of wheat. The reduction in grain yield plot^{-1} (kg) to the extent of 0.13 % in *rabi* 2017-18 as compared with *rabi* 2016-17.

Grain Yield ha^{-1} (qt.)

Top ranking genotype NIAW 2891 has recorded significantly highest grain yield of 35.65 qt ha^{-1} followed by NIAW 3523 (33.83 qt. ha^{-1}) over superior check AKAW 4210-6 (29.55 ha^{-1}) and among all the genotypes tested. Genotypes AKAW 5023 (31.41 qt. ha^{-1}) and PBN 4751-02 (28.39 qt. ha^{-1}) found *at par* with superior check AKAW 4210-6. However, significantly lowest grain yield was recorded in PBN 4905 and AKAW 4927 (22.48 and 26.66 qt. ha^{-1}, respectively) in heat stress condition. The reduction in general mean grain yield (kg ha^{-1}) to the extent of 0.11 % in second year when compared with first year. Economic yield is th*at* part of biomass that is converted into economic product (Nichiporvic, 1960) [10]. Grain yield is influenced by morphological factors such as total dry matter production, leaf area, leaf area index and number of tiller are considered as yield contributing parameters.

Table 1: Effect of heat stress on germination percent and leaf area plant^{-1} of wheat under heat stress condition

Genotypes	Leaf area plant^{-1} (dm^2)											
	2016-17				2017-18				Pooled			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
AKAW 5023	0.685	1.099	1.536	1.350	0.682	1.112	1.408	1.280	0.683	1.105	1.472	1.315
AKAW 4927	0.625	1.025	1.439	1.180	0.643	1.011	1.313	1.150	0.634	1.018	1.375	1.164
PBN 4905	0.616	0.947	1.288	1.120	0.636	0.983	1.263	1.130	0.626	0.964	1.275	1.124
PBN 4751-02	0.630	1.044	1.449	1.230	0.647	1.028	1.347	1.200	0.638	1.035	1.398	1.384
NIAW 3523	0.699	1.113	1.541	1.380	0.692	1.190	1.415	1.320	0.695	1.151	1.478	1.350
NIAW 2891	0.722	1.140	1.628	1.420	0.738	1.230	1.432	1.380	0.730	1.184	1.530	1.400
AKAW4210-6 (C)	0.667	1.076	1.508	1.310	0.666	1.070	1.404	1.260	0.666	1.072	1.456	1.285
NIAW 34 (C)	0.644	1.053	1.458	1.280	0.655	1.050	1.389	1.220	0.649	1.051	1.423	1.249
NIAW1994 (C)	0.621	0.975	1.390	1.150	0.639	0.987	1.291	1.143	0.630	0.981	1.340	1.146
Mean	0.656	1.052	1.471	1.269	0.666	1.073	1.362	1.231	0.661	1.062	1.416	1.268
Range	0.616-0.722	0.94-1.14	1.28-1.62	1.12-1.42	0.636-0.738	0.98-1.23	1.26-1.43-	1.13-1.38	0.63-0.73	0.96-1.18	1.27-1.53	1.12-1.40
SE (m) ±	0.03	0.02	0.05	0.04	0.05	0.04	0.03	0.05	0.03	0.02	0.03	0.03
CD at 5%	NS	0.08	0.16	0.13	NS	0.12	0.10	0.16	NS	0.07	0.09	0.08

Table 2: Effect of heat stress on leaf area index plant^{-1} of wheat under heat stress condition

Genotypes	Leaf area index plant^{-1}											
	2016-17				2017-18				Pooled			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
AKAW 5023	3.80	6.10	8.53	7.50	3.78	6.22	7.82	7.11	3.79	6.16	8.14	7.30
AKAW 4927	3.47	5.69	7.99	6.55	3.57	5.61	7.29	6.38	3.52	5.65	7.64	6.46
PBN 4905	3.42	5.26	7.15	6.22	3.53	5.46	7.01	6.27	3.47	5.36	7.08	6.24
PBN 4751-02	3.50	5.80	8.05	6.83	3.58	5.71	7.48	6.66	3.54	5.75	7.76	6.74
NIAW 3523	3.88	6.48	8.56	7.66	3.84	6.61	7.86	7.33	3.86	6.39	8.21	7.49
NIAW 2891	4.01	6.33	9.04	7.88	4.10	6.83	7.95	7.66	4.06	6.58	8.49	7.77
AKAW 4210-6 (C)	3.70	5.97	8.37	7.27	3.70	5.94	7.80	7.00	3.70	5.95	8.08	7.13
NIAW 34 (C)	3.57	5.85	8.10	7.11	3.63	5.83	7.71	6.77	3.60	5.84	7.90	6.94
NIAW1994 (C)	3.45	5.41	7.72	6.38	3.55	5.35	7.17	6.35	3.50	5.44	7.44	6.36
Mean	3.649	5.845	8.171	7.046	3.698	5.965	7.565	6.837	3.671	5.905	7.865	6.939
Range	3.42-4.01	5.26-6.33	7.15-9.04	6.22-7.88	3.53-4.40	5.46-6.83	7.01-7.95	6.27-7.00	3.48-4.06	5.36-6.58	7.08-8.49	6.24-7.77
SE (m) ±	0.31	0.20	0.23	0.22	0.31	0.26	0.20	0.19	0.27	0.16	0.15	0.13
CD at 5%	NS	0.62	0.71	0.68	NS	0.78	0.62	0.59	NS	0.45	0.44	0.39

Table 3: Effect of heat stress on dry weight plant^{-1} of wheat under heat stress condition

Genotypes	Dry weight plant^{-1} (g)											
	2016-17				2017-18				Pooled			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
AKAW 5023	0.60	1.28	8.00	8.89	0.68	1.34	7.89	8.73	0.63	1.31	7.94	8.81
AKAW 4927	0.55	1.15	6.88	7.45	0.58	1.16	6.57	7.20	0.56	1.15	6.72	7.32
PBN 4905	0.49	1.05	6.58	6.99	0.50	1.04	5.79	6.31	0.49	1.04	6.08	6.65
PBN 4751-02	0.57	1.17	7.09	7.72	0.60	1.20	6.83	7.53	0.58	1.18	6.95	7.62
NIAW 3523	0.60	1.31	8.10	9.06	0.70	1.42	8.20	9.19	0.64	1.36	8.15	9.12
NIAW 2891	0.68	2.24	9.30	10.46	0.73	2.18	9.22	10.28	0.70	2.21	9.26	10.37
AKAW 4210-6 (C)	0.59	1.25	7.75	8.53	0.66	1.30	7.67	8.49	0.62	1.27	7.70	8.50
NIAW 34 (C)	0.57	1.20	7.11	7.85	0.64	1.26	7.48	8.26	0.60	1.23	7.29	8.05
NIAW1994 (C)	0.54	1.12	6.61	7.08	0.54	1.10	6.23	6.81	0.53	1.11	6.42	6.94
Mean	0.58	1.309	7.470	8.228	0.625	1.334	7.321	8.090	0.600	1.321	7.393	8.159
Range	0.49-0.75	1.05-2.24	6.58-9.30	6.99-10.46	0.50-0.73	1.04-2.18	5.79-9.22	6.31-10.28	0.49-0.70	1.04-2.21	6.08-9.26	6.65-10.37
SE (m) ±	0.03	0.03	0.42	0.38	0.05	0.04	0.29	0.33	0.02	0.03	0.24	0.23
CD at 5%	NS	0.11	1.28	1.17	NS	0.14	0.89	0.99	NS	0.08	0.68	0.68

Table 4: Effect of heat stress on plant height and numbers of tillers per meter row length of wheat under heat stress condition

Genotypes	Plant height at harvest (cm)			Numbers of tillers per meter row length		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
AKAW 5023	91.80	84.00	87.90	105.33	108.00	106.66
AKAW 4927	92.83	85.88	89.35	110.33	101.66	106.00
PBN 4905	110.46	106.51	108.49	107.00	105.33	106.16
PBN 4751-02	90.03	83.76	86.89	115.00	116.66	115.83
NIAW 3523	92.03	84.64	88.33	125.33	124.66	125.00
NIAW 2891	94.60	86.72	90.66	116.00	110.66	113.33
AKAW 4210-6 (C)	82.83	82.53	82.68	109.33	104.66	107.00
NIAW 34 (C)	87.26	83.46	85.36	128.66	121.66	125.16
NIAW1994 (C)	84.36	83.05	83.71	123.33	126.00	124.66
Mean	91.80	86.72	89.26	115.59	113.25	114.42
Range	82.83-110.46	82.53-106.51	82.68-108.49	105.33-128.66	101.66-124.66	106-125.16
SE (m) ±	0.58	1.71	1.03	2.81	4.87	2.53
CD at 5%	1.76	5.17	2.95	6.26	14.59	7.23

Table 5: Effect of heat stress on thousand grain weight, grain yield per plant, grain yield per plot and grain yield per ha of wheat under heat stress condition

Genotypes	2016-17				2017-18				Pooled			
	1000 grain wt. (g)	Grain yield per plant (g)	Grain yield per plot (kg)	Grain yield (Q/ha)	1000 grain wt. (g)	Grain yield per plant (g)	Grain yield per plot (kg)	Grain yield (Q/ha)	1000 grain wt. (g)	Grain yield per plant (g)	Grain yield per plot (kg)	Grain yield (Q/ha)
AKAW 5023	46.06	4.40	3.39	31.39	43.60	4.76	3.39	31.44	44.83	4.58	3.39	31.41
AKAW 4927	42.50	3.68	2.80	25.97	40.32	3.86	2.95	27.37	41.41	3.77	2.88	26.66
PBN 4905	38.13	2.81	2.39	22.21	40.15	3.60	2.46	22.77	39.14	3.20	2.42	22.48
PBN 4751-02	43.60	4.15	3.15	29.21	40.64	3.96	2.98	27.59	42.12	4.05	3.06	28.39
NIAW 3523	49.26	5.33	3.77	34.91	47.49	4.77	3.54	32.77	48.37	5.05	3.65	33.83
NIAW 2891	56.83	5.35	3.84	35.63	56.76	5.85	3.85	35.67	56.79	5.59	3.84	35.65
AKAW 4210-6 (C)	44.15	4.40	3.23	29.55	43.08	4.33	3.19	29.56	43.61	4.36	3.20	29.55
NIAW 34 (C)	44.13	4.16	3.16	29.34	40.71	4.20	3.04	28.17	42.42	4.18	3.10	28.75
NIAW1994 (C)	42.36	4.93	2.50	23.23	40.21	3.84	2.67	24.71	41.29	4.38	2.58	23.97
Mean	45.22	4.36	3.14	29.04	43.08	4.35	3.12	28.89	44.44	4.35	3.12	28.96
Range	38.13-56.83	2.81-5.35	2.39-3.84	22.21-35.63	40.15-56.76	3.60-5.85	2.46-3.85	22.77-35.67	39.14-56.79	3.20-5.59	2.42-3.84	22.48-35.65
SE (m) ±	0.44	0.47	0.13	0.96	1.60	0.30	0.24	1.72	0.81	0.33	0.13	0.92
CD at 5%	1.35	1.43	0.41	2.90	4.83	0.92	0.73	5.19	2.44	1.02	0.41	2.65

Conclusion

Plants have different adaptive mechanisms for cropping with heat stress condition. Wheat genotypes have an ability to adapt one or more than one mechanism for escaping and tolerate heat stress condition. From present study it was concluded that NIAW 2891, NIAW 3523, AKAW 5023 and AKAW 4210-6 performed well under heat stress in respect of morphological traits *viz*, leaf area, LAI, total dry weight, plant height, number of tillers per meter row length and affect grain yield. These genotypes maintained better morphology as compared to other genotypes studied under heat stress condition. Therefore they considered as heat tolerant genotypes as use as a parent for the breeding programme.

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