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Navodeeta Raaj
Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

SK Singh
Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Ankit Kumar
Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Avinash Kumar
Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Correspondence
Navodeeta Raaj
Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Assessment of variability parameters in wheat in relation to terminal heat tolerance

Navodeeta Raaj, SK Singh, Ankit Kumar and Avinash Kumar

Abstract

Present study was conducted using twenty four wheat genotypes under two environments namely non stressed (timely sown) and stressed (late sown) in Randomized Block Design with three replications at Wheat Breeding section of Dr. RPCAU, Pusa, Samastipur, Bihar during *RABI* 2016-17 to evaluate the bread wheat (*Triticum aestivum* L.) genotypes for terminal heat tolerance under late sown condition. Observations were recorded on sixteen characters in relation to terminal heat conditions to identify the tolerant genotypes. Analysis of variance revealed highly significant differences among the accessions for all the parameters under both timely and late sown conditions. Under timely sown condition PCV ranged from 5.04 to 19.7 for days to maturity and grain yield respectively. The range of GCV varied from 2.58 for Plant height to 16.21 for grain yield. Days to fifty percent flowering exhibited highest heritability (95.5) and plant height exhibited lowest heritability (24.8). Grain yield possessed highest genetic advance (27.49) whereas plant height possessed lowest genetic advance (2.65). Under late sown condition PCV ranges from 4.00 to 55.39 for days to maturity and thousand grain weight susceptibility index. GCV ranged from 2.59 to 53.07 for days to maturity and thousand grain weight susceptibility index. Days to fifty percent flowering exhibited highest heritability (93.5) and spike length exhibited lowest heritability (21.3). Thousand grain weight susceptibility index possessed highest genetic advance (93.5), whereas spike length possessed lowest genetic advance (2.59). The characters like tillers per plant, flag leaf area, grains per spike, harvest index, grain yield, thousand grain weight susceptibility index, heat susceptibility index exhibited high heritability coupled with high genetic advance as per cent of mean under both environments indicating that simple selection scheme would be effective for these traits to bring genetic improvement in desired direction.

Keywords: Variability parameters, terminal heat tolerance

Introduction

Wheat (*Triticum aestivum* L., 2n = 6x =42) is a one of the most widely grown food grain crop in the world. It is self-pollinated crop belonging to the most diverse and important family ‘Poaceae’ of the plant kingdom. Wheat occupies 17 per cent of crop acreage worldwide, feeding about 40 per cent of the world population and providing 20 per cent of total food calories and protein in human nutrition (Gupta *et al*., 2008) [10]. It is considered to be the second most important food crop in India only after rice and providing foods for about 2 billion people which is about 36 per cent of the total world population. In subcontinent India, Nepal, Bangladesh and Pakistan are major wheat producing countries. Wheat is cultivated over a wide area all over the world and is grown on an area of about 224.82 million hectare and production of about 732.98 million tons with productivity of 3.26 tons per hectare (Anonymous, 2015a) [1]. In India, wheat is grown on an area of about 30.93 million hectare which produces 93.50 million tons of wheat with a productivity of 30.34 quintal per hectare (Director’s report 2017). The crop is best suited to temperate climate, however, it is mainly produced and consumed in the tropical and sub-tropical regions of developing world. Therefore, its cultivation in warmer climates is restricted to cooler months of the year (i.e., winter season). During the last decade there was globally decline in annual growth rate in wheat production associated with an unprecedented increase in the price of food grains. It was partially attributed the impact of variety of abiotic stresses including heat and drought due to increasingly variable climate.

Unfortunately, heat stress is a major environmental factor that substantially reduces wheat grain yield globally especially in arid, semi-arid, tropical, and sub-tropical regions that are associated with higher temperature. Wahid *et al*., 2007 [41] defined heat stress as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. Heat stress can cause partial or total breakdown of anatomy, morphology, biochemistry and physiology of the crop. It is function of the magnitude and rate of temperature increase, as well as the duration of exposure to the raised temperature (Wahid *et al*., 2007) [41]. End-of-season or 'terminal' heat stress is also likely to increase for wheat in the near future (Semenov, 2009) [39] due to increase in global warming. Therefore, breeding for heat tolerance in wheat is a major global concern (Paliwal *et al.,* 2012) [24]. Consequently, development of heat-tolerant cultivars is of importance in wheat breeding programs (Sikder and Paul, 2010) [40]. Success in crop improvement generally depends on the magnitude of genetic variability and the extent to which the desirable characters are heritable (Kahrizi *et al*., 2010) [16]. The knowledge from the germplasm evaluation will be of great significance for selection of heat tolerant genotypes and also for improving grain yield under high temperature. Wheat exposes to heat stress to varying degrees at different phenological stages, but the exposure of the reproductive phase to heat stress is more harmful than exposure during vegetative stages due to its direct effect on grain number and dry weight (Wollenweber *et al*., 2003) [42]. It has been observed that each degree rise in ambient temperature reduces the yield by 3-4 per cent (Mishra 2007) [23]. Wheat breeders are seeking to incorporate late heat tolerance in the wheat germplasm and to develop genotypes that are early in maturity in order to escape the terminal heat stress and, thus suit well in the rice-wheat.

Genetic variability refers to the presence of differences among the individuals of plant population. Variability results due to differences either in the genetic constituent of the individuals of a population or in the environment in which they grown. The study of genetic variability is the pre-requisite for any crop improvement programme. Heritability and genetic advance are other important selection parameters. The estimates of heritability help the plant breeder in determining the character for which selection would be rewarding. The breeders are interested in selection of superior genotypes based on their phenotypic expression. The major function of heritability estimates is to provide information on transmission of characters from the parents to the progeny.

Material and Methods

The present experiment was conducted during *Rabi* 2016-17. The experimental materials of the study comprised of 24 diverse bread wheat (*Triticum aestivum* L.) genotypes. Out of 24 genotypes, 2 varieties namely HD 2733 and DBW14 were used as check for normal and late sowing conditions, respectively in this experiment. In each replication each genotype was grown in a plot of 5 rows of 3 meter length each with a spacing of 23 cm (Timely sown) and 18 cm (Late sown). Genotypes were sown in field when adequate moisture was available. Field was irrigated at regular intervals depending upon the rainfall and recommended standard cultural and agronomic practices were followed to raise the healthy crop. Observation were recorded on plant height, number of tillers per plant, flag leaf area, days to fifty per cent flowering, canopy temperature, relative water content, spike length, number of grains per spike, spike fertility, chlorophyll content, days to maturity, thousand grain weight, harvest index, yield per plant, thousand grain weight susceptibility index and heat susceptibility index.

Result and Discussion

The analysis of variance or estimates of MSS (Table 1) clearly indicated that there was highly significant variation among the genotypes for all the traits studied under both the environments. This in turn indicated that there was sufficient variability in the material studied under both timely and late conditions, which could be utilized in further breeding programme. In other words further analysis of variability for heat tolerance may be meaningful as indicated by significant mean sum of squares under late sown condition i.e., stress condition. Interestingly, the magnitude of MSS of many traits were more under late sown condition than timely sown condition, which indicated directly that the amount of variation for these traits was more desirable under stress condition. More variation under late sown condition is expected as different genotypes responded differentially under late sown (stress condition). The phenotypic variances for all the traits under studied were higher than the genotypic variances Kumar *et al.* (2014) [17]. This may be due to the non-genetic factor which played an important role in the manifestation of these characters. Wide ranges of variance (phenotypic & genotypic) were observed in the experimental material for all the characters under investigation in both environments. The maximum phenotypic and genotypic variance exhibited by the traits like spike fertility, harvest index, number of grains per spike, flag leaf area, relative water content under both environments. A wide range of PCV were observed for the traits under investigation in timely sown condition and it varied from 5.04 (days to maturity) to 19.7 (grain yield per plant). The highest PCV was exhibited by grain yield per plant (19.7) followed by flag leaf area (18.25), tillers per plant (17.42), harvest index (16.15), number of grains per spike (14.02), chlorophyll content (8.87), spike fertility (8.84), spike length (8.39), days to fifty per cent flowering (7.04), thousand grain weight (6.76), whereas relative water content (6.52), canopy temperature (6.18), plant height (5.19) and days to maturity (5.04) showed low PCV.

The ranges of GCV in timely sown condition varied from 2.58 (plant height) to 16.21(grain yield per plant). The maximum GCV was recorded for grain yield per plant (16.21) followed by flag leaf area (15.58), tillers per plant (15.04), harvest index (12.71), grain per spike (10.11), chlorophyll content (7.2), days to fifty per cent flowering (6.89), while low GCV was depicted by the following trait, spike fertility (5.94), spike length (5.84), thousand grain weight (5.36), canopy temperature (4.68), relative water content (3.94), days to maturity (3.91), plant height (2.58). The narrow difference between PCV and GCV were recorded for most of the traits except grain yield per plant, spike length and grain per spike which showed relatively wider difference between PCV and GCV under timely sown condition.

A wide range of PCV was observed for the traits under late sown condition ranged from 4.00 (Days to maturity) to 55.39 (TSI), The high PCV was recorded for the traits TSI (55.39) and HSI (33.54) whereas the traits like grain yield per plant (25.95), flag leaf area (24.17), harvest index (21.74), tillers per plant (17.84), spike fertility (16.82), grain per spike (14.75), chlorophyll content (13.56), 1000 grain weight (10.06) were showed moderate PCV. However, relative water content (8.00), canopy temperature (7.72), plant height (6.73), spike length (5.89), days to fifty per cent flowering (5.56), days to maturity (4.00) showed low PCV value.

GCV ranged from 2.59 (Days to maturity) to 53.07 (TSI). The high GCV was recorded for the traits TSI (53.07) and heat susceptibility index (30.92), whereas moderate GCV was depicted by the traits grain yield per plant (22.78), flag leaf area (21.52), harvest index (19.11), tillers per plant (15.38), spike fertility (15.24), chlorophyll content (12.63), grain per spike (11.94), 1000 grain weight (9.09). The traits relative water content (5.68), canopy temperature (5.41), days to 50% flowering (5.38), plant height (3.94), spike length (2.72) and days to maturity (2.59) exhibited least GCV. Spike fertility show highest phenotypic and genotypic variance. Harvest index and flag leaf area exhibited high genotypic and phenotypic variances under late sown condition indicating importance of these characters in stress condition for further improvement. Many earlier workers, Shipler and Blum (1991) [35], Hanchinal (1994) [11], Samaiya (2000) [33], Desalegn Debelo *et al.* (2001) [6], Sarkar *et al.* (2001) [34], Singh *et al.* (2003) [30], Mahto *et al.* (2004) [21], Prakash *et al.* (2005) [26], Ali *et al.* (2008) [2], Emeka *et al.* (2016) and Kumar *et al*. (2018) [18] reported high variability for different traits in wheat. Thus, it is implied that there was reasonably sufficient variability in material used for their study, which provides ample scope for selecting superior and desire genotypes by the plant breeder for further improvement.

The assessment of heritable and non-heritable components in the total variability observed is indispensable in adopting suitable breeding procedure. The heritable portion of the overall observed variation can be ascertained by studying the components of variation such as GCV, PCV, heritability and genetic advance as per cent of mean. In the present investigation, the genotypic and phenotypic coefficient of variation for grain yield was found to be high in both the conditions, whereas flag leaf area showed high GCV and PCV in late sown condition and moderate GCV and PCV in timely sown condition. These results are in agreement with Kumar *et al.* (2014) [17] for grain yield per plant and Aharizad *et al.* (2012) [4] for flag leaf area.

The results showed that thousand grain weight susceptibility index (TSI) exhibited very high GCV and PCV under late sown condition, indicating the importance of this trait in evaluation for heat tolerance and selecting the genotypes for heat tolerance. In this study, the phenotypic and genotypic coefficient of variance was found to be moderate for grain yield, flag leaf area, harvest index, tillers per plant, spike fertility, grains per spike under both the environment (late and timely). Heat susceptibility index showed moderate GCV and PCV under late sown condition. Similar results were also reported by Aharizad *et al.* (2012) [4] for flag leaf area, number of grains per spike and grain yield, Mahto *et al.* (2004) [21] total number of tillers per plant, Prakash *et al.* (2005) [26], Mukherjee *et al.* (2008) [20] for total number of tillers per plant, Yadav *et al.* (2006) [43] for grain per spike, Ali *et al*. (2008) [2] for total number of tillers per plant, number of grains per spike. They found high GCV and PCV for respective traits. These findings clearly indicated that selecting genotypes through these traits will be effective for heat tolerance. It is interesting to note that the differences between GCV and PCV values were minimum implying least influence of environment and additive gene effects indicating genotypes can be improved and selected for these characters under stress condition for improvement of heat tolerance.

The coefficient of variation indicates the extent of variability present in these characters and does not indicate the heritable portion in total variation. This could be ascertained from the heritability estimates, which in broad sense include both additive and non-additive gene effects and in narrow sense include the portion of heritable variation which is due to additive component (Lush, 1943). The knowledge of heritability is helpful in assessing merits and demerits of a particular trait as it enables the plant breeder to decide the course of selection procedures to be followed under a given situation. Heritability is a measure of the extent of phenotypic variation caused by the action of genes. It is a good index of the transmission of characters from parents to their offspring (Falwner 1989) [9]. For making effective improvement in the characters for which selection is practiced, heritability has been adopted by large number of workers as a reliable indicator. The estimates of heritability are more advantageous when expressed in terms of genetic advance. Hanson (1963) [12] stated that heritability and genetic advance are two complementary concepts. However it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al*., 1955) [12].

Heritability in broad sense and genetic advance as per cent of mean was tabulated in (table 2) for all the characters under timely sown condition. Heritability in broad sense was found high for all the traits, namely days to fifty per cent flowering (95.5), tillers per plant (74.5), flag leaf area (72.9), grain yield per plant (67.7), chlorophyll content (65.9), thousand grain weight (62.9), harvest index (62), days to maturity (60.2), canopy temperature (57.5), grain per spike (52.1), spike length (48.4), spike fertility (48.4), relative water content (36.5), plant height (24.8)

Genetic advance as per cent of mean was found as high (> 20) for grain yield per plant (27.49), flag leaf area (27.41), tillers per pant (26.7), harvest index (20.62), although medium (10-20) for grain per spike(15.03), days to fifty per cent flowering(13.87), chlorophyll content (12.04). However, the traits like thousand grain weight (8.76), spike fertility (8.52), spike length (8.36), canopy temperature (7.32), days to maturity (6.25), relative water content (4.9) and plant height (2.65) depicted low genetic advance as per cent of mean (< 10).

Under late sown condition the high heritability in broad sense (Table 2) was recorded for Days to fifty per cent flowering (93.5) followed by thousand grain weight susceptibility index (91.8), heat susceptibility index (85), spike fertility (82.1), thousand grain weight (81.5), flag leaf area (80.4), harvest index (77.3), grain yield (77.0), total number of tillers per plant (74.3), number of grains per spike (65.5), relative water content (50.4), canopy temperature (49.1), days to maturity (42.1), plant height (34.3) and spike length (21.3). However, Genetic advance as per cent of mean (Table 2) ranges from 2.59 to 104.75. The result showed that eight attributes namely thousand grain weight susceptibility index (104.75), Heat susceptibility index (58.73), grain yield per plant (41.18), flag leaf area (40.06), harvest index(34.61), spike fertility (28.46), tillers per plant (27.33), chlorophyll content (24.24) were exhibited high genetic advance as per cent of mean (> 20). Although, the traits like grain per spike (19.91), thousand grain weight (16.9), days to fifty per cent flowering (10.72) showed medium genetic advance as per cent of mean (10% - 20%). However, the traits like relative water content (8.3), canopy temperature (7.8), plant height (4.75), days to maturity (3.46), spike length (2.59) exhibited low genetic advance as per cent of mean (< 10%). The two characters namely thousand grain weight susceptibility index and heat susceptibility index were found to have high heritability under late sown condition.

High heritability value for these traits indicated that the variation observed was mainly under genetic control and was less influenced by environment. So, these traits may be used as a selection criteria under stress and can be improved for heat tolerance in confirmation with the result of earlier workers Singh *et al.* (1969) [36] for grain yield, Reiter and Leontev (1972) [27] for number of grains per spike, Singh *et al.* (1983) [37] for days to fifty per cent flowering, Sarkar *et al.* (2001) [34] for flag leaf area, Fellahi *et al.* (2013) [8] reported high heritability for chlorophyll content, grain per spike, grain yield, Bolch *et al.* (2014) for number of grains per spike and Yadav *et al.* (2014) [44]. Lush (1949) [19] pointed out that when heritability is high, relevance should be mainly on mass selection or as heritability become lower, more emphasis should be placed on pedigree selection method.

In the present investigation, the characters, namely days to fifty per cent flowering, spike fertility, flag leaf area, chlorophyll content, total number of tillers per plant, number of grains per spike, harvest index, and grain yield exhibited high heritability coupled with high genetic advance as per cent of mean under both environments. Hence, direct selection can be done for these characters for future improvement of genotypes under stress condition for improvement of heat tolerance and under timely sown condition for higher grain yield. Similar results were also reported by earlier workers Singh *et al.* (1977) [32] for grain yield and total number of tillers per plant, Pathak and Nema (1985) [25] for thousand grain weight, Singh (1990) [31] for days to fifty per cent flowering, thousand grain weight, and number of grains per spike, Mandal *et al.* (1991) [22] for thousand grain weight, Kumar *et al.* (2003) for number of grains per spike and thousand grain weight, Khokhar *et al.* (2010) for flag leaf area, grain yield and thousand grain weight, Islam *et al.* (2012) [14] for total number of tillers per plant and chlorophyll content, Bhusan *et al.* (2013) for harvest index and grain yield, Kumar *et al.* (2014) [17] for harvest index, Singh *et al.* (2014) [29] for total numbers tillers per plant, grain yield, thousand grain weight, flag leaf area, chlorophyll content and harvest index. The HSI depicted high heritability coupled with high genetic advance as per cent of mean Kumar *et al.* (2018) [18].

The characters like grain yield, flag leaf area, harvest index, spike fertility, tillers per plant, chlorophyll content revealed high heritability with high genetic advance as per cent of mean under late sown condition, whereas grain yield, flag leaf area, harvest index, tillers per plant showed high heritability with high genetic advance as per cent of mean in timely sown condition. Characters like spike fertility, chlorophyll content revealed high heritability with low genetic advance for spike fertility and moderate genetic advance for chlorophyll content under timely sown condition Singh *et al.* (2014) [29] also recorded high heritability with high genetic advance as percent of mean for total number of tillers per plant, thousand grain weight, flag leaf area, chlorophyll content, harvest index number of grains per spike exhibited moderate heritability with moderate genetic advance as per cent of mean in timely sown condition, whereas high heritability with medium genetic advance as per cent of mean under late sown condition suggesting future improvement of genotypes for these characters through further selection and subsequent use in heat tolerance related breeding programme.

Moderate heritability coupled with low genetic advance as per cent of mean were observed for traits like plant height, spike length, days to maturity, relative water content and canopy temperature in both environment. Days to fifty per cent flowering showed high heritability with low genetic advance, thousand grain weight exhibited moderate genetic advance with high heritability in both environment condition. The pattern of heritability and genetic advances for traits indicated that their manifestation is governed by both additive and non-additive genetic effects and therefore, selection should be practiced in later segregating generations through hybridization programme to exploit heritability. These findings were in accordance of Kumar *et al.* (2014) [17] who reported high heritability coupled with high genetic advance as per cent of mean for harvest index and low genetic advance for days to fifty per cent flowering.

Other traits like, plant height, spike length exhibited low heritability along with low genetic advance indicating greater role of non-fixable genetic effects on the expression of these characters. Therefore, direct selection based on these characters would be less effective.

Table 1: Analysis of variance for different quantitative characters in bread wheat under both conditions

Characters	Mean sum of squares					
	Replication		Treatments		Error	
	Timely	Late	Timely	Late	Timely	Late
Plant height (cm)	9.22	34.12	41.60*	59.85**	20.91	23.34
Total number of tillers per plant	0.30	0.15	2.81**	2.76**	0.29	0.29
Flag leaf area (cm^2)	20.99	12.14	106.47**	140.68**	11.72	10.55
Days to 50 per cent flowering	1.35	0.39	82.04**	38.45**	1.26	0.87
Canopy temperature (°C)	0.23	1.68	4.27**	7.28**	0.84	1.87
RWC (%)	10.26	13.83	48.90**	74.39**	17.96	18.37
Spike length (cm)	0.23	0.07	1.47**	0.45*	0.38	0.25
Number of grains per spike	34.56	3.21	121.60**	116.38**	28.57	17.39
Spike fertility	43.46	7.95	73.43**	275.47**	19.24	18.64
Chlorophyll content (SPAD)	8.08	2.64	26.93**	55.24**	3.96	2.68
Days to maturity	6.01	6.68	75.27**	34.83**	13.61	10.96
1000- grain weight (g)	2.62	3.42	19.37**	35.62**	3.18	2.50
Harvest index (%)	21.13	44.68	160.57**	223.60**	27.24	19.95
Yield per plant (g)	0.16	0.28	29.48**	36.01**	4.04	3.26
Thousand grain weight susceptibility index	0.01	0.01		0.83**	0.02	0.02
Heat susceptibility index	0.01	0.01		0.35**	0.02	0.02

**: Significance at 1 % level

Table 2: Genetic parameters of various characters in bread wheat under both condition

No	Characters	σ^2_g		σ^2_p		GCV		PCV		h^2 (Broad sense) %		GA as % of Mean	
		Timely	Late	Timely	Late	Timely	Late	Timely	Late	Timely	Late	Timely	Late
1	Plant height (cm)	6.896	12.16	27.80	35.11	2.586	3.94	5.19	6.73	24.8	34.3	2.65	4.75
2	Total number of tillers per plant	0.842	0.82	1.13	1.11	15.04	15.38	17.42	17.84	74.5	74.3	26.7	27.32
3	Flag leaf area (cm^2)	31.58	43.37	43.30	53.92	15.58	21.52	18.25	24.17	72.9	80.4	27.41	40.06

4	Days to 50 per cent flowering	26.92	12.52	28.1	13.39	6.89	5.38	7.04	5.56	95.5	93.5	13.87	10.72
5	Canopy temperature(°C)	1.14	1.80	1.98	3.67	4.68	5.41	6.18	7.72	57.5	49.1	7.32	7.80
6	RWC (%)	10.31	18.67	28.27	37.04	3.94	5.68	6.52	8.00	36.5	50.4	4.90	8.30
7	Spike length (cm)	0.36	0.06	0.745	0.31	5.84	2.72	8.39	5.89	48.4	21.3	8.36	2.59
8	Number of grains per spike	31.01	32.99	59.57	50.38	10.11	11.94	14.02	14.75	52.1	65.5	15.03	19.91
9	Spike fertility	18.06	85.60	37.30	104.24	5.94	15.24	8.54	16.82	48.4	82.1	8.52	28.46
10	Chlorophyll content (SPAD)	7.655	17.51	11.617	20.19	7.20	12.63	8.87	13.56	65.9	86.7	12.04	24.24
11	Days to maturity	20.55	7.95	5.04	18.91	3.91	2.59	5.04	4.00	60.2	42.1	6.25	3.46
12	1000- grain weight (g)	5.39	11.03	6.76	13.54	5.36	9.09	6.76	10.06	62.9	81.5	8.76	16.90
13	Harvest index (%)	44.44	67.88	16.15	87.83	12.71	19.11	16.15	21.74	62	77.3	20.62	34.61
14	Yield per plant (g)	8.48	10.91	19.709	14.17	16.21	22.78	19.70	25.95	67.7	77	27.49	41.18
15	Thousand grain weight susceptibility index		0.27		0.29		53.07		55.39		91.8		104.75
16	Heat susceptibility index		0.11		0.12		30.92		33.54		85		58.73

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