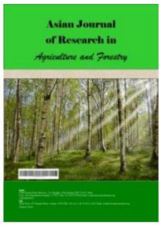

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Wheat Variety Improvement for Climate Resilience

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RRP, ST, RB, SRD and DP supported in cultivation and sampling. Author RRP designed the study. Authors RRP and SRD managed the literature search and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

High temperature stress unfavorably affects plant growth and reduces grain yield (GY). This study was conducted with an aim to identify the terminal heat tolerance of one hundred and two wheat genotypes with three checks. They were sown under normal (non-stress) and late (stress) conditions at Regional Agricultural Research Station (RARS), Tarahara; RARS, Nepalgunj and National Wheat Research Program (NWRP), Bhairahawa, Nepal. The trial was sown in Augmented design during 2014/15 winter season as a Nepal heat tolerance wheat screening nursery (NHTWSN). Grain yield, maturity, stress susceptibility and tolerant indices were estimated to assess the heat tolerance of the genotypes. Combined analysis among the tested wheat lines (102 new entries + 3 checks) showed that KACHU//KIRITATI/WBLL1 ((Heat tolerance index (HTI) = 1.78) possessed the highest level of heat tolerance, followed by SLVS /3/ CROC_1/ AE.SQUARROSA (224)// OPATA/5/ VEE/LIRA//BOW/3/BCN/4/KAUZ/6/ 2*KA/NAC//TRCH (HTI=1.57) while SUP152/VILLA JUAREZ F2009 (HTI=0.83) appeared to be the least heat tolerant. Correlation analysis showed that yield under stress environment had positive (r=0.083) and significant ($p<0.05$) association with that of non-stress environment. Grain yield (Kg/ha) under both environments had significant positive correlation with mean productivity (MP), geometric mean

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productivity (GMP) and HTI. Thirty seven wheat genotypes possessing heat tolerance will be considered in further heat tolerance trial and can also be used directly in varietal development and in the crossing program to breed more heat tolerant genotypes.

Keywords: Terminal heat tolerance; tolerant indices; correlation; heat stress.

1. INTRODUCTION

The average world temperature is reported to be escalating at a rate of 0.18°C every decade. Therefore, the possible impact of heat stress in wheat has recently drawn increasing attention to the wheat breeders [1]. Wheat (*Triticum aestivum*), a temperature sensitive crop, is affected by terminal heat stress on a significant wheat growing area in South Asia with majority being in Eastern Gangetic Plains [2]. As the cool period is shrinking in Nepal, India and other neighboring countries for wheat crop, the threat of terminal heat stress is increasing [2]. It is known that temperature above 30°C after anthesis decreases the rate of grain filling in wheat crop. Additionally, it was also predicted that an increase of 1°C temperature will result in 4-5 million tons (3-4%) of loss in wheat production [3].

The weather of Terai region in Nepal indicates that the winter is getting delayed and shorter while, warm summer days are becoming longer. This change could be unfavorable to wheat cultivation in the whole Indo Gangetic region including Nepal. Long duration wheat varieties are already suffering due to early heat during grain filling period. [4,5] reported that wheat production is affected by increased temperature in all over the world, including South Asian countries like India, Bangladesh and Nepal.

Wheat crop growth is highly dependent to temperature regimes and high temperature reduces the physiological maturity days as well as the grain filling duration, as a result reducing wheat yield [6]. Under such situations, wheat varieties with shorter maturity or fast grain filling rate would be desirable [4]. Therefore, breeding for high-temperature tolerant wheat lines having disease resistance and stay green trait that are capable of producing enough endosperm, bold grains within short grain filling duration should be developed for climate resilience. The present investigation was conducted to identify terminal heat tolerance in breeding lines of wheat.

2. MATERIALS AND METHODS

The experiments were conducted at Regional Agricultural Research Station, Tarahara, Regional Agricultural Research Station, Nepalgunj and National Wheat Research Program, Bhairahawa. The experimental material consisted of One hundred and two spring wheat lines and three checks (Gautam, Bhrikuti and Vijay). These lines were evaluated under two conditions: non stress (Normal sowing: November 20-25) and stress (Late sowing: December 15-20) using augmented design. The plot size was 4 rows of 2 m long and 25 cm row to row spacing. Yield and Yield attributing traits were recorded. Fertilizer and irrigation were applied as per recommendations [7].

2.1 Stress Indices

Yield and yield traits were recorded and the stress susceptibility and tolerance indices were calculated using the formulae [8]:

Stress Susceptibility index (SSI) = [1-(xs/xp)]/[1-(Xs/Xp)]

Tolerance (TOL)= xp-xs

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

Geometric Mean Productivity (GMP)=sqrt (xp*xs)

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

Where, xs is the trait value (grain yield kg/ha) of the genotype under stress and xp is the trait value of the genotype under non stress conditions. Xs and Xp are the mean values of the trait of all the genotypes under stress and non-stress conditions, respectively.

3. RESULTS AND DISCUSSION

3.1 Stress Indices for Wheat Genotypes

Among the tested 105 wheat genotypes including checks from NHTWSN, forty lines (thirty seven new wheat genotypes and three checks) are selected for heat tolerance (Table 1). When the data were pooled, the result among the tested

Table 1. Days to maturity, grain yield and stress indices for spring wheat genotypes

S. no.	Plot no.	Entry no.	Genotypes	DM	Yield (NS)	Yield (LS)	Difference	SSI	TOL	MP	GMP	HTI
1	99	81	KACHU//KIRITATI/WBLL1	115	4000	4000	0	0.00	0.00	4000.00	4000.00	1.78
2	87	46	SLVS/3/CROC_1/AE.SQUARROSA (224)//OPATA/5/VEE/LIRA//BOW/3/BCN/4/KAUZ/6/2 *KA/ NAC//TRCH	117	4000	3500	500	0.13	500.00	3750.00	3741.66	1.56
3	62	16	FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4 /FRET2/TUKURU//FRET2	117	3500	3500	0	0.00	0.00	3500.00	3500.00	1.36
4	28	80	KACHU #1//WBLL1*2/KUKUNA	116	3500	3500	0	0.00	0.00	3500.00	3500.00	1.36
5	73	98	BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	118	3500	3500	0	0.00	0.00	3500.00	3500.00	1.36
6	15	101	CHIBIA//PRLII/CM65531/3/SW89.5181/KAUZ/4/KIRI TATI//ATTILA*2/PASTOR/5/PFAU/WEAVER*2//TRA NSFER#12,P88.272.2	115	3500	3500	0	0.00	0.00	3500.00	3500.00	1.36
7	54	27	KINDE/4/CMH75A.66//H567.71/5*PVN/3/SERI	114	4000	3000	1000	0.25	1000.00	3500.00	3464.10	1.33
8	113	86	FRNCLN/3/GUAM92//PSN/BOW/4/PAURAQ	116	4000	3000	1000	0.25	1000.00	3500.00	3464.10	1.33
9	120	107	Bhrikuti (Check)	117	4000	3000	1000	0.25	1000.00	3500.00	3464.10	1.33
10	74	120	Gautam (Check)	115	4000	3000	1000	0.25	1000.00	3500.00	3464.10	1.33
11	13	1	BL4635	121	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
12	93	52	METSO/ER2000/5/2*SERI*3//RL6010/4*YR/3/PAST OR/4/ BAV92	119	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
13	29	63	MON/IMU//ALD/PVN/3/BORL95/4/OASIS/2*BORL95 /5/ 2*SKAUZ/BAV92	118	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
14	59	64	MON/IMU//ALD/PVN/3/BORL95/4/OASIS/2*BORL95 /5/ 2*SKAUZ/BAV92	117	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
15	119	69	METSO/ER2000//PBW343*2/KUKUNA	118	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
16	69	79	FRET2/TUKURU//FRET2/3/MUNAL #1	119	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
17	32	89	PBW65/2*PASTOR/3/KIRITATI//PBW65/2*SERI.1B/ 4/ DANPHE #1	118	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
18	104	113	Vijay (Check)	116	3500	3000	500	0.14	500.00	3250.00	3240.37	1.17
19	26	44	METSO/ER2000/5/2*SERI*3//RL6010/4*YR/3/PAST OR/4/ BAV92	118	4000	2500	1500	0.38	1500.00	3250.00	3162.28	1.11
20	22	72	WBLL1*2/CHAPIO*2//MURGA	116	4000	2500	1500	0.38	1500.00	3250.00	3162.28	1.11
21	88	6	BECARD//ND643/2*WBLL1	115	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
22	68	11	KA/NAC//TRCH/3/DANPHE #1	115	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00

S. no.	Plot no.	Entry no.	Genotypes	DM	Yield (NS)	Yield (LS)	Difference	SSI	TOL	MP	GMP	HTI
23	105	23	T.DICOCCON CI9309/AE.SQUARROSA (409)//MUTUS/3/2*MUTUS	117	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
24	17	58	PBW343*2/KUKUNA/3/PFAU/WEAVER//KIRITATI/5/ CHEN/AE.SQ//2*OPATA/3/BAV92/4/JARU	118	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
25	36	61	KA/NAC//TRCH/3/VORB	118	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
26	20	62	KA/NAC//TRCH/3/DANPHE #1	115	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
27	77	66	METSO/ER2000/3/PASTOR//HXL7573/2*BAU	118	4500	2000	2500	0.56	2500.00	3250.00	3000.00	1.00
28	12	85	INQALAB 91*2/KUKUNA*2//HUIRIVIS #1	115	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
29	117	88	CHIBIA//PRLII/CM65531/3/FISCAL/4/ND643/2*WBL L1	116	3000	3000	0	0.00	0.00	3000.00	3000.00	1.00
30	94	39	PFAU/MILAN/5/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/VEE#7/BOW/4/PASTOR/6/2*BAVIS #1	116	3500	2500	1000	0.29	1000.00	3000.00	2958.04	0.97
31	30	78	CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL #1	116	3500	2500	1000	0.29	1000.00	3000.00	2958.04	0.97
32	65	90	KACHU/BECARD//WBLL1*2/BRAMBLING	117	3500	2500	1000	0.29	1000.00	3000.00	2958.04	0.97
33	46	102	KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92*2/5/KIRITAT I	118	3500	2500	1000	0.29	1000.00	3000.00	2958.04	0.97
34	102	21	BAJ #1/AKURI	117	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
35	25	25	PAURAQ//AG/5*NAC	116	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
36	24	28	CHYAK//RL6043/3*GEN	114	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
37	71	31	ND643/2*WBLL1/4/WHEAR/KUKUNA/3/C80.1/3*BA TAVIA //2*WBLL1	117	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
38	52	45	QING HAIBEI/WBLL1//BRBT2/3/PAURAQ	121	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
39	64	82	BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	117	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83
40	51	87	SUP152/VILLA JUAREZ F2009	115	3000	2500	500	0.17	500.00	2750.00	2738.61	0.83

NS=Normal sowing and LS=Late sowing

Table 2. Correlation coefficients of yield with stress indices under late and normal conditions, 2014/15

Variables	Yield (NS)	Yield (LS)	Difference	SSI	TOL	MP	GMP	HTI
Yield (LS)	0.083*	1						
Difference	0.68**	-0.67	1					
SSI	0.69**	-0.57	0.92**	1				
TOL	0.68**	-0.67	1**	0.92**	1			
MP	0.74**	0.73**	0.02	0.09	0.02	1		
GMP	0.68**	0.77**	-0.06	0.05	-0.06	0.98**	1	
HTI	0.69**	0.75**	-0.04	0.07	-0.04	0.98**	0.99**	1

*Note: * Significant at P<0.05 and ** at P<0.01* wheat lines showed that KACHU//KIRITATI/WBLL1 (HTI=1.78) possessed the highest level of tolerance, followed by SLVS /3/ CROC_1/ AE.SQUARROSA (224)// OPATA/5/ VEE/LIRA //BOW/3/BCN/4/KAUZ/6/ 2*KA/NAC//TRCH (HTI=1.57). The wheat line KACHU//KIRITATI/WBLL1 produced 4000 Kg/ha mean yield under normal and late sown condition. The TOL of these lines was 0, which was least among the tested new wheat genotypes (Table 1). This indicated that KACHU//KIRITATI/WBLL1 and SLVS/3/ CROC_1/AE.SQUARROSA (224)// OPATA/5/ VEE/LIRA//BOW /3/BCN/4/ KAUZ/6/ 2*KA/ NAC//TRCH appeared to be promising for terminal heat tolerance. Further, molecular analysis would help to identify the genetic information for the crop improvement. The meteorological information revealed that the temperature during late flowering to maturity period exceeded 28^0C in all the locations, which would have affected the grain yield. Despite this high temperature the two lines KACHU// KIRITATI/WBLL1 and SLVS/3/ CROC_1/ AE.SQUARROSA (224)//OPATA/ 5/ VEE/LIRA// BOW /3/BCN/4/ KAUZ/6/ 2*KA/ NAC//TRCH performed well in all these locations. Hence, these two lines are suggested to be used in the crossing program to breed more heat tolerant genotypes.

3.2 Correlation among Traits

Yield under stress condition was positively correlated (r=0.083) with significant association ($p<0.05$) to stress environment. Grain yield (Kg/ha) had significant positive correlation with MP, GMP and HTI in both conditions, while non-significant correlation with SSI and TOL in late sown condition (Table 2). These results are in conformity with those of [9] in durum wheat, [10,11] in synthetic wheat lines.

4. CONCLUSION

High temperatures are posing threats in wheat production. So, the wheat breeders are putting their efforts to improve wheat genotypes for stress prone environments particularly in view of predictions of changing climate. There is a need to develop and/or identify genotypes that perform better under both stress and non-stress environments. The stress tolerance indices like HTI, MP and GMP can be used as selection criteria to identify these genotypes. In the present study, using these indices genotypes KACHU//KIRITATI/WBLL1 (HTI=1.78) possessed the highest level of tolerance, followed by SLVS/3/CROC_1/ AE. SQUARROSA(224) // OPATA /5/ VEE/ LIRA// BOW/3/BCN/4/KAUZ/6/2*KA/ NAC// TRCH (HTI=1.57). Overall 37 wheat genotypes (ignoring the checks) with heat tolerance are identified as sources for heat tolerance. These genotypes will be placed under national systematic yield, pathological and agronomical trials for further wheat improvement program.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. The research was funded by Nepal Agricultural Research Council and the germplasms were received from the National Wheat Research Program and International Maize and Wheat Improvement Centre (CIMMYT).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ni Z, Li H, Zhao Y, Peng H, Hu Z, Xin M, Sun Q. Genetic improvement of heat tolerance in wheat: Recent progress in understanding the underlying molecular mechanisms. The Crop Journal. 2017;6: 32–41.
   DOI: 10.1016/j.cj.2017.09.005
2. Joshi AK, B Mishra, R Chatrath, GO Ferrara and RP Singh. Wheat improvement in India: Present status, emerging challenges and future prospects. Euphytica. 2007;157:431–446.
3. Wardlaw IF, IA Dawson, P Munibi. The tolerance of wheat to high temperatures during reproductive growth: II Grain development. Australian Journal of Agricultural Research. 1989;40:15-24.
4. Mondal S, Singh RP, Crossa J, Huerta-Espino J, Sharma I, Chatrath R, Singhd GP, Sohu VS, Mavi GS, Sukaru VSP, Kalappanavarg IK, Mishra VK, Hussaini M, Gautam NR, Uddin J, Barma NCD, Hakim

A, Joshi AK. Earliness in wheat: A key to adaptation under terminal and continualhigh temperature stress in South Asia. Field Crops Resesearch. 2013;151: 19–26.

5. Hossain A, Farhad M, Jahan MS, Mahboob M, Timsina J, Silva JA. Biplot yield analysis of heat-tolerant spring wheat genotypes (*Triticum aestivum* L.) in multiple growing environments. Open Agriculture. 2018;3(1):404-413. DOI:https://doi.org/10.1515/opag-2018-0045
6. Hossain A, Silva JA, Lozovskaya MV, Zvolinsky VP. High temperature combined with drought affect rainfed spring wheat and barley in South-Eastern Russia: I. Phenology and growth. Saudi J Biol Sci. 2012;9(4):473-487. DOI: 10.1016/j.sjbs.2012.07.005
7. Gautam NR, Bhatta MR, Upadhyaya SR, Thapa DB, Tripathi MP, Chaudhary HK, Pokhrel DN, Yadav GP, Ghimire BR, Chaudhary DP, Paudel RP, Chaudary TN. Development of suitable wheat varieties for increasing wheat productivity in hills of Nepal. Proceedings of 28th National Winter Crops Workshop. 2011;212-219.
8. Jha UC, Jha R, Singh NP, Shil S, Kole PC. Heat tolerance indices and their role in selection of heat stress tolerant chickpea (*Cicer arietinum*) genotypes. Indian Journal of Agricultural Sciences. 2017;88(2):260-267.
9. Boussen H, Salem MB, Slama A, Mallek-Maalej E, Rezgui S. Evaluation of drought tolerance indices in durum wheat recombinant inbred lines. In: Lopez-Francos A. (Comp.), Lopez-Francos A. (Collab.). Economics of drought and drought preparedness in a climate change context. Zaragoza: CIHEAM/FAO/ICARDA/GDAR/CEIGRAM/ MARM. Options Méditerranéennes Série A, Séminaires Méditerranéennes. 201;95:79-83.
10. Sareen S, Tyagi BS, Tiwari V, Sharma I. Response estimation of wheat synthetic lines to terminal heat stress using stress indices. Journal of Agricultural Science. 2012;4(10):97-104.
11. Puri RR, Gautam NR, Joshi AK. Exploring stress tolerance indices to identify terminal heat tolerance in spring wheat in Nepal. Journal of Wheat Research. 2015.7(1):13-17.

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