Original Research Article

Assessment of Combining Ability across Different Environments in Diallel Crosses of Durum Wheat (*Triticum Durum*Desf.)

ABSTACT

Combining ability analysis in durum wheat (*Triticum durum*Desf.) using a half diallel of ten parents revealed the significance of both additive and non-additive genetic variances in controlling various traits.Ten parental lines, 45 hybrids and one standard check (GDW 1255) were evaluated in a Randomize Block Design with three replication at Wheat Research Station, Junagadh Agricultural University, Junagadh during Rabi 2022-23 over three environments created by different dates of sowing.However, the ratio of σ^2GCA/ σ^2SCA revealed preponderance of non-additive gene actions in all the traits. Parents MACS 3949, GW 1348 and NIDW 1158 were the good general combiners, whereas crosses MPO 1336 × RAJ 3307, NIDW 1158 × HD 4758 and WHD 965 × NIDW 1158 were found to be best specific combiners for grain yield per plant and some of the yield contributing traits over environments. However, on the basis of *per se* performance and significant SCA effects for grain yield per plant and some of its important components, hybrids MPO 1336 × RAJ 3307, GW 1348 × NIDW 1158 and NIDW 1158 × HD 4758 were considered to be most promising for further exploitation in breeding programmes.

Keywords: General combining ability, Specific combining ability, Wheat, Diallel

1.INTRODUCTION

Among the world's crops, wheat is notable for its historical importance and its vital role as a staple food for people. The origins of durum wheat can be traced back to the ancient region known as the Fertile Crescent in Southwest Asia, which encompasses areas that are now part of present-day Iraq, Turkey, and Syria. Durum wheat was introduced in India during the mid-20th century, primarily through agricultural research and development programs. It was imported to diversify wheat varieties and meet the growing demand for wheat products. Wheat is an important cereal crop of the family *Poaceae*and genus *Triticum*. There are three natural group of wheat from polyploid series of *Triticum* species *viz. Triticum aestivum* (2n = 6x = 42), *Triticum durum* (2n = 4x = 28) and *Triticumdicoccum* (2n = 4x = 28) are presently grown as commercial crop in India.

Durum wheat makes up a small fraction of the total wheat production in India. It is primarily cultivated in the central region, which includes Madhya Pradesh, Gujarat, parts of Punjab, southern Rajasthan, and Maharashtra. While most durum wheat is grown under rainfed conditions, the crop in Gujarat is irrigated. The grains of durum wheat are typically amber-colored and larger compared to those of other wheat varieties.Durum wheat provides better nutrition, as it is rich in protein, ß-carotene and essential micronutrients like iron and zinc (Zuk Golaszewska *et al*., 2016). Durum is the hardest among the three main wheat species that are primarily cultivated.Its high protein content and gluten strength make durum good for pasta and bread.

Selecting the right parents for a hybridization program is a critical decision for breeders, especially when the goal is to improve complex quantitative traits like yield and its components. This process involves a thorough genetic evaluation of both existing germplasm and newly developed promising lines. Analyzing combining ability and understanding gene action are fundamental tools in identifying the most suitable genotypes for selection. According to Baker (1978), the combining ability is a better biometrical tool to circumvent the plant breeding programme. The success of a plant breeding program largely relies on a clear understanding of the genetic structure of the population, the fundamental genetic mechanisms responsible for creating variability, and the careful selection of parents. Additionally, knowledge of the nature and extent of gene action that governs various agronomically important traits is crucial for effective breeding.Yield is one of the most important economic character and is the end product of the multiplicative interaction of contributing characters. Hence, selection for yield *per se* may not be effective unless the yield contributing characters are given due emphasis as there being no gene for yield *per se* (Grafius, 1964). The knowledge of nature of gene action governing the expression of various traits would be helpful in predicting the effectiveness of selection. Diallel mating design has been extensively used to analyze the combining ability effects of wheat genotypes and also to provide information regarding genetic mechanism controlling grain yield and other traits (Khan *et al*., 2007). The diallel analysis also provides a unique opportunity to test a number of lines in all possible combinations.

It is also important to understand the genetic factors that control yield components, as improving yield largely depends on genetically altering these components. These traits are influenced by multiple genes and display both additive and non-additive genetic variations, as outlined by (Kakar *et al.,* 1999). Understanding the genetic architecture and inheritance patterns of various traits empowers breeders to choose appropriate breeding strategies for crafting high-yielding genotypes.

2. MATERIALS AND METHODS

The experimental materials comprised of ten parents (UAS 475, WHD 965, HI 8830, DDW 55, MPO 1336, MACS 3949, GW 1348, NIDW 1158, RAJ 3307 and HD 4758) along with 45 hybrids (developed by half-diallel) and one check (GDW 1255) were evaluated in a randomized block design with three replications. The experiment was conducted at Wheat Research Station, Junagadh Agricultural University, Junagadh during *Rabi* 2022-23 over three environments created by different dates of sowing [Early (5th November), timely (25th November) and late sowing (15th December)]. Five competitive plants per genotype in each row/replication in each environment were selected randomly for data observations of different characters*viz*., plant height, number of effective tillers per plant, length of main spike, number of spikelets per main spike, peduncle length of main spike, number of grains per main spike, 100-grain weight, grain yield per plant, biological yield per plant and harvest index, while observations on days to heading and days to maturity were recorded on plot basis. The data were first subjected to the usual analysis followed for a Randomized Block Design for individual environment as suggested by Panse and Sukhatme (1985). The combining ability analysis was done following Griffing (1956).

3. RESULTS AND DISCUSSION

3.1 Analysis of variance and components of variance

The analysis of variance of combining ability for twelve characters in three environments as well as pooled over environments is depicted in table 1 and 2, respectively. The combining ability analysis in the individual environment revealed significant mean squares due to GCA and SCA for all the traits in each environments (Table 1). The significant difference of GCA and SCA indicated that both additive and non-additive gene effects played an important role in the genetic control of the traits under study. The results obtained in the present studies are in accordance with the findings of Vanpariya*et al*. (2006), Desale and Mehta (2013), Pansuriya*et al.* (2014), Bajaniya*et al.*(2018), Joshi *et al*. (2020) and Dragov (2022) in wheat.

Theratio of GCA/SCA variance was less than unity indicated the involvement of non-additive gene action for all the twelve characters under investigation. The result were in conformity with findings obtained byVanpariya*et al.* (2006), Pansuriya*et al.* (2014), Jatav *et al.* (2017), Bajaniya*et al.*(2018) andDedaniya*et al.*(2018). The preponderance of non-additive variance for all the characters indicated that the best cross combination might be selected on the basis of SCA for further tangible advancement in wheat.

Combining ability analysis over pooledenvironments revealed that mean squares due to GCA and SCA indicated that both additive and non-additive gene effects played an important role in the genetic control of the traits under study (Table 2). However, the magnitude of SCA variance was higher than GCA variance which indicated the predominance of non-additive type of gene action in the expression of all the characters. Greater importance of non-additive of gene action for all the attributes suggested that heterosis breeding could be highly effective. Preponderance of non-additive variance in the expression of different traits in wheat have also been reported by Vanpariya*et al.* (2006), Pansuriya*et al.* (2014), Jatav *et al.* (2017),Bajaniya*et al.*(2018),Dedaniya*et al.* (2018) and Joshi *et al.* (2020).

Mean squares due to GCA x E was significant for all the characters except length of main spike, peduncle length of main spike and number of grains per main spike. Moreover, mean squares due to SCA x E were significant for all the characters. (Table 2). Significant GCA x E and SCA x E interaction for one or more characters were also observed byTahmasebi *et al.* (2007) and Pansuriya*et al.* (2014). In general, a substantial portion of non-additive gene action was noted for both grain yield and its contributing traits. These components can be effectively utilized through the approach of heterosis breeding.

3.2 General combining ability effects

The Summary of general combining ability effects of parents for different characters based on pooled environments are presented in table 3. The parents were classified as good, average and poor combiners for different characters. The perusal of general combining ability effects of parents revealed that parents MACS 3949, GW 1348 and NIDW 1158 were good general combiners for grain yield per plant havingconcentrated favorable genes indicated by significant and positive gca effects for these parents. Besides having good combining ability effects for grain yield per plant, parent MACS 3949 was also observed good general combiners for days to heading, days to maturity, plant height, number of effective tillers per plant and biological yield per plant; parent GW 1348 was observed good general combiners for number of effective tillers per plant, peduncle length of main spike, 100-grain weight, biological yield per plant and harvest index; and parent NIDW 1158 was observed good general combiners for days to heading, peduncle length of main spike and biological yield per plant.The high gcaeffects for grain yield and its contributing traitsalso reported by Yao *et al.* (2011), Desale and Mehta (2013), Jatav *et al.* (2017), Bajaniya*et al.*(2018), Dedaniya*et al.* (2018) andJoshi *et al.* (2020).

Overall, it is observed in present study (Table 5) that the parent exhibiting significant gca effect in desired direction for particular trait was more or less found to exhibit high *per se* performance. For instance, the parents MACS 3949, GW 1348 and NIDW 1158 which exhibited significant and positive gca effect for grain yield per plant also expressed high *per se* performance for this trait. The association between *per se* performance of parents and their gca effects suggested that while selecting the parents for hybridization, *per se* performance of the parents should be given due to consideration as it might predict the combining ability of a genotype. It would save considerable time required to determine the gca effect of the parents. Thus, if a character is uni-directionally controlled by a set of alleles and additive effects is important forthe choice of parents on the basis of the *per se* performance may be more effective. Similar findings were also reported by Vanpariya*et al*. (2006), Yao *et al.* (2011), Desale and Mehta (2013), Pansuriya*et al.* (2014) and Joshi *et al*. (2020).

3.3 Specific combining ability effects

In the present investigation, most of the crosses evidenced changes in the magnitude as well as direction of sca effects in different environments, which might be outcome of highly significant mean square due to SCA x environment interaction. The estimate of sca effects revealed that none of the top ten crosses was consistently superior for all the characters (Table4). The highest yielding hybrid MPO 1336 × RAJ 3307 (20.86 g) also had significant and positive sca effect (4.30) for grain yield per plant which involves average x average combiner parents. This cross also expressed significant and desirable sca effect for days to heading, days to maturity, number of effective tillers per plant, peduncle length of main spike, 100-grain weight and biological yield per plant. The cross combinations NIDW 1158 × HD 4758 involving good x average general combining parents, were reflected through days to maturity, number of effective tillers per plant, length of main spike, number of spikelets per main spike, number of grains per main spike and biological yield per plant. The high SCA effects for above components were also accompanied with high heterosis as well as high *per se* performance. Similarly, the cross combinations WHD 965 × NIDW 1158 had also significant and positive sca effects for grain yield per plant involved poor x good combiner parents. This cross also possessed significant and desirable sca effects for many yield components. Thus, on the basis of these results it is expected that these crosses could be exploited through heterosis breeding and may also give desirable segregants in subsequent generations and hence, it would be worthwhile to use them for improvement in grain yield *per se* performance. The significant SCA effects for grain yield and different component traits were also recorded by several workers *viz.*, Vanpariya*et al*. (2006),Yao *et al.* (2011), Desale and Mehta (2013), Pansuriya*et al.* (2014), Jatav *et al*. (2017), Bajaniya*et al.*(2018), Dedaniya*et al.*(2018)andJoshi *et al.* (2020).

In contrast to general combining ability effects, the specific combining ability effects represent dominance and epistatic components of variation, which are non-fixable in nature. But, the crosses showing high SCA effects involving either both or one good general combining parents could be successfully exploited for varietal improvement and expected to show stable performance in transgressive segregants carrying fixable gene effects. The cross combinations involving good x poor or average x poor general combiners besides exhibiting favourable additive effect of good or average combining parents, manifested complementary interaction effect and thus resulted in higher SCA effects. In the present study, such combinations for grain yield per plant were WHD 965 × NIDW 1158,WHD 965 × MPO 1336 and WHD 965 × MACS 3949. These crosses may be expected to throw transgressive segregants possessing enhanced yielding ability with stable performance. The cross combination GW 1348 × NIDW 1158 involving both the good general combining parents offer still better possibilities of exploitation of additive x additive type of gene interaction as they are expected to yield stable segregants in the advance generations and need further exploitation in the breeding programme.

A summarized account of the three best *per se* parents, best general combiners, best *per se* crosses and best specific cross combinations revealed that for majority of the characters, the best *per se* parents were also found to be best general combiners though their relative ranking were different (Table 5). It was further revealed that the three best *per se* crosses for different characters also possessed desired sca effects. In this situation, it would be better to look for good transgressive segregants in advance generations to make their use in breeding programme. Similar results in wheat have also been reported by Bajaniya (2018),Joshi *et al.* (2020) andDragov (2022).

Conclusion

It can be concluded that *per se* performance of parents and crosses in most of the cases was related with gca effects of parents and heterotic response of the hybrids, respectively. Thus, the potentiality of a strain to be used as a parent in hybridization programme or a cross to be used as a commercial hybrid may be judged by comparing *per se* performance, high heterosis and significant desirable sca effect for various traits involved either good x good or good x average or average x good or average x average or average x poor or poor x average or poor x poor combining parents. Thus, the crosses exhibiting high sca effect did not always involve the parents with high gca effects. The results, thus, suggested that intrallelic interaction were also important for these characters.

The best three hybrids for grain yield per plant on the basis of *per se* performance, *viz.*, MPO 1336 × RAJ 3307 (average x average), GW 1348 × NIDW 1158 (good x good) and NIDW 1158 × HD 4758 (good x average) had significant desired sca effects. This indicated that generally one or both parents with good gca effects are desirable for producing high yielding hybrids. However, the same three crosses also exhibited higher sca effects though their relative ranking was differed. Similar findings were also reported by Desale and Mehta (2013),Pansuriya*et al.* (2014),Bajaniya*et al.* (2018) and Dragov (2022).

With respect to sca effects, following conclusion could be drawn from the present study;

1. Crosses showing high sca effects for grain yield also depicted high sca effects for one or more of its yield components.
2. No cross combination exhibited consistently high sca effects for all the characters studied.
3. The crosses displaying high sca effects did not always involve both the parents with high gca effects, suggesting that the interallelic interactions were important for the characters.

Disclaimer (Artificial intelligence)

As the author(s), I hereby declare that no generative AI technologies, including Large Language Models (such as ChatGPT, COPILOT, etc.) or text-to-image generators, have been used in the writing or editing of this manuscript.

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Table 1: Analysis of variance (mean squares) for combining ability and component of variance of individual environments for different characters in wheat

Characters	D.F.	GCA (9)	SCA (45)	Error (108)	σ^2 gca	σ^2 sca	σ^2gca/ σ^2 sca
	Env.						
Days to heading	E_1	5.02**	26.53**	0.97	0.34	25.55	0.01
	E_2	11.23**	24.57**	1.11	0.84	23.46	0.04
	E_3	9.12**	23.06**	1.06	0.67	22	0.03
Days to maturity	E_1	6.55**	12.39**	0.88	0.47	11.51	0.04
	E_2	7.25**	9.61**	1.98	0.44	7.62	0.06
	E_3	9.24**	8.50**	1.45	0.65	7.05	0.09
Plant height (cm)	E_1	68.80**	32.53**	4.53	5.36	27.99	0.19
	E_2	53.84**	48.55**	4.59	4.1	43.97	0.09
	E_3	51.94**	43.91**	4.48	3.96	39.43	0.1
Number of effective tillers per plant	E_1	0.59**	1.16**	0.05	0.05	1.11	0.04
	E_2	1.98**	2.12**	0.04	0.16	2.08	0.08
	E_3	2.13**	1.69**	0.03	0.18	1.67	0.11
Length of main spike (cm)	E_1	0.33**	0.76**	0.07	0.021	0.68	0.03
	E_2	0.47**	0.66**	0.09	0.03	0.57	0.06
	E_3	0.54**	1.03**	0.08	0.04	0.96	0.04
Number of spikelets per main spike	E_1	1.41**	3.81**	0.28	0.09	3.52	0.03
	E_2	3.59**	3.70**	0.35	0.27	3.36	0.08
	E_3	1.21**	3.77**	0.36	0.07	3.4	0.02
Peduncle length of main spike (cm)	E_1	10.12**	17.87**	2.36	0.65	15.51	0.04
	E_2	17.35**	15.38**	2.47	1.24	12.91	0.1
	E_3	16.29**	12.66**	2.53	1.15	10.14	0.11
Number of grains per main spike	E_1	50.16**	38.81**	3.37	3.9	35.45	0.11
	E_2	41.67**	42.18**	3.49	3.18	38.68	0.08
	E_3	38.33**	51.62**	4.7	2.8	46.93	0.06
100-grain weight (g)	E_1	0.22**	0.32**	0.02	0.02	0.31	0.05
	E_2	0.21**	0.29**	0.02	0.02	0.27	0.06
	E_3	0.42**	0.26**	0.02	0.03	0.24	0.14
Grain yield per plant (g)	E_1	4.34**	4.66**	0.85	0.29	3.81	0.08
	E_2	5.16**	9.03**	0.9	0.36	8.13	0.04
	E_3	9.37**	6.03**	0.75	0.72	5.28	0.14
Biological yield per plant (g)	E_1	49.31**	29.09**	2.52	3.9	26.57	0.15
	E_2	36.78**	29.28**	2.7	2.84	26.58	0.11
	E_3	43.55**	43.60**	2.8	3.4	40.8	0.08
Harvest index (%)	E_1	36.46**	20.98**	7.89	2.38	13.09	0.18
	E_2	44.55**	48.96**	6.47	3.17	42.49	0.07
	E_3	22.48**	34.00**	7.95	1.21	26.05	0.05

* and ** significant at 5 and 1 per cent levels, respectively

Table 2: Analysis of variance (mean squares) for combining ability and component of variance for different characters in pooled over environments in wheat

Characters/d.f	GCA	SCA	Env's (E)	GCA x E	SCA x E	Error	σ^2 gca	σ^2sca	σ^2gca/ σ^2sca
	9	**45**	**2**	**18**	**90**	**324**	**-**	**-**	**-**
Days to heading	11.30**	31.38**	10.21**	7.04**	21.39**	1.05	0.28	10.11	0.03
Days to maturity	13.09**	19.57**	92.19**	4.97**	5.46**	1.44	0.32	6.04	0.05
Plant height (cm)	152.44**	104.99**	130.49**	11.07**	10.00**	4.53	4.11	33.48	0.12
Number of effective tillers per plant	3.59**	4.40**	4.87**	0.55**	0.28**	0.04	0.1	1.45	0.07
Length of main spike (cm)	1.13**	2.18**	7.95**	0.11	0.14**	0.08	0.03	0.7	0.04
Number of spikelets per main spike	4.30**	9.41**	12.42**	0.96**	0.93**	0.33	0.11	3.03	0.04
Peduncle length of main spike (cm)	36.88**	29.17**	104.19**	3.44	8.37**	2.45	0.96	8.91	0.11
Number of grains per main spike	122.63**	116.36**	463.80**	3.77	8.13**	3.85	3.3	37.5	0.09
100-grain weight (g)	0.42**	0.31**	4.60**	0.21**	0.28**	0.02	0.01	0.1	0.12
Grain yield per plant (g)	12.35**	15.75**	32.70**	3.26**	1.98**	0.83	0.32	4.97	0.06
Biological yield per plant (g)	91.37**	77.40**	214.39**	19.14**	12.29**	2.68	2.46	24.91	0.1
Harvest index (%)	53.32**	63.66**	34.22*	25.09**	20.14**	7.44	1.27	18.74	0.07

* and ** significant at 5 and 1 per cent levels, respectively

Table 3: Summary of general combining ability effects of parents for different characters based on pooled environments in wheat

Characters/ Parents	UAS 475	WHD 965	HI 8830	DDW 55	MPO 1336	MACS 3949	GW 1348	NIDW 1158	RAJ 3307	HD 4758
Days to heading	A	G	A	P	P	G	A	G	G	P
Days to maturity	P	A	G	A	A	G	A	A	P	P
Plant height (cm)	G	G	G	A	A	G	P	P	P	G
Number of effective tillers per plant	P	P	P	P	G	G	G	P	A	P
Length of main spike (cm)	A	G	A	A	G	P	A	P	G	G
Number of spikelets per main spike	P	G	G	G	A	P	A	A	A	G
Peduncle length of main spike (cm)	A	P	A	A	A	A	G	G	G	P
Number of grains per main spike	G	P	G	G	A	P	A	P	A	A
100-grain weight (g)	P	P	G	P	G	P	G	A	G	A
Grain yield per plant (g)	A	P	A	A	A	G	G	G	A	A
Biological yield per plant (g)	P	P	G	P	A	G	G	G	A	P
Harvest index (%)	G	P	P	A	A	P	G	A	A	G

Where, G, A and P indicate good, average and poor general combining ability of parents, respectively.

Table 4: Top ten crosses based on SCA effects for grain yield per plant on pooled basis and its component characters showing desirable SCA effects across the environments

Sr. No.	Crosses	Grain yield per plant	Component character showing desirable SCA effects
1	MPO 1336 × RAJ 3307	4.30** (A × A)	DH, DM, NET, PLS, HW, BY
2	NIDW 1158 × HD 4758	3.29** (G × A)	DM, NET, LS, NSP, NGP, BY
3	WHD 965 × NIDW 1158	3.09** (P × G)	PLS, BY, HI
4	UAS 475 × MACS 3949	2.86** (A × G)	DH, DM, PH, NET, NSP, HW, BY, HI
5	UAS 475 × HI 8830	2.68** (A × A)	NET, HW, BY
6	HI 8830 × RAJ 3307	2.46** (A × A)	DM, NET, BY
7	WHD 965 × MPO 1336	2.40** (P × A)	DH, DM, NET, HW, BY
8	DDW 55 × RAJ 3307	2.09** (A × A)	PH, NET, LS, NSP, HI
9	GW 1348 × NIDW 1158	2.04** (G × G)	DH, NET, PLS, HI
10	WHD 965 × MACS 3949	1.59** (P × G)	DH, DM, PH, NET, HI

* and ** significant at 5 and 1 per cent levels, respectively

G, A, P indicates Good, Average, and Poor general combining ability, respectively.

DH = Days to heading, DM = Days to maturity, PH = Plant height, NET = Number of effective tillers per plant, LS = length of main spike, NSP = Number of spikelets per main spike, PLS = Peduncle length of main spike, NGP = number of grain per main spike, HW = 100 grain weight, BY = Biological yield per plant, HI = Harvest index

Table 5: Summary of the three best *per se* parents, best general combiners, and best *per se* crosses along with their SCA effects, as well as the best specific cross combinations along with their SCA effects for different characters in pooled over environment in wheat

Characters	Best *per se* parents	Best general combiners	Best *per se* crosses	sca effects of best *per se* crosses	Best specific combinations based on sca effects	sca effects of best specific combinations
Days to heading	HI 8830	MACS 3949	WHD 965 × MPO 1336	-5.22**	HI 8830 × MPO 1336	-5.30**
	RAJ 3307	RAJ 3307	HI 8830 × MPO 1336	-5.30**	WHD 965 × MPO 1336	-5.22**
	WHD 965	NIDW 1158 & WHD 965	UAS 475 × MACS 3949 & GW 1348 × NIDW 1158	-4.15** & -4.49**	UAS 475 × HD 4758	-4.58**
Days to maturity	HI 8830	MACS 3949	WHD 965 × MACS 3949	-3.12**	UAS 475 × HD 4758	-3.71**
	WHD 965	HI 8830	UAS 475 × MACS 3949	-2.62**	WHD 965 × MACS 3949	-3.12**
	GW 1348	-	MPO 1336 × MACS 3949 & MACS 3949 × HD 4758	-1.90** & -2.85**	MACS 3949 × HD 4758	-2.85**
Plant height (cm)	WHD 965	WHD 965	RAJ 3307 × HD 4758	-12.45**	RAJ 3307 × HD 4758	-12.45**
	MACS 3949	MACS 3949	UAS 475 × MPO 1336	-10.63**	HI 8830 × DDW 55	-10.93**
	UAS 475	HD 4758	HI 8830 × DDW 55	-10.93**	HI 8830 × GW 1348	-10.82**
Number of effective tillers per plant	GW 1348	GW 1348	MPO 1336 × RAJ 3307	2.93**	MPO 1336 × RAJ 3307	2.93**
	MACS 3949	MACS 3949	DDW 55 × MACS 3949	1.86**	HI 8830 × RAJ 3307	1.95**
	UAS 475	MPO 1336	HI 8830 × RAJ 3307	1.95**	DDW 55 × MACS 3949	1.86**
Length of main spike (cm)	WHD 965	WHD 965	WHD 965 × HI 8830	1.30**	DDW 55 × GW 1348	1.43**
	HD 4758	HD 4758	DDW 55 × GW 1348	1.43**	WHD 965 × HI 8830	1.30**
	MPO 1336	MPO 1336 & RAJ 3307	MPO 1336 × MACS 3949	1.26**	MPO 1336 × MACS 3949	1.26**
Number of spikelets per main spike	WHD 965	WHD 965	WHD 965 × HI 8830	2.40**	UAS 475 × MPO 1336	2.95**
	NIDW 1158	HD 4758	UAS 475 × MPO 1336	2.95**	MACS 3949 × GW 1348	2.77**
	HI 8830	DDW 55	DDW 55 × GW 1348	2.47**	MPO 1336 × MACS 3949	2.48**
Peduncle length of main spike (cm)	RAJ 3307	RAJ 3307	DDW 55 × GW 1348	4.92**	DDW 55 × GW 1348	4.92**
	HI 8830	NIDW 1158	UAS 475 × GW 1348	4.90**	UAS 475 × GW 1348	4.90**
	MPO 1336	GW 1348	UAS 475 × RAJ 3307	3.56**	MPO 1336 × MACS 3949	3.87**
Number of grains per main spike	NIDW 1158	DDW 55	WHD 965 × HI 8830	10.70**	MPO 1336 × MACS 3949	12.71**
	HI 8830	HI 8830	UAS 475 × MPO 1336	9.33**	WHD 965 × HI 8830	10.70**
	DDW 55	UAS 475	MPO 1336 × MACS 3949	12.71**	UAS 475 × MPO 1336	9.33**
100-grain weight (g)	MPO 1336	MPO 1336	MACS 3949 × NIDW 1158	0.85**	MACS 3949 × NIDW 1158	0.85**
	HI 8830	HI 8830	GW 1348 × RAJ 3307	0.56**	DDW 55 × GW 1348	0.58**
	GW 1348	GW 1348	DDW 55 × GW 1348	0.58**	GW 1348 × RAJ 3307	0.56**
Grain yield per plant (g)	GW 1348	GW 1348	MPO 1336 × RAJ 3307	4.30**	MPO 1336 × RAJ 3307	4.30**
	MACS 3949	NIDW 1158	GW 1348 × NIDW 1158	2.04**	NIDW 1158 × HD 4758	3.29**
	DDW 55	MACS 3949	NIDW 1158 × HD 4758	3.29**	WHD 965 × NIDW 1158	3.09**
Biological yield per plant (g)	GW 1348	GW 1348	UAS 475 × HI 8830	11.94**	UAS 475 × HI 8830	11.94**
	NIDW 1158	MACS 3949	MPO 1336 × RAJ 3307	10.63**	MPO 1336 × RAJ 3307	10.63**
	MACS 3949	NIDW 1158	DDW 55 × MACS 3949	6.95**	WHD 965 × GW 1348	7.23**
Harvest index (%)	DDW 55	UAS 475	UAS 475 × HD 4758	9.33**	UAS 475 × HD 4758	9.33**
	HD 4758	HD 4758	GW 1348 × NIDW 1158	8.01**	GW 1348 × NIDW 1158	8.01**
	MPO 1336	GW 1348	UAS 475 × GW 1348	5.27**	WHD 965 × RAJ 3307	7.48**