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COMBINING ABILITY FOR YIELD AND ITS COMPONENTS IN DURUM WHEAT (*TRITICUM DURUM* DESF.) OVER DIFFERENT SOWING TIMES

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ABSTRACT

Nine parents of durum wheat (*Triticum durum* Desf.) were crossed in half diallel fashion and their F1's were evaluated for combining ability for yield and its component traits under two different conditions *viz*., normal and late sown conditions. Mean sum of squares due to GCA and SCA were significant for all the traits under both conditions but mean sum of squares of GCA were higher than those of SCA under both conditions indicating the importance of additive gene effects for these traits. HI 8638, EC 18 and WH 896 were found to be good combiners under both conditions. Crosses *viz*., HI 8638 x PDW 300, HI 8638 x NIDW 225, HI 8638 x WH 896, NIDW 225 x WH 896 and EC 18 x HI 8591(one parent as good general combiner); PDW 291 x PDW 300, NIDW 295 x HI 8645 and HI 8645 x PDW 300 (both parents as poor combiners) and HI 8638 x WH 896 and EC 18 x WH 896 (both parents as good general combiners), were found to be desirable crosses under both conditions.

INTRODUCTION

Triticum durum Desf. is the second most important wheat species under cultivation in the world and India, as well. It is estimated that the world durum wheat production was 33.0 million tons in the year 2012-13 (International Grains Council, 2013). The United States Department of Agriculture (USDA) estimates India's durum production somewhere within the range of 1 and 1.2 million metric tons and almost all of it is consumed domestically (USDA Foreign Agriculture Service, Gain Report 2015). Durum wheat breeder's purpose is to develop genotypes with higher yield and better quality which are mostly negatively associated. However, breeder faces with the problems such as identifying, selecting parents and applying selection for the promising segregation progenies at early generations. The main reason for these difficulties is that the traits considered are under polygenic control with continuous variations. Hence, the breeder makes the preliminary observations on possible parents to choose the appropriate ones and to cross them. For incorporation of desired traits into adapted genetic background, knowledge of gene effects in controlling of such traits is imperative. Combining ability analysis will be helpful in selecting parents that could produce superior segregants in advance generation. From the genetic point of view, general combining ability measures additive gene effects and specific combining ability measures non-additive gene effects, depending on genes with dominance (intra-allelic interactions) and epistasis (inter-allelic interactions). It also provides the vital and necessary information on the nature of gene action governing the expression of the character in question and thus helps in deciding upon the future breeding strategy (Nilkanth *et al*., 2015). Among various diallel forms, the half diallel methods have certain advantages over others, giving maximum information about genetic architecture of a trait, parents and allelic frequency (Iqbal *et al.,* 2007). In addition, the diallel cross technique was reported to provide early information on the genetic behavior of these attributes in the first generation (Schuelter *et al.,* 2010). Sowing time is also a very important contributing factor for grain yield of durum wheat. Timely sowing allows proper emergence, adequate vegetative growth and sufficient grain filling period which permits sufficient photosynthates to be stored in grains leading to healthy grain formation. Delayed sowing alter the germination and provide short period for grain filling causing poor grain formation and resulting in yield loss. Cultivation at proper sowing time, is thus of extreme importance to obtain high yields and better grain quality of durum wheat. The importance of timely sowing of wheat for higher production has been advocated by Nainwal and Singh (2000). Realizing the importance and need for such study in tetraploid wheats, the present investigation of genetic analysis of yield and its components of durum wheat under normal and late sown conditions, is employed to study the magnitude of gene action controlling the inheritance of yield, related quantitative traits and choice of parents and to adopt an efficient breeding programme.

MATERIALS AND METHODS

Nine genotypes of durum wheat (*Triticum durum* Desf.) varieties (Table 1) were crossed in a half diallel design at Research Farm of the Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu during Rabi 2010-2011 and 2011-12. Seeds of 36 F1 along with their parents were sown in randomized block design with three replications under normal and late sown conditions. Each entry was planted in two rows of 2 m each, with a plant-to-plant and row- to-row distance of 15 and 30 cm, respectively. Five guarded plants from each parental and hybrid lines randomly selected and data pertaining to plant height, flag leaf area, days to 50% flowering, number of effective tillers per plant, days to maturity, spike length, number of grains per spike, 1000-grain weight, biological yield per plant, harvest index and grain yield per plant were recorded. The means of five observations in each plot were used for statistical analysis for each character data. Combining ability analysis was run using Method 2 Model 1(Griffing, 1956) in which one set of F1's including parents are included in the matrix.

RESULTS AND DISCUSSION

Analysis of variance for combining ability with respect to yield and its components is presented in Table 2 for both normal and late sown conditions. It is seen that the variance due to

Table 1: Names, source and pedigree of the nine durum wheat parents used in the study

S.No.	Genotypes	Source	Pedigree
1.	PDW 291	PAU-Ludhiana	BOOMER 21/MOJO 2
2.	NIDW 295	NGSN 2005-06, DWR Karnal	BOOMER 33/PLATA 8
3.	HI 8638	NGSN 2005-06, DWR Karnal	SEL. BUTTAH
4.	HI 8645	NGSN 2005-06, DWR Karnal	HI-8185/MESSAPIO, HI-8381/MESSAPIO
5.	PDW 300	PAU, Ludhiana	PDW-242/PDW-233//PDW-232
6.	NIDW 225	NGSN 2005-06, DWR Karnal	SWANE 1/DUKEM 14
7.	EC 18	NGSN 2005-06, DWR Karnal	-
8.	HI 8591	NGSN 2005-06, DWR Karnal	HI-8144/NI 8625
9.	WH 896	Choudhary Charan Singh, HAU, Hisar	SIN'S¼/WH852

Table 2: Analysis of variance for combining ability for yield and it's components in 9 x 9 half diallel sets under normal (E1) and late sown (E2) conditions

Genotype	Time of sowing	Plant height (cm)	Flag leaf area (cm^2)	Days to 50% flowering	No. of effective tillers /plant	Days to maturity	Spike length	No. of grains/ spike	1000-grain wt (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield/ plant (g)
PDW-291	E1	-1.85**	-6.47**	0.38*	-0.04	1.48**	-0.43**	-3.32**	1.89**	-0.90**	0.24	-0.22
	E2	-1.70**	-6.41**	-0.64**	0.18	1.49**	-0.45**	-2.27**	2.14**	-0.87**	-0.14	-0.60**
NIDW-295	E1	-2.76**	-1.20**	2.45**	-0.86**	0.60**	0.23**	4.16**	-0.72*	3.51**	-1.82**	-0.49*
	E2	-2.64**	-1.56**	2.27**	-0.86**	0.43**	0.23**	3.86**	-0.82**	3.38**	-1.29**	-0.22*
HI-8638	E1	-1.24**	1.69**	0.79**	-0.37**	1.99**	-0.56**	-4.29**	-3.08**	1.50**	0.28	1.01**
	E2	-1.07**	1.12**	1.15**	-0.04	2.40**	-0.54**	-4.14**	-3.58**	1.88**	0.28**	1.31**
HI-8645	E1	-1.25**	-1.79**	-1.22**	-0.19	-0.1	0.07**	2.71**	0.14	-1.28**	-0.12	-0.90**
	E2	-1.31**	-1.43**	-1.06**	0.21*	-0.30**	0.04**	2.82**	0.15	-1.16**	-0.64**	-1.40**
PDW-300	E1	2.17**	-0.94**	-0.25	-1.13**	-2.01**	-0.33**	-3.08**	2.22**	-0.34*	-0.47*	-0.98**
	E2	1.64**	-1.18**	-0.48**	-1.10**	-1.90**	-0.31**	-3.36**	2.23**	-0.04	-0.61**	-0.87**
NIDW-225	E1	-2.12**	-1.14**	0.51**	1.47**	0.02	0.61**	4.59**	-0.84**	-1.88**	0.55*	-0.27
	E2	-1.64**	-0.57**	0.70**	0.84**	-0.02	0.60**	4.82**	-0.44**	-1.89**	0.52**	-0.18
EC-18	E1	2.02**	3.46**	-0.95**	0.23	-1.04**	0.04*	-1.71**	1.08**	-0.22	0.69**	0.72**
	E2	1.88**	3.26**	-0.55**	0.57**	-0.81**	0.05**	-2.24**	1.12**	0.02	0.60**	0.81**
HI-8591	E1	1.56**	5.35**	-0.07	-0.53**	0.33*	0.34**	1.47**	-0.70*	-0.14	0.43*	0.41
	E2	1.25**	4.49**	-0.33**	-0.92**	0.49**	0.35**	1.34**	-0.31**	-0.58**	0.69**	0.67**
WH-896	E1	3.46**	1.04**	-1.63**	1.41**	-1.28**	0.03	-0.53*	0.01	-0.25	0.22	0.72**
	E2	3.58**	2.27**	-1.06**	1.11**	-1.78**	0.03*	-0.84**	-0.50**	-0.73**	0.58**	0.49**
S.E. (gi)	E1	0.12	0.13	0.17	0.14	0.13	0.02	0.17	0.22	0.14	0.17	0.2
	E2	0.07	0.08	0.09	0.09	0.08	0.01	0.11	0.1	0.1	0.08	0.1
S.E. (gi-gj)	E1	0.18	0.19	0.26	0.21	0.19	0.03	0.25	0.34	0.21	0.26	0.31
	E2	0.11	0.12	0.14	0.13	0.12	0.02	0.17	0.15	0.15	0.12	0.15

Table 3: Estimates of general combining ability effects for yield and its components in a 9 x 9 half diallel set based on Griffing's Method 2 Model 1 under normal (E1) and late sown (E2) conditions mean squares

Source of variation	df	Time of sowing	Plant height (cm)	Flag leaf area (cm^2)	Days to 50% flowering	No. of effective tillers /plant	Days to maturity	Spike length (cm)	No. of grains/spike	1000-grain wt (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield/ plant (g)
GCA	8	E1	57.53 **	128.23 **	16.69**	9.21 **	18.39**	1.58**	123.78**	28.72**	28.60**	6.46**	6.01**
		E2	49.42**	116.32**	14.13**	7.04*	21.94**	1.56**	119.91**	34.17**	29.62**	5.50**	8.54**
SCA	36	E1	1.29 **	5.39 **	3.59 **	0.88**	1.36**	0.16**	11.32**	8.10**	9.37**	3.59**	4.68**
		E2	1.14**	4.93**	2.80**	1.22**	2.04**	0.22**	12.97**	15.61**	11.23**	5.41**	7.82**
Error	88	E1	0.07	0.08	0.1	0.24	0.2	0	0.35	0.63	0.24	0.36	0.52
		E2	0.18	0.2	0.37	0.1	0.07	0	0.16	0.12	0.12	0.08	0.12

*, ** significant at 5% and 1% level

Table 4: Estimates of specific combining ability effects for yield and its components in a 9 x 9 half diallel set based on Griffing's Method 2 Model 1 under normal (E1) and late sown (E2) conditions

Crosses	Time of sowing	Plant height (cm)	Flag leaf area (cm^2)	Days to 50% flowering	No. of effective tillers/ plant	Days to maturity	Spike length	No. of grains/ spike	1000-grain wt (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield/ plant (g)
PDW-291 x NIDW-295	E1	0.10	-1.63**	-0.84	-0.61	-0.68	-0.47**	0.17	-3.09**	-3.43**	1.88**	0.62
	E2	- 1.18**	-1.36**	0.30	-1.79**	-0.98**	-0.40**	0.42	-4.03**	-4.04**	2.13**	1.11*
PDW-291 x HI-8638	E1	-0.99	2.02**	1.15*	-0.76	-1.08*	0.03	2.96**	2.59**	-3.16**	-0.02	-1.45*
	E2		4.08**	-0.25	-1.28**	-1.28**	-0.03	3.75**	5.13**	-3.74**	0.35	-1.28**
PDW-291 x HI-8645	E1	-0.27	-1.38*	-0.51	0.39	1.68**	-0.01	-0.2	0.67	3.43**	-0.79	0.6
	E2	1.53**	0.84*	-3.70**	-0.19	1.75**	0.12*	052	1.97**	3.83**	-5.03**	-5.21**
PDW-291 x PDW-300	E1	-0.06	-2.59**	2.86**	-0.01	-0.08	-0.11	0.75	-0.162	-3.09**	4.30**	4.51**
	E2	1.32**	-0.42	3.72**	0.12	0.02	-0.53**	1.30*		-2.42**	4.64**	5.19**
PDW-291 x NIDW-225	E1	0.33	-5.79**	-0.57	0.152	0.22	-0.28**	- 2.25**	4.26**	0.09	-1.43*	-1.77*
	E2	0.72*	-6.53**	-0.79*		-0.86*	-0.29**	- 1.88**	4.86**	0.03	-0.89*	-1.13**
PDW-291 x EC-18	E1	1.32**	5.68**	0.22	0.30	-0.72	-0.05	-0.95	0.74	3.16**	-1.13*	0.01
	E2	0.48*	-0.89*	0.78*	-0.22	1.26**	0.07	-0.82*	0.54	3.76**	-0.87*	0.62
PDW-291 x HI-8591	E1	-2.01**	4.32**	-1.32*	2.05**	-1.14*	1.16**	1.87*	4.81**	1.55*	0.06	1.09
	E2	-1.03**	-1.29**	-1.78**	1.60**	-1.36**	1.21**	1.27*	4.63**	1.79**	0.84*	2.06**
PDW-291 x WH-896	E1	0.88	0.69	1.90*	0.45	1.19*	-0.30**	0.53	-0.76	4.83**	-1.96*	-0.99
	E2	0.44	3.17**	1.96**	0.90*	2.23**	-0.37**	0.78*	-1.22**	4.37**	-1.25**	0.34
NIDW-295 x HI-8638	E1	-0.33	-1.59**	1.75*	1.05*	0.47	0.03	4.14**	2.74**	-2.33**	-0.40	-2.05*
	E2	0.56*	-2.73**	1.84**	1.08**	0.78*	0.09*	4.30**	3.66**	-3.30**	0.27	-1.13**
NIDW-295 x HI-8645	E1	-0.73	0.81	-0.57	-0.46	0.56	-0.17*	-1.53*	1.92*	2.55**	1.10	2.33*
	E2	-1.34**	-2.18**	0.05	-1.16**	1.14**	-0.22**	-1.01*	2.30**	3.11**	0.80*	2.58**
NIDW-295 x PDW-300	E1	2.11**	-0.23	1.46*	0.15	0.80	0.80	6.93**	-3.15**	4.61**	-1.08	0.11
	E2	1.62**	0.50	-0.85*	0.81*	1.75**	1.19**	7.84**	-3.92**	4.62**	-2.33**	-1.29**
NIDW-295 x NIDW-225	E1	-1.1	0.67	0.04	0.54	-0.56	-0.40**	-3.07**	3.74**	4.05**	-1.21*	-0.27
	E2		2.09**	-0.37	1.54**	-0.80*	-0.55**	-4.01**	5.13**	4.98**	-2.23**	-0.82*
NIDW-295 x EC-18	E1	-0.23	-0.27	0.16	-0.55	-0.50	0.06	0.90	-2.75**	-1.24	-1.21*	-2.37**
	E2	0.55*	1.20**	0.21	-0.85*	-1.01**	0.10*	1.39**	-2.90**		-2.41**	-3.60**
NIDW-295 x HI-8591	E1	-1.04*	0.44	0.28	1.54*	0.13	0.63*	1.72*	1.53*	1.24*	-0.15	-0.01
	E2	-1.32**	1.00	1.66**	0.30	0.68*	0.73**	2.48**	1.43**	1.84**	-0.53*	0.18
NIDW-295 x WH-896	E1	2.43**	-0.47	0.21	-1.13	-1.26*	-0.07	1.38*	4.22**	2.92**	0.70	1.30
	E2	1.91**		-0.95*		-1.04**		0.66	5.34**	3.35**	-0.13	1.39**
HI-8638 x HI-8645	E1	-0.48	-1.77**	-1.25*	-2.28**	1.16*	0.20*	0.26	-1.46	1.46*	-0.04	0.80
	E2	-1.14**	-1.90**	-1.49**	-1.64**	0.84*	0.19**	0.33	-2.54**	1.84**	0.65*	1.75**
HI-8638 x PDW-300	E1	0.30	0.68	2.45**	-0.01	-1.93**	-0.10	-0.28	1.20	2.61**	1.02	2.81**
	E2	0.82*	-1.19**	1.60**	0.66*	-1.22**	-0.10*	-0.82*	0.14	2.79**	1.16**	2.98**
HI-8638 x NIDW-225	E1	0.66	1.38**	-1.31*	0.72	1.38*	-0.01	0.38	0.60	2.63**	1.86*	4.06**
	E2	-0.24	0.60*	-1.25**	0.39	2.23**	0.05	0.66	1.09*	2.35**	1.46**	3.19**
HI-8638 x EC-18	E1	-0.01	-1.72**	2.15**	-0.70	0.10	-0.27**	-1.32*	-1.66*	3.93**	-2.61**	-1.70*
	E2	0.01	-0.93*	2.99**	-1.34**	0.02	-0.26**	-2.28**	-2.71**	4.04**	-3.02**	-2.36**
HI-8638 x HI-8591	E1	-0.35	-0.21	-0.06	-0.47	0.74	-0.27**	-2.50**	-1.82*	-0.91	-0.29	-0.34
	E2	-0.69*	-0.6.3*	-1.55**		1.06**	-0.13*	-2.19**	-1.61**	1.37**	-1.41**	-1.28**
HI-8638 x WH-896	E1	0.51	1.97**	-1.04	1.12*	-1.65**	0.14*	-1.50*	-0.98	0.16	2.10**	2.44**
	E2	0.24	2.60**	1.51**	1.12**	-0.01	0.33**	-1.67**		0.58	2.60**	3.86**
HI-8645 x PDW-300	E1	-0.40	-0.68	-1.20*	-1.19*	0.50	0.49**	5.72**	-3.15**	-3.83**	4.02**	3.76**
	E2	0.22	-1.53**	-1.19**	-1.25**	0.81*	0.42**	4.54**	-5.08**	-3.64**	4.85**	4.83**
HI-8645 x NIDW-225	E1	0.27	0.76	-0.29	-0.46	-0.53	-0.21*	-1.26	2.31*	-0.66	0.29	0.21
	E2	-0.10	0.29	-1.04*	-0.85*	-2.07**	-0.39**		2.23**	-0.88*	1.25**	1.30**
HI-8645 x EC-18	E1	1.46**	2.42**	0.49	1.12*	0.19	0.26**	4.02**	1.85*	1.98**	-2.65**	-2.58**
	E2	1.65**	3.00**	1.54**	1.75**	0.72*	0.03	3.08**	3.73**	1.84**	-2.90**	-3.08**
HI-8645 x HI-8591	E1	-1.06	-1.77**	3.28**	-0.79	-1.84**	-0.44**	-1.50*	0.29	0.30	0.7791	-1.93*
	E2		0.30	3.33**	-1.10**	-3.59**	-0.37**	-3.82**	0.59	-0.86*		-1.01*
HI-8645 x WH-896	E1	1.02*	0.27	-2.16**	0.60	-0.018	0.03	3.50**	1.79*	-1.66**	0.80	-0.28
	E2	0.21	-0.01	1.05*	0.87*		0.28**	4.69**	2.54**	0.19	0.19	0.37
PDW-300 x NIDW-225	E1	-0.19	-0.02	2.07**	0.48	0.71	0.02	-5.38**	2.90**	-3.27**	-0.99	-2.71**
	E2	-0.38	0.5	2.39**	0.12	1.87**	0.08*	-4.13**	4.04**	-3.30**	-0.61*	-2.33**
PDW-300 x EC-18	E1	-0.56	0.01	-2.48**	-0.28	0.1	-0.04	-1.86*	2.71**	0.37	0.14	0.56
	E2	-1.13**	0.77*	-1.70**	-0.95*	-0.35	-0.06	-1.73**	4.12**	0.96*	-0.16	0.32
PDW-300 x HI-8591	E1	0.40	2.05**	1.31*	-0.52	-1.59**	-0.04	-0.71	1.58*	3.92**	-1.80*	-0.58
	E2	-0.13	2.27**	1.08**	-0.13	-0.32	0.10*	-1.64**	2.08**	3.52**	-1.98**	-1.01*
PDW-300 x WH-896	E1	-0.90*	0.66	-2.13**	0.54	1.35*	-0.53**	-2.38**	2.71**	1.63**	-2.15**	-2.74**
	E2	-0.23	- 0.93*	-0.85*	1.18**	-1.38**	-0.61**	-2.13**	4.20**	2.44**	-2.07**	-1.73**
NIDW-225 x EC-18	E1	-0.50	-0.65	-0.9	0.45	0.41	0.52**	7.81**	-3.09**	-0.52	0.35	0.38
	E2	-0.05	0.67*	-0.88*	0.45	1.44**	0.63**	8.42**	-4.61**	-0.72*	0.21	-0.01
NIDW-225 x HI-8591	E1	2.03**	0.12	1.55*	-0.13	-0.62	0.49**	1.62*	0.08	5.03**	-1.69*	0.17
	E2	2.24**	1.53**	2.24**	1.27**	-0.86*	0.43**	1.18*	1.45**	5.21**	-1.95**	-0.20
NIDW-225 x WH-896	E1	-2.81**	0.63	0.78	-0.40	-0.35	0.63**	5.62**	-2.79**	-2.86**	2.72**	1.78*
	E2	-2.79**	0.79*	1.30**	0.24	1.08**	0.62**	5.69**	-3.43**	-2.18**	3.53**	3.65**
EC-18 x HI-8591	E1	0.08	-2.25**	-0.99	0.78	-1.23*	-0.37**	-0.3384	2.46*	-1.46*	1.51*	1.54*
	E2	-0.87**	-2.40**	-1.85**	0.87*	-1.07**	-0.59**		3.59**	-2.36**	2.34**	2.05**
EC-18 x WH-896	E1	-0.72	1.63**	0.24	0.18	0.71	0.33**	-0.1128	3.58**	0.65	2.59**	3.43**
	E2	-0.70*	2.90**	0.21	0.18	0.53*	0.34**		5.64**	1.45**	2.08**	3.59**

Table 4: Cont......

Crosses	Time of sowing	Plant height (cm)	Flag leaf area (cm^2)	Days to 50% flowering	No. of effective tillers / plant	Days to maturity	Spike length	No. of grains/ spike	1000-grain wt (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield/ plant (g)
HI-8591 x WH-896	E1	0.64	2.30**	1.69*	-1.73**	-0.99	-0.16	2.75**	-2.27*	-1.63**	-2.01**	1.48*
	E2	2.09**	3.00**	1.66**	-0.67*	-0.44		3.18**	-2.53**	2.72**	2.13**	1.57**
S. E. (Sij)	E1	0.39	0.41	0.55	0.45	0.41	0.06	0.54	0.72	0.45	0.55	0.66
	E2	0.23	0.26	0.3	0.29	0.25	0.04	0.36	0.32	0.31	0.26	0.31
S. E. (Sij – Sik)	E1	0.57	0.61	0.82	0.66	0.6	0.09	0.8	1.07	0.66	0.81	0.97
	E2	0.35	0.38	0.44	0.43	0.36	0.06	0.53	0.47	0.46	0.38	0.46
S. E. (Sij – Skl)	E1	0.55	0.58	0.77	0.63	0.57	0.08	0.76	1.01	0.63	0.77	0.92
	E2	0.33	0.36	0.41	0.4	0.35	0.06	0.51	0.44	0.44	0.36	0.44

GCA as well as SCA were highly significant for all the traits studied under both conditions. The variances for GCA were greater than the mean squares for SCA for all the traits which indicated that additive type of gene effects were more pronounced than those of non-additive ones. Similar results are reported by Zalewski (2001) and Mahmood and Chowdhry, (2002). General combining ability effects of durum wheat for morphological traits (Table 3) under normal and late sown conditions indicated that certain lines/varieties may contribute to high yields through individual yield components (Jaiswal *et al.,* 2013) . For grain yield per plant, parents HI 8638, EC 18 and WH 896 were found to be good general combiners under both normal and late sown conditions. In addition, parents PDW 291, NIDW 295, HI 8638, HI 8645 and NIDW 225 for plant height; HI 8638, EC 18, HI 8591 and WH 896 for flag leaf area; HI 8645, EC 18 and WH 896 for days to 50% flowering; NIDW 225 and WH 896 for number of effective tillers per plant; PDW 300, EC 18 and WH 896 for days to maturity; NIDW 295, HI 8645, NIDW 225, EC 18 and HI 8591 for spike length; NIDW 295, HI 8645, NIDW 225 and HI 8591 for number of grains per spike; PDW 291, PDW 300 and EC 18 for 1000-grain weight; NIDW 295 and HI 8638 for biological yield per plant and NIDW 225, EC 18 and HI 8591 for harvest index.

The crosses *viz.,* PDW 291 x PDW 300, NIDW 295 x HI 8645, HI 8638 x PDW 300, HI 8638 x NIDW 225, HI 8638 x WH 896, HI 8645 x PDW 300, NIDW 225 x WH 896, EC 18 x HI 8591, EC 18 x WH 896 and HI 8591 x WH 896 for yield and its components were found desirable under normal and late sown conditions (Table 4). High yield cross combinations *viz*. PDW 291 x PDW 300 showed significant SCA effects for harvest index; NIDW 295 x HI 8645 for 1000-grain weight and biological yield per plant; HI 8638 x PDW 300 for days to maturity and biological yield per plant; HI 8638 x NIDW 225 for flag leaf area, days to 50% flowering, biological yield per plant and harvest index ; HI 8638 x WH 896 for flag leaf area, number of effective tillers per plant, spike length and harvest index; HI 8645 x PDW 300 for days to 50% flowering, spike length, number of grains per spike and harvest index; NIDW 225 x WH 896 for plant height, spike length, number of grains per spike and harvest index; EC 18 x HI 8591 for days to maturity, 1000-grain weight and harvest index; EC 18 x WH 896 for flag leaf area, spike length, 1000-grain weight and harvest index and HI 8591 x WH 896 for flag leaf area, number of grains per spike and harvest index under both normal and late sown conditions. Therefore crosses *viz.,* HI 8638 x PDW 300, HI 8638 x NIDW 225, HI 8638 x WH 896, NIDW 225 x WH 896 and EC 18 x HI 8591 involved at least one parent as good general combiner indicated the superiority due to additive gene action. Three cross combinations *viz*., PDW 291 x PDW 300, NIDW 295 x HI 8645 and HI 8645 x PDW 300 in which both parents are poor combiners indicated superiority due to non-additive type of gene action. Rest above two crosses viz., HI 8638 x WH 896 and EC 18 x WH 896 have both parents as good general combiners in the present study. Similar results were observed by Sheikh and Singh, (2000); Mehmood and Chowdhary, (2000) and Singh *et al.*, 2010. These cross combinations showing desirable SCA effects for grain yield per plant and yield contributing traits and may produce transgressive segregants in succeeding generations, which can be selected and improved for increasing yield.

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