Plant Archives Vol. 25, No. 2, 2025 pp. 2167-2181 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.311

AVERAGE HETEROSIS FOR YIELD AND ITS COMPONENT TRAITS IN EARLY AND LATE SOWN WHEAT (*TRITICUM AESTIVUM*. L)

Gandhodi Himaja[1]*, Swati G. Bharad[1], Ghorade R. B.[1], Potdhuke N.R.[1], Hadole S. S.[2], Walke R. D.[3], Nilesh Magar [4], Bichewar Nagesh[1], Anjali R. Talape[1] and Ch. S. N. Raju[1]
[1]Department of Agricultural Botany, Dr. PDKV, Akola, Maharashtra, India
[2]Department of Soil Science, Dr. PDKV, Akola, Maharashtra, India
[3]Department of Agricultural Statistics, Dr. PDKV, Akola, Maharashtra, India
[4]Agricultural Research Station, Niphad, MPKV, Rahuri, Maharashtra, India.
*Corresponding author E-mail: gandhodihimaja@gmail.com
(Date of Receiving : 16-08-2025; Date of Acceptance : 18-10-2025)

ABSTRACT

The present investigation was carried out to estimate Average heterosis for yield and its component traits viz., days to 50% flowering, days to maturity, grain yield (kg/plot), plant height (cm), number of effective tillers per plant, number of grains per earhead, thousand grain weight (g), grain weight per plant (g) and harvest index (%) under early and late sown conditions in Akola and Niphad as well as over the environments. Fourty five crosses generated by using 10x10 half diallel mating design were evaluated in randomized block design with three replications to study the magnitude and direction of heterosis for yield and its component traits in wheat. Significant heterosis was found over mid parent for all the traits studied in desirable direction. The findings revealed highly significant differences between parents and F1's as well as among parents for the majority of attributes. Present investigation has revealed that among 45 crosses, the Cross AKAW 2862-1 x HS 628 in early sowing, Akola; QLD 122 x AKAW 2862-1 in early sowing, Niphad; HS 628 x GW 477 in late sowing, Akola; QLD 122 x AKAW 2862-1 in late sowing, Niphad whereas over the environments QLD 122 × AKAW 2862-1 manifested significant and highest positive heterosis over mid parent for grain weight per plant. These hybrids may be further tested over various locations before release for commercial cultivation. High estimates of heterosis obtained in hybrid combinations revealed considerable genetic divergence among the parental lines and reveals good scope for commercial exploitation of heterosis in wheat.
***Keywords*:** Average heterosis, F1's, Crosses, Mid parent and Half-diallel.

Introduction

India, the world's second-largest wheat producer after China, is presently encountering serious challenges in sustaining wheat productivity. Among the most pressing constraints are abiotic stresses, particularly heat stress, which adversely affects crop growth and yield. Elevated temperatures during the grain-filling phase are a critical concern, as they accelerate crop development, shorten the duration of grain filling and ultimately reduce yields (Mitra and Bhatia, 2008).

In the context of global climate change, devising adaptive strategies to minimize the negative effects of rising temperatures has become indispensable. A key step in this direction is the identification of genetic variation for heat stress tolerance across diverse wheat genotypes. This approach not only facilitates the selection of resilient germplasm but also provides a scientific basis for breeding heat-tolerant cultivars that can withstand future climatic uncertainties (Jagadish *et al.*, 2015).

The development of high-yielding, climate-resilient cultivars requires the exploitation of genetic diversity through heterosis breeding. Heterosis or hybrid vigour, refers to the phenomenon where F_1 hybrids outperform their parents in terms of growth, yield or adaptability, owing to gene interactions under specific environmental conditions (Shull, 1908).

Unlike conventional breeding, heterosis-based strategies hold greater potential for breaking yield plateaus and achieving significant productivity gains in wheat.

For self-pollinated crops like wheat, the success of heterosis depends primarily on its direction and magnitude (Singh *et al*., 2004). Crosses displaying higher heterotic values offer greater chances of yielding superior lines in later generations, whereas poorly performing hybrids can be eliminated at the F_1 stage. Thus, assessing heterosis becomes a valuable tool for prioritizing effective parental combinations. Importantly, the exploitation of heterosis depends on genetic divergence and parental compatibility, some parental lines consistently combine better than others, highlighting the significance of systematic parent selection in hybrid breeding.

Materials and Methods

The experimental material consisted of 10 parents which includes AKW 1071, QLD 122, AKAW 3722, AKAW 3717, AKAW 2862-1, HS 628, RWP 2018-32, GW 477, QLD 118, WSM 253 and 45 crosses. The crosses (F1s) were generated during rabi, 2023-2024 by 10x10 half diallel method and the experiment was carried out under Early and Late sown conditions during rabi, 2024-2025 at the field of Wheat Research Unit, Dr. PDKV, Akola and Agricultural research station, Niphad, MPKV, Rahuri. The genotypes were grown in a Randomized Block Design (RBD) with three replications. Each entry was sown in a single-row plot of one meter length with row-to-row and plant-to-plant distances of 30 and 5 centimeters. Panse and Sukhatme's method of analysis of variance (ANOVA) for Randomized Block Design was used (1985).

Observations were recorded on five randomly selected competitive plants from each plot, except days to 50% flowering, days to maturity and grain yield per plot, where it was observed on a plot basis. The following observations were taken in each replication in the case of parents, F_1s and checks in both Early and Late sown conditions separately.

Number of days to 50% flowering

The number of days from the date of sowing to the date of emergence of earheads from 50% of the plants in a plot was calculated.

Number of days to maturity

The number of days taken from sowing up to physiological maturity was calculated in a plot.

Grain yield per plot (Kg)

The total dry weight of grains harvested per plot was calculated and expressed as Kilo grams per plot.

Plant height (cm)

The height of the main shoot of randomly selected five plants was measured from the soil level to the tip of the spike, excluding awns in centimeters and the average value was worked out.

Number of effective tillers per plant

The number of tillers bearing ear heads was counted from randomly selected five plants per plot at the time of harvest and the mean value was calculated.

Number of grains per ear head

The total number of grains in the main ear head was counted from randomly selected five plants and the average was worked out at the time of harvest.

Thousand grain weight (g)

Thousand grains were counted from each treatment and the weight was measured using an electronic weighing balance and recorded in grams.

Grain weight per plant (g)

The total dry weight of grains harvested per plant was calculated from five observational plants and the mean was worked out and recorded in grams.

Harvest index (%)

The ratio of grain yield (g) to biological yield (g) (excluding roots) was calculated and expressed in percentage as per the formula described by Donald and Hamblin (1976) as,

Harvest index = (economic yield / biological yield) × 100

Estimation of Average heterosis:

It is estimated as per cent increase or decrease over mid parent (Briggle,1963) as given below.

(%) Average heterosis, $$H_1 = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\overline{MP} = \frac{\overline{P}_1 + \overline{P}_2}{2}$$

where,

F1 = Mean performance of F_1

MP = Mean performance of both parents

$\overline{P}_1$ = Mean performance of parent 1

$\overline{P}_2$ = Mean performance of parent 2

Results and Discussion

Analysis of Variance

The analysis of variance for experimental design for various characters in each environment and the pooled analysis of variance over all the environments are presented in Table.1 and Table. 2 respectively. The findings revealed highly significant differences between parents and F1's as well as among parents, for the majority of attributes. The pooled analysis of variance across the four environments revealed that the environmental effects were significant for all the traits, thereby justifying the evaluation of genotypes under multiple environments. The detection of significant variability among parents and crosses highlights the availability of ample genetic diversity that can be effectively utilized for further crop improvement programs. Similar findings were reported by Farooq *et al*. (2015), Chaudhary *et al*. (2023), Kumar *et al*. (2021), Burdak *et al*. (2023) and Santhoshini *et al*. (2023).

Table 1 : Analysis of variance for experimental design for yield and its component traits in individual environment

Sources of variation	df	Mean sum of squares							
		Days to 50% flowering				Days to maturity			
		Early		Late		Early		Late	
		Akola	Niphad	Akola	Niphad	Akola	Niphad	Akola	Niphad
Replications	2	7.09	10.98	11.58	24.77	16.43	29.70	9.83	8.59
Treatments	54	80.20**	18.98**	53.44**	49.82**	81.21**	84.99**	94.49**	91.09**
Parents	9	68.55**	10.74**	43.85**	39.22**	71.14**	59.35**	68.03**	73.35**
Crosses	1	83.88**	21.10**	56.39**	52.31**	84.94**	92.12**	102.05**	96.43**
Parents vs. Crosses	44	23.64**	0.04	10.07**	35.56**	7.48**	2.00	0.00	16.00*
Error	108	0.68	0.88	0.72	0.87	3.27	3.19	3.54	3.40

Sources of variation	df	Mean sum of squares							
		Grain yield per plot (Kg)				Plant height (cm)			
		Early		Late		Early		Late	
		Akola	Niphad	Akola	Niphad	Akola	Niphad	Akola	Niphad
Replications	2	9.21	5.64	8.41	6.26	19.78	11.14	2.27	3.14
Treatments	54	26.04**	15.70**	40.76**	16.69**	329.44**	399.53**	214.57**	222.39**
Parents	9	42.28**	12.00**	64.35**	16.36**	287.76**	342.58**	145.58**	367.83**
Crosses	1	22.86**	16.78**	36.71**	17.13**	344.74**	419.43**	224.86**	196.47**
Parents vs. Crosses	44	20.05**	1.42	6.59**	0.39	31.51**	36.32**	382.78**	53.83**
Error	108	0.78	0.79	0.80	0.71	4.13	4.72	3.16	3.30
Sources of variation	**df**	**Mean sum of squares**							
		Effective tillers per plant				**Grains per ear head**			
		Early		**Late**		**Early**		**Late**	
		Akola	**Niphad**	**Akola**	**Niphad**	**Akola**	**Niphad**	**Akola**	**Niphad**
Replications	2	0.59	0.03	0.74	0.66	0.93	2.43	0.66	2.97
Treatments	54	5.53**	5.39**	8.92**	6.10**	192.50**	186.26**	156.89**	140.95**
Parents	9	6.71**	8.71**	7.61**	8.45**	231.26**	236.86**	165.51**	142.80**
Crosses	1	5.24**	4.77**	9.36**	5.74**	187.90**	179.72**	158.39**	143.77**
Parents vs. Crosses	44	7.75**	2.52**	1.10*	1.02*	46.15**	18.72**	13.22**	0.28
Error	108	0.37	0.27	0.26	0.24	1.03	1.58	0.70	0.51

Sources of variation	df	Mean sum of squares							
		1000 grain weight (g)				Grain weight per plant (g)			
		Early		Late		Early		Late	
		Akola	Niphad	Akola	Niphad	Akola	Niphad	Akola	Niphad
Replications	2	10.78	6.52	10.05	11.76	0.34	2.43	2.34	10.06
Treatments	54	63.84**	97.69**	58.71**	103.37**	24.51**	29.08**	29.57**	25.32**

Parents	9	114.41**	144.93**	91.82**	169.13**	28.76**	39.21**	34.76**	21.52**
Crosses	1	54.66**	90.19**	52.36**	92.09**	23.72**	27.48**	28.69**	26.24**
Parents vs. Crosses	44	12.46**	2.52*	40.07**	7.81*	21.27**	8.48**	21.82**	19.33**
Error	108	0.99	0.59	1.10	1.79	2.19	0.57	1.09	48.52

*- significant at 5% level of significance **- significant at 1% level of significance

Source of variations	df	Mean Sum of Squares					
		Days to 50% flowering	Days to maturity	Grain yield per plot	Plant height	Effective tillers per plant	Grains per earhead
Environments	3	1360.65**	4066.11**	181.59**	8575.90**	2538.68**	5286.03**
Replications within Environments	8	13.61	45.76	7.38	9.09	51.18	1.75
Treatments	54	94.00**	326.21**	71.43**	761.41**	2010.59**	628.92**
Parents	9	85.78**	247.77**	101.38**	789.12**	2571.40**	725.28**
Crosses	44	97.72**	349.30**	66.77**	764.60**	1918.03**	623.23**
Parents vs. Crosses	1	4.15*	16.37*	6.84**	371.38**	1035.92**	12.08**
Treatments * Environments	162	36.15**	8.52**	9.26**	134.84**	195.08**	15.89**
Parents * Environments	27	25.53**	8.04**	11.21**	118.21**	192.57**	17.06**
Crosses * Environments	132	38.65**	8.75**	8.90**	140.30**	198.47**	15.52**
Parents vs. Crosses * Environments.	3	21.73**	3.04**	7.21**	44.36**	68.37**	22.10**
Pooled Error	432	0.79	3.35	0.77	3.83	29.11	0.96

Sources of variation	df	Harvest index (%)			
		Early		Late	
Replications	2	4.61	7.88	0.96	4.99
Treatments	54	49.31**	91.26**	52.15**	72.56**
Parents	9	57.45**	76.03**	48.47**	78.22**
Crosses	1	48.50**	96.41**	53.93**	72.61**
Parents vs. Crosses	44	11.53**	1.56	6.97	19.24**
Error	108	0.83	2.48	2.96	1.28

*- significant at 5% level of significance **- significant at 1% level of significance

Table 2 : Pooled analysis of variance for experimental design over the environments

Source of variations	df	Mean Sum of Squares		
		Thousand grain weight	Grain weight per plant	Harvest index
Environments	3	2917.08**	446.96**	519.20**
Replications within Environments	8	9.78	3.80	4.61*
Treatments	54	288.51**	95.90**	163.81**
Parents	9	495.59**	109.25**	183.80**
Crosses	44	251.56**	93.78**	163.31**
Parents vs. Crosses	1	50.72**	68.83**	5.95
Treatments * Environments	162	11.70**	4.20**	33.82**
Parents * Environments	27	8.24**	5.00**	25.46**
Crosses * Environments	132	12.58**	4.12**	36.05**
Parents vs. Crosses * Environments.	3	4.05**	0.69**	11.12**
Pooled Error	432	1.12	1.09	1.89

*- significant at 5% level of significance **- significant at 1% level of significance

Estimation of average heterosis

The average heterosis for the 26 characters was studied under early and late sown conditions in Akola and Niphad and over the environments and are presented character-wise (Table 3.).

Estimation of average heterosis under early sowing Akola

Under early sowing at Akola, estimates of average heterosis indicated that the cross AKAW 2862-1 × HS 628 (−15.05%) recorded the highest negative average heterosis for days to 50% flowering, while AKAW 3722 × HS 628 (−12.14%) showed the maximum negative average heterosis for days to maturity. For grain yield per plot (kg), the highest positive average heterosis was expressed by RWP 2018-32 × QLD 118 (50%). In case of plant height (cm), the cross AKAW 3722 × WSM 253 (−23.86%) recorded the maximum desirable reduction. The cross AKAW 2862-1 × RWP 2018-32 (66.71%) exhibited the highest average heterosis for effective tillers per plant, whereas for grains per ear head, it was AKW 1071 × AKAW 2862-1 (81.8%). Thousand grain weight (g) was maximum in QLD 118 × WSM 253 (30.68%), while grain weight per plant (g) showed the highest value in AKAW 2862-1 × HS 628 (89.52%). For harvest index (%), the cross AKAW 2862-1 × RWP 2018-32 (48.7%) was superior.

Estimation of average heterosis under early sowing Niphad

Under early sowing at Niphad, the cross AKAW 2862-1 × GW 477 (−7.85%) recorded the highest negative average heterosis for days to 50% flowering, while AKAW 3722 × HS 628 (−12.1%) showed the maximum negative average heterosis for days to maturity. For grain yield per plot (kg), the maximum positive average heterosis was expressed by AKW 1071 × HS 628 (30.77%). In case of plant height (cm), the cross AKAW 3722 × WSM 253 (−24.57%) showed the maximum desirable reduction. The cross AKW 1071 × AKAW 2862-1 exhibited the highest average heterosis for effective tillers per plant (84.85%) and grains per ear head (83.84%). Thousand grain weight (g) was maximum in HS 628 × GW 477 (39.75%), whereas grain weight per plant (g) showed the highest value in QLD 122 × AKAW 2862-1 (109.44%). For harvest index (%), the cross QLD 122 × RWP 2018-32 (56.68%) was superior.

Estimation of average heterosis under late sowing Akola

Under late sowing at Akola, the cross AKW 1071 × AKAW 3722 (−11.05%) recorded the highest negative average heterosis for days to 50% flowering, while AKAW 2862-1 × HS 628 (−9.79%) showed the maximum negative average heterosis for days to maturity. For grain yield per plot (kg), the maximum positive average heterosis was expressed by RWP 2018-32 × QLD 118 (80%). In case of plant height (cm), the cross QLD 122 × AKAW 3717 (−28.77%) showed the maximum desirable reduction. The cross AKAW 2862-1 × HS 628 (94.64%) exhibited the highest average heterosis for effective tillers per plant, whereas grains per ear head was maximum in AKW 1071 × AKAW 2862-1 (109.53%). Thousand grain weight (g) was highest in QLD 122 × AKAW 2862-1 (37.39%), while grain weight per plant (g) showed the maximum value in HS 628 × GW 477 (81.37%). For harvest index (%), the cross AKAW 2862-1 × WSM 253 (47.97%) was superior.

Estimation of average heterosis under late sowing Niphad

Under late sowing at Niphad, the cross AKAW 3717 × WSM 253 (−11.31%) recorded the highest negative average heterosis for days to 50% flowering, while AKAW 2862-1 × WSM 253 (−9.71%) showed the maximum negative average heterosis for days to maturity. For grain yield per plot (kg), the maximum positive average heterosis was expressed by AKAW 2862-1 × RWP 2018-32 (38.67%). In case of plant height (cm), the cross RWP 2018-32 × GW 477 (−21.98%) recorded the maximum desirable reduction. The same cross, RWP 2018-32 × GW 477 (85.96%), also exhibited the highest average heterosis for effective tillers per plant. For grains per ear head, the maximum was observed in AKW 1071 × HS 628 (75.18%). Thousand grain weight (g) was highest in RWP 2018-32 × QLD 118 (39.28%), whereas grain weight per plant (g) showed the maximum value in QLD 122 × AKAW 2862-1 (117.47%). For harvest index (%), the cross AKAW 2862-1 × RWP 2018-32 (64.15%) was superior.

Estimation of pooled average heterosis over the environments

In pooled analysis across environments, the cross AKAW 2862-1 × GW 477 (−6.85%) recorded the highest negative average heterosis for days to 50% flowering, while AKAW 2862-1 × HS 628 (−9.44%) showed the maximum negative average heterosis for days to maturity. For grain yield per plot (kg), the maximum positive average heterosis was expressed by HS 628 × WSM 253 (34.57%). In case of plant height (cm), the cross AKAW 3722 × GW 477 (−21.06%) recorded the maximum desirable reduction. The cross AKW 1071 × AKAW 2862-1 exhibited the highest average heterosis for effective tillers per plant (52.19%) as well as grains per ear head (84.26%). Thousand grain weight (g) was highest in HS 628 × GW 477 (36.22%), whereas grain weight per plant (g) showed the maximum value in QLD 122 × AKAW 2862-1 (93.02%). For harvest index (%), the cross AKAW 2862-1 × RWP 2018-32 (49.55%) was superior.

Similar trends for average heterosis were reported by Beche *et al*. (2013) for grain yield per plant, Thomas *et al*. (2017) for days to maturity and plant height while Kumar *et al*. (2021a) also documented comparable results under heat stress for days to 50% flowering, days to maturity, grain yield per plant and grains per earhead. Under early sown conditions, Farooq *et al*. (2013) reported similar findings for days to 50% flowering and Thomas *et al*. (2017) for days to maturity, grain yield per plant, plant height and thousand grain weight.

Table 3 : Average heterosis (%) for different characters under individual and over the environments

S.N.	Genotype	Days to 50% flowering				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	3.61**	1.06	5.17**	5.85**	3.85**
2	AKW 1071 x AKAW 3722	1.44*	5.00**	-11.05**	-5.78**	-2.51**
3	AKW 1071 x AKAW3717	-0.53	-0.56	4.71**	5.11**	2.10**
4	AKW 1071 x AKAW 2862-1	-4.57**	-3.65**	-0.86	1.13	-2.09**
5	AKW 1071 x HS 628	3.05**	8.11**	5.78**	8.67**	6.32**
6	AKW 1071 x RWP 2018-32	6.04**	-0.82	-2.19**	-0.54	0.61
7	AKW 1071 x GW 477	10.17**	6.08**	10.31**	8.59**	8.77**
8	AKW 1071 x QLD 118	7.99**	4.40**	-2.96**	-5.85**	1.07
9	AKW 1071 x WSM 253	3.19**	4.76**	9.20**	11.49**	7.03**
10	QLD 122 x AKAW 3722	19.22**	2.14**	5.56**	8.64**	8.91**
11	QLD 122 x AKAW3717	9.79**	6.45**	6.25**	5.45**	7.09**
12	QLD 122 x AKAW 2862-1	-7.39**	-3.02**	8.21**	10.24**	1.30*
13	QLD 122 x HS 628	5.42**	3.65**	22.09**	21.60**	12.36**
14	QLD 122 x RWP 2018-32	8.51**	4.49**	-6.36**	-8.05**	-0.07
15	QLD 122 x GW 477	17.49**	6.38**	6.19**	7.96**	9.58**
16	QLD 122 x QLD 118	14.67**	0.53	9.43**	10.00**	8.55**
17	QLD 122 x WSM 253	7.22**	2.04**	14.63**	16.56**	9.62**
18	AKAW 3722 x AKAW3717	0.86	9.60**	1.90**	-5.39**	1.85**
19	AKAW 3722 x AKAW 2862-1	-9.59**	-0.53	17.54**	15.48**	5.12**
20	AKAW 3722 x HS 628	-5.21**	10.38**	8.70**	10.98**	6.01**
21	AKAW 3722 x RWP 2018-32	5.67**	0.83	2.92**	-1.70*	1.87**
22	AKAW 3722 x GW 477	8.31**	6.15**	12.24**	8.45**	8.74**
23	AKAW 3722 x QLD 118	7.78**	0.56	27.39**	22.84**	14.11**
24	AKAW 3722 x WSM 253	0.29	-4.81**	9.88**	6.67**	2.69**
25	AKAW3717 x AKAW 2862-1	2.54**	-2.12**	11.53**	5.85**	4.11**
26	AKAW3717 x HS 628	5.58**	5.49**	5.03**	5.39**	5.39**
27	AKAW3717 x RWP 2018-32	17.58**	10.86**	2.96**	-2.23**	7.40**
28	AKAW3717 x GW 477	0.56	10.11**	16.01**	9.46**	8.92**
29	AKAW3717 x QLD 118	3.58**	9.50**	14.84**	6.06**	8.30**
30	AKAW3717 x WSM 253	9.57**	5.91**	-5.62**	-11.31**	0.14
31	AKAW 2862-1 x HS 628	-15.05**	-2.56**	-2.14**	-0.60	-5.53**
32	AKAW 2862-1 x RWP 2018-32	0.00	-2.34**	9.51**	6.67**	3.26**
33	AKAW 2862-1 x GW 477	-8.60**	-7.85**	-5.29**	-5.41**	-6.85**
34	AKAW 2862-1 x QLD 118	-8.14**	-5.73**	4.08**	-1.20	-3.11**
35	AKAW 2862-1 x WSM 253	-9.64**	-5.53**	-0.30	-5.33**	-5.41**
36	HS 628 x RWP 2018-32	9.95**	8.89**	3.49**	0.00	5.73**
37	HS 628 x GW 477	14.52**	-3.80**	8.61**	4.96**	6.06**
38	HS 628 x QLD 118	11.29**	1.62*	5.70**	6.17**	6.25**
39	HS 628 x WSM 253	6.60**	1.04	15.34**	16.36**	9.34**
40	RWP 2018-32 x GW 477	18.13**	1.38*	7.56**	4.63**	7.77**
41	RWP 2018-32 x QLD 118	7.12**	5.21**	14.29**	11.49**	9.43**
42	RWP 2018-32 x WSM 253	5.49**	-3.96**	-4.05**	-4.52**	-1.73**
43	GW 477 x QLD 118	4.40**	3.87**	-0.30	-2.06**	1.53*
44	GW 477 x WSM 253	2.26**	1.60*	10.32**	8.41**	5.52**
45	QLD 118 x WSM 253	7.99**	0.53	1.26*	-1.84**	2.09**
	SE(m) +/-	0.58	0.66	0.60	0.65	0.62
	CD @5%	1.15	1.31	1.19	1.30	1.23
	CD @ 1 %	1.53	1.74	1.58	1.72	1.62

S.N.	Genotype	Days to maturity				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	9.58**	2.10	2.18	6.02**	4.89**
2	AKW 1071 x AKAW 3722	-7.07**	-5.95**	-5.51**	-5.64**	-6.05**
3	AKW 1071 x AKAW3717	1.00	0.79	2.10	-0.66	0.79
4	AKW 1071 x AKAW 2862-1	-1.14	-5.09**	-1.84	-3.23*	-2.88*
5	AKW 1071 x HS 628	1.14	-0.90	1.34	1.30	0.68
6	AKW 1071 x RWP 2018-32	5.32**	3.13*	6.76**	5.68**	5.16**
7	AKW 1071 x GW 477	8.45**	3.86**	7.72**	4.38**	6.03**
8	AKW 1071 x QLD 118	8.28**	5.51**	5.57**	2.74*	5.52**
9	AKW 1071 x WSM 253	4.38**	4.05**	3.18*	-1.01	2.67*
10	QLD 122 x AKAW 3722	1.11	-2.01	3.21*	4.06**	1.51
11	QLD 122 x AKAW3717	9.00**	6.54**	4.86**	1.77	5.55**
12	QLD 122 x AKAW 2862-1	6.43**	3.47**	5.47**	3.91**	4.78**
13	QLD 122 x HS 628	-0.64	-3.19*	-4.98**	-4.57**	-3.34**
14	QLD 122 x RWP 2018-32	11.15**	8.46**	12.10**	11.67**	10.77**
15	QLD 122 x GW 477	16.81**	8.36**	13.18**	12.54**	12.59**
16	QLD 122 x QLD 118	9.68**	8.65**	7.22**	7.13**	8.18**
17	QLD 122 x WSM 253	9.12**	9.61**	7.61**	7.67**	8.53**
18	AKAW 3722 x AKAW3717	-6.27**	-3.78**	-4.84**	-5.26**	-5.03**
19	AKAW 3722 x AKAW 2862-1	-10.94**	-6.03**	-9.29**	-4.50**	-7.65**
20	AKAW 3722 x HS 628	-12.14**	-12.10**	-5.60**	-6.08**	-9.08**
21	AKAW 3722 x RWP 2018-32	-4.68**	-6.01**	-5.26**	-4.62**	-5.16**
22	AKAW 3722 x GW 477	-5.30**	-1.54	-2.98*	-5.03**	-3.68**
23	AKAW 3722 x QLD 118	-3.90**	-6.18**	-5.48**	-7.06**	-5.66**
24	AKAW 3722 x WSM 253	-4.44**	-2.99*	-5.90**	-7.59**	-5.18**
25	AKAW3717 x AKAW 2862-1	1.43	5.33**	1.51	-1.28	1.79
26	AKAW3717 x HS 628	2.69*	6.26**	6.02**	3.86**	4.71**
27	AKAW3717 x RWP 2018-32	9.52**	11.64**	13.88**	11.07**	11.49**
28	AKAW3717 x GW 477	14.73**	17.18**	19.85**	14.73**	16.58**
29	AKAW3717 x QLD 118	0.34	3.53**	4.49**	0.34	2.15
30	AKAW3717 x WSM 253	5.90**	9.35**	10.25**	5.67**	7.77**
31	AKAW 2862-1 x HS 628	-9.66**	-8.99**	-9.79**	-9.37**	-9.44**
32	AKAW 2862-1 x RWP 2018-32	1.64	-1.51	2.21	2.15	1.06
33	AKAW 2862-1 x GW 477	-0.50	-0.93	-1.58	-1.85	-1.21
34	AKAW 2862-1 x QLD 118	-4.78**	-3.19*	-1.37	-5.59**	-3.75**
35	AKAW 2862-1 x WSM 253	-4.67**	-2.10	-6.60**	-9.71**	-5.69**
36	HS 628 x RWP 2018-32	7.19**	6.97**	6.12**	5.82**	6.54**
37	HS 628 x GW 477	6.20**	6.83**	8.77**	5.92**	6.91**
38	HS 628 x QLD 118	7.39**	6.54**	7.03**	5.30**	6.56**
39	HS 628 x WSM 253	4.33**	4.52**	6.76**	4.89**	5.09**
40	RWP 2018-32 x GW 477	12.92**	9.42**	14.61**	11.15**	11.93**
41	RWP 2018-32 x QLD 118	10.57**	8.11**	13.35**	16.34**	11.97**
42	RWP 2018-32 x WSM 253	2.88*	2.52*	5.40**	4.32**	3.73**
43	GW 477 x QLD 118	13.88**	11.26**	13.04**	13.06**	12.77**
44	GW 477 x WSM 253	3.47**	4.19**	4.83**	0.53	3.26*
45	QLD 118 x WSM 253	0.68	1.74	1.63	-0.34	0.93
	SE(m) +/-	1.27	1.26	1.33	1.30	1.29
	CD @5%	2.53	2.50	2.63	2.58	2.54
	CD @ 1 %	3.35	3.30	3.49	3.41	3.34

S.N.	Genotype	Grain yield per plot (kg)				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	5.05**	-0.00	3.53**	17.07**	6.04**
2	AKW 1071 x AKAW 3722	-17.02**	-25.53**	-13.92**	-10.14**	-17.26**
3	AKW 1071 x AKAW3717	-20.00**	-22.77**	-6.02**	-12.82**	-15.97**
4	AKW 1071 x AKAW 2862-1	25.93**	20.99**	9.33**	31.34**	21.71**
5	AKW 1071 x HS 628	20.48**	30.77**	23.29**	36.36**	27.33**
6	AKW 1071 x RWP 2018-32	10.59**	16.46**	-8.11**	26.47**	11.11**
7	AKW 1071 x GW 477	20.93**	24.39**	36.00**	31.34**	27.74**
8	AKW 1071 x QLD 118	16.13**	8.51**	27.50**	21.52**	17.92**
9	AKW 1071 x WSM 253	24.75**	6.93**	50.00**	30.77**	27.17**
10	QLD 122 x AKAW 3722	20.72**	-3.45**	42.22**	-14.29**	10.78**
11	QLD 122 x AKAW3717	-35.71**	-41.46**	-29.79**	-36.00**	-36.13**
12	QLD 122 x AKAW 2862-1	20.41**	-4.85**	39.53**	19.10**	17.55**
13	QLD 122 x HS 628	0.00	-2.00**	35.71**	-2.27**	6.99**
14	QLD 122 x RWP 2018-32	3.92**	-0.99	34.12**	-0.00	8.47**
15	QLD 122 x GW 477	-2.91**	-7.69**	16.28**	-5.62**	-0.52
16	QLD 122 x QLD 118	-7.27**	-8.62**	18.68**	0.99	0.00
17	QLD 122 x WSM 253	-11.86**	-17.07**	13.13**	-12.00**	-7.73**
18	AKAW 3722 x AKAW3717	-14.02**	-15.97**	-15.91**	5.75**	-10.72**
19	AKAW 3722 x AKAW 2862-1	-11.83**	-21.21**	-25.00**	-2.63**	-15.52**
20	AKAW 3722 x HS 628	-11.58**	-12.50**	-5.13**	-1.33*	-8.14**
21	AKAW 3722 x RWP 2018-32	-1.03	11.34**	6.33**	24.68**	9.71**
22	AKAW 3722 x GW 477	-2.04**	-4.00**	20.00**	10.53**	5.08**
23	AKAW 3722 x QLD 118	-0.95	-10.71**	3.53**	0.00	-2.56**
24	AKAW 3722 x WSM 253	16.81**	-0.84	48.39**	31.03**	21.84**
25	AKAW3717 x AKAW 2862-1	-4.26**	-18.87**	-23.81**	-10.59**	-14.36**
26	AKAW3717 x HS 628	12.50**	10.68**	36.59**	35.71**	22.74**
27	AKAW3717 x RWP 2018-32	2.04**	-3.85**	13.25**	4.65**	3.50**
28	AKAW3717 x GW 477	3.03**	6.54**	16.67**	20.00**	10.93**
29	AKAW3717 x QLD 118	-28.30**	-31.09**	-14.61**	-17.53**	-23.60**
30	AKAW3717 x WSM 253	-26.32**	-7.94**	-38.14**	8.33**	-15.94**
31	AKAW 2862-1 x HS 628	21.95**	15.66**	37.84**	15.07**	22.44**
32	AKAW 2862-1 x RWP 2018-32	28.57**	28.57**	30.67**	38.67**	31.45**
33	AKAW 2862-1 x GW 477	3.53**	10.34**	0.00	16.22**	7.45**
34	AKAW 2862-1 x QLD 118	-10.87**	-15.15**	-18.52**	-6.98**	-12.85**
35	AKAW 2862-1 x WSM 253	10.00**	1.89**	19.10**	10.59**	10.00**
36	HS 628 x RWP 2018-32	20.93**	20.99**	12.33**	18.92**	18.47**
37	HS 628 x GW 477	24.14**	26.19**	13.51**	26.03**	22.64**
38	HS 628 x QLD 118	17.02**	10.42**	13.92**	8.24**	12.43**
39	HS 628 x WSM 253	41.18**	8.74**	58.62**	33.33**	34.57**
40	RWP 2018-32 x GW 477	23.60**	24.71**	30.67**	33.33**	27.78**
41	RWP 2018-32 x QLD 118	50.00**	17.53**	80.00**	-44.83**	25.00**
42	RWP 2018-32 x WSM 253	5.77**	11.54**	0.00	18.60**	8.90**
43	GW 477 x QLD 118	-5.15**	-4.00**	11.11**	6.98**	1.65**
44	GW 477 x WSM 253	-14.29**	-19.63**	-12.36**	-8.24**	-13.99**
45	QLD 118 x WSM 253	39.29**	-0.84	65.96**	13.40**	27.96**
	SE(m) +/-	0.62	0.62	0.63	0.59	0.62
	CD @5%	1.23	1.24	1.25	1.18	1.22
	CD @ 1 %	1.63	1.64	1.66	1.56	1.60

S.N.	Genotype	Plant height (cm)				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	-1.54	-3.38*	2.30	-12.70**	-3.89**
2	AKW 1071 x AKAW 3722	-3.83**	-6.89**	-5.00**	-7.88**	-5.92**
3	AKW 1071 x AKAW3717	-2.91*	2.36	9.66**	17.12**	6.02**
4	AKW 1071 x AKAW 2862-1	-2.35	-4.94**	21.64**	23.65**	7.57**
5	AKW 1071 x HS 628	1.28	4.76**	17.26**	19.48**	10.00**
6	AKW 1071 x RWP 2018-32	-9.70**	-13.53**	0.27	-9.92**	-8.67**
7	AKW 1071 x GW 477	0.16	0.22	-6.45**	-7.54**	-3.20*
8	AKW 1071 x QLD 118	4.28**	-0.69	30.19**	8.14**	9.11**
9	AKW 1071 x WSM 253	-16.76**	-19.00**	4.78**	-2.54*	-9.99**
10	QLD 122 x AKAW 3722	7.25**	5.76**	6.65**	12.58**	8.01**
11	QLD 122 x AKAW3717	-5.76**	-2.48	-28.77**	-12.91**	-12.33**
12	QLD 122 x AKAW 2862-1	-21.81**	-22.11**	-6.52**	6.33**	-12.47**
13	QLD 122 x HS 628	0.47	-1.91	-6.08**	-0.57	-1.98
14	QLD 122 x RWP 2018-32	-4.40**	-10.22**	5.09**	-3.78**	-3.65**
15	QLD 122 x GW 477	-16.91**	-19.24**	-13.58**	-18.06**	-17.01**
16	QLD 122 x QLD 118	-1.18	-3.09*	8.97**	-2.85*	0.10
17	QLD 122 x WSM 253	4.32**	6.69**	9.34**	3.85**	5.99**
18	AKAW 3722 x AKAW3717	-20.58**	-21.93**	-25.08**	-14.48**	-20.73**
19	AKAW 3722 x AKAW 2862-1	-19.24**	-19.82**	-13.31**	-11.50**	-16.42**
20	AKAW 3722 x HS 628	13.94**	10.85**	8.96**	41.23**	18.14**
21	AKAW 3722 x RWP 2018-32	-10.58**	-12.30**	-1.97	-7.42**	-8.30**
22	AKAW 3722 x GW 477	-20.19**	-22.83**	-22.52**	-18.54**	-21.06**
23	AKAW 3722 x QLD 118	9.35**	9.72**	8.00**	4.30**	7.91**
24	AKAW 3722 x WSM 253	-23.86**	-24.57**	-13.40**	-9.76**	-18.76**
25	AKAW3717 x AKAW 2862-1	-12.00**	-7.15**	-21.85**	4.37**	-9.76**
26	AKAW3717 x HS 628	0.70	0.70	9.67**	33.37**	9.68**
27	AKAW3717 x RWP 2018-32	7.45**	3.41*	12.58**	23.19**	11.03**
28	AKAW3717 x GW 477	11.56**	13.25**	-11.01**	-2.20	3.32*
29	AKAW3717 x QLD 118	17.10**	20.95**	7.31**	1.98	12.54**
30	AKAW3717 x WSM 253	-4.29**	-3.71*	-19.59**	11.27**	-4.45**
31	AKAW 2862-1 x HS 628	-17.15**	-12.62**	-8.95**	-1.48	-10.91**
32	AKAW 2862-1 x RWP 2018-32	-14.89**	-18.61**	-20.58**	2.95*	-13.51**
33	AKAW 2862-1 x GW 477	-17.94**	-22.58**	-10.49**	-2.48	-14.37**
34	AKAW 2862-1 x QLD 118	-12.10**	-12.21**	-16.91**	-14.40**	-13.61**
35	AKAW 2862-1 x WSM 253	-13.21**	-14.00**	0.02	10.22**	-6.33**
36	HS 628 x RWP 2018-32	-1.64	-5.40**	-11.15**	14.25**	-1.27
37	HS 628 x GW 477	11.42**	6.69**	23.21**	10.80**	12.76**
38	HS 628 x QLD 118	2.04	-1.46	0.29	-1.26	-0.09
39	HS 628 x WSM 253	-13.81**	-16.64**	11.86**	22.23**	-2.01
40	RWP 2018-32 x GW 477	9.75**	5.24**	-8.44**	-21.98**	-3.22*
41	RWP 2018-32 x QLD 118	-12.64**	-15.44**	10.29**	-8.32**	-7.68**
42	RWP 2018-32 x WSM 253	-17.77**	-19.95**	5.63**	5.76**	-8.64**
43	GW 477 x QLD 118	-6.75**	-9.30**	3.66**	-7.29**	-5.34**
44	GW 477 x WSM 253	-15.70**	-21.37**	0.85	1.95	-10.06**
45	QLD 118 x WSM 253	2.17	-3.80*	16.95**	22.97**	7.74**
	SE(m) +/-	1.43	1.53	1.25	1.28	1.38
	CD @5%	2.84	3.04	2.49	2.54	2.71
	CD @ 1 %	3.76	4.02	3.30	3.36	3.58

S.N.	Genotype	Effective tillers per plant				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	23.20**	34.76**	8.01**	41.31**	26.23**
2	AKW 1071 x AKAW 3722	-14.20**	18.14**	-18.68**	29.18**	2.11**
3	AKW 1071 x AKAW3717	23.55**	9.45**	-27.15**	-13.09**	-3.04**
4	AKW 1071 x AKAW 2862-1	50.41**	84.85**	22.05**	50.43**	52.19**
5	AKW 1071 x HS 628	32.89**	29.40**	50.42**	12.47**	31.74**
6	AKW 1071 x RWP 2018-32	38.85**	29.36**	9.34**	-7.75**	18.21**
7	AKW 1071 x GW 477	13.01**	45.28**	23.79**	32.74**	27.90**
8	AKW 1071 x QLD 118	52.56**	45.03**	14.62**	26.14**	33.46**
9	AKW 1071 x WSM 253	38.43**	43.92**	46.91**	35.10**	41.27**
10	QLD 122 x AKAW 3722	19.05**	30.23**	27.81**	21.27**	24.64**
11	QLD 122 x AKAW3717	-16.34**	0.14	-18.33**	-14.19**	-12.23**
12	QLD 122 x AKAW 2862-1	33.69**	41.49**	66.66**	-3.26**	33.20**
13	QLD 122 x HS 628	5.15**	10.89**	16.54**	0.93**	8.16**
14	QLD 122 x RWP 2018-32	32.72**	40.73**	33.89**	33.26**	35.14**
15	QLD 122 x GW 477	26.19**	28.65**	20.25**	9.02**	21.47**
16	QLD 122 x QLD 118	24.00**	20.40**	28.43**	6.50**	19.71**
17	QLD 122 x WSM 253	-4.00**	-16.38**	7.38**	-14.60**	-7.13**
18	AKAW 3722 x AKAW3717	13.68**	-22.97**	-28.21**	-22.97**	-15.92**
19	AKAW 3722 x AKAW 2862-1	-4.13**	-23.40**	-32.13**	-33.79**	-23.53**
20	AKAW 3722 x HS 628	7.46**	-15.79**	-33.33**	-7.98**	-12.07**
21	AKAW 3722 x RWP 2018-32	20.58**	41.50**	-5.50**	9.05**	16.16**
22	AKAW 3722 x GW 477	0.27	22.60**	-14.89**	10.99**	4.37**
23	AKAW 3722 x QLD 118	10.28**	8.67**	-19.89**	-14.03**	-4.54**
24	AKAW 3722 x WSM 253	19.05**	15.56**	29.36**	18.18**	20.58**
25	AKAW3717 x AKAW 2862-1	-2.47**	12.03**	-31.11**	-19.80**	-10.50**
26	AKAW3717 x HS 628	-10.75**	2.91**	-0.39	0.13	-1.99**
27	AKAW3717 x RWP 2018-32	54.01**	47.13**	30.22**	6.08**	34.11**
28	AKAW3717 x GW 477	39.38**	53.60**	22.12**	36.95**	37.61**
29	AKAW3717 x QLD 118	24.86**	2.39**	-36.38**	-6.24**	-6.11**
30	AKAW3717 x WSM 253	2.59**	9.18**	-40.03**	-6.53**	-9.43**
31	AKAW 2862-1 x HS 628	55.07**	41.78**	94.64**	12.56**	48.02**
32	AKAW 2862-1 x RWP 2018-32	66.71**	37.11**	20.51**	14.52**	35.00**
33	AKAW 2862-1 x GW 477	-27.12**	-10.73**	-41.13**	-19.57**	-24.14**
34	AKAW 2862-1 x QLD 118	9.43**	-6.38**	-27.09**	-40.10**	-17.32**
35	AKAW 2862-1 x WSM 253	6.15**	-3.66**	35.55**	-9.41**	6.00**
36	HS 628 x RWP 2018-32	62.13**	58.29**	52.44**	31.02**	51.40**
37	HS 628 x GW 477	35.24**	26.97**	53.01**	80.55**	47.30**
38	HS 628 x QLD 118	45.56**	14.00**	23.46**	17.43**	24.56**
39	HS 628 x WSM 253	15.90**	6.34**	18.63**	8.12**	12.02**
40	RWP 2018-32 x GW 477	35.57**	63.97**	12.92**	85.96**	47.85**
41	RWP 2018-32 x QLD 118	52.07**	27.96**	22.56**	51.96**	38.12**
42	RWP 2018-32 x WSM 253	7.66**	26.73**	7.69**	22.51**	16.16**
43	GW 477 x QLD 118	35.89**	17.16**	16.44**	10.86**	19.93**
44	GW 477 x WSM 253	28.23**	0.09	21.24**	10.09**	14.99**
45	QLD 118 x WSM 253	30.00**	10.64**	0.33	4.34**	10.53**
	SE(m) +/-	0.43	0.37	0.36	0.35	0.38
	CD @5%	0.85	0.73	0.72	0.69	0.74
	CD @ 1 %	1.13	0.97	0.95	0.92	0.98

S.N.	Genotype	Grains per ear head				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	19.75**	25.13**	33.77**	50.44**	30.35**
2	AKW 1071 x AKAW 3722	6.90**	2.70**	39.48**	-11.24**	8.71**
3	AKW 1071 x AKAW3717	-14.69**	-2.93**	-9.65**	-10.74**	-9.56**
4	AKW 1071 x AKAW 2862-1	81.80**	83.84**	109.53**	65.70**	84.26**
5	AKW 1071 x HS 628	39.54**	64.34**	51.32**	75.18**	55.77**
6	AKW 1071 x RWP 2018-32	12.82**	27.65**	23.12**	13.38**	19.16**
7	AKW 1071 x GW 477	43.63**	64.48**	51.76**	60.27**	54.47**
8	AKW 1071 x QLD 118	11.15**	21.93**	33.79**	42.11**	25.12**
9	AKW 1071 x WSM 253	53.70**	49.55**	77.93**	63.33**	59.64**
10	QLD 122 x AKAW 3722	32.65**	14.30**	44.42**	26.76**	28.49**
11	QLD 122 x AKAW3717	-4.58**	-4.64**	2.91**	-19.21**	-6.11**
12	QLD 122 x AKAW 2862-1	72.12**	47.98**	90.19**	66.20**	67.30**
13	QLD 122 x HS 628	27.83**	37.51**	37.49**	51.99**	37.26**
14	QLD 122 x RWP 2018-32	29.34**	33.62**	39.07**	31.34**	33.03**
15	QLD 122 x GW 477	23.13**	22.46**	32.30**	44.99**	29.27**
16	QLD 122 x QLD 118	8.43**	3.59**	28.81**	44.44**	18.24**
17	QLD 122 x WSM 253	28.12**	16.71**	39.52**	45.41**	30.56**
18	AKAW 3722 x AKAW3717	-22.82**	-22.65**	-27.32**	-30.63**	-25.51**
19	AKAW 3722 x AKAW 2862-1	-22.45**	-20.91**	-10.93**	-33.52**	-22.26**
20	AKAW 3722 x HS 628	-19.00**	-29.64**	-3.60**	-25.04**	-20.00**
21	AKAW 3722 x RWP 2018-32	9.17**	7.68**	8.83**	0.06	6.62**
22	AKAW 3722 x GW 477	37.04**	33.13**	59.06**	39.52**	41.14**
23	AKAW 3722 x QLD 118	12.77**	-1.01	18.85**	12.58**	9.95**
24	AKAW 3722 x WSM 253	25.49**	16.70**	37.55**	24.54**	25.24**
25	AKAW3717 x AKAW 2862-1	6.68**	6.93**	1.15	-19.08**	-0.45
26	AKAW3717 x HS 628	20.61**	19.95**	45.30**	51.86**	32.30**
27	AKAW3717 x RWP 2018-32	19.02**	16.15**	44.80**	16.10**	22.93**
28	AKAW3717 x GW 477	7.50**	6.78**	24.22**	15.04**	12.53**
29	AKAW3717 x QLD 118	-23.04**	-23.92**	-14.15**	-36.35**	-24.25**
30	AKAW3717 x WSM 253	-26.91**	-26.68**	-24.82**	-36.24**	-28.45**
31	AKAW 2862-1 x HS 628	58.39**	41.40**	64.80**	44.12**	51.83**
32	AKAW 2862-1 x RWP 2018-32	36.57**	14.07**	43.65**	9.86**	25.25**
33	AKAW 2862-1 x GW 477	19.21**	15.90**	30.29**	8.74**	18.09**
34	AKAW 2862-1 x QLD 118	-16.64**	-22.08**	-2.25**	-13.41**	-14.71**
35	AKAW 2862-1 x WSM 253	38.00**	9.26**	30.73**	17.80**	23.47**
36	HS 628 x RWP 2018-32	27.94**	26.07**	48.85**	33.54**	32.93**
37	HS 628 x GW 477	36.28**	33.02**	61.77**	58.19**	45.12**
38	HS 628 x QLD 118	2.76**	18.65**	22.70**	36.43**	17.94**
39	HS 628 x WSM 253	48.16**	49.05**	65.36**	64.91**	55.38**
40	RWP 2018-32 x GW 477	28.63**	53.85**	39.43**	35.00**	39.20**
41	RWP 2018-32 x QLD 118	50.00**	47.64**	72.11**	50.00**	53.85**
42	RWP 2018-32 x WSM 253	29.73**	22.47**	41.24**	21.43**	28.20**
43	GW 477 x QLD 118	19.80**	22.37**	28.66**	37.62**	25.97**
44	GW 477 x WSM 253	15.76**	22.94**	21.00**	41.51**	24.32**
45	QLD 118 x WSM 253	39.02**	35.53**	35.94**	45.80**	38.69**
	SE(m) +/-	0.71	0.88	0.59	0.50	0.69
	CD @5%	1.42	1.76	1.17	1.00	1.36
	CD @ 1 %	1.88	2.33	1.55	1.32	1.79

S.N.	Genotype	1000 grain weight (g)				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	-4.49**	-13.42**	1.14	-15.37**	-5.55**
2	AKW 1071 x AKAW 3722	6.59**	-6.50**	11.54**	-2.02*	3.40**
3	AKW 1071 x AKAW3717	-1.74*	-15.76**	0.64	-18.53**	-6.46**
4	AKW 1071 x AKAW 2862-1	24.83**	3.66**	23.42**	5.14**	16.00**
5	AKW 1071 x HS 628	17.40**	13.51**	12.41**	16.05**	15.33**
6	AKW 1071 x RWP 2018-32	11.03**	-14.26**	7.56**	-15.02**	-1.15
7	AKW 1071 x GW 477	22.88**	18.09**	32.36**	16.85**	24.69**
8	AKW 1071 x QLD 118	0.76	7.30**	1.76*	1.44	4.49**
9	AKW 1071 x WSM 253	21.93**	19.59**	23.70**	18.40**	23.09**
10	QLD 122 x AKAW 3722	17.46**	28.63**	24.15**	26.28**	26.06**
11	QLD 122 x AKAW3717	-10.27**	-18.88**	0.39	-16.25**	-10.42**
12	QLD 122 x AKAW 2862-1	17.92**	35.86**	37.39**	35.57**	35.08**
13	QLD 122 x HS 628	-7.97**	11.85**	-2.64**	14.11**	4.85**
14	QLD 122 x RWP 2018-32	-0.57	14.06**	6.73**	17.61**	10.88**
15	QLD 122 x GW 477	8.14**	-1.72**	25.39**	-7.01**	10.72**
16	QLD 122 x QLD 118	1.30	6.53**	8.81**	2.17*	5.18**
17	QLD 122 x WSM 253	10.16**	3.87**	18.44**	1.75	9.31**
18	AKAW 3722 x AKAW3717	-17.19**	-24.18**	-8.90**	-23.37**	-16.87**
19	AKAW 3722 x AKAW 2862-1	1.03	-11.95**	7.11**	-16.58**	-3.04**
20	AKAW 3722 x HS 628	6.70**	-8.67**	10.88**	-9.86**	0.78
21	AKAW 3722 x RWP 2018-32	25.08**	36.23**	29.05**	32.69**	30.47**
22	AKAW 3722 x GW 477	16.21**	34.45**	32.08**	33.55**	30.91**
23	AKAW 3722 x QLD 118	9.62**	9.57**	15.19**	2.65**	10.95**
24	AKAW 3722 x WSM 253	24.98**	23.57**	30.29**	19.04**	26.24**
25	AKAW3717 x AKAW 2862-1	-9.93**	-22.54**	6.20**	-17.20**	-7.80**
26	AKAW3717 x HS 628	3.53**	19.45**	13.35**	21.84**	15.30**
27	AKAW3717 x RWP 2018-32	3.28**	14.90**	6.53**	19.13**	11.78**
28	AKAW3717 x GW 477	9.37**	28.61**	22.43**	11.96**	21.47**
29	AKAW3717 x QLD 118	-9.75**	-17.81**	-11.83**	-24.99**	-15.62**
30	AKAW3717 x WSM 253	-3.96**	-29.07**	1.75*	-20.80**	-12.35**
31	AKAW 2862-1 x HS 628	9.86**	18.64**	16.96**	18.76**	17.21**
32	AKAW 2862-1 x RWP 2018-32	6.91**	23.79**	11.59**	30.55**	18.71**
33	AKAW 2862-1 x GW 477	5.65**	-6.55**	10.56**	-13.07**	0.44
34	AKAW 2862-1 x QLD 118	-13.27**	-24.91**	-5.17**	-27.68**	-14.83**
35	AKAW 2862-1 x WSM 253	2.54**	-1.40*	10.19**	10.79**	8.17**
36	HS 628 x RWP 2018-32	19.87**	32.70**	21.53**	26.90**	24.72**
37	HS 628 x GW 477	26.85**	39.75**	34.16**	35.79**	36.22**
38	HS 628 x QLD 118	14.00**	28.38**	17.57**	25.47**	22.39**
39	HS 628 x WSM 253	12.99**	28.00**	13.28**	20.79**	19.86**
40	RWP 2018-32 x GW 477	27.83**	37.32**	34.07**	33.39**	35.38**
41	RWP 2018-32 x QLD 118	19.53**	36.90**	20.95**	39.28**	30.03**
42	RWP 2018-32 x WSM 253	9.88**	3.97**	12.75**	5.38**	9.73**
43	GW 477 x QLD 118	8.43**	13.51**	22.69**	7.08**	16.63**
44	GW 477 x WSM 253	6.74**	17.66**	23.00**	19.33**	19.92**
45	QLD 118 x WSM 253	30.68**	25.26**	34.92**	35.71**	31.76**
	SE(m) +/-	0.70	0.54	0.74	0.94	0.74
	CD @5%	1.39	1.07	1.47	1.87	1.47
	CD @ 1 %	1.84	1.42	1.95	2.48	1.93

S.N.	Genotype	Grain weight per plant (g)				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	30.04**	-7.09**	15.80**	24.40**	15.98**
2	AKW 1071 x AKAW 3722	-7.31**	-26.71**	-16.69**	-29.04**	-19.00**
3	AKW 1071 x AKAW3717	13.56**	-17.89**	-7.57**	-11.57**	-5.19**
4	AKW 1071 x AKAW 2862-1	63.20**	58.07**	47.88**	42.76**	52.72**
5	AKW 1071 x HS 628	64.86**	59.89**	67.52**	23.75**	54.95**
6	AKW 1071 x RWP 2018-32	33.72**	-17.58**	1.25	2.38**	5.79**
7	AKW 1071 x GW 477	86.26**	81.68**	62.53**	49.33**	69.84**
8	AKW 1071 x QLD 118	70.09**	42.18**	42.05**	54.74**	52.30**
9	AKW 1071 x WSM 253	83.24**	56.90**	66.98**	72.75**	70.31**
10	QLD 122 x AKAW 3722	19.79**	36.32**	27.28**	67.77**	35.03**
11	QLD 122 x AKAW3717	8.98**	-23.86**	-44.37**	-52.99**	-26.34**
12	QLD 122 x AKAW 2862-1	81.96**	109.44**	73.02**	117.47**	93.02**
13	QLD 122 x HS 628	39.07**	35.87**	17.92**	39.59**	32.62**
14	QLD 122 x RWP 2018-32	36.55**	19.00**	20.54**	48.57**	30.23**
15	QLD 122 x GW 477	39.97**	25.83**	55.79**	88.07**	50.96**
16	QLD 122 x QLD 118	12.78**	-17.66**	37.48**	75.29**	23.94**
17	QLD 122 x WSM 253	0.44	-27.18**	1.16	23.84**	-1.50*
18	AKAW 3722 x AKAW3717	-10.12**	-36.04**	-39.06**	-34.55**	-29.14**
19	AKAW 3722 x AKAW 2862-1	-1.48	-10.75**	-21.17**	-14.77**	-11.95**
20	AKAW 3722 x HS 628	-20.19**	-29.59**	-4.64**	-4.74**	-14.92**
21	AKAW 3722 x RWP 2018-32	10.47**	-1.16*	-0.43	-3.85**	1.79*
22	AKAW 3722 x GW 477	27.39**	21.65**	38.51**	40.79**	32.01**
23	AKAW 3722 x QLD 118	16.85**	18.95**	16.30**	33.41**	20.46**
24	AKAW 3722 x WSM 253	24.29**	54.35**	43.04**	64.61**	44.56**
25	AKAW3717 x AKAW 2862-1	22.73**	-39.94**	5.74**	12.93**	2.14**
26	AKAW3717 x HS 628	28.80**	8.44**	25.06**	11.78**	19.44**
27	AKAW3717 x RWP 2018-32	16.53**	10.81**	28.42**	34.89**	22.62**
28	AKAW3717 x GW 477	23.81**	11.21**	27.06**	55.54**	29.03**
29	AKAW3717 x QLD 118	-13.65**	-37.51**	-34.13**	-45.46**	-31.66**
30	AKAW3717 x WSM 253	-12.88**	-64.90**	-3.42**	-15.55**	-22.96**
31	AKAW 2862-1 x HS 628	89.52**	100.34**	70.14**	63.28**	80.54**
32	AKAW 2862-1 x RWP 2018-32	57.41**	50.09**	30.64**	41.32**	44.28**
33	AKAW 2862-1 x GW 477	27.63**	27.79**	22.70**	7.15**	21.33**
34	AKAW 2862-1 x QLD 118	-9.22**	-32.22**	-13.60**	-14.04**	-16.78**
35	AKAW 2862-1 x WSM 253	67.92**	73.57**	56.68**	76.82**	67.88**
36	HS 628 x RWP 2018-32	58.12**	84.14**	73.56**	76.34**	72.23**
37	HS 628 x GW 477	76.55**	65.99**	81.37**	78.87**	75.91**
38	HS 628 x QLD 118	40.44**	49.53**	56.75**	66.92**	52.42**
39	HS 628 x WSM 253	81.96**	100.19**	77.01**	99.74**	88.59**
40	RWP 2018-32 x GW 477	67.07**	63.83**	78.88**	69.66**	70.19**
41	RWP 2018-32 x QLD 118	80.95**	49.95**	73.02**	71.39**	69.32**
42	RWP 2018-32 x WSM 253	27.27**	6.77**	5.23**	14.99**	13.67**
43	GW 477 x QLD 118	37.21**	20.44**	69.52**	47.09**	43.81**
44	GW 477 x WSM 253	20.31**	20.64**	70.73**	50.75**	40.59**
45	QLD 118 x WSM 253	75.08**	49.02**	53.21**	69.19**	61.45**
	SE(m) +/-	1.04	0.53	0.73	0.49	0.73
	CD @5%	2.07	1.05	1.46	0.97	1.44
	CD @ 1 %	2.74	1.39	1.93	1.29	1.90

S.N.	Genotype	Harvest index (%)				
		Early		Late		Pooled
		Akola	Niphad	Akola	Niphad	
1	AKW 1071 x QLD 122	22.15**	19.58**	1.80	32.59**	18.32**
2	AKW 1071 x AKAW 3722	-10.52**	-17.62**	38.07**	-19.86**	-4.47**
3	AKW 1071 x AKAW3717	-1.03	14.38**	11.19**	8.97**	8.27**
4	AKW 1071 x AKAW 2862-1	47.28**	26.46**	39.86**	52.04**	41.23**
5	AKW 1071 x HS 628	7.73**	0.72	41.19**	5.50**	12.33**
6	AKW 1071 x RWP 2018-32	37.06**	9.73**	25.06**	51.03**	30.32**
7	AKW 1071 x GW 477	40.75**	56.64**	8.14**	52.99**	36.75**
8	AKW 1071 x QLD 118	35.44**	46.97**	24.62**	43.62**	37.02**
9	AKW 1071 x WSM 253	26.27**	52.17**	27.54**	26.16**	33.02**
10	QLD 122 x AKAW 3722	8.64**	12.29**	4.24**	-33.65**	-2.37*
11	QLD 122 x AKAW3717	-19.77**	-13.26**	-33.60**	-22.50**	-23.14**
12	QLD 122 x AKAW 2862-1	22.32**	46.20**	11.04**	18.33**	23.70**
13	QLD 122 x HS 628	-4.53**	12.66**	5.19**	-19.85**	-2.13*
14	QLD 122 x RWP 2018-32	22.41**	56.68**	-0.49	12.86**	20.95**
15	QLD 122 x GW 477	13.92**	44.03**	-10.19**	8.50**	11.61**
16	QLD 122 x QLD 118	10.82**	32.87**	1.22	15.01**	13.92**
17	QLD 122 x WSM 253	5.19**	32.66**	11.44**	1.38	12.25**
18	AKAW 3722 x AKAW3717	-4.93**	-9.59**	12.73**	-1.93*	-1.02
19	AKAW 3722 x AKAW 2862-1	-5.07**	-25.95**	13.09**	-12.30**	-8.51**
20	AKAW 3722 x HS 628	-20.02**	-32.17**	21.47**	-31.41**	-19.15**
21	AKAW 3722 x RWP 2018-32	0.72	-2.97**	30.85**	5.26**	7.90**
22	AKAW 3722 x GW 477	0.74	7.98**	2.14	-1.48	2.33*
23	AKAW 3722 x QLD 118	3.09**	-3.04**	16.31**	-8.77**	1.47
24	AKAW 3722 x WSM 253	3.42**	7.82**	36.71**	-1.10	9.89**
25	AKAW3717 x AKAW 2862-1	16.38**	-3.19**	-4.54**	8.79**	4.03**
26	AKAW3717 x HS 628	2.50**	17.34**	21.42**	11.11**	12.90**
27	AKAW3717 x RWP 2018-32	17.22**	33.06**	-1.44	23.11**	16.12**
28	AKAW3717 x GW 477	20.80**	38.32**	-0.22	40.81**	21.72**
29	AKAW3717 x QLD 118	-11.34**	5.32**	-17.83**	2.54**	-6.50**
30	AKAW3717 x WSM 253	-10.63**	-21.75**	-22.48**	1.17	-13.64**
31	AKAW 2862-1 x HS 628	9.74**	19.13**	36.24**	-9.99**	12.53**
32	AKAW 2862-1 x RWP 2018-32	48.70**	50.52**	37.73**	64.15**	49.55**
33	AKAW 2862-1 x GW 477	25.35**	23.43**	8.63**	35.48**	21.91**
34	AKAW 2862-1 x QLD 118	8.65**	2.03	0.99	10.21**	5.40**
35	AKAW 2862-1 x WSM 253	29.89**	36.89**	47.97**	28.83**	35.67**
36	HS 628 x RWP 2018-32	7.82**	-4.30**	17.28**	-7.41**	3.00**
37	HS 628 x GW 477	13.36**	-5.41**	15.47**	1.26	6.31**
38	HS 628 x QLD 118	9.62**	-2.07	19.69**	-6.72**	4.63**
39	HS 628 x WSM 253	4.82**	4.92**	35.33**	-11.81**	6.32**
40	RWP 2018-32 x GW 477	42.62**	50.65**	7.20**	52.66**	34.88**
41	RWP 2018-32 x QLD 118	28.31**	37.93**	2.81*	-42.06**	6.26**
42	RWP 2018-32 x WSM 253	21.82**	17.31**	43.44**	31.73**	28.65**
43	GW 477 x QLD 118	10.05**	28.29**	-4.12**	28.16**	13.52**
44	GW 477 x WSM 253	0.90	4.95**	4.85**	9.07**	4.76**
45	QLD 118 x WSM 253	18.93**	19.73**	19.70**	10.92**	17.34**
	SE(m) +/-	0.64	1.11	1.21	0.80	0.97
	CD @5%	1.27	2.20	2.41	1.58	1.91
	CD @ 1 %	1.69	2.91	3.19	2.09	2.51

Conclusion

The highest value for average heterosis and standard heterosis for grain weight per plant was recorded by Cross AKAW 2862-1 x HS 628 (89.52%) in early sowing, Akola; QLD 122 x AKAW 2862-1 (109.44%) in early sowing, Niphad; HS 628 x GW 477 (81.37%) in late sowing, Akola; QLD 122 x AKAW 2862-1 (117.47%) in late sowing, Niphad whereas over the environments QLD 122 × AKAW 2862-1 (93.02%) manifested significant and positive heterosis over mid parent. The above mentioned highly heterotic crosses also manifested significant heterosis in desired direction for one or more yield attributing characters. These hybrids may further be tested over various locations before release for commercial cultivation. High estimates of heterosis obtained in hybrid combinations revealed considerable genetic divergence among the parental lines and reveals good scope for commercial exploitation of heterosis in wheat.

Acknowledgements

The authors are thankful to all the members who are part of the research work for their support and help and for providing necessary facilities to carry out this experimental work.

Author Contributions

Gandhodi Himaja: Designed the model, analysed the data, computational framework original draft preparation and wrote the manuscript. Dr. Swati G. Bharad: Conceived the original idea Designed the model and Project Administration. Dr. R. B. Ghorade: Supervision and Investigation. Dr. N.R. Potdukhe: Visualization and Supervision. Dr. S.S. Hadole, R.D. Walke, Dr. N. Magar: Supervision and Methodology. Dr. N.D. Bichewar: Reviewing and Editing. T. Anjali, Ch.S.N. Raju: Support and helping hand.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors declare no competing interest

References

Beche, E., da Silva, C.L., Pagliosa, E.S., Capelin, M.A., Franke, J., Matei, G. and Benin, G. (2013). Hybrid performance and heterosis in early segregant populations of Brazilian spring wheat. *Aust J Crop Sci.,* **7**(1):51-57.

Briggle, L.W. (1963). Heterosis in wheat. A review. *Crop Sci.,* **3**, 407-412.

Burdak, A., Prakash, V., Kakralya, B.L., Gupta, D., Choudhary, R. (2023) Heterotic Performance and Inbreeding Depression for Yield and Component Traits in Bread Wheat (*Triticum aestivum* L. em. Thell.). *International Journal of Environment and Climate Change*., **13**(3):56-64.

Chaudhary, P.L., Kumar, B., Kumar, R. (2023) Analysis of Heterosis and Heterobeltiosis for Earliness, Yield and Its Contributing Traits in Okra (*Abelmoschus esculentus* L. Moench). *International Journal of Plant and Soil Science*, **35**(11):84-98.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv Agron.,* **28**, 361-405.

Farooq, S., Shahid, M., Khan, M.B., Hussain, M. and Farooq, M. (2015). Improving the productivity of bread wheat by good management practices under terminal drought. *J Agron Crop Sci.,* **201**(3), 173-88.

Jagadish, K.S., Kavi Kishor, P.B., Bahuguna, R.N., von Wirén, N. and Sreenivasulu, N. (2015). Staying alive or going to die during terminal senescence-an enigma surrounding yield stability. *Front Plant Sci.,* **6**, 1070.

Kumar, A., Swati, S.A., Joshi, A., Kumar, L., Bharati, A., Prasad, B. and Kumar, A. (2021a). Heterotic performance of Morpho-Physiological Traits for Heat Tolerance in Bread Wheat (*Triticum aestivum* L.). In: Biological Forum–An *International Journal*, 13(3b):16-24.

Kumar, P., Singh, H., Lal, C., Choudhary, R. (2021). Heterosis analysis for yield and its component traits in bread wheat (*Triticum aestivum* L.) over different environments. *Journal of Environmental Biology*; **42**, 438-45.

Mitra, R. and Bhatia, C.R. (2008). Bioenergetic cost of heat tolerance in wheat crop. *Current Sci.,* pp.1049-1053.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural research. ICAR, New Delhi, **8**, 308-18.

Santhoshini, A., Dubey, N., Avinashe, H.A., Thonta, R., Kumar, R. (2023). Inheritance Studies in Segregating Population of Bread Wheat (*Triticum aestivum* L.). *International Journal of Environment and Climate Change*, **13**(9), 277–287.

Shull, G.H. (1908). The composition of a field of maize. *J Hered*, **4**, 296-301.

Singh, H., Sharma, S.N. and Sain, R.S. (2004). Heterosis studies for yield and its components in bread wheat over environments. *Hereditas,* **141**(2):106-114.

Thomas, N., Marker, S., Lal, G.M. and Dayal, A. (2017). Study of heterosis for grain yield and its components in wheat (*Triticum aestivum*) over normal and heat stress condition. *J Pharmacogn Phytochem,* **6**(4): 824-830.