

Responses of bread wheat genotypes to heat stress at different developmental stages

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KC-4512 KC-4511
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KC-4511 % % % KC-7168 KC-7732
KC-7168 %

(Rawson, 1993)

(*Triticum aestivum* L.)

(Li *et al.*, 2002)

Hunt *et al.*, 1991; Stone and Nicolas, 1995;)

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(Gibson and Paulsen, 1999)

(Stone and Nicolas, 1994)

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(Reynolds *et al.*, 2001)

(NARSs³)

(Midmore *et al.*, 1984)

(Berry and Bjorkam, 1980)

(Anon, 1995)

(Alkhatib and Paulsen, 1984)

(Jenner, 1991)

(Warrington *et al.*, 1977)

(Kirby and Appleyard, 1984)

(Alkhatib and Paulsen, 1984)

(Garcia Del Moral *et al.*, 1991)

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(Gibson and Paulsen, 1999)

(Kirby and Appleyard, 1984)

(Fokar *et al.*, 1998)

1- Continual heat stress
3- National Research Agricultural Sytems
5- Apical meristem

2- Terminal heat stress
4- Double ridge

Dupont and Altenbach, 2003)

(Reynolds *et al.*, 1994)

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(Reynolds *et al.*, 2001)

(Alkhatib and Paulsen, 1984)

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(Ferris *et al.*, 1998)

(Wardlaw *et al.*, 2002)

Stone and Nicolas, 1995; Stone and stone, 1998a;)

Stone and stone, 1998b; Corbellini *et al.*, 1997;

(Gibson and Paulsen, 1999

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(Tashiro and Wardlaw, 1990; Wardlaw *et al.*, 1995)

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Blumenthal *et al.*, 1995; Stone and Nicolas, 1994;)

Stone and Nicolas, 1995; Stone and stone, 1998a;

(Stone and stone, 1998b

(CIMMYT¹)

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Stone and Nicolas, 1994;)

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(Stone and Nicolas 1995; Stone and stone, 1998a

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(Stone and Nicolas, 1995; Stone and stone, 1998a)

(Gibson and Paulsen, 1999

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1- International Maize and Wheat Improvement Center = CIMMYT

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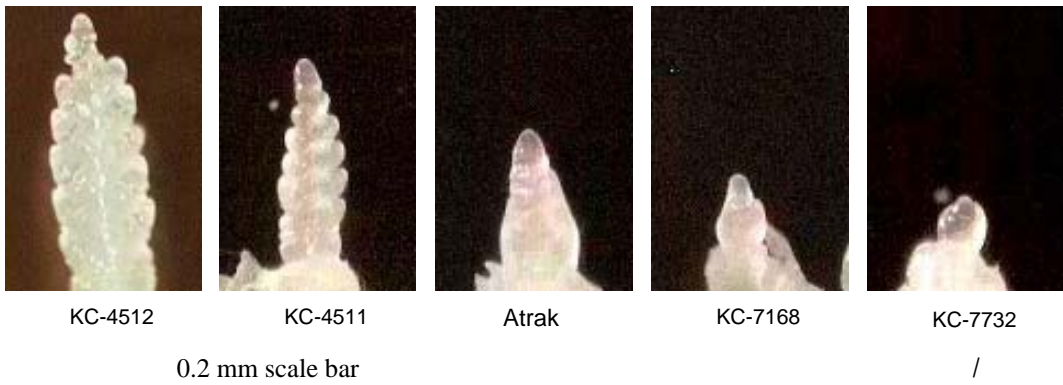


Fig. 2. Variation of wheat genotypes for the rate of development in 30 days after emergence

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Table 1. Combined analysis of variance for yield related traits under normal and heat stress of 35°C at double ridge stage

Trait	Source of variation	Degree of freedom	Mean square	F	Coefficient of variation
Vegetative duration	Environment (E)	1	0.13	0.12	2
	Rep./ E	4	1.03		
	Genotype (G)	4	561.2	502**	
	G * E	4	1.63	1.46	
	E	16	1.12		
Reproductive duration	Environment (E)	1	5.63	3.25	2.43
	Rep./ E	4	1.73		
	Genotype (G)	4	398.8	105.6**	
	G * E	4	20.2	536**	
	E	16	3.78		
Days to flowering	Environment (E)	1	2.13	2	1.84
	Rep./ E	4	1.06		
	Genotype (G)	4	528.4	304.9**	
	G * E	4	16.21	6.39**	
	E	16	1.73		
Spikelets per spike	Environment (E)	1	0.3	0.13	6
	Rep./ E	4	2.27		
	Genotype (G)	4	26.2	32.41**	
	G * E	4	4.47	5.53**	
	E	16	0.81		
Grains per spike	Environment (E)	1	4.03	0.19	9.6
	Rep./ E	4	20.87		
	Genotype (G)	4	141.7	25.9**	
	G * E	4	27.5	6.6**	
	E	16	4.2		
Single grain weight	Environment (E)	1	0.09	30**	13
	Rep./ E	4	0.003		
	Genotype (G)	4	0.309	18.15**	
	G * E	4	0.042	2.5	
	E	16	0.017		
Grain weight per spike	Environment (E)	1	65.3	6.66**	11
	Rep./ E	4	9.81		
	Genotype (G)	4	63.4	7**	
	G * E	4	7.3	0.81	
	E	16	9.06		
Plant height	Environment (E)	1	85	4.27*	7.4
	Rep./ E	4	19.9		
	Genotype (G)	4	1445.1	57.6**	
	G * E	4	63.2	2.52	
	E	16	25.08		

* and **: Significant at 0.05 and 0.01 probability levels, respectively.

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(Stone and Nicolas, 1995)

(Owen, 1971)

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Table 2- Mean of yield related traits under normal and heat stress of 35°C conditions at double ridge stage

Trait	Growth condition	Genotype					Mean
		KC-7732	KC-7168	KC-4512	KC-4511	Atrak	
Vegetative duration ()	Normal	45.3	41	25	25.3	32	33.72
	Stress	47.3	40.7	24.7	24	30	33.34
Reproductive duration ()	Normal	75	77	61	57	64.5	66.9
	Stress	77	80	59	57	64	67.4
Spikelets per spike	Normal	13	16	14	13	18	14.8
	Stress	11	15	15	15	17	14.6
Grains per spike	Normal	20	20	21	20	35	23.2
	Stress	18	19	24	23	27*	22.2
Grain weight per spike (mg)	Normal	800.8	540	610	630	750	666.16
	Stress	730.2	510	570	440*	610	572.04
Days to spiking (day) ()	Normal	85	71	66	64	68	70.8
	Stress	88*	76*	66	64	64*	71.6
Plant height (cm) ()	Normal	85	85	56	63	55	68.8
	Stress	76*	87	57	62	50	66.4

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*: Significant at 0.05 probability level, based on Duncan Multiple Range Test, between two environments

(Lucas, 1971)

(Rahman and Wilson, 1978)

(Rahman and Wilson, 1978)

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Table 3. Combined analysis of variance for yield related traits under heat stress at anthesis stage

Trait	Source of variation	DF	Mean square	F	CV
Grains per spike	Environment (E)	1	3307	67.9**	13
	Rep./ E	4	48.7		
	Genotype (G)	4	90.6	4.81**	
	G * E	4	167	8.91**	
	E	16	18.8		
Single grain weight	Environment (E)	1	4	13.3**	16
	Rep./ E	4	0.3		
	Genotype (G)	4	0.03	0.47	
	G * E	4	0.2	2.38	
	E	16	0.08		
Grain weight per spike	Environment (E)	1	2780	146.3**	11
	Rep./ E	4	19		
	Genotype (G)	4	43	6.26**	
	G * E	4	76	11.09**	
	E	16	7		
Grain filling duration	Environment (E)	1	2066	386.8**	3.5
	Rep./ E	4	5.3		
	Genotype (G)	4	103	3.5*	
	G * E	4	304	10**	
	E	16	29.5		

* and **: Significant at 0.05 and 0.01 probability levels, respectively

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(Ferris *et al.*, 1998)

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Table 4. Mean of yield related traits under normal and heat stress of 40°C conditions at anthesis stage

Trait	Growth condition	Genotype					Mean
		KC-7732	KC-7168	KC-4512	KC-4511	Atrak	
Grains per spike	Normal	20	21.7	20.7	16.3	39	23.5
	Stress	0	0	5	6.7	1	2.5
	Reduction percent	100	100	76	59	98	87
Single grain weight (mg)	Normal	36.9	28.2	26.2	28.1	24.5	28.8
	Stress	0	0	26.4	11.8	39.5	15.5
	Reduction percent	100	100	0	58	0	52
Grain weight per spike (mg)	Normal	740	610	550	560	950	682
	Stress	0	0	130	80	10	44
	Reduction percent	100	100	76	83	99	92
Grain filling duration (days)	Normal	55	57	39	42	44	47
	Stress	19	31	32	26	34	28
	Reduction percent	65	46	12	48	23	39

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(Tashiro and Wardlaw, 1990)

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Stone and Nicolas,1995;)

(Gibson and Paulson, 1999

KC-4511

(Corbelini *et al.*, 1997)

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(Stone and Nicolas, 1995)

(Tashiro and Wardlaw, 1990)

(Stone and Nicolas, 1995)

(Stone and Stone, 1998b)

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(Gibson and Paulsen,1999)

(Stone and Nicolas, 1995)

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(Stone and Nicolas, 1994)

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(KC-7168)
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(Gibson and Paulsen, 1999)

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Table 5. Combined analysis of variance for yield related traits under heat stress of 40°C at grain filling stage

Trait	Source of variation	DF	Mean square	F	CV
Grains per spike	Environment (E)	1	12.03	0.94	12
	Rep./ E	4	12.77		
	Genotype (G)	4	565.2	23.78**	
	G * E	4	32.6	1.37	
	E	16	23.8		
Single grain weight	Environment (E)	1	1.48	246.6**	9
	Rep./ E	4	0.006		
	Genotype (G)	4	0.135	9.94**	
	G * E	4	0.005	0.814	
	E	16	0.014		
Grain weight per spike	Environment (E)	1	0.744	186**	14
	Rep./ E	4	0.004		
	Genotype (G)	4	0.104	6.56**	
	G * E	4	0.036	0.109	
	E	16	0.016		
Grain filling duration	Environment (E)	1	2358	649.6**	6
	Rep./ E	4	3.63		
	Genotype (G)	4	136.7	10.51**	
	G * E	4	224.2	17.24**	
	E	16	13		

* and **: Significant at 0.05 and 0.01 probability levels, respectively

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Table 6. Mean of yield related traits under normal and heat stress of 40°C at grain filling stage

Trait	Growth condition	Genotype					Mean
		KC-7732	KC-7168	KC-4512	KC-4511	Atrak	
Grains per spike	Normal	20	21.7	20.7	16.3	39	23.5
	Stress	15	19.7	22	19	43	23.7
	Reduction percent	25	0	0	9	0	6.8
Single grain weight (mg)	Normal	36.9	28.2	26.2	28.1	24.5	28.8
	Stress	22.7	11.1	14.2	14.8	10.7	14.7
	Reduction percent	38	61	46	47	56	49.6
Grain weight per spike (mg)	Normal	740	610	550	560	950	682
	Stress	340	220	310	340	470	336
	Reduction percent	54	64	44	39	51	50.4
Grain filling duration (days)	Normal	55	57	39	42	44	47
	Stress	31	20	27	31	27	27
	Reduction percent	44	65	31	26	39	41

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(Warrington *et al.*, 1977)

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Table 7. Stepwise regression analysis for spike yield under treatment of heat stress of 35°C at double ridge, anthesis and grain filling stages

growth condition			R ²
Heat stress at double ridge stage	Fierst step	Y = 0.156 + 16.99 (SGW)	0.647
	Second step	Y = - 0.566 + 21.76 (SGW) + 0.025 (GNS)	0.971
Heat stress at anthesis stage	Fierst step	Y = 0.007 + 0.017 (GNS)	0.817
	Second step	Y = - 0.001 + 0.015 (GNS) + 2.28 (SGW)	0.880
Heat stress at grain filling stage	Fierst step	Y = 129 + 0.008 (GNS)	0.571
	Second step	Y = -0.19 + 0.12 (GNS) + 16.19 (SGW)	0.960

SGW = GNS = Y =

Y = Spike dry weight, GNS= No. of grain spike⁻¹, SGW = Single grain weight

Dupont and Altenbach,)

(2003)

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Responses of wheat genotypes to heat stress at different developmental stages

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ABSTRACT

Alikhani, M., J. Mozaffari, F. Darvish and Y. Arshad. 2007. Responses of wheat genotypes to heat stress at different developmental stages. Iranian Journal of Crop Sciences. 9(1): 45-59.

Heat stress during crop developmental stages, particularly in reproductive phase, is considered a major factor reducing wheat yield in tropical and subtropical regions of the world. The effect of heat shock on yield components of five selected spring wheat genotypes was studied. The heat shock of 35°C and 40°C were imposed during double ridge, anthesis and grain filling stages under controlled environments (greenhouse and growth chamber). Genotypes responded differently to heat stress during all three stages. All genotypes except genotype KC-4511 were tolerant to heat stress of 35°C at double ridge stage of the shoot apex, while all genotypes examined were killed by the heat shock of 40°C at this stage. Heat shock of 40°C at anthesis dramatically reduced the number of grains per spike in genotypes Atrak, KC-4511 and KC-4512, while no kernel was produced in genotypes KC-7168 and KC-7732. Heat shock of 40°C at grain filling stage caused serious loss of grain weight and spike weight; however, it didn't have any significant effect on the number of grains per spike. Grain weight was reduced by 38% in genotype KC-7732 and 61% in genotype KC-7168. Spike weight reduction ranged from 39% in genotype KC-4511 to 64% in genotype KC-7168. According to the results of this research short periods of heat shock which may occur in wheat growing areas of Iran, could substantially reduce the wheat yield. Results reported here implies that in a wheat breeding program for heat tolerance, necessary attention should also be paid to genotypic variation for heat tolerance at anthesis stage, in addition to the grain filling stage, because heat stress, usually, takes place from anthesis stage in Iran.

Key words: Heat stress, Wheat development, Yield components, Heat tolerance, Genotypic variation.

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