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Genetic study of attributes impacting development of source and sink in wheat under high temperature condition

H. R. PANKUTA[1], S. ACHARYA[2] and J. B. PATEL[1]

Department of Plant Breeding and Genetics, C. P. College of Agriculture
S. D. Agricultural University, Sardarkrushinagar-385 506 (Gujarat)

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ABSTRACT

High temperatures affects development of both source and sink attributes and conspicuous yield impacts in wheat. The genetics of fourteen attributes impacting source, sink and quality was ascertained using fourteen parents and their ninety-one cross combinations that were evaluated under high temperature condition created by late sowing during rabi 2005-06 at Sardarkrushinagar (Gujarat). There was considerable genetic variation among the parents and hybrids for all the traits. The higher yielding genotypes exhibited better source development with concomitant development of sink and deployment of source to sink. On the basis of mean performance, GW 344 x KYZ 9636 followed by KYZ 9712 x GW 323 and KYZ 9712 x GW 337 were the best cross combinations for grain yield per plant as also for sink development (number of spikelets per spike) and harvest index that is indicative of strong carbohydrate carriage chain. There were significant differences among the parents and crosses for combining ability. Lesser ratio of σ gca/σsca indicated greater role of non-additive genetic component in the inheritance of all the traits impacting source and sink development under high temperature. Among the good general combiners, GW 323 exhibited good general combining ability for source and sink impacting attributes. Among the different good specific combinations, KYZ 9712 x GW 323 involved both the parents with high gca and may be exploited to select better transgressive segregants. Considering mean performance, general and specific combining ability, the parents GW 323, ABV 2002-120 and KYZ 9712 and cross combinations like GW 344 x KYZ 9636, GW 344 x GW 337, KO 123 x Inqualab 91 and KYZ 9712 x KYZ 9636 may be exploited for development of better source, sink and quality attributes under high temperature conditions. Further crosses like GW 344 x GW 337 and KO 123 x Inqualab 91 can be exploited for the amelioration of source development that is so precarious and affected most under high temperature growing conditions in wheat. Similarly KYZ 9712 x KYZ 9636 can be exploited for improvement of sink.

Key words : Combining ability, source, sink, wheat

Wheat is a crop of temperate climate. Growing wheat most parts of India, in general, and Gujarat in articular is hemmed in short and mild winter with gh temperatures rigors on either end of the crop eason that affects both source and sink evelopment putting a production ceiling irrespective timely, late or early sowing conditions. There hardly eeds any emphasis on the impact of imminent rise global temperatures on wheat production that has ready begun to take food off the world's table and the forecast is still frightening with 51% decline in India's wheat-growing land, potentially leaving hundreds of millions hungry. The best hope lies in breeding heat-resistant varieties by engineering characters related to source and sink development. Lately broad leaved, long ear types and stay green habits called "buitre" have been used to expand the sink to avail the maximum advantage of developed source but have not succeeded mainly due to poor mobilization of source to the sink. Therefore, for precise success of the breeding efforts, information on genetics of component characters conditioning source and sink need to be ascertained under high temperature condition.

gril. Officer, Department of Agriculture, Government of Gujarat, roda, [2] Research Scientist, Centre of Excellence for Research on heat, Vijapur, [3]Asstt. Research Scientist, Potato Research ation, Deesa

MATERIALS AND METHODS

Fourteen selfed homozygous parents representing gamut of genetic oddities were selected from the available genetic resources at the Main Wheat Research Station, S. D. Agricultural University, Vijapur, Gujarat on the basis of components of source [leaf characteristics like width, length, stay green habit and number etc.] and sink development [ear size, number of spikelets, grain size and plumpness etc.]. The selected lines were crossed as in diallel fashion, excluding reciprocals. Ninety-one F_1 crosses were developed during rabi 2004-05. Self-seeds of parental lines were also obtained simultaneously. The complete set of 105 entries comprising 14 parents and 91 F_1's were planted for evaluation in Randomized Block Design (RBD) with three replications in high temperature environment created by late sowing on 29th November during rabi 2005-06. Each entry was accommodated in a single row plot of 1 meter length with inter and intra row spacing of 30 cm and 5 cm, respectively. The observations were recorded on 1000-grain weight, grain yield per plant, leaf area at spike initiation, leaf area at maturity, flag leaf area, chlorophyll content, spikelets per spike, spikelet length, harvest index, leaf area index, leaf area ratio, protein content, sedimentation value and hectoliter weight. The data were subjected to analysis of variance as per Panse and Sukhatme (1978). The combining ability analysis was done as per the method of Griffing's, (1956) Model I (Fixed model), Method II.

RESULTS AND DISCUSSION

The analysis of variance for experimental design revealed considerable genetic variation among the parents and hybrids for all the traits under study (Table 1). Mean values of various traits that affected source and sink evinced that the performance of crosses was better than the parental lines. ABV 2002-120 was the best yielding genotype (15.66g) followed by GW 323 (13.57g) and Raj 4038 (13.24g). The perusal of the characters that affected source and sink indicated that these higher yielding genotypes exhibited better source development as indicated by higher chlorophyll content, leaf area at maturity, leaf area index, leaf area ratio and flag leaf area with concomitant development of sink (spikelets/spike) and deployment of source to sink (100-grain weight and harvest index). On the basis of mean performance, GW 344 x KYZ 9636 (18.78g) followed by KYZ 9712 x GW 323 (16.36g) and KYZ 9712 x GW 337 (15.02g) were the best cross combinations for grain yield per plant.

Table 1 ANOVA of various characters impacting source, sink and quality attributes in wheat under high temperature condition

Source	d.f.	Characters													
		Chloro-phyll content	Leaf area at spike initiation (cm^2)	Leaf area at maturity (cm^2)	Leaf area index	Leaf area ratio	Flag leaf area (cm^2)	No. Spikelet per spike	Spike length (cm)	1000-grain weight (g)	Harvest index (%)	Protein content (%)	Sedim-entation value	Hecto-liter weight (kg/hl)	Grain yield/ plant (g)
Replication	2	12.09	18.81	64.44	0.19	0.005	104.69	0.847	0.25	0.43	0.11	0.36	1.97	27.89	2.25
Genotype	104	331.4**	35998.6**	112452.9**	235.6**	4.99**	206.64**	12.69**	7.71**	136.82**	144.22**	7.37**	55.19**	122.24**	22.0**
Parents	13	2951.31**	314861.4**	1164312.4**	1707.5**	51.75**	1068.21**	432.22**	127.08**	671.59**	1514.1**	148.45**	1130.84**	924.8**	259.9**
Hybrids	90	30303.8**	3354655.9**	10521551.0**	215.87**	467.7**	20366.0**	908.76**	644.4**	13389.6**	13386.1**	599.37**	4472.06**	11295.1**	1998.41**
Parents vs hybrids	1	1213.87**	74342.08**	9173.90**	1217.44**	0.4124**	57.32**	0.420	30.62**	162.1**	1.16**	18.90**	136.9**	493.2**	30.45**
Error	208	7013.69	85671.72	152708.3	919.92	6.79	3623.0	379.5	38.18	390.79	6904.67	49.78	1177.71	3763.0	378.21

** Significant at p = 0.05 and 0.01 level of significance, respectively

These crosses were better for sink development (number of spikelets per spike) and harvest index that is indicative of strong carbohydrate carriage chain.

The analysis of variance for combining ability indicated that the mean squares due to general combining ability and specific combining ability effects were significant for all the traits under study (Table 2). This indicated that there were significant differences among the parents for combining ability. Similarly different crosses also differed in combing ability. The ratio of σ^2 gca/σ^2 sca was less then one for all the characters, which indicated greater role of non-additive genetic component in the inheritance of all the traits impacting source and sink development under high temperature conditions at the terminal end of wheat crop. These results are in consonance with the findings of Manon and Sharma (1995), Mishra *et al.*, (1996), Katiyar (1998) and Sharma *et al.*,(2003) who have also reported predominance of dominance genes in late planting conditions.

Combining ability effects have been successfully employed for identifying superior parents and their utilization in further breeding programme. The estimates of gca effects in the present study showed no consistent pattern for all the characters. Consequently it was arduous to pick one good general combiner for all the characters. The gca effects of the parents revealed that seven parental lines *viz.*, ABV 2002-120 (1.48), KYZ 9712 (1.10), GW 337 (0.86), GW 323 (0.63), Inqualab 91 (0.52), KO 123 (0.45) and Raj 4038 (0.36) exhibited the positive and significant general combining ability effects for grain yield per plants. Thus, these lines were identified as good general combiners for grain yield per plant (Table 3). Among these, GW 323 exhibited good general combining ability for source developing attributes (leaf area at spike initiation, leaf area at maturity, leaf area index, leaf area ratio and flag leaf area); sink attributes (no. of spikelets per spike and spike length) and good carriage to the sink (1000-grain weight and harvest index). Similarly, GW 337 was good general combiner for source development attributes (leaf area at spike initiation, leaf area at maturity, chlorophyll content, leaf area ratio and flag leaf area), good carriage to the sink (1000-grain weight) and quality attributes (sedimentation value and hectoliter weight); KYZ 9712 for source development attributes (leaf area at spike initiation, leaf area at maturity, leaf area index, leaf area ratio and flag leaf area) and sink attributes (number of spikelet per spike and spike length); ABV 2002-120 for leaf area at maturity, chlorophyll content and leaf area ratio, spike length, 1000-seed weight,

Table 2 ANOVA for gca and sca for different characters impacting source, sink and quality attributes in wheat under high temperature condition

Source	d.f.	Characters													
		Chloro-phyll content	Leaf area at spike initiation (cm2)	Leaf area at maturity (cm^2)	Leaf area index	Leaf area ratio	Flag leaf area (cm^2)	No. Spikelet per spike	Spike length (cm)	1000-grain weight (g)	Harvest index (%)	Protein content (%)	Sedim-entation value	Hecto-liter weight (kg/hl)	Grain yield/ plant (g)
gca	13	134.20**	14674.2**	79802.4**	194.05**	3.54**	135.22**	16.87**	0.72*	80.01**	91.96**	2.99**	17.13**	59.79**	12.24**
sca	90	107.00**	11617.404**	31435.4**	62.06**	1.39**	59.40**	2.5**	21.26**	40.69**	41.80**	2.35**	18.57**	38.02**	6.63**
Error	208	11.24	137.28	244.63	1.47	0.01	5.80	0.55	0.06	0.62	11.06	0.07	1.88	6.03	0.60
σ gca		1.7	191.04	3022.75	0.195	0.134	4.738	0.898	0.65	2.45	3.13	0.038	0.09	1.36	0.35
σ sca		95.76	11480.16	31393.77	60.59	1.38	53.6	1.95	1.20	40.07	30.74	2.31	16.69	31.99	6.03
σgca/ σsca		0.017	0.016	0.096	0.003	0.097	0.088	0.46	0.54	0.06	0.1	0.016	0.005	0.042	0.06

** Significant at p = 0.05 and 0.01 level of significance, respectively

harvest index and sedimentation value; Raj 4038 for chlorophyll content, leaf area at spike initiation, leaf area at maturity, protein content and sedimentation value; KO 123 for leaf area at spike initiation, leaf area at maturity and leaf area ratio besides hectoliter weight; and Inqualab 91 for leaf area at maturity, leaf area index, and leaf area ratio in addition to spike length and protein content.

The estimates of gca effects were compared with the per se performance of parents, it was observed that parents with high gca effects also evinced excellent per se performance. Thus, the choice of parents on the basis of *per se* performance and gca effects may be very effective for enhancing grain yield under high temperature growing condition at grain filling and development stage wheat.

The estimates of specific combining ability revealed that 25 hybrids exhibited significant positive sca effects for grain yield per plant. Cross GW 344 x KZY 9636 (10.72) followed by KYZ 9712 x GW 323 (5.09) and PHR 1010 x Raj 4038 (3.92) having high sca effects for grain yield and representing combinations among poor x poor, good x good and poor x good general combiners, respectively, may be exploited (Table 4). This also indicated that gca in general has no bearing on the sca effects of the crosses. Further the cross KYZ 9712 x GW 323 involved both the parents with high gca and there are ample chances to get transgressive segregants in large populations. Thus such cross may be exploited to select better transgressive segregants either in large segregating populations or by recurrent selection method or by diallel selective mating designs or by biparental mating (Comstock *et al.*, (1949) and Jensen (1980). GW 344 x GW 337 (leaf area at spike initiation), KYZ 9712 x Inqualab 91 and GW 323 x ABV 2002-120 (leaf area at maturity and leaf area ratio), PHR 1010 x GW 323 (flag leaf area) and Lok Bold x KYZ 9636 (1000-grain weight) were the other crosses that involved both parents having high gca and may be exploited to have transgressive segregants for specific characters.

The cross, GW 344 x KYZ 9636 that illustrated the highest and significant sca effects for grain yield per plant also exhibited positive and significant sca effects for the characters like leaf area at spike initiation, leaf area at maturity, leaf area index and leaf area ratio (source attributing characters); number of spikelets per spike and spike length (sink attributes) and 1000-grain weight and hectoliter weight (source to sink carriage attributes). The second best specific cross combination viz., KYZ 9712 x GW 323 for grain yield per plant also manifested significant sca effects

Table 3 Estimates of gca effects for various attributes impacting source and sink development in wheat under high temperature condition

Genotype	Chlorophyll content	Leaf area at spike initiation (cm^2)	Leaf area at maturity (cm^2)	Leaf area index	Leaf area ratio	Flag leaf area (cm^2)	No. Spikelet per spike	Spike length (cm)	1000-grain weight (g)	Harvest index (%)	Protein content (%)	Sedimentation value	Hecto-liter weight (kg/hl)	Grain yield/ plant (g)
PARENTS														
PHR 1010	-1.87*	-40.55**	-63.89**	-5.78**	-0.43**	4.73**	1.32**	1.89**	-1.21**	-2.64**	0.17 *	-1.29**	-3.83**	-0.53**
GW 344	1.20	23.02**	-22.07**	-1.98**	-0.15**	-3.00**	1.09**	-0.30**	-3.10**	-4.62**	-0.06	-0.40	-2.57**	-0.41 *
KO 123	-4.85**	9.94**	16.53**	-0.17	0.11**	-3.73	0.29	-0.37**	-3.44**	-1.84 *	-0.25**	-1.82**	1.56 *	0.45 *
KYZ 9712	-2.31**	40.51**	141.83**	5.41**	0.95**	1.60**	1.10**	1.32**	-3.01**	-0.42	-0.40**	-0.87**	-0.60	1.10**
GW 273	-4.42**	-1.48	-40.53**	-0.92**	-0.07**	0.01	0.54**	0.36**	-1.34**	-1.22	0.05	1.39**	-2.34**	-0.89**
GW 323	-0.24	24.28**	77.38**	7.52**	0.52**	3.54**	1.29**	0.58**	1.67**	3.42**	0.1	1.10**	0.17	0.63**
Inqualab 91	-0.14	-10.08**	61.77**	3.71**	0.41**	0.12	-0.13	0.14*	-0.02	1.23	0.24**	-0.23	-021	0.52**
ABV-2002-120	3.98**	3.05	50.54**	0.48	0.34**	-4.50**	0.16	0.29**	1.55**	2.64**	-0.68**	0.34**	-1.29	1.48**
Raj-4081	-0.30	24.26**	-7.38**	-0.56	-0.05**	-2.44**	-0.64**	-0.12*	0.87**	-2.91**	0.58**	1.65**	1.67**	-0.38 *
Raj-4038	3.60**	19.00**	30.63**	0.48	0.27	-0.03	0.17	-0.24**	-0.73**	0.82	0.21**	0.47 *	2.44	0.36 *
Lok Bold	-0.27	-42.16**	-87.85**	-2.59**	-0.59**	0.65	-0.91**	-0.85**	3.59**	3.06**	0.91**	-0.72 *	1.63**	-0.92**
GW 173	0.74	-19.19**	-81.06**	-2.32**	-0.54**	0.41	-1.76**	-0.97**	0.35	1.39	-0 11	-0.44	1.72**	-1.19**
GW 337	5.11**	27.96**	24.13**	-0.74*	0.16**	4.42**	-1.13**	-1.17**	2.25**	0.74	-0.57**	1.02**	2 01**	0.86**
KZY 9636	-0.23	-58.56**	-100.86**	-2.53**	-0.67**	-1.78	-1.37**	-0.56**	2.28**	0.36	-0.22**	-0.18	0.03	-1.07**
S E gi	0.8	2.82	3.76	0.29	0.02	0.58	0.18	0.05	0.19	0.80	0.06	0.33	0.59	0.18
SE (gi - gl)	1.21	4.11	5.53	0.42	0.03	0.85	0.19	0.11	0.28	1.17	0 09	0.48	0.86	0.27

** Significant at p = 0.05 and 0.01 level of significance, respectively

Table 4 Three best crosses on the basis of sca effects along with per se performance and gca combinations for different traits impacting source, sink and quality attributes in wheat under high temperature condition.

Characters	Crosses	sca effects	gca of the parents	*Per se* performance	Rank recorded to *per se* performance
Source attributes					
Chlorophyll content	GW 344 x Lok Bold	23.44	AxA	91.47	3
	ABV 2002-120 x Raj 4081	21.29	GxA	92.07	2
	GW 173 x GW 337	19.72	AxG	92.57	1
Leaf area of spike initiation (cm^2)	GW 344 x GW 337	356.98	GxG	711.27	1
	Inqualab 91 x GW 337	256.00	PxG	578.00	2
	KO 123 x Inqualab 91	219.67	GxP	522.83	3
Leaf are at maturity (cm^2)	KYZ 9712 x Inqualab 91	754.52	GxG	1477.87	1
	GW 344 x GW 337	477.63	PxG	999.00	2
	GW 323 x ABV 2002-120	327.10	GxG	937.33	4
Leaf area index	GW 323 x BAV 2002-120	20.79	GxA	57.95	1
	GW 344 x GW 337	17.16	PxP	43.59	7
	KO 123 x Inqualab 91	16.29	AxG	48.98	2
Leaf area ratio	KYZ 9712 x Inqualab 91	5.03	GxG	9.85	1
	GW 344 x GW 337	3.18	PxG	6.66	2
	GW 323 x ABV 2002-120	2.18	GxG	6.49	4
Flag leaf area (cm^2)	PHR 1010 x GW 323	21.74	GxG	53.27	1
	KYZ 9712 x Lok Bold	18.80	GxA	44.91	2
	GW 344 x Lok Bold	14.74	PxA	36.24	7
Sink attributes					
No. of spiklets per spike	GW 344 x Lok Bold	6.63	GxP	19.17	32
	PHR 1010 x GW 337	2.85	GxP	21.40	3
	KYZ 9712 x KYZ 9636	2.81	GxP	20.90	5
Spike length	PHR 1010 x GW 173	3.08	GxP	16.45	1
	KYZ 9712 x KYZ 9636	2.59	GxP	15.80	3
	GW 344 x Lok Bold	2.37	PxP	13.67	18
1000 grain weight (g)	Lok Bold x GW 337	19.85	GxA	68.83	1
	Lok Bold x KYZ 9636	17.22	GxG	66.53	2
	PHR 1010 x Inqualab 91	10.76	PxA	52.57	4
Harvest index	PHR 1010 x KYZ 9712	13.43	PxA	45.66	9
	GW 344 x Lok Bold	11.96	PxG	45.69	10
	KO 123 x GW 337	11.81	PxA	15.01	6
Quality attributes					
Protein content	KYZ 9712 x KYZ 9636	3.04	PxP	13.96	4
	KO 123 x GW 173	2.98	PxA	14.17	2
	GW 323 x Raj 4081	2.89	AxG	15.12	1
Sedimentation value	PHR 1010 x Raj 4038	10.14	PxA	41.73	1
	GW 323 x KYZ 9636	7.96	GxA	41.30	2
	Raj 4081 x Lok Bold	7.89	GxP	41.23	3
Hectoliter weight	PHR 1010 x GW 344	9.88	PxP	66.99	24
	GW 344 x KYZ 9712	8.74	PxA	66.08	36
	ABV 2002-120 x KYZ 9636	8.41	PxA	70.67	6
Grain yield per plant (g)	GW 344 x KYZ 9636	10.72	PxP	18.78	1
	KYZ 9712 x GW 323	5.09	GxG	9.20	47
	PHR 1010 x Raj 4038	3.92	PxG	13.30	9

for chlorophyll content, harvest index and protein content and third best cross, PHR 1010 x Raj 4038 for leaf area at maturity, chlorophyll content, leaf area ratio, flag leaf area (source attributes); spike length, harvest index and sedimentation value. Three best crosses with respect to sca effects were given in Table 4 along with their per se performance and ranking. A perusal of data revealed that none of the cross registered high sca effects for all the characters. Although, six crosses with top ranking in sca effects for one characters also exhibited top ranking sca effects for some other important characters. They were, PHR 1010 x Raj 4038, (grain yield per plant, sedimentation value), GW 344 x GW 337 (leaf area of spike initiation, leaf area at maturity, leaf area ratio and leaf area index), KO 123 x Inqualab 91 (leaf area at spike initiation and leaf area index), GW 323 x ABV 2002-120 (leaf area at maturity, leaf area index and leaf area ratio), GW 344 x Lok Bold (chlorophyll content, spikelets per spike, spike length and harvest index) and KYZ 9712 x KYZ 9636 (spikelets per spike, spike length and protein content). Thus, crosses like GW 344 x GW 337 and KO 123 x Inqualab 91 can be exploited for the amelioration of source development that is so precarious and affected most under high temperature growing conditions in wheat. Similarly KYZ 9712 x KYZ 9636 can be exploited for improvement of sink.

For grain yield per plant and other characters, it was observed that the crosses which exhibited the highest sca effects were not necessarily good in per se performance (Table 4). From this, it can be ascertained that additive and/or non-additive gene effects were involved in the expression of yield and other traits among top ranking hybrids. The data given in Table 4 palpably indicated that the crosses having high sca effects involved all combinations of good x good, good x average, average x good, good x poor, poor x good, poor x poor, poor x average and average x poor general combining parents. This indicated the involvement of non-additive gene effects along with inter-allelic interaction. Better performance of hybrids having poor x poor or average x poor general combiners indicated interaction of recessive epistasis. This indicated possibility to obtain desirable transgressive segregants from these crosses by adopting cyclic method of selection or bi-parental mating.

It is evident form the Table 4 that for most of the traits, there was no correspondence between high ranking sca and *per se* performance of the crosses. Thus it can be concluded that the high magnitude of sca effects alone is not sufficient for explaining the good performance of any cross.

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