International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM November 2023, 14(11):1460-1466 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR4863

Research Article Stress Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.4863

Assessing Genetic Variability in Wheat (*Triticum aestivum* L.) Under Timely and Late Sown Conditions for Tolerance Towards Terminal Heat Stress

Uttej Karla[1], Vinay Kumar Choudhary[2], Satish Kumar Singh[1], Vignesh S.[1] and Anvesh Ellandula[1]

[1]Dept. of Genetics & Plant Breeding, Post Graduate College of Agriculture, DRPCAU, Pusa, Bihar (848 125), India
[2]Directorate of Seed, TCA Campus, DRPCAU, Pusa, Bihar (848 125), India

Open Access

Corresponding uthejreddyk111@gmail.com

0000-0003-1744-5471

ABSTRACT

A field experiment was conducted at wheat experimental farm, Post Graduate College of Agriculture, DRPCAU, Pusa, Bihar to quantify the genetic variability among twenty-nine wheat genotypes under timely and late sowing conditions for tolerance towards terminal heat stress during *rabi* 2020–2021. The trial was performed in three replications using Randomized Block Design. The study included estimates of genetic variability parameters such as mean, range, phenotypic coefficient of variability, genotypic coefficient of variability, broad-sense heritability, and genetic advance over % of mean. The ANOVA estimations showed that there's considerable variation across genotypes for all twelve traits investigated across both environments. Traits like grains spike^{-1} and harvest index displayed considerable genotypic and phenotypic variances across both environments indicating the relevance of these traits in stress conditions. Tillers plant^{-1} and grain yield plant^{-1} displayed high genotypic and phenotypic coefficient of variation in timely and late conditions respectively. High heritability reported for traits like days to 50% flowering, canopy temperature, harvest index, grain yield plant^{-1}, tillers plant^{-1}, thousand grain weight and grains spike^{-1} in both conditions. Under both conditions, tillers plant^{-1}, grains spike^{-1}, harvest index and grain yield plant^{-1} reported strong heritability along with high genetic advance over % of mean. As a result, direct selection may be made using these features for further genotype improvement under stress conditions for improved heat tolerance.

KEYWORDS: Genetic variability, heat stress, heat susceptibility index, wheat

***Citation* (VANCOUVER):** Karla et al., Assessing Genetic Variability in Wheat (*Triticum aestivum* L.) Under Timely and Late Sown Conditions for Tolerance Towards Terminal Heat Stress. *International Journal of Bio-resource and Stress Management,* 2023; 14(11), 1460-1466. HTTPS://DOI.ORG/10.23910/1.2023.4863.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The research was conducted with the kind and supports from Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur, Bihar.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 24th August 2023 RECEIVED in revised form on 16th October 2023 ACCEPTED in final form on 29th October 2023 PUBLISHED on 15th November 2023

1. INTRODUCTION

Wheat (*Triticum aestivum* L.), a member of the Poaceae family, is a self-pollinating allohexaploid plant. it is the paramount significant crop of the world which feeds almost one third of global population. The global wheat production for the year 2021–22 is estimated at 780.62 million metric tons (Anonymous, 2022). In India, the wheat production for the year 2020–21 was estimated at 109.24 million metric tons (Anonymous, 2021).

Various factors, both living (biotic) and non-living (abiotic), pose a threat to wheat cultivation. Among these challenges, heat stress is a significant factor affecting the wheat growth and yield. Due to increased rising temperatures, wheat terminal heat stress is also expected to rise in the coming years (Semenov, 2009). Late sown crop usually gets exposed to terminal heat stress conditions, which occurs during the reproductive phase of the crop, one of the primary factors that restricts wheat yield and productivity (Lobell et al., 2012). Even briefly exposing to elevated temperatures (>35°C) will severely reduce wheat grain yield (Hawker and Jenner, 1993). The escalation of temperature beyond the optimal range may lead to a substantial decline in global wheat production, as much as 3–6% for every 1°C rise in temperature (Mishra, 2007), which could ultimately result in a loss of approximately 120 million tons of wheat by 2050. (Asseng et al., 2020). High temperature stress in arid or semi-arid regions has had a significant impact on wheat productivity in recent years. This has become a major contributor to the decrease in wheat yield worldwide (Rane and Nagarajan, 2004; Singh et al., 2021). This has emerged as a major factor in the reduction of wheat yield around the world. As a result, wheat breeding for heat resistance is a big global priority (Paliwal et al., 2012). Thus, wheat breeding systems must prioritize the production of heat-tolerant varieties (Sikder and Paul, 2010).

A thorough evaluation of variability is necessary for successful breeding methods. The selection of a breeding method depends on trait relationships and heritability. To establish a productive breeding program, it is imperative to conduct a thorough investigation into the variability and genetic potentiality of different genotypes. The success in a crop improvement breeding program depends greatly on both the level of genetic divergence within the crop and the degree of inheritance. The presence of a higher degree of variability in a given population is likely to enhance the efficacy of selection towards the desired traits (Vavilov, 1951). The genotypic and phenotypic coefficient of variation can be utilized to determine the extent of genetic variation that exists in a population (Mallor et al., 2011). Heritability estimates provide a measure of the inheritance of traits from one generation to the next (Saidaiah et al., 2021). Knowing the heritability of a trait is helpful in devising successful breeding plans as it aids in measuring the extent of the trait's inheritance (Porta et al., 2014). It is highly beneficial and effective for plant breeder when the selection is based on high heritability estimates in combination with high genetic advance for a particular trait (Barman et al., 2020). These factors play a crucial role in shaping the breeding outcomes and the development of improved crop varieties with desirable traits (Bello et al., 2012). Hence, to develop heat-tolerant wheat varieties, it is important to understand the genetic variability for important morpho-physiological traits, including yield, grain number, canopy temperature, days to 50% flowering, days to maturity, chlorophyll content, spike length, heat susceptibility index etc.

2. MATERIALS AND METHODS

An investigation was performed at wheat experimental farm, DRPCAU, Pusa, Bihar to quantify the genetic variability among twenty-nine wheat genotypes under timely sown (TS) and late sown (LS) conditions during *rabi* 2020-21 (Table 1). The trial was performed in three replications using one way ANOVA with row-to-row distance of 23 cm under TS and 18 cm under LS conditions. Twelve morpho-physiological characters were evaluated in the current study i.e., plant height (PH), tillers plant^{-1} (TPP), days to 50% flowering (DFF), canopy temperature (CT), spike length (SL), grains spike^{-1} (GPS), chlorophyll content (CC), days to maturity (DM), 1000-grain weight (TGW), harvest index (HI), grain yield plant^{-1} (GYP), heat

Table 1: List of 29 bread wheat genotypes in the present experiment

Genotype no.	Genotype	Genotype no.	Genotype
G1	RAUW401	G16	RAUW416
G2	RAUW402	G17	RAUW417
G3	RAUW403	G18	RAUW418
G4	RAUW404	G19	RAUW419
G5	RAUW405	G20	RAUW420
G6	RAUW406	G21	RAUW421
G7	RAUW407	G22	RAUW422
G8	RAUW408	G23	RAUW423
G9	RAUW409	G24	RAUW424
G10	RAUW410	G25	DBW16
G11	RAUW411	G26	ANKUR
G12	RAUW412	G27	HUW234
G13	RAUW413	G28	HD2824
G15	RAUW415	G29	Rajendra Ghehu 3 (check)

susceptibility index (HSI). The approach recommended by Singh and Chaudhary (1985) was employed to compute the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (h^2), genetic advance (GA), and genetic advance as % of mean (GAM).

3. RESULTS AND DISCUSSION

The ANOVA or MSS estimations revealed significant variation across genotypes for every trait investigated across both environments (Table 2). This, in turn, implied that the material evaluated had adequate variability under both sowing conditions, which can be used in future crop improvement programmes. Additional assessment of variability for heat stress may be relevant, as evidenced by considerable MSS under late sown conditions, i.e., stress conditions. Interestingly, the degree of MSS for few traits was greater under LS conditions than under TS conditions, indicating that the extent of diversity for such attributes was more preferable under stress conditions. The results reported considerable differences among all the 12 characters evaluated (Table 3). The study also included estimates of various genetic variability parameters such as mean, range, PCV, GCV, h^2, and GAM for various traits. These parameters are crucial biometrical tools employed for quantifying genetic variability (Table 1). The GCV is employed to quantify variability across different genotypes for different traits, which emerges from innate potentiality of the genotype (Table 2). Both PCV, GCV are required to comprehend the effect of E (environment) on quantitative traits. The disparity amidst the coefficients of variation (GCV and PCV) provides insights into the role of G (genotype) and E (environment) in shaping the character.

Table 2: ANOVA of quantitative traits in bread wheat under TS and LS conditions

Characters	Mean sum of squares					
	Replications		Treatments		Error	
	Timely	Late	Timely	Late	Timely	Late
PH (cm)	30.2	11.25	225.39*	111.82*	41.60	26.96
TPP	0.08	0.14	4.62*	1.644*	0.20	0.13
DFF	60.58	7.06	81.26*	50.381*	2.56	2.20
CT (°C)	0.26	0.14	5.39*	6.849*	0.66	0.33
SL (cm)	0.84	0.26	0.84*	1.56*	0.73	0.17
GPS	8.35	25.11	153.07*	119.98*	18.23	9.59
CC	13.72	20.74	27.42*	36.22*	9.38	4.77
DM	55.80	6.06	73.49*	41.28*	23.23	7.06
TGW (g)	2.91	0.66	26.69*	30.82*	4.25	1.43
HI (%)	47.89	0.39	83.71*	156.43*	12.81	8.04
GYP (g)	1.36	4.46	25.57*	28.12*	2.26	0.83
HSI		0.00068		0.16*		0.07

*: Significance at (p<0.01) level

3.1. *Estimates of phenotypic and genotypic variance*

Under timely sown conditions, plant height (102.87 and 61.26) exhibited the largest variability estimate (σp^2 and σg^2) followed by grains spike^{-1} (63.17 and 44.94), days to maturity (39.99 and 16.75), harvest index (36.44 and 23.63), days to 50% flowering (28.80 and 26.23), chlorophyll content (15.40 and 6.01) and grain yield plant^{-1} (10.03 and 7.77). Conversely, low variance estimates (σp^2 and σg^2) had been found for canopy temperature (2.24 and 1.58), tillers plant^{-1} (1.67 and 1.47) and spike length (1.74 and 0.74).

In case of Late sown scenario, harvest index (57.50 and 49.46) reported the largest variability estimates (σp^2 and σg^2) followed by plant height (55.25 and 28.28), grains spike^{-1} (46.39 and 36.79), days to maturity (18.47 and 11.40), days to 50 % flowering (18.26 and 16.05), chlorophyll content (15.25 and 10.48), thousand grain weight (11.23 and 9.79) and grain yield plant^{-1} (9.92 and 9.09). Low variability was reported in canopy temperature (2.50 and 2.17), tillers plant^{-1} (0.63 and 0.50) and heat susceptibility index (0.108 and 0.029) (Table 4).

In both conditions, significant amount of variation (phenotypic and genotypic) were seen in the investigating material for most traits included in study. Characters like plant height, grains spike^{-1} and harvest index reported high phenotypic and genotypic variance which are similar to the

Table 3: Estimations of different parameters for all the traits

Trait	Mean		Range				C.V		σ² g		σ² p	
	T	L	T		L		T	L	T	L	T	L
			Min	Max	Min	Max						
PH	96.56	85.87	75.66	109	69.62	97.28	6.68	6.04	61.26	28.28	102.87	55.25
TPP	6.26	5.32	4.79	10.53	4.33	7.53	7.22	6.80	1.47	0.50	1.67	0.63
DFF	76.93	66.63	69.66	87.76	61.60	75.41	2.22	2.08	26.23	16.05	28.80	18.26
CT	22.49	25.37	20.38	24.91	22.20	27.82	3.61	2.29	1.58	2.17	2.24	2.50
SL	10.95	9.53	8.16	13.23	7.60	10.90	7.81	4.36	0.74	0.463	1.74	0.636
GPS	55.80	47.48	38.45	66.25	32.45	58.61	7.65	6.52	44.94	36.79	63.17	46.39
CC	38.52	33.85	33.30	44.27	25.92	40.97	7.95	6.45	6.01	10.48	15.40	15.25
DM	117.73	109.78	106.53	127.19	101.58	116.66	4.09	2.42	16.75	11.40	39.99	18.47
TGW	43.40	37.42	36.85	48.30	31.27	42.78	4.75	3.19	7.48	9.79	11.73	11.23
HI	50.74	44.02	37.68	60.52	30.33	57.62	7.05	6.44	23.63	49.46	36.44	57.50
GYP	19.56	14.50	15.10	24.18	10.26	21.77	7.68	6.29	7.77	9.09	10.03	9.92
HSI		1.01			0.31	1.33		14.18		0.029		0.108

Table 4: Estimations of different parameters for all the traits

Traits	GCV		PCV		h^2 (BS) %		GAM	
	T	L	T	L	T	L	T	L
PH	8.10	6.19	10.50	8.65	59.5	51	12.44	9.13
TPP	19.38	13.34	20.68	14.97	87.8	79.3	37.40	24.48
DFF	6.65	6.01	6.97	6.41	91.1	87.9	13.09	11.61
CT	5.58	5.80	6.65	6.24	70.5	86.5	9.66	11.13
SL	7.85	7.13	11.08	8.36	50.3	72.8	11.48	12.54
GPS	12.01	12.77	14.24	14.34	71.1	79.3	20.88	23.43
CC	6.36	9.56	10.18	11.53	39.0	68.7	8.19	16.32
DM	3.47	3.07	5.37	3.91	41.9	61.7	4.63	4.97
TGW	6.30	8.36	7.89	8.95	63.7	87.2	10.36	16.09
HI	9.58	15.97	11.89	17.22	64.8	86	15.89	30.51
GYP	14.25	20.80	16.19	21.73	77.5	91.6	25.83	41.02
HSI		16.77		32.53		26.6		17.81

outcomes of Naik et al. (2015). Under late sown conditions, grains spike^{-1} and harvest index displayed substantial genotypic and phenotypic variances, indicating the relevance of these characters in stress conditions.

3.2. Phenotypic and genotypic coefficient of variation

In timely sown conditions, the highest PCV was displayed for traits tillers plant^{-1} (20.68) followed by grain yield plant^{-1} (16.19), grains spike^{-1} (14.24), harvest index (11.89), spike length (11.08), chlorophyll content (10.18) and plant height (10.50). Whereas, thousand grain weight (7.89), days to 50% flowering (6.97), canopy temperature (6.65) and days to maturity (5.37) exhibited low PCV. Maximum GCV was reported for tillers plant^{-1} (19.38) followed by grain yield plant^{-1} (14.25), grains spike^{-1} (12.01), harvest index (9.58), plant height (8.10), spike length (7.85), days to 50% flowering (6.65), chlorophyll content (6.36) and thousand grain weight (6.30). While low GCV was exhibited by the traits like canopy temperature (5.58) and days to maturity (3.47).

whereas, in case of late sown scenario, all traits exhibited very low variation between PCV and GCV under late sown conditions except heat susceptibility index. The range of PCV in late sown scenario varied from 3.91 (days to maturity) to 32.53 (HSI) and it was exhibited highest for Heat susceptibility index followed by grain yield plant^{-1} (21.73), harvest index (17.22), tillers plant^{-1} (14.97), grains spike^{-1} (14.34), chlorophyll content (11.53), thousand grain weight (8.95), plant height (8.65), spike length (8.36), days to 50% flowering (6.41), canopy temperature (6.24) and days to maturity (3.91). The range of GCV in late sown conditions varied between 3.07 (DM)-20.80 (GYP). Days to maturity followed by canopy temperature (5.80), days to 50% flowering (6.01), plant height (6.19), spike length (7.13), thousand grain weight (8.36), chlorophyll content (9.56), grains spike^{-1} (12.77), tillers plant^{-1} (13.34) and harvest index (15.97).

Tillers plant^{-1} and grain yield plant^{-1} displayed high GCV and PCV in TS and LS conditions respectively. These results were comparable as claimed by Bhushan et al. (2013). The findings revealed that in LS conditions, grain yield plant^{-1} and harvest index reported extremely high GCV and PCV, emphasizing relevance of this feature in evaluating heat tolerance thereby choosing heat tolerant genotypes. These results are similar to outcomes of Baranwal et al. (2012) and Bhushan et al. (2013). These findings showed that choosing genotypes based on these characters is a good way to improve heat tolerance. It is worth noting that the disparity among both GCV and PCV estimates were minimal, implying that the environment had little influence and that additive gene effects were minimal, signifying those genotypes can be enhanced and chosen for these traits under stress conditions to enhance heat tolerance.

3.3. Heritability and genetic advance

In time sown conditions, heritability in a broad sense indicated that it was high for every parameter under investigation, including days to 50 % flowering (91.1), tillers plant^{-1} (87.8), grain yield plant^{-1} (77.5), grains spike^{-1} (71.1), canopy temperature (70.5), harvest index (64.8), thousand grain weight (63.7), plant height (59.5), spike length (50.3), days to maturity (41.9) and chlorophyll content (39). Tillers plant^{-1} (37.40), grain yield plant^{-1} (25.83), grains spike^{-1} (20.88), had reported high genetic advance (GA) (>20), whereas, traits like harvest index (15.89), days to 50% flowering (13.09), plant height (12.44), spike length (11.48) and thousand grain weight (10.36) reported moderate GA (10–20%). Low GA (<10) was observed in traits like canopy temperature (9.66), chlorophyll content (8.19) and days to maturity (4.63)

In Late sown conditions, all traits reported high heritability except plant height (51.0) and heat susceptibility index (26.6) with moderate and low heritability respectively. Grain yield plant^{-1} (91.6) has shown high heritability followed by days to 50% flowering (87.9), thousand grain weight (87.2), canopy temperature (86.5), harvest index (86). Genetic advance as % of mean ranged between 4.97–41.02 for days to maturity and grain yield plant^{-1} respectively. Four characters *viz*., grain yield plant^{-1} (41.02), harvest index (30.51), tillers plant^{-1} (24.48) and grains spike^{-1} (23.43) exhibited high GAM (>20%) while six traits i.e., heat susceptibility index (17.81), chlorophyll content (16.32), thousand grain weight (16.09), spike length (12.54), days to 50% flowering (11.61) and canopy temperature (11.13) showed medium GAM (10%–20%) and low GAM (<10%) was reported by plant height (9.13) and days to maturity (4.97).

Heritability was shown to be high in both conditions for traits studied, including days to 50% flowering, canopy temperature, harvest index, grain yield plant^{-1}, tillers plant^{-1}, thousand grain weight and grains spike^{-1}. High heritability estimations of these variables suggested that reported variability was primarily due to genetic influence and little influenced by environmental conditions. These traits can be utilized for selecting under stress and can be enhanced for heat tolerance in accordance with findings of previous researchers. Sabit et al. (2017) reported high heritability for grains spike^{-1}, Arya et al. (2017) for grain yield plant^{-1}. However, estimations of heritability can help to determine the efficiency of a trait for selection if they are combined with the GAM, as given by Panse (1942). Under both conditions, tillers plant^{-1}, grains spike^{-1}, harvest index and grain yield plant^{-1} reported strong heritability along with high GAM. As a result, direct selection may be made using these features for further genotype improvement under stress conditions for improved heat-tolerance and under normal conditions for greater grain production. Salman et al. (2014) and Tripathi et al. (2015) were stated similar findings which supports these findings. The high heritability linked with the high GA suggested that the variance was primarily caused by additive gene effects. It suggested that if such traits are exposed to any selection method for exploitation of fixable genetic variance, genotypes with a broad adoption can be produced.

4. CONCLUSION

The 29 genotypes displayed a considerable range of genetic variability across all traits examined. PCVs displayed greater predominance than GCVs across all traits across both conditions. Notably, traits such as tillers plant^{-1}, grains spike^{-1}, harvest index and grain yield plant^{-1} reported strong heritability along with high GAM coupled with substantial GA indicating that such traits are controlled by additive gene effects. Thus, a judicial selection can be effectively employed in crop improvement programs to develop heat tolerant wheat varieties.

5. ACKNOWLEDGEMENT

Author(s) acknowledge the supports from institutes involved.

6. REFERENCES

Anonymous, 2021. CIMMYT. (2021). Climate Change Threatens South Asia's Wheat Production. Available from https://www.cimmyt.org/news/climate-change-threatens-south-asias-wheat-production/

Anonymous, 2021. Department of Agriculture, Cooperation & Farmers Welfare. (2021). 3rd Advance estimates of production of food grains for 2020-21. Available from https://agricoop.gov.in/sites/default/files/3rd%20Advance%20Estimate%20English_0.pdf

Anonymous, 2022. United States Department of Agriculture. (2022). Grain: World Markets and Trade. Available from https://apps.fas.usda.gov/psdonline/circulars/grain.pdf

Arya, V.K., Singh, J., Kumar, L., Kumar, R., Kumar, P., Chand, P., 2017. Genetic variability and diversity analysis for yield and its components in wheat (*Triticum aestivum* L.). Indian Journal of Agricultural Research 51(2), 128–134.

Asseng, S., Ewert, F., Rosenzweig, C., Jones, J.W., Hatfield, J.L., Ruane, A.C., Reynolds, M.P., 2020. Climate change impact and adaptation for wheat protein. Global Change Biology 26(1), 1–13.

Baranwal, D.K., Mishra, V.K., Vishwakarma, M.K., Yadav, P.S., Arun, B., 2012. Studies on genetic variability, correlation and path analysis for yield and yield contributing traits in wheat (*T. aestivum* L. em Thell.). Plant Archives 12(1), 99–104.

Barman, M., Choudhary, V.K., Singh, S.K., Singh, M.K., Parveen, R., 2020. Genetic variability analysis in bread wheat (*Triticum aestivum* L.) genotypes for morpho-physiological characters and grain micronutrient content. International Research Journal of Pure and Applied Chemistry 21(22), 1–8.

Bello, O., Ige, S., Azeez, M., Afolabi, M., Abdulmaliq, S., Mahamood, J., 2012. Heritability and genetic advance for grain yield and its component characters in maize (*Zea mays* L.). International Journal of Plant Research 2(5), 138–145.

Bhushan, B., Bharti, S., Ojha, A., Pandey, M., Gourav, S.S., Tyagi, B.S., Singh, G., 2013. Genetic variability, correlation coefficient and path analysis of some quantitative traits in bread wheat. Journal of Wheat Research 5(1), 24–29.

Hawker, J.S., Jenner, C.F., 1993. High temperature affects the activity of enzymes in the committed pathway of starch synthesis in developing wheat endosperm. Functional Plant Biology 20(2), 197–209.

Lobell, D.B., Sibley, A., Ortiz-Monasterio, J.I., 2012. Extreme heat effects on wheat senescence in India. Nature Climate Change 2, 186–189.

Mallor, C., Balcells, M., Mallor, F., Sales, E., 2011b. Genetic variation for bulb size, soluble solids content and pungency in the Spanish sweet onion variety Fuentes de Ebro response to selection for low pungency. Plant Breeding 130(1), 55–59.

Mishra, B., 2007. Challenges and preparedness for increasing wheat production in India. Journal of Wheat Research I(1 and 2), 1–12.

Naik, V.R., Biradar, S.S., Yadawad, A., Desai, S.A., Veeresha, B.A., 2015. Study of genetic variability parameters in bread wheat (*Triticum aestivum* L.) genotypes. Research Journal of Agriculture Sciences 6(1), 123–125.

Paliwal, R., Roder, M.S., Kumar, U., Srivastava, J.P., Joshi, A.K., 2012. QTL mapping of terminal heat tolerance in hexaploid wheat (*T. aestivum* L.) Theoretical Applied Genetics 125, 561–575

Panse, V.G., Sukhatme, P.V., 1957. Genetics and qualitative characters in relation to plant breeding. Indian Journal Genetics 17, 312–328.

Porta, B., Rivas, M., Gutierrez, L., Galvan, G.A., 2014. Variability, heritability, and correlations of agronomic traits in an onion landrace and derived S1 lines. Crop Breeding and Applied Biotechnology 14(1), 29–35.

Rane, J., Nagarajan, S., 2004. High temperature index-for field evaluation of heat tolerance in wheat varieties. Agricultural Systems 79(2), 243–255.

Reynolds, M.P., Nagarajan, S., Razzaque, M.A., Ageeb, O.A.A., 2001. Heat tolerance. In: Reynolds, M.P., Ortiz-Monasterio, J.I., McNab, A. (Eds.), Application of physiology in wheat breeding. Mexico DF CIMMYT, 124–135.

Sabit, Z., Yadav, B., Rai, P.K., 2017. Genetic variability, correlation and path analysis for yield and its components in f5 generation of bread wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry 6(4), 680–687.

Saidaiah, P., Pandravada, S.R., Geetha, A., 2021c. Per seperformance and variability in dwarf roselle germplasm for yield and yield attributing traits. International Journal of Bio-resource and Stress Management 12(4), 271–277.

Salman, S., Shah, J., Khan, J., Rehmat, K., Khan, U., Khan, I., 2014. Genetic variability studies in bread wheat (*Triticum aestivum* L.) accessions. Pakistan Journal of Agricultural Research 27(1), 1–7.

Semenov, M.A., 2009. Impacts of climate change on wheat in England and Wales. Journal of Royal Society Interface 6, 343–350.

Sikder, S., Paul, N.K., 2010. Evaluation of heat tolerance wheat cultivars through physiological approaches. Thai Journal of Agricultural Science 43(4), 251–258.
Singh, Y.P., Singh, S., Dhangrah, V.K., Mishra, T., 2021. Effects of sowing dates on yield and yield components of different varieties of wheat (*Triticum aestivum* L.) in Western Uttar Pradesh. International Journal of Economic Plants 8(4), 188–192.
Tripathi, G.P., Parde, N.S., Zate, D.K., Lal, G.M., 2015. Genetic variability and heritability studies on bread wheat (*Triticum aestivum* L.). International Journal of Plant Sciences (Muzaffarnagar) 10(1), 57–59.
Vavilov, N.I., 1951. Origin, variation, immunity and breeding of cultivated plants. Soil Science 72(6), 482.