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Research Note

Identification of terminal heat tolerant bread wheat genotypes

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Abstract
Late sown irrigated wheat crop under Maharashtra condition always adversely affected by terminal heat during flowering and grain filling stage which results in reduced grain yield. A study was undertaken to identify terminal heat tolerant bread wheat genotypes on the basis of different stress indices. Material under study comprised of newly developed nineteen bread wheat genotypes and three recommended varieties as check. Two separate experiments were conducted at Niphad under timely and late sown conditions during rabi 2013-14. Yield trait was recorded and per cent yield reduction under late sown condition as compared to timely sown condition was estimated. On the basis of yield trait different stress susceptibility and tolerance indices were estimated. Among the new genotypes studied, NIAW 2972 had highest yield potential under both, timely (48.66 q/ha) and late sown condition (46.99 q/ha) with minimum yield reduction (3.43 %) under late sown condition except the check variety NIAW 34 (1.75 % yield reduction). On the basis of combined analysis of performance of wheat genotypes under both the sowing conditions, per cent yield reduction under late sown condition and estimates of different stress indices, variety NIAW 34 was found to be most terminal heat tolerant which was closely followed by the genotype NIAW 2972. NIAW 34 (SSI=0.17) possessed highest level of terminal heat tolerance followed by NIAW 2972 (SSI=0.34) and HI 977 (SSI=0.39). Correlation analysis indicated that yield under stress environment had significant ($p<0.05$) positive ($r=0.95$) association with that of non stress environment. Yield under both sowing condition had significant positive correlation with MP, GMP and HTI while negative significant correlation with SSI and TOL. First two factors of Principal component analysis explained 99% variation to which 93% and 6% was contributed by first and second factor respectively while maximum contribution to first component was from YLS followed by HTI, GMP and MP. The Genotype NIAW 2972 and two check varieties *viz*., NIAW 34 and HI 977 were identified as terminal heat tolerant and can be used directly as well as in the crossing programme for developing terminal heat tolerant variety or line.

Key words
Tolerant, Stress Susceptibility Index, Correlation, Biplot

Bread wheat (*Triticum aestivum* L.) is an important *rabi* season crop of India and Maharashtra with 29.65 m ha and 5.94 lakh ha, of area under wheat cultivation respectively. Productivity of Maharashtra (14.73 q/ha) is half that of India (31.19 q/ha). Late sown irrigated (sowing after 1st December) wheat crop is exposed to high temperatures during flowering and grain filling stages as compared to timely sown irrigated (sowing during 1-15, November) crop, this could be one of the reasons for lower productivity of the state. Wheat crop is sensitive to different abiotic stresses at almost all the growth stages. Hanchinal *et al*., (1994) reported reduction in the duration of GS2 and GS3 growth phases under late planting. The optimum range of temperatures for wheat growth is 18 - 24°C. Temperature beyond this range even for short period of 5-6 days cause 20% or more yield losses in wheat (Stone and Nicolas, 1994). Higher temperatures (>30° C) after anthesis can decrease the rate of grain-filling (Wardlaw and Moncur, 1995). Reduction of 23% in grain yield has been reported from as little as 4 days of exposure to very high temperatures (Stone and Nicolas, 1994). Currently around 9 million ha of wheat in tropical or subtropical areas experience yield losses due to high-temperature stress (Lillemo *et al*., 2005). Present trend in India and neighboring countries indicate that the “cool period” for wheat crop is shrinking indicating threat of increasing terminal heat stress (Joshi *et al*., 2007) hence, wheat crop improvement programme aimed at development of varieties tolerant to late heat stress and is a demand of time. Different stress indices or selection criteria, *viz*., GMP = Geometric mean yield (Ramirez Vallejo and Kelly, 1998); SSI = Stress Susceptibility Index (Fischer and Maurer, 1978); STI = Stress Tolerance Index (Fernandez, 1992) have been proposed as ways to identify genotypes with better stress tolerance.

Experimental material consisted of nineteen new bread wheat lines developed at Agricultural Research Station, Niphad and three varieties released for cultivation under late sown conditions of Maharashtra State *viz*., NIAW 34, PBW 533 and HI 977 (Table 2). The experiments were conducted at Agricultural Research Station, Niphad , MS, India. Experiments were sown by following recommended sowing dates for timely sown irrigated condition (November 10) and late sown irrigated condition (December 12) to expose experimental material to two different temperature regimes during *rabi* 2013-14. The experiments were conducted in Augmented Block Design by providing four rows of six meter length to each genotype. Line spacing of 20 cm and 18 cm was adopted in timely and late sown irrigated

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experiments, respectively. Recommended package of practices for respective sowing condition was adopted to grow the crop. The experimental fields were irrigated whenever necessary to maintain at field capacity to avoid water stress**.**

Stress indices: Economical grain yield recorded under both the sowing conditions was used to estimate stress susceptibility and tolerance indices by following (Puri *et al*., 2015)

Stress Susceptibility Index (SSI) = [1-(xs/sp)] / [1-(Xs/Xp)]

Tolerance (TOL) = xp-xs

Mean Productivity (MP) = (xp+xs)/2

Geometric Mean Productivity (GMP) = sqrt(xp*xp) / (Xp)2

Heat Tolerance Index (HTI) = (xs*xp) / (Xp)2

Where, xs is the trait value (grain yield in q/ha) of the genotype under stress and xp is the trait value of the genotype under non stress conditions. Xs and Xp are mean values of the trait of all the genotypes under stress and non-stress conditions, respectively. *Statistical Analysis:* Different stress indices were estimated, correlation and principal component analysis was done and biplot and three dimentional plots drawing were arrived using MINITAB 15 and Excels.

The genotypes under study were exposed to varied temperatures by conducting the experiments in two different environmental conditions *i.e.* sowing dates. Optimum temperature requirements of wheat and prevailing temperatures during the conduct of experiments are presented in table 1. Yield under timely sown and late sown conditions along with stress indices are presented in table 2.

Yield and stress indices: Data on prevailing temperatures (Table 1) reveals that late sown crop was exposed to higher maximum temperatures than timely sown crop particularly during anthesis and grain development stage. On the basis of combined analysis of performance of wheat genotypes under both the sowing conditions, per cent yield reduction under late sown condition and estimates of different stress indices (Table 2), check variety NIAW 34 was found to be most stress tolerant. Among the genotypes under study, NIAW 2972 had highest yield potential under timely sown (48.66 q/ha) and late sown condition (46.99 q/ha) with minimum yield reduction (3.43 %) under late sown condition. The second check variety HI 977 (SSI=0.39) also exhibited considerable level of terminal heat tolerance following NIAW 34 (SSI=0.17).

NIAW 34 had lowest yield reduction of 1.75 % while that of NIAW 2972 was 3.43 % followed by HI 977 (3.86%). However, NIAW 2972 (48.66 q/ha & 46.99 q/ha) had better yields levels than NIAW 34 (47.49 & 46.66 q/ha) under timely and late sown condition, respectively. Therefore, the genotypes NIAW 2972 can be used as donar parent to breed better terminal heat tolerant wheat lines or directly as terminal heat tolerant variety but only after multilocation testing under late sown irrigated conditions in remaining areas of Maharashtra State where late sown planting is practice.

Correlation among traits: Correlation analysis (Table 3) indicated that yield under stress environment had significant ($p<0.05$) positive ($r=0.95$) association with that of non stress environment. Yield under both sowing condition had significant positive correlation with MP, GMP and HTI while, negative significant correlation with SSI and TOL. Similar correlations have been reported in wheat (Sareen *et al*., 2012 and Puri *et al*., 2015).

Principal component analysis: First two factors of Principal component analysis explained 99% variation to which 93% and 6% was contributed by first and second factor respectively (Table 4). Similar results were also reported in wheat (Sareen *et al*., 2012 and Puri *et al.*, 2015). Maximum contributed to first component was from YLS followed by GMP, MP and HTI.

Biplot for genotypes and stress indices was drawn by using principal components (Fig 1). Angles and direction between the attribute vectors illustrated the strength and the direction of correlation between any two attributes (Fernandez, 1992). Significant positive correlation was observed between Yield (TS/LS) and MP, MP and GMP, GMP and HTI. These observations were confirmatory with correlation results suggesting that HTI, GMP and MP could be reliable selection criteria for developing or identifying the lines with better terminal heat tolerance.

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Table 1. Optimum and prevalent Temperature (^{0}C) during wheat growth period

Days after sowing	Growth stage	Optimum temperature (^{0}C)	Prevalent temperature (^{0}C)			
			Timely sown		Late sown	
			Minimum	Maximum	Minimum	Maximum
Up-to 60	Vegetative	13 to 25	6.00	30.30	7.30	29.70
60-90	Anthesis	Below 25	8.00	29.70	10.58	33.70
90-125	Grain development	25 to 30	9.90	35.70	9.90	36.10

Table 2. Mean grain yield (q/ha) under timely, late sown condition and different stress indices for new bread wheat genotypes

Genotype	Yield (q/ha)		% yield reduction	SSI	TOL	MP	GMP	HTI
	YTS	YLS						
NIAW 2966	40.99	33.99	17.08	1.32	7.00	37.49	37.33	0.77
NIAW 2967	40.49	33.33	17.68	1.77	7.16	36.91	36.74	0.74
NIAW 2968	42.33	35.33	16.54	1.65	7.00	38.83	38.67	0.82
NIAW 2969	41.99	34.66	17.46	1.75	7.33	38.33	38.15	0.80
NIAW 2970	42.66	35.99	15.64	1.56	6.67	39.33	39.18	0.85
NIAW 2971	41.33	33.99	17.76	1.78	7.34	37.66	37.48	0.77
NIAW 2972	48.66	46.99	3.43	0.34	1.67	47.83	47.82	1.26
NIAW 2973	40.33	32.66	19.02	1.90	7.67	36.50	36.29	0.73
NIAW 2974	42.66	34.33	19.53	1.95	8.33	38.50	38.27	0.81
NIAW 2975	41.99	37.33	11.10	1.11	4.66	39.66	39.59	0.86
NIAW 2976	42.83	38.99	8.97	0.90	3.84	40.91	40.86	0.92
NIAW 2977	42.49	33.83	20.38	2.04	8.66	38.16	37.91	0.79
NIAW 2978	42.33	38.83	8.27	0.83	3.50	40.58	40.54	0.91
NIAW 2979	40.66	33.66	17.22	1.72	7.00	37.16	36.99	0.75
NIAW 2980	41.83	36.66	12.36	1.24	5.17	39.25	39.16	0.85
NIAW 2981	41.99	35.33	15.86	1.59	6.66	38.66	38.52	0.82
NIAW 2982	42.16	38.33	9.08	0.91	3.83	40.25	40.20	0.89
NIAW 2983	42.33	37.33	11.81	1.18	5.00	39.83	39.75	0.87
NIAW 2984	41.99	35.99	14.29	1.43	6.00	38.99	38.87	0.83
NIAW 2985	42.16	34.66	17.79	1.78	7.50	38.41	38.23	0.81
NIAW 34 ©	47.49	46.66	1.75	0.17	0.83	47.08	47.07	1.22
PBW 533©	44.66	42.49	4.86	0.49	2.17	43.58	43.56	1.05
HI 977 ©	42.99	41.33	3.86	0.39	1.66	42.16	42.15	0.98
Mean	42.58	37.07						
SE+	0.41	0.83						
PCV %	9.52	10.5						

YTS= Yield under timely sown condition , YLS= Yield under late sown condition

Table 3. Correlation coefficients of yield with stress indices under stress and non stress conditions

	Yield (TS)	Yield(LS)	SSI	TOL	MP	GMP
Yield(LS)	0.950**	1				
SSI	-0.601**	-0.933**	1			
TOL	-0.502*	-0.939**	0.988**	1		
MP	0.984**	0.991**	-0.880**	-0.883**	1	
GMP	0.982**	0.993**	-0.886**	-0.890**	1.000**	1
HTI	0.978**	0.966**	-0.868**	-0.860**	0.977**	0.975**

*Significant at 5% and ** Significant at 5%

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Table 4. First two principal components for grain yield and stress indices under stress, non-stress conditions

Variable	PC1	PC2	PC3
YTS	0.361	0.576	0.236
YLS	0.391	-0.032	-0.206
SSI	-0.364	0.536	-0.762
TOL	-0.364	0.543	0.554
MP	0.388	0.173	-0.061
GMP	0.389	0.151	-0.073
HTI	0.388	0.183	-0.073
Eigenvalue	6.541	0.447	0.011
Variability (%)	0.934	0.064	0.002
Cumulative	0.934	0.998	1.000

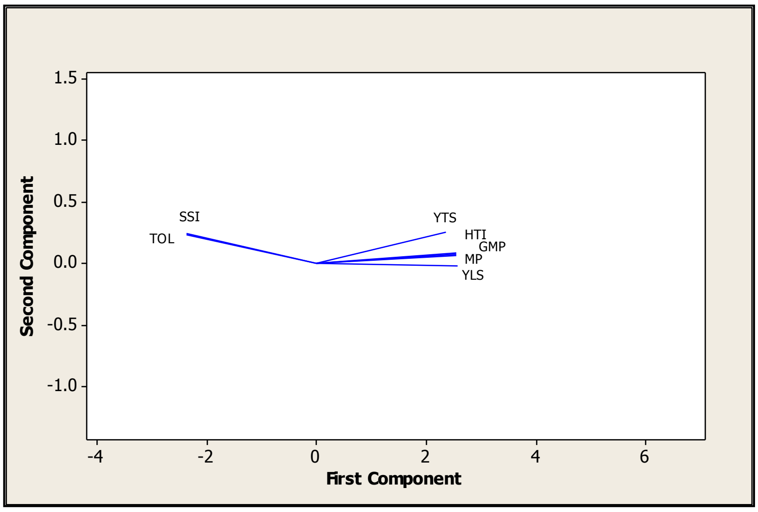

Fig 1. Biplot for wheat genotypes and stress indices using first two principal components