The present study was undertaken to evaluate the durum wheat genotypes for yield and quality traits under early sown and moisture stress conditions with the following objectives: 1. to study the physiological and biochemical changes in durum wheat genotypes for high grain yield, good grain quality and drought tolerance; 2. nature and magnitude of associations between yield, quality and related morphological traits to develop a selection index, and 3. to identify the better cross combinations having high photosynthetic efficiency (Chlorophyll content).

The experimental material of 101 durum wheat genotypes was grown for three crop seasons during *rabi* 2010-13; and stability of 10 high yielding genotypes selected based on the performance of first year along with bread wheat check varieties *i.e.*., HI 1500 © and HI 1531 © was studied for two *rabi* seasons in fields of ICAR-Indian Agricultural Research Institute – Regional Station, Indore. The results of the experimental findings for both rainfed and restricted irrigation conditions were presented in the following heads:

I. To study the physiological and biochemical changes in durum wheat genotypes for high grain yield, good grain quality and drought tolerance

   4.1 Analysis of variance and estimation of parameters of genetic variability
   4.2 Performance of genotypes along with stability parameters
   4.3 Performance and stability of high yielding durum genotypes

II. To determine the nature and magnitude of associations between yield, quality and related morphological traits to develop a selection index

   4.4 Correlation coefficients between characters
   4.5 Path coefficient analysis

III. To identify the better cross combinations having high photosynthetic efficiency (Chlorophyll content)

   4.6 Line x Tester analysis
   4.7 Generation mean analysis
4.1 Analysis of variance and estimation of parameters of genetic variability

Morphological, quality and biochemical traits

Rainfed conditions: The mean sum of squares based on ANOVA of 101 durum wheat genotypes plus a bread wheat check variety ‘NP 4’ under pooled analysis over 3 years *i.e.*, *rabi* 2010-13 for 19 morphological, quality and biochemical characters *viz.*, days to flowering, days to maturity, plant height, spike length, number of tillers/plant, flag leaf length, flag leaf width, number of grains/spike, biomass/plant, harvest index, 1000 grain weight, hectoliter weight, sedimentation value, carotene content, protein content, phosphorus content, potassium content, phytic acid and grain yield/plant has been presented in Table 4.1. Highly significant variances among the genotypes were observed for all the 19 traits studied in all the years indicating appreciable variability for all the characters. Pooled analysis of variance among three years under rainfed conditions further supported the above findings. Highly significant year x genotype interactions indicated that appreciable influence of environmental conditions on all the traits in the genotypes. The coefficient of variation (CV) in pooled analysis ranged from 2.2 (hectoliter weight) to 21.7 (carotene content). Other significant findings for each character were described separately.

Restricted irrigated conditions: The mean sum of square based on ANOVA of 101 durum wheat genotypes plus a bread wheat check variety ‘NP 4’ under pooled analysis over 3 years *i.e.*, *rabi* 2010-13 for the above mentioned 19 characters has been presented in Table 4.2. Highly significant differences among the genotypes were observed for all the 19 traits in all the years indicating appreciable variability for all the characters under early heat stress and restricted irrigation conditions. Pooled analysis of variance among three years under restricted irrigation conditions further supported the above findings. Highly significant year x genotype interactions indicated that appreciable influence of environmental conditions on all the traits in the genotypes. The coefficient of variation (CV) in pooled analysis ranged from 2.2 (hectoliter weight) to 22.0 (carotene content). Other significant findings for each character were described separately.

Pooled analysis: The mean sum of square based on ANOVA of 101 durum wheat genotypes plus a bread wheat check variety ‘NP 4’ in pooled analysis *i.e.*, rainfed and restricted irrigation
over 3 years i.e., *rabi* 2010-13 for the above mentioned 19 characters have been presented in Table 4.3. From Barlett’s test for heterogeneity of error variances, it was inferred that error mean squares for grain yield over environments for rainfed condition, restricted irrigation condition and pooled analysis were homogeneous; therefore, pooled analysis was carried out further (Table 4.4). Highly significant differences were observed among genotypes for all the 19 traits in pooled analysis indicating appreciable variability for all the characters in the genotypes under early heat stress conditions. Highly significant differences were observed for year x genotype interactions, which indicated that appreciable influence of environmental conditions on all the traits in the genotypes.

**Phenotypic and genotypic co-efficient of variation for morphological, quality and biochemical traits:** In general, the values of phenotypic co-efficient of variation (PCV) were higher than that of the genotypic coefficient of variation (GCV) for all the characters in rainfed and restricted irrigation conditions (Table 4.6). Under rainfed conditions, PCV was estimated to be high for carotene content (21.7) followed by phosphorus content (21.1), sedimentation value (16.5), number of tillers/plant (12.3) and plant height (11.9); while it was moderate for phytic acid (11.0) and number of grains/spike (10.8); and low for days to maturity (5.0), potassium content (4.3) and hectoliter weight (2.2). Under restricted irrigation conditions, PCV was estimated to be high for carotene content (22.0) followed by phosphorus content (19.0), sedimentation value (15.0), plant height (13.9) and days to flowering (12.3); while it was moderate for grain yield/plant (11.4) and number of tillers/plant (11.1); and low for days to maturity (4.3), potassium content (4.0) and hectoliter weight (2.2).

Under rainfed conditions, GCV also showed the similar trend as PCV for some of the traits and observed to be high for carotene content (21.4), followed by phosphorus content (18.0), sedimentation value (16.0), plant height (11.7) and days to flowering (10.7); and while it was moderate for spike length (9.6) and 1000 grain weight (9.3); and low for potassium content (3.4), harvest index (2.7) and hectoliter weight (2.0). Difference between the PCV and GCV was high for number of tillers per plant (6.9) followed by flag leaf width (3.8) and grain yield per plant (3.3). Under restricted irrigation conditions, GCV was observed to be high for carotene content (21.2), followed by phosphorus content (16.5), sedimentation value (14.5), plant height (13.8) and days to flowering (12.3); and while it was moderate for grain yield per plant (9.6), spike
length (9.3) and flag leaf length (8.2); and low for protein content (4.1), potassium content (3.1) and hectoliter weight (2.0). Difference between the PCV and GCV was high for number of tillers/plant (5.3) followed by phosphorus content (2.4) and flag leaf width (2.0).

**Heritability:** Heritability in broad sense under rainfed conditions was observed to be high for days to flowering (99.4%), followed by 1000 grain weight (99.3%), days to maturity (99.0%), carotene content (96.9%), spike length (96.6%) and plant height (96.1%); and moderate for phytic acid (88.6%) and hectolitre weight (83.7%); and low for flag leaf width (38.0%), grain yield per plant (29.9%) and harvest index (25.3%). Whereas, under restricted irrigation conditions, heritability in broad sense was observed to be high for days to flowering (99.4%), followed by plant height (99.0%), 1000 grain weight (98.7%), days to maturity (98.1%), spike length (95.2%), and sedimentation value (93.7%); and moderate for flag leaf length (87.6%) and hectolitre weight (83.5%); and low for protein content (58.5%) and number of tillers/plant (27.0%).

**Genetic advance:** Genetic advance under rainfed conditions was found to be highest for plant height (18.3) followed by days to flowering (16.2), days to maturity (12.9) and sedimentation value (10.2); and it was low for grain yield per plant (0.6) and flag leaf width (0.1). While, genetic advance over its mean is high for carotene content (43.8%), sedimentation value (31.9%) and phosphorus content (31.4%); and moderate for plant height (23.5%) and days to flowering (21.9%); and low for hectoliter weight (3.7%) and harvest index (2.7%). Whereas, under restricted irrigation conditions, genetic advance was found to be highest for plant height (24.9) followed by days to flowering (18.8), days to maturity (10.8) and sedimentation value (10.0); and it was low for number of tillers/plant (0.5) and flag leaf width (0.2). While, genetic advance over its mean is high for carotene content (42.2%), phosphorus content (29.5%), and sedimentation value (29.0 %); and moderate for plant height (28.3%) and days to flowering (25.1%); and low for potassium content (5.0%) and hectoliter weight (3.7%).

In general, under rainfed and restricted irrigation conditions, high to moderate heritability coupled with high to moderate genetic advance as percentage of mean was exhibited for 11 traits viz., days to flowering, days to maturity, number of grains/spike, flag leaf length, 1000 grain weight, carotene content, sedimentation value, phosphorus content, biomass/plant, plant height and grain yield/plant.
Physiological traits

Rainfed conditions: The mean sum of squares based on ANOVA of 101 durum wheat genotypes plus a bread wheat check variety ‘NP 4’ under pooled analysis over 3 years i.e., *rabi* 2010-13 for 11 characters viz., canopy temperature at vegetative stage (CT I), canopy temperature at flowering (CT II), canopy temperature at grain filling stage (CT III), flag leaf area/plant, leaf weight, stem weight, chlorophyll content at vegetative stage (Chl I), chlorophyll content at flowering stage (Chl II), chlorophyll content at grain filling stage (Chl III) and grain yield/plant has been presented in Table 4.7. Genotypic variances for all the 11 traits studied were highly significant among three years indicating appreciable variability for all the characters. Pooled analysis of variance further supported the above findings. Highly significant year x genotype interactions indicated that appreciable influence of environmental conditions for all the traits in the genotypes. The coefficient of variation (CV) in pooled analysis ranged from 3.0 (canopy temperature at grain filling stage) to 17.6 (stem weight). Other significant findings for each character were described separately.

Restricted irrigated conditions: The mean sum of squares based on ANOVA of 101 durum wheat genotypes plus a bread wheat check variety ‘NP 4’ under pooled analysis over 3 years i.e., *rabi* 2010-13 for the above mentioned 11 characters has been presented in Table 4.8. Highly significant differences were observed for all the 11 traits in all the years indicating appreciable variability for all the characters under early heat stress and restricted irrigation conditions. Pooled analysis of variance further supported the above findings. Highly significant year x genotype interactions indicated that appreciable influence of environmental conditions on all the traits. The coefficient of variation (CV) in pooled analysis ranged from 3.4 (CT III) to 27.7 (CT II). Other significant findings for each character were described separately.

Phenotypic and genotypic co-efficient of variation: In general, the values of phenotypic co-efficient of variation (PCV) were higher than that of the genotypic coefficient of variation (GCV) for all the characters in rainfed and restricted irrigation conditions (Table 4.9). Under rainfed conditions, PCV was estimated to be high for stem weight (17.6) followed by leaf weight (16.9), number of effective spikes (13.0) and flag leaf area/plant (12.4); while, it was moderate for Chl III (10.6), Chl II (10.5) and Chl I (8.8); and low for CT II (4.4) and CT III (3.0). Under restricted irrigation conditions PCV was estimated to be high for CT II (27.7) followed by stem weight
flag leaf area/plant (13.9), number of effective spikes (13.5) and leaf weight (12.8); while, it was moderate for grain yield/plant (11.4) and Chl III (10.9); and low for canopy CT II (3.9) and CT III (3.4).

Under rainfed conditions, GCV also showed the similar trend as PCV for some of the traits and observed to be high for stem weight (13.7) followed by flag leaf area/plant (10.2), Chl III (9.9), Chl II (9.8) and leaf weight (8.5); while, it was moderate for Chl I (8.0); low for CT I (0.6), CT II (0.1) and CT III (0.1). Difference between the PCV and GCV was high for number of effective spikes (12.6) followed by leaf weight (8.4) and CT II (4.3). Under restricted irrigation conditions, GCV also showed the similar trend as PCV for some of the traits and observed to be high for stem weight (11.4), followed by flag leaf area/plant (11.2), Chl III (10.3), grain yield/plant (9.6) and Chl II (9.4); while it was moderate for Chl I (7.9) and leaf weight (6.2); low for number of effective spikes (3.8), CT II (0.2) and CT III (0.1). Difference between the PCV and GCV was high for CT II (23.3) followed by number of effective spikes (9.7) and leaf weight (6.7).

**Heritability:** Heritability in broad sense under rainfed condition was observed to be high for Chl II (89.7 %), followed by Chl III (87.3 %), Chl I (84.1 %), and flag leaf area/plant (66.1 %); and moderate for grain yield/plant (30.1 %) and leaf weight (25.4 %); and low for CT II (14.2 %), number of effective spikes (13.5 %) and CT I (10.0 %). Whereas, under restricted irrigation conditions, heritability in broad sense was observed to be high for Chl III (90.0 %), followed by Chl II (89.6 %), Chl I (87.2 %), and number of effective spikes (81.6 %); and moderate for grain yield/plant (72.1 %) and flag leaf area/plant (65.1 %); and low for CT I (16.4 %) and CT III (11.0 %).

**Genetic advance:** Genetic advance under rainfed conditions was found to be highest for Chl II (9.7) followed by Chl III (9.0), Chl I (8.3) and stem weight (6.0); and it was low for CT I (0.1) and number of effective spikes (0.1). While, genetic advance over its mean is high for stem weight (21.9%), Chl III (19.2%) and Chl II (19.1%); and moderate for flag leaf area/plant (17.3%) and Chl I (15.1 %); and low for CT I (0.5 %) and CT III (0.5 %). Whereas, under restricted irrigation conditions, genetic advance was found to be highest for Chl III (9.7) followed by Chl II (9.5), Chl I (8.7) and stem weight (5.9); and it was low for CT I (0.2) and CT III (0.1). While, genetic advance over its mean is high for Chl III (20.2 %), flag leaf area/plant
(18.5 %) and Chl II (18.3 %); and moderate for grain yield/plant (16.7 %) and stem weight (16.7 %); and low for CT I (0.8 %) and CT III (0.5 %).

In general, under rainfed and restricted irrigation conditions, high to moderate heritability coupled with high to moderate genetic advance as percentage of mean was exhibited for 6 traits viz., flag leaf area/plant, stem weight, number of effective spikes/plant, Chl II, Chl III and grain yield/plant.

4.2 Performance of genotypes along with stability parameters

Mean performance of the 102 genotypes for morphological, quality and biochemical traits

Days to flowering: Days to flowering ranged from ranged 60 days to 93 days with a mean value of 74 days under rainfed conditions; 54 days to 92 days with a mean value of 75 under restricted irrigation conditions; and 58 days to 92 days with a mean value of 74 days under pooled analysis. Under rainfed conditions (7.1 ºC to 24.0 ºC), early flowering was observed in V 21 (60 days) followed by Vijay (61 days), Jay (62 days), V21/23 (62 days) and MACS 9 (63 days); while, late flowering was observed in WH 912 (91 days) and DBP 02-08 (93 days). The coefficient of variation estimated is 0.81 % (Table 4.10). Under restricted irrigation conditions (9.2 ºC to 24.7 ºC), early flowering was observed in Jay (54 days) followed by MACS 9 (55 days), NP 4 (57 days), Vijay (59 days) and IWP 5070 (60 days); while, late flowering was observed in Raj 6562 (92 days) and WH 912 (92 days). The coefficient of variation estimated is 0.98 %. In pooled analysis, early flowering was observed in Jay (58 days) followed by MACS 9 (59 days), Vijay (60 days), V 21 (60 days) and NP 4 (61 days), while, MPO 215 (91 days) and WH 912 (92 days) were late to flower. The coefficient of variation estimated is 0.94 %.

Days to maturity: Days to maturity ranged from 115 days to 143 days with a mean value of 127 days under rainfed conditions; 107 days to 140 days with a mean value of 123 days under restricted irrigation conditions; and 111 days to 139 days with a mean value of 125 days under pooled analysis. Under rainfed conditions (16.5 ºC to 36.9 ºC), early maturity was observed in V 21 (115 days) followed by MACS 1967 (117 days), Jay (118 days), HI 8691 (119 days) and GW 1209 (119 days); while, late maturity was observed in DBP 02-08 (143 days) and Trinakaria (143 days). The coefficient of variation estimated is 0.50 % (Table 4.11). Under restricted
irrigation conditions (15.6 °C to 35.8 °C), early maturity was observed in V 21 (107 days) followed by GW 1114 (114 days), GW 1 (115 days), HI 8691 (116 days) and IWP 5070 (116 days); while, late maturity was observed in Raj 6562 (138 days) and GS 27 (140 days). The coefficient of variation estimated is 0.60 %.

In pooled analysis, early maturity was observed in V 21 (111 days) followed by HI 8691 (117 days), IWP 5070 (118 days), Jay (118 days) and GW 1114 (119 days), while, GS 27 (139 days) and Trinakaria (139 days) were late to mature. The coefficient of variation estimated is 0.53 %.

**Plant height (cm):** Plant height ranged from ranged 58 cm to 100 cm with a mean value of 78 cm under rainfed conditions; 58 cm to 88 cm with a mean value of 88 cm under restricted irrigation conditions; and 62 cm to 109 cm with a mean value of 86 cm under pooled analysis. Under rainfed conditions (11.2 °C to 29.5 °C), lowest plant height was observed in IWP 5007 (58 cm) followed by GW 1240 (60 cm), GW 1114 (64 cm), HI 7747 (64 cm) and GW 1139 (65 cm); while, highest plant height was observed in Bijaga Red (100 cm) and Guji ‘S’ (100 cm). The coefficient of variation estimated is 2.34 % (Table 4.12). Under restricted irrigation conditions (10.2 °C to 28.4 °C), lowest plant height was observed in GW 1114 (63 cm) followed by IWP 5007 (65 cm), GW 1240 (68 cm), HI 7747 (68 cm) and MACS 3061 (71 cm); while, highest plant height was observed in CPAN 6236 (86 cm) and Guji ‘S’ (88 cm). The coefficient of variation estimated is 1.42 %. In pooled analysis, lowest plant height was observed in IWP 5007 (62 cm) followed by GW 1114 (64 cm), GW 1240 (64 cm), HI 7747 (66 cm) and GW 1139 (70 cm), while, highest plant height was observed in CPAN 6236 (108 cm) and Guji’s’ (109 cm). The coefficient of variation estimated is 2.10 %.

**Spike length (cm):** Spike length ranged from 5.1 cm to 8.9 cm with a mean value of 6.7 cm under rainfed conditions; 5.5 cm to 9.0 cm with a mean value of 7.2 cm under restricted irrigation conditions; and 5.3 cm to 8.8 cm with a mean value of 7.0 cm under pooled analysis. Under rainfed conditions (10.8 °C to 31.6 °C), spike length was maximum in NP 404 (8.9 cm) followed by MPO 1243 (8.6 cm), GW 1245 (8.5 cm), Kathia 25 (8.5 cm) and Karnataka local (8.1 cm); while, lowest spike length was observed in B-4446-BA (5.1 cm) and IWP 5007 (5.1 cm). The coefficient of variation estimated is 1.80 % (Table 4.13). Under restricted irrigation conditions (9.5 °C to 28.3 °C), spike length was maximum in MPO 1243 (9.0 cm) followed by A 206 (8.7 cm), A 9-30-1 (8.7 cm), Jay (8.6 cm), DWR 137 (8.5 cm) and GW 1245 (8.5 cm);
while, lowest spike length was observed in DBP 01-09 (5.6 cm) and IWP 5007 (5.5 cm). The coefficient of variation estimated is 2.08 %. In pooled analysis, spike length was maximum in MPO 1243 (8.8 cm) followed by NP 404 (8.7 cm), GW 1245 (8.5 cm), Karnataka local (8.3 cm) and Kathia 25 (8.3 cm); while, lowest spike length was observed NI 5759 (5.6 cm) and IWP 5007 (5.3 cm). The coefficient of variation estimated is 2.0 %

**Number of tillers/plant:** Number of tillers/plant ranged from 5.8 to 10.0 with a mean value of 7.0 under rainfed conditions; 6.1 to 12.2 with a mean value of 8.0 under restricted irrigation conditions; and 6.1 to 9.7 with a mean value of 8.0 under pooled analysis. Under rainfed conditions (16.5 °C to 36.9 °C), highest number of tillers/plant was observed in B4447-BA (10.0) followed by Mandsour local (9.4), GW 1209 (9.3), NP 4 (9.2) and NP 404 (9.0); while, lowest number of tillers/plant was observed in GW 1139 (5.9) and MACS 3061 (5.8). The coefficient of variation estimated is 12.33 % (Table 4.14). Under restricted irrigation conditions (10.5 °C to 30.8 °C), highest number of tillers/plant was observed in Amrut (12.2) followed by A 9-30-1 (10.3), GW 1 (10.2), GW 1209 (10.0), HD 4672 (10.0) and GW 1225 (9.9); while, lowest number of tillers/plant was observed in AKDW 4151 (6.4) and HI 8381 (6.1). The coefficient of variation estimated is 9.45 %. In pooled analysis, highest number of tillers/plant was observed in GW 1209 (9.7) followed by Amrut (9.6), B 4447-BA (9.1), NP 4 (9.0) and GW 1 (8.9), while, lowest number of tillers/plant was observed in AKDW 4151 (6.3) and HI 8381 (6.1). The coefficient of variation estimated is 7.28 %.

**Flag leaf length (cm):** Flag leaf length ranged from 11.6 cm to 21.7 cm with a mean value of 17.1 cm under rainfed condition; 14.8 cm to 25.7 cm with a mean value of 21.0 cm under restricted irrigation conditions; and 13.2 cm to 22.7 cm with a mean value of 19.6 cm under pooled analysis. Under rainfed conditions (9.4 °C to 30.1 °C), highest flag leaf length was observed in Bijaga Red (21.7 cm) followed by MACS 9 (21.6 cm), A 9-30-1 (21.1 cm), A 206 (20.9 cm) and HG 110 (20.6 cm); while, lowest flag leaf length was observed in Raj 6562 (13.6 cm) and WH 912 (11.6 cm). The coefficient of variation estimated is 3.77 % (Table 4.15). Under restricted irrigation conditions (10.6 °C to 31.3 °C), highest flag leaf length was observed in NP 404 (25.7 cm) followed by DWR 137 (25.1 cm), Dohad local (25.0 cm) and A 206 (24.5 cm); while, lowest flag length was observed in MACS 3061 (15.9 cm) and WH 912 (14.8 cm). The coefficient of variation estimated is 3.06 %. In pooled analysis, highest flag leaf length was
observed in A 206 (22.7 cm) followed by Dohad local (22.7 cm), Bijaga yellow (22.6 cm), NP 404 (22.5 cm) and Karnataka local (22.2 cm); while, lowest flag leaf length was observed in MACS 3061 (14.8 cm) and WH 912 (13.2 cm). The coefficient of variation estimated is 2.38 %.

**Flag leaf width (cm):** Flag leaf width ranged from 1.2 cm to 1.8 cm with a mean value of 1.4 cm under rainfed conditions; 1.3 cm to 2.1 cm with a mean value of 1.6 cm under restricted irrigation conditions; and 1.3 cm to 1.9 cm with a mean value of 1.5 cm under pooled analysis. Under rainfed conditions (9.2 °C to 27.7 °C), highest flag leaf width was observed in Bijaga Red (1.8 cm) followed by Bijaga Yellow (1.7 cm), MACS 9 (1.7 cm), Sarangpur local (1.7 cm) and AKDW 4240 (1.6 cm); while, lowest flag leaf width was observed in GW 1240 (1.2 cm) and Mandsour local (1.2 cm). The coefficient of variation estimated is 7.87 % (Table 4.16). Under restricted irrigation (10.1 °C to 28.3 °C), highest flag leaf width was observed in Sarangpur local (2.1 cm) followed by Baxi 228-18 (1.9 cm), Bijaga Red (1.9 cm), Bijaga Yellow (1.9 cm) and CDW 04 (1.9 cm); while, lowest flag leaf width was observed in GW 1240 (1.3 cm) and Mandsour local (1.3 cm). The coefficient of variation estimated is 5.64 %. In pooled analysis, highest flag leaf width was observed in Bijaga Red (1.9 cm) followed by Sarangpur local (1.9 cm), A 9-30-1 (1.8 cm), Bijaga yellow (1.8 cm) and CDW 04 (1.8 cm), while, GW 1240 (1.3 cm) and Mandsour local (1.3 cm) showed lowest flag leaf width. The coefficient of variation estimated is 5.08 %.

**Number of grains/spike:** Number of grains/spike ranged from 26.8 to 59.7 with a mean value of 39.0 under rainfed conditions; 31.6 to 54.7 with a mean value of 42.0 under restricted irrigation conditions; and 29.2 to 54.6 with a mean value of 40.8 under pooled analysis. Under rainfed conditions (18.8 °C to 36.1 °C), highest number of grains/spike was observed in HI 8627 (59.7) followed by HI 8550 (53.5), CPAN 6236 (53.1), Altar 84 (52.3) and NIDW 15 (51.2); while, lowest number of grains/spike was observed in Motia (27.3) and Mandsour local (26.8). The coefficient of variation estimated is 3.05 % (Table 4.17). Under restricted irrigation conditions (17.2 °C to 37.7 °C), highest number of grains/spike was observed in CPAN 6236 (54.7) followed by GW 1170 (50.2), Dohad local (49.8), HG 110 (49.7) and HI 8627 (49.4); while, lowest number of grains/spike was observed in B 4447-BA (33.4) and Mandsour local (31.6). The coefficient of variation estimated is 4.01 %. In pooled analysis, highest number of grains/spike was observed in HI 8627 (54.6) followed by CPAN 6236 (53.9), Altar 84 (50.8),
HI 8550 (49.3) and HI 8638 (48.8), while, Motia (30.5) and Mandsour local (29.2) showed lowest number of grains/spike. The coefficient of variation estimated is 3.82 %.

**Grain yield/plant (g):** Grain yield/plant ranged from 8.7 g to 22.2 g with a mean value of 14.2 g under rainfed condition; 11.5 g to 26.5 g with a mean value of 17.5 g under restricted irrigation condition and 11.5 g to 23.2 g with a mean value of 15.9 g under pooled analysis. Under rainfed condition (38.6 °C to 20.3 °C), highest grain yield/plant was observed in HD 4672 (22.2 g) followed by HI 8550 (20.7 g), A 206 (19.8 g), HD 4676 (18.6 g) and HI 8627 (18.6 g); while, lowest grain yield/plant was observed in B 4446-WA (9.7 g) and HI 8592 (8.7 g). The coefficient of variation estimated is 6.03 % (Table 4.18). Under restricted irrigation condition (21.3 °C to 39.1 °C), highest grain yield/plant was observed in HI 8627 (26.5 g) followed by HI 8638 (26.2 g), HD 4676 (25.6 g), HI 8671 (24.1 g) and HD 4672 (24.1 g); while, lowest grain yield/plant was observed in IWP 5007 (11.6 g) and bread wheat variety NP 4 (11.5 g). The coefficient of variation estimated is 6.06 %. In pooled analysis, HD 4672 (23.2 g) followed by HI 8627 (22.6 g), HD 4676 (22.1 g), HI 8638 (21.9 g) and HI 8550 (21.6 g) were of highest grain yield/plant; while, NP 4 (12.0 g) and HI 8592 (11.5 g) were of lowest grain yield/plant. The coefficient of variation estimated is 4.38 %.

**Stability for grain yield per plant:** Barlett’s test of significance for homogeneity of variances showed that error variances in each year for the grain yield over environment was homogenous, therefore, pooled analysis was carried out further (Table 4.4). ANOVA of stability analysis conducted for combined data over 3 years was presented in Table 4.5. Stability parameters (Eberhart and Russell’s 1996 stability model) of 35 high grain yielding genotypes selected from 102 genotypes each for some yield contributing traits and quality traits under rainfed, restricted irrigation and pooled conditions *i.e.*, mean, regression coefficient, deviation from regression and mean of ranks of each genotypes for different traits over three environments were showed in Tables 4.19 to 4.21. Under rainfed condition, the variation in yield among 35 genotypes ranged from 10.0 g (HD 4502) to 22.2 g (HD 4672). The regression coefficient is significant for Bijaga Red, while non-significant to rest of all the genotypes; whereas deviations from regression were non-significant for A 9-30-1, A 206, DBP 01-09, GW 1225, GW 1240, HD 4672, HD 4676, HI 8645, HI 8663, HI 8666, HI 8691, IWP 5004-1, IWP 5007, Line 1172, MACS 2694, Bijaga red, Bijaga yellow and PDW 215, while, others were non-significant. Based
on the stability parameters, HD 4672 (22.2 g), A 206 (19.8 g), HI 8627 (18.6 g), HD 4676 (18.6 g) and MACS 9 (17.8 g) for mean yield; HI 8663 (1.00), AKDW 4240 (1.02), Altar 84 (0.91), MACS 1967 (0.91) and Amrut (0.86) for regression coefficients; and HD 4502 (-0.10), HI 8638 (0.11), DBP 02-08 (-0.17) and AKDW 4151 (-0.23) for low deviations for regression value were found to be stable under rainfed condition over years (Table 4.19). When mean of ranks were taken into consideration, IWP 5007, Line 1172, A 9-30-1, Bijaga Red, PDW 215 and GW 1225 were found to be most stable under rainfed condition over years. Under restricted irrigation condition, the mean value ranged from 11.6 g (IWP 5007) to 26.5 g (HI 8627). The regression coefficient were non-significant for all genotypes; whereas deviations from regression were significant for all the genotypes except Bijaga Red, Altar 84, HI 8666, PDW 215, PDW 233, DBP 01-09 and MACS 1967. Based on the stability parameters, HI 8627 (26.5 g), HI 8638 (26.2 g), HD 4676 (25.6 g), HI 8671 (24.1 g) and HD 4672 (23.3 g) for mean yield; HI 8722 (1.00), PDW 215 (1.02), Line 1172 (1.05), Bijaga Yellow (0.90) and A 206 (1.13) for regression coefficients; and Bijaga Red (0.11), Altar 84 (-0.14), HI 8666 (-0.20), PDW 215 (-0.25) and PDW 233 (-0.37) for low deviations for regression value were found to be stable under restricted irrigation condition over years (Table 4.20). When mean of ranks were taken into consideration, AKDW 4240, GW 1245, MACS 2694, HI 8691 and MACS 9 were found to be most stable under restricted irrigation condition over years. Under pooled conditions, the mean value ranged from 12.4 g (HD 4676) to 22.7 g (HI 8627). The regression coefficients were non-significant for all genotypes; whereas deviations from regression were significant for all the genotypes except HI 8663 (1.19). Based on the stability parameters, HI 8627 (22.7 g), HI 8645 (22.6 g), HI 8638 (22.1 g), HI 8653 (21.8 g) and A 206 (21.1 g) for mean yield; A 9-30-1 (0.99), GW 1245 (0.99), HD 4676 (0.94) MACS 9 (0.92) and DBP 01-11 (1.03) for regression coefficients; and GW 1225 (0.01) and PDW 233 (-0.02) for low deviations for regression value were found to be stable over the environment, as they had low ranks for the traits as well (Table 4.21). When mean of ranks were taken into consideration, DBP 02-08, HI 8638, MACS 9, HI 8627 and HI 8722 were found to be most stable over all the environments.

**Biomass/plant (g):** Biomass/plant ranged from 25.2 g to 62.3 g with a mean value of 39.7 g under rainfed conditions; 28.7 g to 62.1 g with a mean value of 45.7 g under restricted irrigation conditions; and 32.2 g to 59.0 g with a mean value of 44.0 g under pooled analysis. Under rainfed conditions (20.3 ºC to 38.6 ºC), highest biomass/plant was observed in MACS 9 (62.3 g)
followed by MACS 1967 (57.5 g), HD 4672 (55.9 g), V 21 (54.1 g) and HI 8550 (53.4 g); while, lowest biomass/plant was observed in HD 4502 (26.4 g) and B 4446-WA (25.2 g). The coefficient of variation estimated is 4.44 % (Table 4.22). Under restricted irrigation (19.4 °C to 38.4°C), highest biomass/plant was observed in HD 4672 (62.1 g) followed by HD 4676 (59.8 g), Amrut (59.3 g), HI 8550 (57.9 g) and V 21 (57.4 g); while, lowest biomass/plant was observed in B 4447-BA (30.5 g) and NIDW 295 (28.7 g). The coefficient of variation estimated is 3.90 %. In pooled analysis, highest biomass/plant was observed in HD 4672 (59.0 g) followed by MACS 9 (58.1 g), V 21 (55.8 g), HI 8550 (55.7 g) and MACS 1967 (53.3 g); while, IWP 5007 (32.4 g) and B 4447 BA (32.2 g) showed lowest biomass/plant. The coefficient of variation estimated is 3.23 %.

**Stability of Biomass per plant:** Under rainfed conditions, the mean values varied from 26.4 g (HD 4502) to 57.5 g (Bijaga Red). The regression coefficient is significant to Bijaga Red, while, non-significant to rest of all the genotypes; whereas, deviations from regression were significant for GW 1245, HI 8653, MACS 1967 and Bijaga yellow. Based on the stability parameters, MACS 9 (49.2 g), Bijaga yellow (48.2 g), A 206 (47.9 g), HI 8638 (46.4 g) and GW 1245 (45.4 g) for mean biomass yield; HI 8645 (1.06), HI 8691 (1.09), Amrut (1.10), MACS 2694 (0.97) and HI 8666 (0.96) for regression coefficients; HI 8653 (0.14), Bijaga yellow (0.82), MACS 1967 (-0.45) and GW 1245 (-1.0) for low deviations for regression value were found to be stable under rainfed conditions over years, since they had low ranks for the traits (Table 4.23). When mean of ranks were taken into consideration, AKDW 4151, IWP 5007, HI 8663, HI 8627, Line 1172 and Bijaga red were found to be most stable under rainfed conditions over years. Under restricted irrigation conditions, the mean values varied from 31.9 g (IWP 5007) to 62.1 g (HD 4672). The regression coefficients of AKDW 4240, DBP 02-08 and MACS 2694 were significant, while, rest of all the genotypes had non-significant regression coefficients; whereas, deviations from regression were significant for all the genotypes except HI 8666 and MACS 2694. Based on the stability parameters, HD 4672 (62.1 g), Amrut (59.4 g), HD 4676 (56.4 g), HI 8671 (56.2 g) and HI 8638 (55.6 g) for mean biomass yield; Line 1172 (1.00),GW 1225 (1.01), PDW 233 (1.03), A 206 (1.03) and HI 8653 (0.96) for regression coefficients; and HI 8666 (-0.97), MACS 2694 (0.21), Altar 84 (2.85), PDW 215 (3.04), A 206 (3.17), IWP 5007 (3.55) and HI 8653 (4.48) for low deviations for regression value were found to be stable under restricted irrigation conditions over years, since they had low ranks for the traits (Table 4.24). When mean of ranks were taken
into consideration, DBP 01-09, HI 8627, A 9-30-1, Bijaga yellow, AKDW 4240 and IWP 5004-1 found to be most stable under restricted irrigation conditions over years. In pooled analysis, the mean values varied from 32.36 g (MACS 9) to 59.01 g (HI 8627). The regression coefficient is significant for Bijaga yellow, while, non-significant for rest of all the genotypes; whereas, deviations from regression were significant for all the genotypes. Based on the stability parameters, HI 8627 (59.1 g), DBP-01-09 (53.3 g), A 206 (51.6 g), MACS 2694 (51.5 g), and HI 8653 (51.0 g) for mean biomass yield; HI 8666 (1.05), GW 1245 (1.06), HI 8645 (1.06), MACS 9 (0.95) and A 9-30-1 (0.93) for regression coefficients, since they had low ranks for the traits (Table 4.25). When mean of ranks were taken into consideration, Amrut, DBP-02-08, MACS 1967, GW 1240, HI 8691 and Bijaga yellow were found to be most stable over all the environments.

**Harvest Index (%)**: Harvest index ranged from 26.1 % to 44.1 % with a mean value of 39.7 % under rainfed conditions; 27.9 % to 52.4 % with a mean value of 39.0 % under restricted irrigation conditions; 27.8 % to 49.2 % with a mean value of 36.6 % under pooled analysis. Under rainfed conditions (15.8 ºC to 36.6 ºC), highest harvest index was observed in HI 8627 (44.1 %) followed by HD 4676 (43.6 %), HI 8671 (43.3 %), HI 8722 (41.4 %) and MACS 2846 (41.4 %); while, lowest harvest index was observed in Sawer local (29.5 %) and Baxi 228-18 (26.1 %). The coefficient of variation estimated is 4.55 % (Table 4.26). Under restricted irrigation conditions (16.4 ºC to 35.6 ºC), highest harvest index was observed in HI 8627 (52.4 %) followed by GW 1225 (47.1 %), HI 8638 (46.7 %), Bansli local (45.3 %) and HD 4676 (45.3 %); while, lowest harvest index was observed in MACS 3125 (32.0 %) and WH 896 (27.9 %). The coefficient of variation estimated is 4.66 %. In pooled analysis, highest harvest index was observed in HI 8627 (49.2 %) followed by HD 4676 (44.5 %), HI 8671 (43.4 %), GW 1225 (42.9 %) and HI 8638 (41.7 %); while, Baxi 228-18 (29.8 %) and A 9-30-1 (27.8 %) showed lowest harvest index. The coefficient of variation estimated is 4.01 %.

**Stability for harvest index**: The mean values for this trait varied from 26.6 % (A 9-30-1) to 44.1 % (HI 8627). The regression coefficient was non-significant for all genotypes; whereas deviations from regression were significant for all the genotypes except A 206, AKDW 4151, Amrut, DBP 01-09, GW 1240, HD 4672, HD 4676, HI 8666, Line 1172 and PDW 233. Based on the stability parameters HI 8627 (44.1 %), HD 4676 (43.6 %), HI 8671 (43.3 %), HI 8722
(41.4 %) and A 206 (40.5 %) for mean harvest index; AKDW 4240 (1.02), HI 8691 (0.94), GW 1240 (0.84), HI 8663 (0.77) and HI 8653 (1.45) for regression coefficient; and HI 8666 (0.20), HD 4672 (0.47), GW 1240 (0.48) and PDW 233 (0.84) for low deviations for regression value were found to be stable under rainfed conditions over years, since they had low ranks for the traits (Table 4.27). When mean of ranks were taken into consideration, Bijaga yellow, PDW 215, MACS 9, Bijaga red, GW 1225 and HD 4502 were found to be most stable under rainfed conditions over years. Under restricted irrigation condition, the mean values for this trait ranged from 29.1 % (A 9-30-1) to 63.3 % (HI 8627). The regression coefficient was non-significant for all genotypes; whereas a deviation from regression was significant for all the genotypes except AKDW 4151, Amrut, HD 4676, HI 8666 and PDW 215. Based on the stability parameters, HI 8627 (63.3 %), GW 1225 (47.1 %), HI 8638 (46.7 %), HD 4676 (45.3 %) and HI 8671 (43.6 %) for mean harvest index; GW 1240 (0.97), HI 8645 (0.92), Altar 84 (0.70), HD 4676 (0.48) and MACS 9 (0.31) for regression coefficients; and AKDW 4151 (-0.05), Amrut (0.19), HD 4676 (-0.33) and HI 8666 (-0.73) for low deviations for regression value were found to be stable under restricted irrigation conditions over years, since they had low ranks for the traits (Table 4.28). When mean of ranks were taken into consideration, HD 4502, MACS 2694, IWP 5004-1, HD 4672, HI 8627 and HI 8722 were found to be most stable under restricted irrigation conditions over years. In pooled analysis the mean values varied from 27.8 % (A 9-30-1) to 53.7 % (HI 8645). The regression coefficients were significant for HI 8645 and all genotypes were found non-significant; whereas deviations from regression were significant for all the genotypes (Table 4.26). Based on the stability parameters, HI 8645 (53.7 %), HI 8638 (44.4 %), HI 8722 (43.4 %), GW 1244 (42.9 %) and A 206 (40.7 %) for mean harvest index; HI 8671 (1.00), Altar 84 (0.95), HI 8722 (0.95), HD 4676 (0.91) and MACS 9 (0.90) for regression coefficients (Table 4.29). When mean of ranks were taken into consideration, Amrut, HI 8663, MACS 2694, DBP 01-11, PDW 215 and HI 8645 were found to be most stable over all the environments.

**1000 grain weight (g):** 1000 grain weight ranged from 38.6 g to 60.8 g with a mean value of 47.9 g under rainfed conditions; 40.1 g to 61.9 g with a mean value of 50.7 g under restricted irrigation conditions; 39.8 g to 60.0 g with a mean value of 47.7 g under pooled analysis. Under rainfed conditions (20.0 ºC to 37.7 ºC), highest 1000 grain weight was observed in MACS 9 (60.8 g), followed by MPO 1106 (57.9 g), HI 8671 (57.2 g), MPO 1215 (56.2 g) and HD 4676...
(55.9 g); while, lowest 1000 grain weight was observed in Sawer local (39.5 g) and WH 912 (38.6 g). The coefficient of variation estimated is 2.77 % (Table 4.30). Under restricted irrigation conditions (18.3 °C to 36.4 °C), highest 1000 grain weight was observed in MPO 1243 (61.9 g) followed by HI 8671 (59.6 g), MACS 9 (59.2 g), NIDW 15 (58.2 g) and HI 8498 (57.8 g); while, lowest 1000 grain weight was observed in HD 4502 (41.2 g) and Sawer local (40.1 g). The coefficient of variation estimated is 2.82 %. In pooled analysis, genotypes MACS 9 (60.0 g), followed by MPO 1243 (58.7 g), HI 8671 (58.7 g), GW 1245 (56.5 g) and HD 4676 (56.4 g) were of highest 1000 grain weight; while, HD 4502 (40.4 g) and Sawer local (39.8 g) were of lowest 1000 grain weight. The coefficient of variation estimated in pooled analysis is 2.50 %.

**Stability for 1000 grain weight:** Under rainfed conditions, the mean values for this trait varied from 39.5 g (HD 4502) to 60.8 g (MACS 9). The regression coefficients were significant for DBP 01-11, GW 1240 and HI 8645 and all genotypes were found non-significant; whereas deviations from regression were significant for all the genotypes except GW 1240, HI 8653, HI 8663, HI 8671, HI 8722, IWP 5004-1, IWP 5007, MACS 1967, Bijaga yellow and PDW 233. Based on the stability parameters, MACS 9 (60.8 g), HI 8671 (57.2 g), HD 4676 (55.9 g), HI 8645 (55.6 g) and GW 1245 (55.5 g) for mean 1000 grain weight; HI 8627 (0.97), HI 8722 (0.96), Amrut (0.79), PDW 215 (0.78) and IWP 5007 (1.23) for regression coefficients; and HI 8722 (0.01), HI 8691 (-0.03), AKDW 4151 (-0.03), HD 4672 (-0.04) and MACS 2694 (-0.05) for low deviations for regression value were found to be stable under rainfed conditions over years, since they had low ranks for the traits (Table 4.31). When mean of ranks were taken into consideration, HD 4502, DBP 01-11, Bijaga Red, AKDW 4240 and DBP 02-08 were found to be most stable under rainfed conditions over years. Under restricted irrigation conditions, the mean values varied from 41.2 g (HD 4502) to 59.6 g (HI 8671). The regression coefficients were significant for DBP 01-11 and all the genotypes show non-significant; whereas deviations from regression were significant for all the genotypes except AKDW 4151, AKDW 4240, HD 4502, HI 8627, HI 8653, HI 8691 and PDW 215. Based on the stability parameters, HI 8671 (59.6 g), MACS 9 (59.2 g), GW 1245 (57.4 g), Amrut (57.2 g) and HD 4676 (56.8g) for mean 1000 grain weight; Altar 84 (1.02), AKDW 4240 (1.11), GW 1245 (1.16), HI 8638 (0.84) and A 9-30-1 (0.83) for regression coefficients; and AKDW 4240 (0.02), HD 4502 (0.04), PDW 215 (0.13), HI 8653 (0.23) and HI 8691 (0.55) for low deviations for regression value were found to be stable under restricted irrigation conditions over years, since they had low ranks for the traits.
(Table 4.32). When mean of ranks were taken into consideration, DBP 02-08, GW 1240, Line 1172, DBP 01-11 and MACS 9 were found to be most stable under restricted irrigation conditions over years. Under pooled analysis, the mean values varied from 40.4 g (HD 4502) to 60.0 g (MACS 9). The regression coefficients were significant for DBP 01-11 and all the genotypes show non-significant; whereas deviations from regression were significant for all most all the genotypes except HI 8653, HI 8691, IWP 5004-1, IWP 5007, MACS 2694 and PDW 215. Based on the stability parameters, MACS 9 (60.0 g), HI 8671 (58.4 g), GW 1245 (56.4 g), HD 4676 (56.3 g) and Amrut (55.8 g) for mean 1000 grain weight; HI 8666 (1.01), A 9-30-1 (0.99), DBP 02-08 (0.99), IWP 5007 (1.00) and HI 8691 (1.20) for regression coefficients; and PDW 215 (0.54), IWP 5007 (0.98), HI 8691 (1.20) and IWP 5004-1 (1.60) for low deviations for regression value were found to be stable over the environments, since they had low ranks for the traits (Table 4.33). When mean of ranks were taken into consideration, DBP 01-11, GW 1240, HD 4502, HI 8627, Line 1172 and Bijaga yellow were found to be most stable over all the environments.

**Hectolitre weight (kg/l):** Hectoliter weight ranged from 75.8 kg/l to 83.1 kg/l with a mean value of 80.6 kg/l under rainfed conditions; 75.4 kg/l to 83.4 kg/l with a mean value of 80.7 kg/l under restricted irrigation conditions; 75.9 kg/l to 83.2 kg/l with a mean value of 80.6 kg/l under pooled analysis. Under rainfed conditions (26.2 °C to 39.3 °C), highest hectolitre weight was observed in HI 8638 (83.1 kg/l) followed by GW 1209 (83.0 kg/l), HI 8498 (83.0 kg/l), HI 8663 (83.0 kg/l) and HI 8722 (82.9 kg/l); while lowest hectolitre weight was shown by Kathia 25 (76.2 kg/l) and Baxi 228-18 (75.8 kg/l). The coefficient of variation estimated is 0.88 % (Table 4.34). Under restricted irrigation conditions (25.1 °C to 38.4 °C), highest hectolitre weight was observed in HI 8498 (83.4 kg/l) followed by HI 8666 (83.4 kg/l), MACS 3063 (83.2 kg/l), PDW 245 (83.0 kg/l) and DWL 5023 (82.9 kg/l); while lowest hectolitre weight was showed in Meghdoot (76.4 kg/l) and GW 1245 (75.4 kg/l). The coefficient of variation estimated is 0.87 %. In pooled analysis, genotypes HI 8498 (83.2 kg/l) followed by HI 8666 (82.9 kg/l), HI 8663 (82.8 kg/l), HI 8638 (82.6 kg/l) and MPO 1106 (82.6 kg/l) were of highest hectolitre weight; while Jay (76.5 kg/l) and GW 1245 (75.9 kg/l) were of lowest hectolitre weight. The coefficient of variation estimated in pooled analysis is 0.76 %.
**Sedimentation value (ml):** Sedimentation value ranged from 20.3 ml to 50.7 ml with a mean value of 32 ml under rainfed condition; 20.8 ml to 47.7 ml with a mean value of 34.0 ml under restricted irrigation condition; 20.8 ml to 49.2 ml with a mean value of 33.3 ml under pooled analysis. Under rainfed condition (21.3 °C to 36.8 °C), highest sedimentation value was observed in NP 4 (50.7 ml), followed by DBP 01-11 (41.9 ml), CPAN 6236 (41.7 ml), A 9-30-1 (40.8 ml) and A 206 (40.3 ml); while, lowest sedimentation value was observed in HD 4502 (20.6 ml) and HI 7747 (20.3 ml). The coefficient of variation estimated is 4.15 % (Table 4.35). Under restricted irrigation condition (20.1 °C to 35.3 °C), highest sedimentation value was observed in NP 4 (47.7 ml), followed by HI 8691 (43.7 ml), HI 8663 (43.3 ml), IWP 5070 (42.9 ml) and NIDW 295 (42.6 ml); while, lowest sedimentation value was observed in HI 7747 (21.2 ml) and HI 8591 (20.8 ml). The coefficient of variation estimated is 3.74 %. In pooled analysis, NP 4 (49.2 ml), followed by CPAN 6236 (41.9 ml), IWP 5070 (40.9 ml), A 206 (40.6 ml) and Dohad local (40.6 ml) were of highest sedimentation value; while, HI 8591 (20.9 ml) and HI 7747 (20.8 ml) were of lowest sedimentation value. The coefficient of variation estimated in pooled analysis is 3.51 %.

**Carotene content (ppm):** Carotene content ranged from 2.8 ppm to 7.8 ppm with a mean value of 4.5 ppm, under rainfed condition; 2.6 ppm to 7.7 ppm with a mean value of 4.1 ppm under restricted irrigation condition and 2.9 ppm to 7.8 ppm with a mean value of 4.4 ppm under pooled analysis. Under rainfed condition (25.8 °C to 35.8 °C), highest carotene content was observed in AKDW 4151 (7.8 ppm) followed by WH 896 (7.6 ppm), DBP 01-11 (7.4 ppm), MPO 1243 (7.1 ppm) and WH 912 (6.7 ppm); while, lowest carotene content was observed in NP 4 (3.1 ppm) and GW 1240 (2.8 ppm). The coefficient of variation estimated is 3.81 % (Table 4.36). Under restricted irrigation conditions (24.1 °C to 34.4 °C), highest carotene content was observed in AKDW 4151 (7.7 ppm) followed by WH 896 (7.5 ppm), V21/23 (6.5 ppm), MPO 1243 (6.2 ppm) and B 4447-BA (6.0 ppm), while, lowest carotene content was observed in Bijaga Red (2.7 ppm) and Jay (2.6 ppm). The coefficient of variation estimated is 5.76 %. In pooled analysis, AKDW 4151 (7.8 ppm) followed by WH 896 (7.6 ppm), MPO 1243 (6.7 ppm), V21/23 (6.5) and WH 912 (6.4 ppm) were of highest carotene content; while, GW 1240 (3.0 ppm) and Jay (2.9 ppm) were of lowest carotene content. The coefficient of variation estimated is 3.51 %.
Stability for carotene content: The mean values for this trait varied from 2.8 ppm (GW 1240) to 7.8 ppm (AKDW 4151). The regression coefficients were significant for HI 8722 and all the genotypes show non-significant; whereas deviations from regression were significant only for DBP 01-09. Based on the stability parameters, AKDW 4151 (7.8 ppm), DBP 01-11 (7.4 ppm), PDW 233 (6.5 ppm), HI 8627 (6.4 ppm) and HI 8722 (5.9 ppm) for mean carotene content; Bijaga Yellow (0.74), GW 1244 (0.65), IWP 5004-1 (0.54), HI 8666 (1.39), and IWP 5007 (1.53) for regression coefficients; and HD 4502 (0.00), HI 8627 (0.01), Bijaga red (0.01), A 9-30-1 (-0.01), HI 8645 (-0.01) and HI 8691 (-0.01) for low deviations for regression value were found to be stable under rainfed condition over years, since they had low ranks for the traits (Table 4.37). When mean of ranks were taken into consideration, HD 4676, MACS 2694, PDW 215, HI 8722 and Bijaga Red were found to be most stable under rainfed condition over years. Under restricted irrigation condition, the mean values ranged from 2.7 ppm (Bijaga Red) to 7.7 ppm (AKDW 4151). The regression coefficients were significant for DBP 01-11, GW 1240, HI 8663 and PDW 233 and all the genotypes were non-significant; whereas deviations from regression were significant for AKDW 4151, HI 8627, HI 8663 and PDW 233. Based on the stability parameters, AKDW 4151 (7.7 ppm), PDW 233 (6.0 ppm), DBP 02-08 (5.9 ppm), Altar 84 (5.9 ppm) and AKDW 4240 (5.6 ppm) for mean carotene content; Bijaga Yellow (1.00), HD 4676 (0.96), A 206 (0.85), HI 8671 (0.84) and A 9-30-1 (0.81) for regression coefficients; GW 1240 (0.00), A9-30-1 (-0.01), GW 1244 (0.02), Bijaga Red (0.02), GW 1245 (0.04) and A 206 (0.05) for low deviations for regression value were found to be stable under restricted irrigation condition over years, since they had low ranks for the traits (Table 4.38). When mean of ranks were taken into consideration, AKDW 4151, DBP 01-09, HI 8663, PDW 233, GW 1225, HI 8638, HI 8691 and IWP 5004-1 were found to be most stable under restricted irrigation condition over years. In pooled conditions, the mean values varied from 3.0 ppm (GW 1245) to 7.8 ppm (AKDW 4151). The regression coefficients were significant for DBP 02-08, GW 1225, HI 8671 and IWP 5007 and all the genotypes show non-significant; whereas deviations from regression were non-significant for all the genotypes. Based on the stability parameters, AKDW 4151 (7.7 ppm), PDW 233 (6.3 ppm), Altar 84 (5.8 ppm), GW 1225 (5.8 ppm) and HI 8645 (5.4 ppm) for mean carotene content; AKDW 4151 (0.99), HI 8722 (0.95), Line 1172 (1.07), HI 8666 (1.10) and A 206 (1.18) for regression coefficients; and HD 4676 (0.03), HD 4502 (0.05), HD 4672 (0.10) and A 9-30-1 (0.21) with low deviations from regression value were found to be stable over the environments, since they had low ranks for the
traits (Table 4.39). When mean of ranks were taken into consideration, DBP 02-08, HI 8638, HI 8671, Bijaga Yellow and IWP 5007 were found to be most stable over all the environments.

**Protein content (%)**: Protein content ranged from 11.6 % to 15.2 % with a mean value of 12.9 % under rainfed conditions; 11.4 % to 15.2 % with a mean value of 12.9 % under restricted irrigation conditions and 11.7 % to 15.2 % with a mean value of 13.0 % under pooled analysis. Under rainfed conditions (26.0 ºC to 37.9 ºC), highest protein content was observed in IWP 5004-1 (15.2 %) followed by IWP 5007 (15.2 %), Amrut (15.0 %), IWP 5013 (14.2 %) and Guji ‘S’ (14.0 %); while lowest protein content was observed in WH 896 (11.7 %) and HI 8550 (11.6 %). The coefficient of variation estimated is 2.89 %. Under restricted irrigation condition (24.7 ºC to 37.6 ºC), highest protein content was observed in Trinakaria (15.2 %) followed by IWP 5007 (15.1 %), IWP 5004-1 (14.6 %), Amrut (14.5 %) and N 59 (14.5 %); while lowest protein content was observed in MACS 3125 (11.6 %) and Altar 84 (11.4 %). The coefficient of variation estimated is 3.40 %. In pooled analysis, genotypes IWP 5007 (15.2 %) followed by IWP 5004-1 (14.9 %), Amrut (14.8 %), Trinakaria (14.6 %) and N 59 (14.3 %) were of highest protein content; while Altar 84 (11.7 %) and WH 896 (11.7 %) were of lowest protein content. The coefficient of variation estimated is 3.11 %.

**Stability for protein content**: The mean values for this trait varied from 11.9 % (DBP 01-09) to 15.2 % (IWP 5007). The regression coefficients were significant for Altar 84 and HD 4502 and all the genotypes were non-significant; whereas deviations from regression were significant only for AKDW 4151. Based on the stability parameters, IWP 5007 (15.2 %), IWP 5004-1 (15.2 %), Amrut (15.0 %), AKDW 4240 (13.9 %), Bijaga yellow (13.9 %), MACS 1967 (13.8 %) for mean protein content; A 206 (1.01), Bijaga Yellow (1.01), PDW 215 (1.08), HI 8722 (1.10), DBP 01-11 (1.14) and MACS 9 (1.14) for regression coefficient; and HI 8666 (0.01), PDW 233 (0.01), IWP 5004-1 (-0.01), MACS 1967 (-0.01), HI 8663 (0.02) and Bijaga red (0.02) for low deviations for regression value, were found to be stable under rainfed condition over years, since they had low ranks for the traits (Table 4.41). When mean of ranks were taken into consideration, GW 1240, HD 4672, GW 1245, AKDW 4151, AKDW 4240 and HD 4676 found to be most stable under rainfed condition over years. Under restricted irrigation condition, the mean values for this trait ranged from 11.4 % (Altar 84) to 15.1 % (IWP 5007). The regression coefficients were significant for HD 4502; HI 8645 and HI 8653 and all the genotypes were non-
significant; whereas deviations from regression were significant only for DBP 02-08 and MACS 9. Based on the stability parameters, IWP 5007 (15.1 %), IWP 5004-1 (14.6 %), Amrut (14.5 %), DBP 02-08 (14.3 %) and Bijaga Yellow (13.7 %) for mean protein content; HI 8666 (1.03), HD 4676 (0.99), HI 8691 (0.99), HI 8638 (0.97) and Bijaga Yellow (0.96) for regression coefficients; and HD 4676 (0.00), Line 1172 (0.00), GW 1225 (0.01) and MACS 2694 (-0.01) for low deviations for regression value were found to be stable under restricted irrigation condition over years, since they had low ranks for the trait (Table 4.42). When mean of ranks were taken into consideration, HI 8627, AKDW 4151, HD 4502, AKDW 4240, Altar 84, DBP 02-08 and MACS 9 were found to be most stable under restricted irrigation condition over years. In pooled analysis, the mean values for this trait ranged from 11.7 % (Altar 84) to 15.2 % (MACS 9). The regression coefficients were significant for HD 4676 and all the other genotypes were non-significant; whereas deviations from regression were significant only for GW 1240. Based on the stability parameters, MACS 9 (15.2 %), Line 1172 (14.9 %), Amrut (14.8 %), GW 1240 (13.9 %) and DBP 01-11 (13.8) for mean protein content; AKDW 4240 (1.00), DBP 01-09 (1.02), DBP 01-11 (0.99), HI 8671 (0.95) and Bijaga Red (0.93) for regression coefficients; and GW 1245 (0.02), MACS 1967 (0.03), PDW 233 (-0.03) and HI 8638 (0.07) for low deviations for regression value were found to be stable under restricted irrigation condition over years, since they had low ranks for the traits (Table 4.43). When mean of ranks were taken into consideration, AKDW 4151, HI 8627, Altar 84, GW 1244 and HI 8691 were found to be most stable over all the environments.

**Phosphorus content (g):** Phosphorus content ranged from 3.3 g to 8.2 g with a mean value of 4.9 g under rainfed condition; 3.3 g to 8.6 g with a mean value of 5.6 g under restricted irrigation condition; and 3.3 g to 7.5 g with a mean value of 5.3 g under pooled analysis. Under rainfed conditions (17.2 °C to 36.4 °C), highest phosphorus content was observed in HI 8663 (8.2 g) followed by GW 1139 (7.4 g), MACS 1967 (7.3 g), B 4447-BA (7.0 g) and HI 8666 (6.7 g); while lowest phosphorus content was observed in DWR 137 (3.3 g) and NP 4 (3.3 g). The coefficient of variation estimated is 11.03 % (Table 4.44). Under restricted irrigation condition (16.7 °C to 36.0 °C), highest phosphorus content was observed in HI 8645 (8.6 g) followed by HI 8666 (8.3 g), IWP 5004-1 (8.2 g), HI 8691 (8.0 g) and HI 8627 (7.9 g); while lowest phosphorus content was observed in bread wheat variety NP 4 (3.3 g) and PDW 233 (3.3 g). The coefficient of variation estimated is 9.24 %. In pooled analysis, HI 8666 (7.5 g) followed by
IWP 5004-1 (7.4 g), HI 8627 (7.2 g), GW 1139 (7.0 g) and HI 8663 (7.0 g) were found to have highest phosphorus content; while PDW 233 (3.4 g) and NP 4 (3.3 g) were found to have lowest phosphorus content. The coefficient of variation estimated is 8.01 %.

**Potassium content (g):** Potassium content ranged from 38.3 g to 47.6 g with a mean value of 41.7 g under rainfed condition; 37.9 g to 46.6 g with a mean value of 41.4 g under restricted irrigation condition; and 39.1 g to 44.4 g with a mean value of 41.4 g under pooled analysis. Under rainfed condition (37.2 ºC to 27.4 ºC), highest potassium content was observed in HD 4672 (47.6 g) followed by GW 1170 (45.5 g), NI 5759 (45.3 g), NP 404 (44.8 g) and AKDW 4151 (44.6 g); while lowest potassium content was observed in GW 2 (38.4 g) and MPO 215 (38.3 g). The coefficient of variation estimated is 2.68 % (Table 4.4). Under restricted irrigation condition (28.1 ºC to 38.4 ºC), highest potassium content was observed in Jay (46.6 g) followed by MACS 3063 (45.6 g), Kathia 25 (45.5 g), MACS 9 (44.8 g) and IWP 5070 (44.3 g); while lowest potassium content was observed in Bijaga Yellow (38.2 g) and DBP 02-08 (37.9 g). The coefficient of variation estimated is 2.47 %. In pooled analysis, HD 4672 (44.4 g) followed by Kathia 25 (44.2 g), MACS 2846 (44.0 g), Jay (43.8 g) and IWP 5004-1 (43.6 g) were of highest potassium content; while HD 4709 (39.3 g) and DBP-02-08 (39.1 g) were of lowest potassium content. The coefficient of variation estimated is 2.13 %.

**Phytic acid content (g):** Phytic acid content ranged from 22.2 g to 35.8 g with a mean value of 28.6 g under rainfed condition; 23.9 g to 34.4 g with a mean value of 29.0 g under restricted irrigation condition; and 24.0 g to 33.4 g with a mean value of 28.4 g under pooled analysis. Under rainfed condition (27.2 ºC to 36.9 ºC), lowest phytic acid content was observed in CDW 04 (22.8 g) followed by B 4446-WA (22.2 g), VD 97-15 (34.2 g), HI 8663 (34.4 g) and DBP 01-09 (35.0 g); while highest phytic acid showed in DBP-01-09 (35.0) and HI 8645 (35.8 g). The coefficient of variation estimated is 3.69 % (Table 4.46). Under restricted irrigation condition (27.9 ºC to 38.8 ºC), lowest phytic acid content was observed in HI 8722 (23.9 g) followed by Raj 6069 (24.7 g), IWP 5013 (32.7 g), MACS 1967 (33.2 g) and MACS 3061 (34.0 g); while highest phytic acid content was found in IWP 5070 (34.3) and JU 12 (34.4 g). The coefficient of variation estimated is 4.02 %. In pooled analysis, GW 1139 (24.0) followed by HD 4676 (24.0 g), HI 8381 (24.5 g), WH 912 (25.0 g) and HI 8722 (25.2) were found to have lowest phytic acid.
content; while HI 8663 (33.1 g) and JU 12 (33.4 g) were found to have highest phytic acid content. The coefficient of variation estimated is 3.88%.

The following genotypes HI 8627 (22.6 g, 7.2 g) and HI 8550 (21.6 g, 6.5 g) were found to have high grain yield and high phosphorus content; HI 8550 (21.6 g, 43.5 g), HD 4672 (23.2 g, 44.4 g) and A 206 (21.1 g, 43.4 g) were found to have high grain yield with high potassium content; HI 8722 (17.9 g, 25.2 g), HD 4676 (22.1 g, 24.0 g) and HD 4672 (23.2 g, 25.9 g) were found to have high grain yield along with low phytic acid content.

Mean performance of 102 genotypes for physiological and biochemical traits

Canopy temperature I (vegetative stage) (°C): Canopy temperature at vegetative stage ranged from 19.6 °C to 24.6 °C, with a mean value of 21.5 °C under rainfed conditions; 17.3 °C to 22.5 °C, with a mean value of 20.4 °C under restricted irrigation conditions; and 18.7 °C to 23.4 °C, with a mean value of 21.3 °C under pooled analysis. Under rainfed conditions, lowest canopy temperature at vegetative stage was observed in GW 1114 (19.6 °C) followed by Jay (19.6 °C), MACS 1967 (19.7 °C), MACS 2846 (19.7 °C) and bread wheat variety NP 4 (19.7 °C); while highest canopy temperature at vegetative stage was showed by Raj 6516 (24.2 °C) and CPAN 6236 (24.6 °C). The coefficient of variation was estimated is 4.64 % (Table 4).

Under restricted irrigation sown conditions, the lowest canopy temperature at vegetative stage was observed in VD 97-15 (17.3 °C) followed by NP 4 (17.6 °C) (bread wheat variety), Raj 6069 (17.8 °C), MACS 2846 (17.9 °C) and MACS 1967 (18.0 °C); and highest canopy temperature at vegetative stage was seen in GS 27 (22.4 °C) and HI 8381 (22.5 °C). The coefficient of variation estimated is 3.92 %. Under pooled analysis, the lowest canopy temperature at vegetative stage was observed in NP 4 (18.7 °C) followed by MACS 2846 (18.8 °C), MACS 1967 (18.9 °C), NP 404 (19.3 °C), and HG 110 (19.3 °C); and highest canopy temperature at vegetative stage was seen in HI 8381 (23.3 °C) and CPAN 6236 (23.4 °C). The coefficient of variation estimated is 3.11 %.

Canopy temperature II (flowering stage) (°C): Canopy temperature at flowering stage ranged from 20.6 °C to 25.4 °C with a mean value of 22.9 °C under rainfed conditions; 18.3 °C to 24.5 °C with a mean value of 22.1 °C under restricted irrigation conditions; and 20.0 °C to 24.9 °C with a mean value of 22.5 °C under pooled analysis. Under rainfed conditions, lowest canopy
temperature at flowering stage was observed in Bijaga Yellow (20.6 °C) followed by Raj 1555 (20.6 °C), Jairaj (20.7 °C), NP 4 (20.7 °C) and PDW 215 (20.8 °C); while, highest canopy temperature at flowering stage was seen in HD 4502 (25.2 °C) and CPAN 6236 (25.4 °C). The coefficient of variation estimated is 4.35 % (Table 4.48). Under restricted irrigation conditions, the lowest canopy temperature at flowering stage was observed in VD 97-15 (18.3 °C) followed by HI 8691 (19.0 °C), GS 27 (24.1 °C), WH 912 (24.2 °C) and DBP 02-08 (24.3 °C); while, highest canopy temperature at flowering stage was seen in GW 1170 (24.4 °C) and CPAN 6236 (24.5 °C). The coefficient of variation estimated is 7.31 %. Under pooled analysis, the lowest canopy temperature at flowering stage was observed in NP 4 (20.0 °C) followed by Raj 1555 (20.0 °C), Raj 6566 (20.0 °C), HI 8691 (20.2 °C) and Jairaj (20.2 °C); while, highest canopy temperature at flowering stage was seen in CPAN 6236 (24.7 °C) and AKDW 4151 (24.9 °C). The coefficient of variation estimated is 6.02 %.

**Canopy temperature III (grain filling stage) (°C):** Canopy temperature at grain filling stage ranged from 23.7 °C to 28.4 °C with a mean value of 25.8 °C under rainfed conditions; 22.0 °C to 27.2 °C with a mean value of 24.6 °C under restricted irrigation conditions; and 23.3 °C to 27.4 °C with a mean value of 25.1 °C under pooled analysis. Under rainfed conditions, lowest canopy temperature at grain filling stage was observed in Jay (23.7 °C) followed by HG 110 (23.8 °C), DBP 01-09 (23.9 °C), MACS 2846 (24.1 °C) and Bijaga Yellow (24.2 °C); while, canopy temperature at grain filling stage was observed in CPAN 6236 (28.1 °C) and Raj 6516 (28.4 °C). The coefficient of variation estimated is 3.03 % (Table 4.49). Under restricted irrigation conditions, the lowest canopy temperature at grain filling stage was observed in bread wheat variety NP 4 (22.0 °C) followed by MACS 2846 (22.5 °C), GS 27 (26.4 °C), CPAN 6236 (26.4 °C) and WH 912 (26.5 °C); while highest canopy temperature at grain filling stage was seen in AKDW 4151 (26.6 °C) and GW 1170 (27.2 °C). The coefficient of variation estimated is 3.35 %. Under pooled analysis, the lowest canopy temperature at grain filling stage was observed in MACS 2846 (23.3 °C) followed by NP 4 (23.3 °C), MACS 1967 (23.6 °C), Bijaga yellow (23.7 °C) and Jay (23.7 °C); while, highest canopy temperature at grain filling stage was seen in Raj 6516 (27.3 °C) and GW 1170 (27.4 °C). The coefficient of variation estimated is 3.22 %.

**Flag leaf area/plant (cm):** Flag leaf area/plant ranged from 12.0 cm to 22.3 cm with a mean value of 16.4 cm under rainfed conditions; 15.8 cm to 27.5 cm with a mean value of 21.8 cm
under restricted irrigation conditions; and 14.6 cm to 24.2 cm with a mean value of 19.4 cm under pooled analysis. Under rainfed conditions (11.0 °C to 28.3 °C), maximum flag leaf area/plant was observed in Baxi 228-18 (22.3 cm) followed by Jay (21.5 cm), Bijaga Yellow (21.0 cm), NI 5759 (20.9 cm) and NIDW 15 (20.5 cm); while minimum flag leaf area/plant was seen in IWP 5070 (12.4 cm) and NIDW 295 (12.0 cm). The coefficient of variation estimated is 7.08% (Table 4.5). Under restricted irrigation conditions (9.4 °C to 29.4 °C), the maximum flag leaf area/plant was observed in NI 5759 (27.5 cm) followed by MACS 9 (26.3 cm), N 59 (26.3 cm), NIDW 9 (25.9 cm) and Amrut (25.7 cm); while, minimum flag leaf area/plant was seen in MACS 3061 (16.2 cm) and Raj 6069 (15.8 cm). The coefficient of variation estimated is 8.27%. Under pooled analysis, the maximum flag leaf area/plant was observed in NI 5759 (24.2 cm) followed by Baxi 228-18 (23.4 cm), MACS 1967 (22.6 cm), Jay (22.5 cm) and N 59 (22.4 cm); while, minimum flag leaf area/plant was showed in Raj 6516 (15.0 cm) and MACS 3061 (14.6 cm). The coefficient of variation estimated in pooled analysis is 7.21%.

**Leaf weight/plant (g):** Leaf weight ranged from 1.2 g to 2.5 g with a mean value of 1.7 g under rainfed conditions; 1.5 g to 3.0 g with a mean value of 2.2 g under restricted irrigation conditions; and 1.5 g to 2.6 g with a mean value of 2.0 g under pooled analysis. Under rainfed conditions (9.5 °C to 27.2 °C), highest leaf weight was observed in Kathia 25 (2.5 g) followed by Baxi 228-18 (2.4 g), Bijaga red (2.3 g), Motia (2.3 g) and NIDW 9 (2.3 g); while, lowest leaf weight was seen in MPO 1106 (1.3 g) and HG 110 (1.2 g). The coefficient of variation estimated is 14.58% (Table 4.51). Under restricted irrigation conditions (10.4 °C to 28.1 °C), the highest leaf weight was observed in CDW 04 (3.0 g) followed by Sawer local (2.9 g), Bijaga Red (2.8 g), HI 8638 (2.8 g) and IWP 5004-1 (2.8 g); while, lowest leaf weight was observed in MPO 1215 (1.5 g) and Raj 6069 (1.5 g). The coefficient of variation estimated is 11.25%. Under pooled analysis, the highest leaf weight was observed in Bijaga red (2.6 g) followed by Sawer local (2.5 g), V 21 (2.5 g), CDW 04 (2.4 g) and JU 12 (2.4 g); while, lowest leaf weight was showed in MPO 1106 (1.5 g) and Raj 6069 (1.5 g). The coefficient of variation estimated is 10.23%.

**Stem weight/plant (g):** Stem weight ranged from 18.2 g to 44.4 g with a mean value of 27.3 g under rainfed conditions; 21.4 g to 46.2 g with a mean value of 35.1 g under restricted irrigation conditions; and 20.6 g to 41.8 g with a mean value of 31.3 g under pooled analysis. Under rainfed conditions (11.1 °C to 29.3 °C), highest stem weight was observed in Sarangpur local
(44.4) followed by Kathia 25 (40.8 g), Raj 6516 (38.5 g), Karnataka local (38.3 g) and Sawer local (37.3 g); while, lowest stem weight was seen in IWP 5007 (18.9 g) and GW 1245 (18.2 g). The coefficient of variation estimated in pooled analysis is 11.11 % (Table 4.52). Under restricted irrigation conditions (11.2 °C to 28.8 °C), the highest stem weight was observed in Sawer local (46.2 g) followed by IWP 5004-1 (44.7 g), HI 8638 (44.3 g), GS 27 (43.6 g) and MACS 1967 (43.6 g); while, lowest stem weight was seen in VD 97-15 (22.3 g) and HI 8671 (21.4 g). The coefficient of variation estimated is 11.23 %. Under pooled analysis, the highest stem weight was observed in Sawer local (41.8 g) followed by IWP 5004-1 (44.7 g), HI 8638 (44.3 g), GS 27 (43.6 g) and WH 912 (38.3 g); while lowest stem weight was seen in GW 1245 (23.1 g) and HI 8671 (20.6 g). The coefficient of variation estimated is 10.29 %.

**Number of effective spikes/plant:** Number of effective spikes ranged from 5.0 to 9.0 with a mean value of 6.6 under rainfed conditions; 5.0 to 9.0 with a mean value of 7.5 under restricted irrigation conditions; and 5.2 to 9.1 with a mean value of 7.0 under pooled analysis. Under rainfed conditions (17.4 °C to 35.7 °C), highest number of effective spikes was observed in bread wheat variety NP 4 (9.3) followed by Bansi local (9.0), NP 404 (8.2), HI 8645 (8.1) and HI 8691 (8.1); whereas lowest number of effective spikes was seen in MACS 3061 (5.1) and HI 8381 (5.0). The coefficient of variation estimated is 13.02 % (Table 4.53). Under restricted irrigation conditions (19.3 °C to 36.4 °C), the highest number of effective spikes was observed in AKDW 4151 (9.4) followed by Altar 84 (9.2), GW 1209 (9.2), HD 4672 (9.2) and Amrut (8.9); while lowest number of effective spikes was seen in NIDW 295 (5.8) and HI 8381 (5.3). The coefficient of variation estimated is 12.91 %. Under pooled analysis, the highest number of effective spikes was observed in NP 4 (9.1) followed by Jairaj (8.2), NP 404 (8.2), GW 1209 (8.1) and Malvi local (8.1); while lowest number of effective spikes was seen in HI 7747 (5.9) and HI 8381 (5.2). The coefficient of variation estimated is 11.72 %.

**Chlorophyll content I (vegetative stage) (%):** Chlorophyll content at vegetative stage (photosynthetic efficiency) ranged from 42.4 % to 61.0 with a mean value of 55.0 % under rainfed conditions; 46.5 % to 64.3 % with a mean value of 56.8 % under restricted irrigation conditions; and 47.2 % to 61.2 % with a mean value of 55.9 % under pooled analysis. Under rainfed conditions (12.9 °C to 26.8 °C), highest chlorophyll content at vegetative stage was observed in HI 8653 (61.0 %) followed by HI 8663 (60.8 %), NIDW 70 (60.0 %), HI 8591
(59.8 %) and HD 4709 (59.7 %); while lowest chlorophyll content at vegetative stage was seen in Bijaga Red (46.1 %) and Jay (42.4 %). The coefficient of variation estimated is 3.54 % (Table 4.54). Under restricted irrigation conditions (10.4 °C to 25.3 °C), the highest chlorophyll content at vegetative stage was observed in WH 912 (64.3 %) followed by Raj 6516 (63.1 %), MACS 3125 (62.8 %), MPO 215 (62.8 %) and Guji ‘S’ (62.4 %); while lowest chlorophyll content at vegetative stage was seen in Motia (47.9 %) and Vijay (46.5 %). The coefficient of variation estimated is 3.05 %. Under pooled analysis, the highest chlorophyll content at vegetative stage was observed in WH 912 (64.3 %) followed by Raj 6516 (63.1 %), MACS 3125 (62.8 %), MPO 215 (62.8 %) and Guji ‘S’ (62.4 %); while lowest chlorophyll content at vegetative stage was seen in Motia (47.9 %) and Vijay (46.5 %). The coefficient of variation estimated is 3.05 %. Under restricted irrigation conditions (10.4 °C to 25.3 °C), the highest chlorophyll content at vegetative stage was observed in WH 912 (64.3 %) followed by Raj 6516 (63.1 %), MACS 3125 (62.8 %), MPO 215 (62.8 %) and Guji ‘S’ (62.4 %); while lowest chlorophyll content at vegetative stage was seen in Motia (47.9 %) and Vijay (46.5 %). The coefficient of variation estimated is 3.05 %. Under pooled analysis, the highest chlorophyll content at vegetative stage was observed in WH 912 (64.3 %) followed by Raj 6516 (63.1 %), MACS 3125 (62.8 %), MPO 215 (62.8 %) and Guji ‘S’ (62.4 %); while lowest chlorophyll content at vegetative stage was seen in Motia (47.9 %) and Vijay (46.5 %). The coefficient of variation estimated is 3.05 %.

Chlorophyll content II (flowering stage) (%): Chlorophyll content at flowering stage (Photosynthetic efficiency) ranged from 38.0 % to 57.7 % with a mean value of 50.8 % under rainfed conditions; 43.0 % to 64.8 % with a mean value of 52.1 % under restricted irrigation conditions; and 42.2 % to 60.9% with a mean value of 51.5 % under pooled analysis. Under rainfed conditions (10.5 °C to 25.8 °C), highest chlorophyll content at flowering stage was observed in HI 8653 (57.7 %) followed by HI 7747 (57.1 %), Trinakaria (57.0 %), AKDW 4240 (56.9 %) and WH 912 (56.9 %); while, lowest chlorophyll content at flowering stage was seen in Baxi 228-18 (40.8 %) and Jay (38.0 %). The coefficient of variation estimated is 3.53 % (Table 4.55). Under restricted irrigation conditions (11.1 °C to 26.0 °C), the highest chlorophyll content at flowering stage was observed in WH 912 (64.8 %) followed by Raj 6516 (60.6 %), MPO 1243 (59.1 %), WH 896 (58.9 %) and V 21/23 (58.6 %); and lowest chlorophyll content at flowering stage was seen in Motia (44.9 %) and Ju 12 (43.0 %). The coefficient of variation estimated is 3.23 %. Under pooled analysis, the highest chlorophyll content at flowering stage was observed in WH 912 (60.9 %) followed by Trinakaria (56.7 %), WH 896 (56.7 %), HI 7747 (56.5 %) and MPO 1243 (56.4 %); while, lowest chlorophyll content at flowering stage was showed in Baxi 228-18 (43.8 %) and Jay (42.2 %). The coefficient of variation estimated is 2.21 %.

Chlorophyll content III (grain filling stage) (%): Chlorophyll content (Photosynthetic efficiency) at grain filling stage ranged from 35.7 % to 55.2 % with a mean value of 46.9 % under rainfed conditions; 37.6 % to 60.2 % with a mean value of 47.8 % under restricted irrigation conditions; and 38.7 % to 56.2 % with a mean value of 47.3 % under pooled analysis.
Under rainfed conditions (7.3 °C to 23.8 °C), highest chlorophyll content at grain filling stage was observed in HI 8653 (55.2 %) followed by AKDW 4240 (54.4 %), HI 8591 (54.2 %), CPAN 6236 (53.1 %) and HI 8498 (53.0 %); while, lowest chlorophyll content at grain filling stage was seen in Baxi 228-18 (37.3 %) and Jay (35.7 %). The coefficient of variation estimated is 3.80 % (Table 4.56). Under restricted irrigation conditions (7.8 °C to 24.0 °C), the highest chlorophyll content at grain filling stage was observed in WH 912 (60.2 %) followed by Raj 6516 (56.3 %), PDW 245 (54.4 %), Raj 6069 (53.8 %) and MPO 1243 (53.8 %); while, lowest chlorophyll content at grain filling stage was seen in GW 1244 (39.5 %) and JU 12 (37.6 %). The coefficient of variation estimated is 3.47 %. Under pooled analysis, the highest chlorophyll content at grain filling stage was observed in WH 912 (56.2 %) followed by Raj 6516 (53.3 %), HI 8591 (52.3 %), HI 8498 (52.0 %) and CPAN 6236 (51.7 %); while lowest chlorophyll content at grain filling stage was observed in JU 12 (40.2 %) and Jay (38.7 %). The coefficient of variation estimated is 2.89 %.

4.3 Performance and stability parameters of early heat tolerant high yielding durum wheat genotypes

Ten early heat tolerant and high yielding durum wheat genotypes were selected based on first year yield performance and evaluated for two more years (2011-12 and 2012-13) under rainfed and restricted irrigation conditions in randomized block design in 6 rows with row length of 6 m along with two bread wheat checks i.e., HI 1500 © and HI 1531 ©. Analysis of variance for 18 morphological, quality and biochemical characters and 11 physiological traits are presented in Tables 4.57 and 4.62 respectively. The general mean, range, genotypic and phenotypic coefficient of variances under pooled analysis for 18 morphological, quality and biochemical characters and 11 physiological traits are presented in Tables 4.58 and 4.63 respectively. The mean performance of 12 genotypes under rainfed, restricted irrigation and pooled stability parameters for 18 morphological, quality and biochemical characters and 11 physiological traits are presented in Tables 4.59 to 4.61 and 4.64 & 4.65 respectively.
Analysis of variance and estimation of parameters for genetic variability among 12 high yielding genotypes

Morphological, quality and biochemical traits

Highly significant differences were observed between genotypes for all the 12 traits in pooled analysis indicating appreciable variability for all the characters in the genotypes under early heat stress conditions. Highly significant differences were observed for year x genotype interactions, which indicated that appreciable influence of environmental conditions on all the traits in the genotypes. (Table 4.57)

Phenotypic and genotypic co-efficient of variation: In general, the values of phenotypic co-efficient of variation (PCV) were higher than that of the genotypic coefficient of variation (GCV) for all the characters (Table 4.58). PCV was estimated to be high for phosphorus content (22.7) followed by carotene content (19.7), sedimentation value (18.6), phytic acid content (16.4) and number of grains/spike (11.7); while, it was moderate for plant height (10.2) and flag leaf length (9.7); and low for hectolitre weight (2.4) and days to maturity (3.9). GCV also showed the similar trend as PCV for some of the traits and observed to be high for phosphorus content (20.7) followed by carotene content (18.5), sedimentation value (18.0) and phytic acid content (15.8); while, it was moderate for number of grains/spike (11.2) and plant height (10.1); and low for harvest index (0.1) and hectolitre weight (2.3). Difference between the PCV and GCV was high for harvest index (3.9) followed by grain yield/plant (3.3) and number of tillers/plant (2.8).

Heritability: Heritability was higher for days to flowering (99.1) followed by plant height (99.0), 1000 grain weight (98.2), spike length (97.2), days to maturity (95.4), hectarlitter weight (94.4), sedimentation value (93.5), phytic acid (93.1) and potassium content (92.3); moderate in carotene content (88.2), phosphorus content (83.5) and biomass/plant (67.6); and low in harvest index (10.1) and grain yield/plant (26.2).

Genetic advance over mean: Genetic advance over mean was higher for phosphorus content (38.8 %) followed by sedimentation value (35.8 %) and carotene content (35.8 %); and low for harvest index (0.3 %) and hectolitre weight (4.4 %)
Overall high to moderate heritability coupled with high to moderate genetic advance as percentage of mean was exhibited by sedimentation value, phosphorus content, carotene content, phytic acid and plant height.

In general, under rainfed and restricted irrigation conditions, high to moderate heritability coupled with high to moderate genetic advance as percentage of mean was exhibited for 9 traits viz., days to flowering, plant height, 1000 grain weight, sedimentation value, carotene content, phosphorus content, biomass/plant, harvest index and grain yield/plant.

**Physiological traits**

Highly significant differences were observed between genotypes for all the 11 traits in pooled analysis indicating appreciable variability for all the characters in the genotypes under early heat stress conditions (Table: 4.59). Highly significant differences were observed for year x genotype interactions, which indicated that appreciable influence of environmental conditions on all the traits in the genotypes.

**Phenotypic and genotypic co-efficient of variation:** In general, the values of phenotypic co-efficient of variation (PCV) were higher than that of the genotypic coefficient of variation (GCV) for all the characters (Table 4.60). PCV was estimated to be high for number of effective spikes (11.3) followed by flag leaf area/plant (11.2) and leaf weight (9.2); while it was moderate for Chl III (7.4), Chl II (6.8) and grain yield/plant (6.6); and low for CT III (4.4) and CT I (3.7). GCV also showed the similar trend as PCV for some of the traits and observed to be high for flag leaf area/plant (10.4) followed by number of effective spikes (8.6); while it was moderate for Chl III (6.8) and Chl II (6.5); low for CT III (1.5), CT II (1.3) and CT I (0.2). Difference between the PCV and GCV was high for CT II (3.6) followed by CT I (3.5) and leaf weight (3.3).

**Heritability:** Heritability in broad sense was observed to be high for Chl II (91.5 %), followed be flag leaf area/plant (86.1 %), Chl III (85.6 %) and Chl I (65.7 %); and moderate for grain yield/plant (62.8 %) and number of effective spikes (58.3 %); and low for CT III (12.8 %) and CT I (10.6 %).

**Genetic advance:** Genetic advance was found to be highest for Chl II (6.5) followed by Chl III (6.2), Chl I (4.6) and flag leaf area/plant (4.7); and it was low for CT III (0.3), CT II (0.3) and CT
I (0.1). While, genetic advance over its mean is high for flag leaf area/plant (28.9 %), grain yield/plant (16.0 %) and number of effective spikes (13.6 %); and moderate for Chl III (12.9) and Chl II (12.7); and low for CT II (1.4 %), CT III (1.1 %) and CT I (0.1 %).

In general, under rainfed and restricted irrigation conditions, high to moderate heritability coupled with high to moderate genetic advance as percentage of mean was exhibited by 7 traits viz., Chl II, Chl III, flag leaf area/plant, grain yield/plant and number of effective spikes, CT II and CT III.

Per se performance of morphological, quality and biochemical traits in high grain yielding early heat tolerant genotypes:

Days to flowering: Days to flowering ranged from ranged 53 days to 70 days with a mean value of 63.5 days under rainfed conditions; 52 days to 73 days with a mean value of 64.3 under restricted irrigation conditions; and 53 days to 72 days with a mean value of 64.0 days under pooled analysis. Under rainfed conditions (8.2 °C to 25.3 °C), early flowering was observed in MACS 9 (53 days) followed by MPO 1243 (55 days), HD 4676 (59 days), HI 8638 (63 days) and HI 8671 (64 days); while, late flowering was observed in GW 1225 (69 days) and HI 8627 (70 days). The coefficient of variation estimated is 1.2 % (Table 4.61). Under restricted irrigation conditions (10.3 °C to 27.3 °C), early flowering was observed in MACS 9 (52 days) followed by MPO 1243 (55 days), HD 4676 (59 days), HI 8638 (65 days) and GW 1225 (65 days); while, late flowering was observed in HI 8550 (72 days) and HI 8627 (73 days). The coefficient of variation estimated is 1.2 %. In pooled analysis, early flowering was observed in MACS 9 (53 days) followed by MPO 1243 (55 days), HD 4676 (59 days), HI 8638 (64 days) and HI 8671 (65 days), while, HI 8550 (70 days) and HI 8627 (72 days) were late to flower. The coefficient of variation estimated is 1.2 %.

Days to maturity: Days to maturity ranged from 111 days to 128 days with a mean value of 119.6 days under rainfed conditions; 112 days to 126 days with a mean value of 118.5 days under restricted irrigation conditions; and 112 days to 127 days with a mean value of 119.1 days under pooled analysis. Under rainfed conditions (17.5 °C to 35.4 °C), early maturity was observed in MACS 9 (111 days) followed by MPO 1243 (114 days), HI 8638 (115 days), HI 8671 (116 days) and HI 1500 © (117 days); while late maturity was observed in HI 8627 (126
days) and A 206 (128 days). The coefficient of variation estimated is 0.9 % (Table 4.61). Under restricted irrigation conditions (16.2 ºC to 34.2 ºC), early maturity was observed in MPO 1243 (112 days) followed by MACS 9 (112 days), HI 8671 (115 days), HI 8638 (115 days) and HD 4672 (116 days); while late maturity was observed in A 206 and HI 1531 © (126 days). The coefficient of variation estimated is 0.9 %. In pooled analysis, early maturity was observed in MACS 9 (112 days) followed by MPO 1243 (113 days), HI 8638 (115 days), HI 8671 (116 days) and HI 1500 © (117 days), while, HI 8627 (125 days) and A 206 (127 days) were the late to mature. The coefficient of variation estimated is 0.9 %.

**Plant height:** Plant height ranged from 63 cm to 92 cm with a mean value of 77 cm under rainfed conditions; 68 cm to 104 cm with a mean value of 88 cm under restricted irrigation conditions; and 66 cm to 98 cm with a mean value of 81 cm under pooled analysis. Under rainfed conditions (12.3 ºC to 30.2 ºC), lowest plant height was observed in HI 8671 (63 cm) followed by MPO 1243 (69 cm), HD 4672 (74 cm), HI 8627 (75 cm) and HI 1531 © (75 cm); while highest plant height was observed in GW 1225 (88 cm) and HI 1500 © (92 cm). The coefficient of variation estimated is 1.3 % (Table 4.61). Under restricted irrigation conditions (12.1 ºC to 28.8 ºC), lowest plant height was observed in HI 8671 (68 cm) followed by MPO 1243 (71 cm), HD 4676 (77 cm), HD 4672 (78 cm) and A 206 (81 cm); while, highest plant height was observed in GW 1225 (92 cm) and HI 1500 © (104 cm). The coefficient of variation estimated is 1.1 %. In pooled analysis, lowest plant height was observed in HI 8671 (66 cm) followed by MPO 1243 (70 cm), HD 4672 (76 cm), HD 4676 (77 cm) and HI 8627 (79 cm), while highest plant height was observed in GW 1225 (90 cm) and HI 1500 © (98 cm). The coefficient of variation estimated is 1.2 %.

**Spike length (cm):** Spike length ranged from 6.1 cm to 8.4 cm with a mean value of 6.9 cm under rainfed conditions; 5.8 cm to 8.1 cm with a mean value of 6.7 cm under restricted irrigation conditions; and 6.0 cm to 8.2 cm with a mean value of 6.8 cm under pooled analysis. Under rainfed conditions (11.2 ºC to 31.5 ºC), spike length was maximum in HI 1500 © (8.4 cm) followed by HI 8550 (7.4 cm), A 206 (7.4 cm), HI 1531 © (7.3 cm) and HD 4672 (7.1 cm); while, lowest spike length was observed in GW 1225 (6.2 cm) and HI 8671 (6.1 cm). The coefficient of variation estimated is 1.3 % (Table 4.61). Under restricted irrigation conditions (11.2 ºC to 28.3 ºC), spike length was maximum in HI 1500 © (8.1 cm) followed by MACS 9
HI 1531 © (7.2 cm), HD 4676 (7.1 cm) and HD 4672 (6.8 cm); while, lowest spike length was observed in GW 1225 (5.9 cm) and A 206 (5.8 cm). The coefficient of variation estimated is 1.7 %. In pooled analysis, spike length was maximum in HI 1500 © (8.3 cm) followed by MACS 9 (7.3 cm), HI 1531 © (7.3 cm), HD 4676 (7.1 cm) and HD 4672 (6.9 cm); while, lowest spike length was observed HI 8671 (6.2 cm) and GW 1225 (6.0 cm). The coefficient of variation estimated is 1.5 %

**Number of tillers/plant:** Number of tillers/plant ranged from 4.5 to 7.0 with a mean value of 6.1 under rainfed conditions; 5.5 to 9.7 with a mean value of 6.8 under restricted irrigation conditions; and 5.0 to 8.0 with a mean value of 6.5 under pooled analysis. Under rainfed conditions (15.4 °C to 34.6 °C), highest number of tillers/plant was observed in HI 1500 © (7.0) followed by HD 4672 (6.9), HD 4676 (6.7), GW 1225 (6.5) and HI 8671 (6.4); while, lowest number of tillers/plant was observed in MPO 1243 (6.0) and HI 8550 (4.5). The coefficient of variation estimated is 5.0 % (Table 4.61). Under restricted irrigation conditions (13.5 °C to 30.8 °C), highest number of tillers/plant was observed in A 206 (9.7) followed by HD 4676 (7.7), HI 8627 (7.0), HI 1500 © (6.9) and HD 4672 (6.8); while, lowest number of tillers/plant was observed in MACS 9 (5.9) and HI 8550 (5.5). The coefficient of variation estimated is 7.0 %. In pooled analysis, highest number of tillers/plant was observed in A 206 (8.0) followed by HD 4676 (7.2), HI 1500 © (7.0), HD 4672 (6.9) and HI 8627 (6.5), while, lowest number of tillers/plant was observed in MPO 1243 (6.0) and HI 8550 (5.0). The coefficient of variation estimated is 6.2 %.

**Flag leaf length (cm):** Flag leaf length ranged from 13.6 cm to 20.3 cm with a mean value of 16.7 cm under rainfed condition; 16.6 cm to 23.2 cm with a mean value of 20.4 cm under restricted irrigation conditions; and 16.2 cm to 21.5 cm with a mean value of 18.6 cm under pooled analysis. Under rainfed conditions (11.4 °C to 31.6 °C), highest flag leaf length was observed in HD 4672 (20.3 cm) followed by MACS 9 (19.0 cm), HI 8671 (18.4 cm), HI 8638 (17.5 cm) and A 206 (17.4 cm); while, lowest flag length was observed in HI 1500 © (13.8 cm) and HI 1531 © (13.6 cm). The coefficient of variation estimated is 2.9 % (Table 4.61). Under restricted irrigation conditions (10.8 °C to 31.3 °C), highest flag leaf length was observed in GW 1225 (23.2 cm) followed by HI 8550 (23.1 cm), HD 4672 (22.7 cm), HI 8627 (22.1 cm) and HD 4676 (22.0 cm); while, lowest flag length was observed in MPO 1243 (18.0 cm) and MACS
9 (16.6 cm). The coefficient of variation estimated is 3.0 %. In pooled analysis, highest flag leaf length was observed in HD 4672 (21.5 cm) followed by HI 8550 (19.9 cm), HI 8671 (19.4 cm), HI 8627 (19.4 cm) and GW 1225 (19.2 cm); while, lowest flag length was observed in HI 1500 © (16.7 cm) and HI 1531 © (16.2 cm). The coefficient of variation estimated is 3.0 %.

**Number of grains/spike:** Number of grains/spike ranged from 26.5 to 54.0 with a mean value of 38.5 under rainfed conditions; 32.7 to 52.2 with a mean value of 40.1 under restricted irrigation conditions; and 30.7 to 53.1 with a mean value of 39.3 under pooled analysis. Under rainfed conditions (16.8 °C to 35.8 °C), highest number of grains/spike was observed in HI 8550 (54.0) followed by HI 8627 (42.5), MACS 9 (41.7), HD 4672 (40.0) and HI 8638 (39.7); while, lowest number of grains/spike was observed in HI 1500 © (33.5) and HI 4676 (26.5). The coefficient of variation estimated is 3.5 % (Table 4.6). Under restricted irrigation conditions (17.3 °C to 36.7 °C), highest number of grains/spike was observed in HI 8550 (52.2) followed by HI 8627 (46.0), MACS 9 (44.7), GW 1225 (42.2) and HI 8671 (41.5); while, lowest number of grains/spike was observed in A 206 (33.4) and HI 1500 © (32.7). The coefficient of variation estimated is 3.1 %. In pooled analysis, highest number of grains/spike was observed in HI 8550 (53.1), followed by HI 8627 (44.3), MACS 9 (43.2), HD 4672 (40.3) and HI 8638 (40.1), while, HI 1500 © (33.1) and HD 4676 (30.7) showed lowest number of grains/spike. The coefficient of variation estimated is 3.3 %.

**Biomass/plant (g):** Biomass/plant ranged from 27.8 g to 43.2 g with a mean value of 35.7 g under rainfed conditions; 30.2 g to 40.6 g with a mean value of 35.4 g under restricted irrigation conditions; and 30.0 g to 39.6 g with a mean value of 35.6 g under pooled analysis. Under rainfed conditions (22.3 °C to 38.3 °C), highest biomass/plant was observed in HI 1500 © (43.2 g) followed by GW 1225 (42.3 g), HD 4672 (41.9g), MACS 9 (41.4 g) and HI 8638 (40.4 g); while, lowest biomass/plant was showed in HI 8671 (28.9 g) and HD 4676 (27.8 g). The coefficient of variation estimated is 4.0 % (Table 4.6). Under restricted irrigation conditions (21.3 °C to 37.3 °C), highest biomass/plant was observed in HI 8627 (40.6 g) followed by HI 8550 (38.1 g), A 206 (38.1 g), HI 8671 (38.0 g) and GW 1225 (37.0 g); while, lowest biomass/plant was seen in MPO 1243 (31.3 g) and HI 1531 © (30.2 g). The coefficient of variation estimated is 2.4 %. In pooled analysis, highest biomass/plant was observed in GW 1225 (39.6 g), followed by HI 1500 © (39.1 g), HD 4672 (39.0 g), HI 8638 (37.7 g) and MACS 9.
(37.1 g); while MPO 1243 (30.9 g) and HD 4676 (30.1 g) showed lowest biomass/plant. The coefficient of variation estimated is 3.3 %.

**Harvest Index (%)**: Harvest index ranged from 29.0 % to 34.4 % with a mean value of 32.2 % under rainfed conditions; 31.2 % to 40.9 % with a mean value of 36.2 % under restricted irrigation conditions; and 31.3 % to 37.1 % with a mean value of 34.2 % under pooled analysis. Under rainfed conditions (20.1 °C to 36.8 °C), highest harvest index was observed in MPO 1243 (34.4 %) followed by MACS 9 (33.9 %), A 206 (33.6 %), GW 1225 (33.3 %) and HD 4676 (33.2 %); while lowest harvest index was seen in HI 8627 (30.6 %) and HI 1500 © (29.0 %). The coefficient of variation estimated is 4.4 % (Table 4.6). Under restricted irrigation conditions (19.8 °C to 36.9 °C), highest harvest index was observed in HD 4676 (40.9 %) followed by HI 8671 (40.5 %), HI 8638 (38.2 %), HI 8627 (37.8 %) and HD 4672 (37.7 %); while lowest harvest index was seen in GW 1225 (31.3 %) and HI 1531 © (31.2 %). The coefficient of variation estimated is 3.6 %. In pooled analysis, highest harvest index was observed in HD 4676 (37.1 %) followed by HI 8671 (36.2 %), HI 8638 (35.3 %), MPO 1243 (35.2 %) and MACS 9 (35.1 %); while HI 1500 © (32.0 %) and HI 1531 © (31.3 %) showed lowest harvest index. The coefficient of variation estimated is 4.0 %.

**1000 grain weight (g)**: 1000 grain weight ranged from 40.5 g to 58.3 g with a mean value of 51.1 g under rainfed conditions; 44.7 g to 59.4 g with a mean value of 52.3 g under restricted irrigation conditions; 42.6 g to 58.8 g with a mean value of 51.7 g under pooled analysis. Under rainfed conditions (16.3 °C to 34.2 °C), highest 1000 grain weight was observed in HI 8671 (58.3 g), followed by MACS 9 (56.5 g), HD 4676 (56.2 g), HD 4672 (54.4 g) and HI 8638 (53.6 g); while, HI 8550 (45.4 g) and HI 1531 © (40.5 g) showed lowest 1000 grain weight. The coefficient of variation estimated is 1.7 % (Table 4.6). Under restricted irrigation conditions (15.3 °C to 36.6 °C), highest 1000 grain weight was observed in HI 8671 (59.4 g) followed by MPO 1243 (56.2 g), MACS 9 (56.2 g), HD 4672 (55.1 g) and HI 8638 (54.9 g); while, lowest 1000 grain weight was showed in HI 8550 (47.1 g) and HI 1531 © (44.7 g). The coefficient of variation estimated is 1.2 %. In pooled analysis, genotypes HI 8671 (58.8 g), followed by MACS 9 (56.3 g), HD 4676 (55.4 g), MPO 1243 (54.8 g) and HD 4672 (54.7 g) were of highest 1000 grain weight; while, HI 8550 (46.2 g) and HI 1531 © (42.6 g) were of lowest 1000 grain weight. The coefficient of variation estimated in pooled analysis is 1.5 %.
**Hectolitre weight (kg/l):** Hectolitre weight ranged from 75.5 kg/l to 82.5 kg/l with a mean value of 80.7 kg/l under rainfed conditions; 77.8 kg/l to 83.7 kg/l with a mean value of 81.8 kg/l under restricted irrigation conditions; 76.7 kg/l to 83.0 kg/l with a mean value of 81.3 kg/l under pooled analysis. Under rainfed conditions (21.2 °C to 37.3 °C), highest hectolitre weight was observed in HI 8627 (82.5 kg/l) followed by HI 1500 © (82.2 kg/l), HI 8671 (82.0 kg/l), GW 1225 (82.0 kg/l) and HI 8638 (81.7 kg/l); while, lowest hectolitre weight was seen in HD 4676 (79.3 kg/l) and A 206 (75.5 kg/l). The coefficient of variation estimated is 0.7 % (Table 4.6). Under restricted irrigation conditions (19.8 °C to 37.2 °C), highest hectolitre weight was observed in GW 1225 (83.7 kg/l) followed by HI 8627 (83.5 kg/l), HI 8638 (83.5 kg/l), HI 1500 © (83.5 kg/l) and HI 1531 © (83.0 kg/l); while, lowest hectolitre weight was seen in MACS 9 (79.2 kg/l) and A 206 (77.8 kg/l). The coefficient of variation estimated is 0.8 %. In pooled analysis, genotypes HI 8627 (83.0 kg/l), followed by HI 1500 © (82.9 kg/l), GW 1225 (82.9 kg/l), HI 8638 (82.5 kg/l) and HI 1531 © (82.3 kg/l) were of highest hectolitre weight; while HD 4676 (79.3 kg/l) and A 206 (76.7 kg/l) were of lowest hectolitre weight. The coefficient of variation estimated in pooled analysis is 0.8 %.

**Sedimentation value (ml):** Sedimentation value ranged from 24.7 ml to 44.2 ml with a mean value of 33.3 ml under rainfed condition; 23.7 ml to 43.9 ml with a mean value of 33.5 ml under restricted irrigation condition; 24.2 ml to 44.1 ml with a mean value of 33.4 ml under pooled analysis. Under rainfed condition (26.3 °C to 38.6 °C), highest sedimentation value was observed in HI 1500 © (44.2 ml), followed by HI 1531 © (42.9 ml), MPO 1243 (38.4 ml), HI 8550 (36.7 ml) and A 206 (33.7 ml); while, lowest sedimentation value was seen in HI 8627 (24.9 ml) and GW 1225 (24.7 ml). The coefficient of variation estimated is 4.9 % (Table 4.6). Under restricted irrigation condition (25.1 °C to 38.4 °C), highest sedimentation value was observed in HI 1500 © (43.9 ml), followed by HI 1531 © (43.4 ml), A 206 (38.7 ml), MPO 1243 (37.2 ml) and HI 8550 (37.0 ml); while, lowest sedimentation value was seen in HD 4672 (25.7 ml) and GW 1225 (23.7 ml). The coefficient of variation estimated is 4.9 %. In pooled analysis, HI 1500 © (44.1 ml), followed by HI 1531 © (43.2 ml), MPO 1243 (37.8 ml), HI 8550 (36.9 ml) and A 206 (36.2 ml) were of highest sedimentation value; while, HD 4672 (26.0 ml) and GW 1225 (24.2 ml) were of lowest sedimentation value. The coefficient of variation estimated in pooled analysis is 4.9 %.
**Carotene content (ppm):** Carotene content ranged from 3.6 ppm to 6.7 ppm with a mean value of 4.7 ppm, under rainfed condition; 3.4 ppm to 5.5 ppm with a mean value of 4.2 ppm under restricted irrigation condition; 3.5 ppm to 5.7 ppm with a mean value of 4.5 ppm under pooled analysis. Under rainfed condition (22.1 °C to 35.7 °C), highest carotene content was observed in HI 8627 (6.7 ppm) followed by HD 4672 (6.1 ppm), HI 8638 (6.0 ppm), MACS 9 (5.2 ppm) and MPO 1243 (4.9 ppm); while, lowest carotene content was observed in HI 1500 © (3.6 ppm) and HI 1531 © (3.6 ppm). The coefficient of variation estimated is 6.0 % (Table 4.63). Under restricted irrigation condition (21.8 °C to 34.2 °C), highest carotene content was observed in HI 8638 (5.5 ppm) followed by MACS 9 (5.5 ppm), HI 8627 (4.6 ppm), A 206 (4.5 ppm) and HD 4672 (4.1 ppm), while, lowest carotene content was observed in HI 8671 (3.4 ppm) and HI 1531 © (3.4 ppm). The coefficient of variation estimated is 7.1 %. In pooled analysis, HI 8638 (5.7 ppm), followed by HI 8627 (5.6 ppm), MACS 9 (5.4 ppm), HD 4672 (5.1 ppm) and MPO 1243 (4.5 ppm) were of highest carotene content; while HI 1500 © (3.6 ppm) and HI 1531 © (3.5 ppm) were of lowest carotene content. The coefficient of variation estimated is 6.5 %.

**Protein content (%):** Protein content ranged from 9.5 % to 12.3 % with a mean value of 11.3 % under rainfed conditions; 10.0 % to 12.8 % with a mean value of 11.8 %, under restricted irrigation conditions and 9.8 % to 12.4 % with a mean value of 11.6 %, under pooled analysis. Under rainfed conditions (26.7 °C to 38.4 °C), highest protein content was observed in MACS 9 (12.3 %) followed by MPO 1243 (12.2 %), GW 1225 (11.9 %), HI 8550 (11.6 %) and A 206 (11.6 %); while, lowest protein content was observed in HI 1500 © (10.2 %) and HI 1531 © (9.5 %). The coefficient of variation estimated is 4.5 % (Table 4.63). Under restricted irrigation conditions (25.8 °C to 37.3 °C), highest protein content was observed in HI 8638 (12.8 %) followed by HI 1500 © (12.7%), MACS 9 (12.6 %), HD 4676 (12.4 %) and HI 8671 (12.2 %); while lowest protein content was observed in HI 1531 © (10.0 %) and HI 8550 (11.1 %). The coefficient of variation estimated is 2.8 %. In pooled analysis, genotypes MACS 9 (12.4 %) followed by HI 8638 (12.1 %), MPO 1243 (12.1 %), HI 8671 (11.8 %) and GW 1225 (11.8 %) were of highest protein content; while, HI 8550 (11.3 %) and HI 1531 © (9.8 %) were of lowest protein content. The coefficient of variation estimated is 3.7 %.
Phosphorus content (g): Phosphorus content ranged from 3.3 g to 6.6 g with a mean value of 5.0 g under rainfed condition; 3.7 g to 6.9 g with a mean value of 5.1 g under restricted irrigation condition; and 3.5 g to 6.3 g with a mean value of 5.1 g under pooled analysis. Under rainfed conditions (18.5 ºC to 35.8 ºC), highest phosphorus content was observed in HI 8627 (6.6 g) followed by HD 4672 (6.3 g), MPO 1243 (6.2 g), HI 8550 (5.7 g) and HI 8638 (5.6 g); while lowest phosphorus content was observed in HI 1500 © (3.3 g) and HI 1531 © (3.3 g). The coefficient of variation estimated is 10.6 % (Table 4.6). Under restricted irrigation conditions (18.9 ºC to 36.0 ºC), highest phosphorus content was observed in MACS 9 (6.9 g) followed by HD 4676 (6.4 g), HI 8627 (6.0 g), A 206 (5.9 g) and GW 1225 (5.9 g); while, lowest phosphorus content was observed in HI 1531 © (3.8 g) and HI 1500 © (3.7 g). The coefficient of variation estimated is 8.2 %. In pooled analysis, HI 8627 (6.3 g) followed by HD 4676 (5.8 g), MPO 1243 (5.8 g), MACS 9 (5.7 g) and HI 8550 (5.4 g) were of highest phosphorus content; while, HI 1500 © (3.5 g) and HI 1531 © (3.5 g) were of lowest phosphorus content. The coefficient of variation estimated is 9.4 %.

Potassium content (g): Potassium content ranged from 35.1 g to 48.1 g with a mean value of 42.8 g under rainfed condition; 33.1 g to 44.2 g with a mean value of 40.9 g under restricted irrigation condition; and 34.1 g to 44.9 g with a mean value of 41.9 g under pooled analysis. Under rainfed conditions (26.8 ºC to 37.5 ºC), highest potassium content was observed in HD 4672 (48.1 g) followed by HD 4676 (47.4 g), HI 8550 (45.5 g), A 206 (44.8 g) and HI 8627 (44.3 g); while, lowest potassium content was observed in HI 1531 © (36.9 g) and HI 1500 © (35.1 g). The coefficient of variation estimated is 2.2 % (Table 4.6). Under restricted irrigation conditions (29.3 ºC to 38.4 ºC), highest potassium content was observed in HI 8627 (44.2 g) followed by HI 8550 (43.9 g), A 206 (43.9 g), HI 8638 (42.8 g) and MPO 1243 (42.0 g); while, lowest potassium content was observed in HI 1531 © (35.4 g) and HI 1500 © (33.1 g). The coefficient of variation estimated is 2.8 %. In pooled analysis, HD 4672 (44.9 g) followed by HI 8550 (44.7 g), HD 4676 (44.6 g), A 206 (44.3 g) and HI 8627 (44.2 g) were of highest potassium content; while, HI 1531 © (36.1 g) and HI 1500 © (34.1 g) were of lowest potassium content. The coefficient of variation estimated is 2.5 %.

Phytic acid content (g): Phytic acid content ranged from 20.5 g to 35.0 g with a mean value of 25.0 g under rainfed condition; 19.9 g to 32.8 g with a mean value of 26.8 g under restricted
irrigation condition; and 20.3 g to 30.3 g with a mean value of 25.9 g under pooled analysis. Under rainfed conditions (26.3 °C to 36.5 °C), lowest phytic acid content was observed in HI 1500 © (20.5 g) followed by HI 1531 © (20.7 g), HD 4676 (21.6 g), HD 4672 (22.1 g) and GW 1225 (22.3 g); while, highest phytic acid was seen in MPO 1243 (35.0 g) and HI 8627 © (30.0 g). The coefficient of variation estimated is 4.0 % (Table 4.6). Under restricted irrigation conditions (28.4 °C to 38.8 °C), lowest phytic acid content was observed in HI 1531 © (19.9 g) followed by HI 1500 © (21.9 g), HD 4676 (24.4 g), MPO 1243 (25.6 g) and HI 8627 (26.1 g); while highest phytic acid content was seen in HI 8671 (32.8) and HD 4672 (32.0 g). The coefficient of variation estimated is 4.5 %. In pooled analysis, HI 1531 © (20.3) followed by HI 1500 © (21.2 g), HD 4676 (23.0 g), MACS 9 (24.9 g) and HI 8550 (25.9) were of lowest phytic acid content; while MPO 1243 (30.3 g) and HI 8671 (28.6 g) were of highest phytic acid content. The coefficient of variation estimated is 4.3 %.

**Grain yield/plant (g):** Grain yield/plant ranged from 9.2 g to 13.9 g with a mean value of 11.4 g under rainfed condition; 9.4 g to 15.6 g with a mean value of 12.9 g under restricted irrigation condition and 10.0 g to 13.5 g with a mean value of 12.2 g under pooled analysis. Under rainfed condition, highest grain yield/plant was observed in MACS 9 (13.9 g) followed by GW 1225 (13.3 g), HD 4672 (13.1 g), HI 8638 (13.1 g) and HI 1500 © (12.4 g); while lowest grain yield/ plant was observed in HI 8671 (9.5 g) and HD 4676 (9.2 g). The coefficient of variation estimated is 6.1 % (Table 4.6). Under restricted irrigation condition, highest grain yield/plant was observed in HI 8627 (15.6 g) followed by HI 8671 (15.5 g), HD 4672 (13.9 g), A 206 (13.8 g) and HI 8638 (13.3 g); while, lowest grain yield/ plant was observed in MPO 1243 (11.0 g) and HI 1531 © (9.4 g). The coefficient of variation estimated is 4.5 %. In pooled analysis, HD 4672 (13.5 g) followed by HI 8638 (13.2 g), MACS 9 (12.9 g), A 206 (12.8 g) and HI 8627 (12.6 g) were of highest grain yield/ plant; while, MPO 1243 (11.0 g) and HI 1531 © (10.0 g) were of lowest grain yield/plant. The coefficient of variation estimated is 5.3 %.

*Per se* performance of physiological traits in high grain yielding early heat tolerant genotypes

**Canopy temperature I (vegetative stage) (°C):** Canopy temperature at vegetative stage ranged from 20.9 °C to 23.4 °C with a mean value of 22.1 °C under rainfed conditions; 18.4 °C to 20.1 °C with a mean value of 19.3 °C under restricted irrigation conditions; and 19.9 °C to 21.4 °C
with a mean value of 20.7 °C under pooled analysis. Under rainfed conditions, lowest canopy temperature at vegetative stage was observed in HI 8671 (20.9 °C) followed by HD 4676 (21.3 °C), MPO 1243 (21.5 °C), MACS 9 (21.5 °C) and HI 1531 © (21.8 °C); while highest canopy temperature at vegetative stage was seen in HD 4672 (22.8 °C) and HI 8627 (23.4 °C). The coefficient of variation estimated is 4.3 % (Table 4.64). Under restricted irrigation conditions, the lowest canopy temperature at vegetative stage was observed in HI 1500 © (18.4 °C) followed by HI 1531 © (18.4 °C), HD 4676 (18.6 °C), GW 1225 (19.1 °C) and MPO 1243 (19.1 °C); and highest canopy temperature at vegetative stage was seen in HD 4672 (20.1 °C) and HI 8550 (20.1 °C). The coefficient of variation estimated is 2.9 %. Under pooled analysis, the lowest canopy temperature at vegetative stage was observed in HD 4676 (19.9 °C) followed by HI 1500 © (20.1 °C), HI 1531 © (20.1 °C), HI 8671 (20.2 °C) and MPO 1243 (20.3 °C); and highest canopy temperature at vegetative stage was seen in HI 8627 (21.4 °C) and HI 8638 (21.4 °C). The coefficient of variation was estimated is 3.8 %.

**Canopy temperature II (flowering stage) (°C):** Canopy temperature at flowering stage ranged from 22.8 °C to 25.8 °C with a mean value of 24.1 °C under rainfed conditions; 20.2 °C to 22.7 °C with a mean value of 21.6 °C under restricted irrigation conditions; and 22.1 °C to 24.2 °C with a mean value of 22.8 °C under pooled analysis. Under rainfed conditions, lowest canopy temperature at flowering stage was observed in MACS 9 (22.8 °C) followed by HI 1500 © (23.1 °C), HI 8550 (23.6 °C), HI 8671 (23.8 °C) and A 206 (23.8 °C); while, highest canopy temperature at flowering stage was seen in HI 8671 (25.0 °C) and MPO 1243 (25.8 °C). The coefficient of variation estimated is 5.1 % (Table 4.64). Under restricted irrigation sown conditions, the lowest canopy temperature at flowering stage was observed in HI 8638 (20.2 °C) followed by HI 8671 (20.7 °C), HI 8550 (21.2 °C), GW 1225 (21.2 °C) and HI 1500 © (21.4 °C); while, highest canopy temperature at flowering stage was seen in MACS 9 (22.4 °C) and MPO 1243 (22.7 °C). The coefficient of variation estimated is 3.9 %. Under pooled analysis, the lowest canopy temperature at flowering stage was observed in HI 8638 (22.1 °C) followed by HI 1500 © (22.2 °C), HI 8550 (22.4 °C), HD 4676 (22.6 °C) and MACS 9 (22.6 °C); while, highest canopy temperature at flowering stage was seen in HD 4672 (23.2 °C) and MPO 1243 (24.2 °C). The coefficient of variation was estimated is 4.6 %.
Canopy temperature III (grain filling stage) (°C): Canopy temperature at grain filling stage ranged from 25.4 °C to 27.9 °C with a mean value of 26.2 °C under rainfed conditions; 23.8 °C to 26.0 °C with a mean value of 24.3 °C under restricted irrigation conditions; and 24.5 °C to 27.1 °C with a mean value of 25.3 °C under pooled analysis. Under rainfed conditions, lowest canopy temperature at grain filling stage was observed in HI 8550 (25.4 °C) followed by HI 1500 © (25.4 °C), HI 8638 (25.6 °C), HI 8627 (25.1 °C) and HI 1531 © (25.8 °C); while, canopy temperature at grain filling stage was observed in MPO 1243 (27.3 °C) and MACS 9 (27.9 °C). The coefficient of variation estimated is 4.2 % (Table 4.64). Under restricted irrigation sown conditions, the lowest canopy temperature at grain filling stage was observed in HI 8638 (23.8 °C) followed by HD 4676 (23.9 °C), GW 1225 (24.0 °C), HD 4672 (24.1 °C) and HI 8550 (24.1 °C); while, highest canopy temperature at grain filling stage was seen in MACS 9 (24.6 °C) and MPO 1243 (26.0 °C). The coefficient of variation estimated is 4.1 %. Under pooled analysis, the lowest canopy temperature at grain filling stage was observed in HI 8638 (24.7 °C) followed by HI 8550 (24.8 °C), HI 1500 © (24.8 °C), A 206 (25.2 °C) and HI 1531 © (25.1 °C); while, highest canopy temperature at grain filling stage was seen in MACS 9 (26.3 °C) and MPO 1243 (26.7 °C). The coefficient of variation estimated is 4.1 %.

Flag leaf area/plant (cm): Flag leaf area/plant ranged from 11.7 cm to 18.6 cm with a mean value of 15.0 cm under rainfed conditions; 13.9 cm to 21.4 cm with a mean value of 17.7 cm under restricted irrigation conditions; and 14.0 cm to 18.8 cm with a mean value of 16.4 cm under pooled analysis. Under rainfed conditions (12.3 °C to 29.4 °C), maximum flag leaf area/plant was observed in HD 4672 (18.6 cm) followed by HI 8638 (17.1 cm), HI 8671 (16.6 cm), MACS 9 (16.3 cm) and MPO 1243 (15.8 cm); while minimum flag leaf area/plant was seen in HI 1500 © (12.0 cm) and HI 1531 © (11.7 cm). The coefficient of variation estimated is 3.8 % (Table 4.64). Under restricted irrigation sown conditions (10.2 °C to 28.3 °C), the maximum flag leaf area/plant was observed in HI 8550 (21.4 cm) followed by GW 1225 (20.6 cm), HI 8627 (20.2 cm), HD 4676 (19.4 cm) and HD 4672 (19.1 cm); while minimum flag leaf area/plant was seen in MPO 1243 (14.8 cm) and MACS 9 (13.9 cm). The coefficient of variation estimated is 4.6 %. Under pooled analysis, the maximum flag leaf area/plant was observed in HD 4672 (18.8 cm) followed by HI 8550 (17.8 cm), GW 1225 (17.3 cm), HI 8627 (17.1 cm) and HI 8671 (16.9 cm); while minimum flag leaf area/plant was showed in HI 1500 © (14.6 cm) and HI 1531 © (14.1 cm). The coefficient of variation was estimated in pooled analysis is 4.3 %.
**Leaf weight/plant (g):** Leaf weight ranged from 1.2 g to 2.0 g with a mean value of 1.6 g under rainfed conditions; 1.2 g to 2.0 g with a mean value of 1.5 g under restricted irrigation conditions; and 1.2 g to 1.9 g with a mean value of 1.5 g under pooled analysis. Under rainfed conditions (10.1 °C to 28.3 °C), highest leaf weight was observed in GW 1225 (2.0 g) followed by HI 1500 © (1.9 g), HD 4672 (1.8 g), HI 8671 (1.6 g) and HI 8550 (1.6 g); while, lowest leaf weight was seen in MACS 9 (1.3 g) and A 206 (1.2 g). The coefficient of variation estimated is 8.8 % (Table 4.64). Under restricted irrigation sown conditions (11.3 °C to 28.7 °C), the highest leaf weight was observed in HI 8627 (2.0 g) followed by HI 1500 © (1.9 g), HD 4672 (1.6 g), HD 4676 (1.6 g) and HI 8638 (1.5 g); while, lowest leaf weight was observed in HI 8550 (1.2 g) and HI 1531 © (1.2 g). The coefficient of variation estimated is 4.4 %. Under pooled analysis, the highest leaf weight was observed in HI 1500 © (1.9 g) followed by HD 4672 (1.7 g), HI 8627 (1.7 g), GW 1225 (1.7 g) and HD 4676 (1.6 g); while, lowest leaf weight was showed in HI 1531 © (1.4 g) and A 206 (1.3 g). The coefficient of variation estimated is 7.1 %.

**Stem weight/plant (g):** Stem weight ranged from 22.1 g to 42.4 g with a mean value of 30.5 g under rainfed conditions; 17.8 g to 38.4 g with a mean value of 26.2 g under restricted irrigation conditions; and 22.0 g to 33.8 g with a mean value of 28.4 g under pooled analysis. Under rainfed conditions (14.3 °C to 32.4 °C), highest stem weight was observed in A 206 (42.4 g) followed by GW 1225 (40.2 g), HI 8638 (38.5 g), HI 8671 (30.0 g) and HD 4672 (29.6 g); while, lowest stem weight was seen in MACS 9 (22.2 g) and HI 8627 (22.1 g). The coefficient of variation estimated is 3.6 % (Table 4.64). Under restricted irrigation sown conditions (13.4 °C to 33.8 °C), the highest stem weight was observed in HI 1500 © (38.4 g) followed by HI 8627 (34.2 g), HD 4672 (28.5 g), GW 1225 (27.4 g) and HI 8671 (27.3 g); while, lowest stem weight was showed in A 206 (20.1 g) and HI 8550 (17.8 g). The coefficient of variation estimated is 2.5 %. Under pooled analysis, the highest stem weight was observed in GW 1225 (33.8 g) followed by HI 1500 © (33.8 g), HI 8638 (31.6 g), A 206 (31.2 g) and HD 4672 (29.1 g); while, lowest stem weight was showed in HI 8550 (23.3 g) and MACS 9 (22.0 g). The coefficient of variation estimated is 3.2 %.

**Number of effective spikes/plant:** Number of effective spikes ranged from 4.0 to 6.5 with a mean value of 5.7 under rainfed conditions; 4.7 to 8.5 with a mean value of 6.1 under restricted irrigation conditions; and 4.4 to 7.3 with a mean value of 5.9 under pooled analysis. Under
rainfed conditions (18.5 ºC to 34.7 ºC), highest number of effective spikes was observed in HD 4672 (6.5) followed by HI 1500 © (6.5), HI 1531 © (6.2), A 206 (6.0) and HD 4676 (6.0); whereas lowest number of effective spikes was seen in HI 8671 (5.2) and HI 8550 (4.0). The coefficient of variation estimated is 6.5 % (Table 4.65). Under restricted irrigation sown conditions (17.5 ºC to 35.3 ºC), the highest number of effective spikes was observed in A 206 (8.5) followed by HD 4676 (7.2), HD 4672 (6.3), GW 1225 (6.3) and HI 8627 (6.2); while, lowest number of effective spikes showed in HI 8550 (4.8) and MPO 1243 (4.7). The coefficient of variation estimated is 8.1 %. Under pooled analysis, the highest number of effective spikes was observed in A 206 (7.3) followed by HD 4676 (6.6), HD 4672 (6.4), HI 1500 © (6.4); while, lowest number of effective spikes was seen in MPO 1243 (5.3) and HI 8550 (4.4). The coefficient of variation estimated is 7.4 %.

**Chlorophyll content I (vegetative stage) (%):** Chlorophyll content at vegetative stage ranged from 46.8 % to 57.9 % with a mean value of 54.7 % under rainfed conditions; 51.5 % to 61.1 % with a mean value of 57.4 % under restricted irrigation conditions; and 51.0 % to 59.3 % with a mean value of 56.1 % under pooled analysis. Under rainfed conditions (13.4 ºC to 27.3 ºC), highest chlorophyll content at vegetative stage was observed in HI 8638 (57.9 %) followed by HD 4672 (57.6 %), HI 8550 (57.4 %), HI 8671 (56.6 %) and HD 4676 (56.6 %); while, lowest chlorophyll content at vegetative stage was seen in HI 8627 (52.8 %) and A 206 (56.8 %). The coefficient of variation estimated is 5.3 % (Table 4.65). Under restricted irrigation sown conditions (10.3 ºC to 28.4 ºC), the highest chlorophyll content at vegetative stage was observed in HD 4672 (61.1 %) followed by HI 8638 (60.4 %), HI 8671 (58.8 %), GW 1225 (58.6 %) and HI 8627 (58.5 %); while, lowest chlorophyll content at vegetative stage showed in A 206 (55.2 %) and HI 1500 © (51.5 %). The coefficient of variation estimated is 2.5 %. Under pooled analysis, the highest chlorophyll content at vegetative stage was observed in HD 4672 (59.3 %) followed by HI 8638 (59.1 %), HI 8671 (57.7 %), HI 8550 (57.7 %) and HD 4676 (56.3 %); while, lowest chlorophyll content at vegetative stage was seen in HI 1500 © (54.0 %) and A 206 (51.0 %). The coefficient of variation estimated is 4.0 %.

**Chlorophyll content II (flowering stage) (%):** Chlorophyll content at flowering stage ranged from 43.9 % to 54.0 % with a mean value of 50.1 % under rainfed conditions; 49.3 % to 58.8 % with a mean value of 52.9 % under restricted irrigation conditions; and 47.4 % to 56.4 % with a
mean value of 51.5% under pooled analysis. Under rainfed conditions (10.8 °C to 25.3 °C), highest chlorophyll content at flowering stage was observed in HD 4672 (54.0 %) followed by HI 8550 (53.1 %), HI 8638 (53.1 %), MPO 1243 (53.1 %) and HI 8671 (52.1 %); while, lowest chlorophyll content at flowering stage was showed in HI 1531 © (44.1 %) and A 206 (43.9 %). The coefficient of variation estimated is 2.1 % (Table 4.65). Under restricted irrigation sown conditions (11.1 °C to 26.3 °C), the highest chlorophyll content at flowering stage was observed in HD 4672 (58.8 %) followed by HI 8671 (56.4 %), HI 8550 (55.2 %), MPO 1243 (54.1 %) and HI 8627 (53.4 %); and lowest chlorophyll content at flowering stage showed in HI 8638 (50.1 %) and HI 1500 © (49.3 %). The coefficient of variation estimated is 1.9 %. Under pooled analysis, the highest chlorophyll content at flowering stage was observed in HD 4672 (56.4 %) followed by HI 8671 (54.2 %), HI 8550 (54.1 %), MPO 1243 (53.6 %) and HI 8627 (51.8 %); while, lowest chlorophyll content at flowering stage was seen in GW 1225 (47.9 %) and A 206 (47.4 %). The coefficient of variation estimated is 2.0 %.

**Chlorophyll content III (grain filling stage) (%)**: Chlorophyll content at grain filling stage ranged from 40.7 % to 49.9 % with a mean value of 46.0 % under rainfed conditions; 46.6 % to 55.9 % with a mean value of 49.8 % under restricted irrigation conditions; and 44.0 % to 52.5 % with a mean value of 47.9 % under pooled analysis. Under rainfed conditions (8.9 °C to 24.3 °C), highest chlorophyll content at grain filling stage was observed in HI 8550 (49.9 %) followed by HI 8671 (49.8 %), HD 4672 (49.0 %), MPO 1243 (48.6 %) and HI 8638 (48.5 %); while lowest chlorophyll content at grain filling stage was seen in GW 1225 (40.9 %) and HI 1531 © (40.7 %). The coefficient of variation estimated is 3.5 % (Table 4.65). Under restricted irrigation sown conditions (9.6 °C to 25.3 °C), the highest chlorophyll content at grain filling stage was observed in HD 4672 (55.9 %) followed by HI 8671 (53.1 %), HI 1531 © (52.5 %), MPO 1243 (51.4 %) and HI 8550 (50.6 %); while, lowest chlorophyll content at grain filling stage was seen in HI 1500 © (46.7 %) and HI 8638 (46.6 %). The coefficient of variation estimated is 2.3 %. Under pooled analysis, the highest chlorophyll content at grain filling stage was observed in HD 4672 (52.5 %) followed by HI 8671 (51.4 %), HI 8550 (50.2 %), MPO 1243 (50.0 %) and HI 8627 (47.9 %); while, lowest chlorophyll content at grain filling stage was observed in GW 1225 (44.4 %) and A 206 (44.0 %). The coefficient of variation estimated is 2.9 %.
4.4 Correlation coefficients between characters

Correlation co-efficient of 102 durum wheat genotypes for morphological, quality and biochemical traits

Coefficient of correlation among 19 characters involving grain yield, yield contributing, biochemical and quality traits under rainfed and restricted irrigation conditions is worked out for durum wheat genotypes have been presented in Table 4.66.

Rainfed conditions: Grain yield/plant showed highly significant positive correlation with plant height (0.25**), number of grains/spike (0.27**), biomass/plant (0.65**), harvest index (0.38**), 1000 grain weight (0.36**), hectolitre weight (0.19*), sedimentation value (0.22**), carotene content (0.27**), protein content (0.26**) and potassium content (0.32**); while it showed significant and negative correlation with days to flowering (-0.23*) and number of tillers/plant (-0.66**). Days to flowering showed highly significant positive correlation with days to maturity (0.67**) and carotene content (0.23*), while, significant and negative correlation was observed with number of tillers/plant (-0.21*), flag leaf length (-0.64**), 1000 grain weight (-0.44**) and grain yield/plant (-0.23**). Days to maturity showed highly significant positive correlation with carotene content (0.34**), while highly significant and negative correlation was observed with flag leaf width (-0.59**) and 1000 grain weight (-0.37**). Plant height showed significant positive correlation with spike length (0.38**), flag leaf width (0.36**), biomass/plant (0.67**), protein content (0.48**) and grain yield/plant (0.25**), while highly significant and negative association was observed with harvest index (-0.57**), hectoliter weight (-0.45**) and phosphorus content (-0.28**). Spike length showed significant positive correlation with number of grains/spike (0.38**) and biomass/plant (0.36**), while highly significant and negative association with harvest index (-0.27**) and hectoliter weight (-0.45**). Number of tillers showed highly significant and negative correlation was observed with number of grains/spike (-0.58**), biomass/plant (-0.45**), harvest index (-0.22*) and grain yield/plant (-0.66**). Flag leaf length showed positive and significant association with 1000 grain weight (0.24*), while highly significant and negative association with hectoliter weight (-0.28**) and carotene content (-0.54**). Flag leaf width showed positive and significant association with number of grains/spike (0.31**), biomass/plant (0.31**) and protein content (0.38**), while highly significant and negative association with harvest index (-0.24*) and hectoliter weight
(-0.27**). Number of grains/spike showed positive and highly significant association with harvest index (0.25**), sedimentation value (0.24*), carotene content (0.29**), phosphorus content (0.20**) and grain yield/plant (0.27**); while, negative and significant association with protein content (-0.20*). Biomass/plant showed positive and highly significant correlation with protein content (0.23*) and grain yield/plant (0.65**), while, negative and highly significant correlation was observed with harvest index (-0.42**), hectoliter weight (-0.41**), phosphorus content (-0.20*) and grain yield/plant (0.65**). Harvest index showed positive and significant association with 1000 grain weight (0.28**), hectoliter weight (0.65**), carotene content (0.48**), potassium content (0.30**) and grain yield/plant (0.38**), while highly significant and negative correlation with protein content (-0.62**). 1000 grain weight showed positive and highly significant correlation with grain yield/plant (0.36**). Hectoliter weight showed positive and highly significant association with carotene content (0.30**) and grain yield/plant (0.19*), while highly significant and negative correlation was observed with protein content (-0.33**). Sedimentation value showed positive and highly significant association with grain yield/plant. Carotene content showed significant and positive correlation with grain yield/plant (0.27**), while significant and negative correlation with phytic acid (-0.22*). Protein content showed highly significant and positive correlation with grain yield/plant (0.26**), while, potassium content showed positive association with grain yield/plant (0.32**).

**Restricted irrigation conditions:** Grain yield/plant showed highly significant positive correlation with plant height (0.49**), spike length (0.44**), flag leaf length (0.32**), flag leaf width (0.28**), number of grains/spike length (0.43**), biomass/plant (0.74**), harvest index (0.86**), 1000 grain weight (0.43**), hectolitre weight (0.36**), sedimentation value (0.19*), carotene content (0.20*), protein content (0.19*) and potassium content (0.33**); while it showed significant and negative correlation with days to maturity (-0.19*). Days to flowering showed highly significant positive correlation with days to maturity (0.77**), biomass/plant (0.24*), hectoliter weight (0.19*) and carotene content (0.37**), while significant and negative correlation was observed with number of tillers/plant (-0.19*), flag leaf length (-0.27**), harvest index (-0.25**), 1000 grain weight (-0.29**), and potassium content (-0.19*). Days to maturity showed highly significant positive correlation with plant height (0.40**), biomass/plant (0.61**), carotene content (0.19*) and protein content (0.26**), while significant and negative correlation was observed with flag leaf length (-0.20*), harvest index (-0.31**), 1000 grain weight (-0.32**)
and grain yield/plant (-0.19*). Plant height showed significant positive correlation with spike length (0.37**), flag leaf length (0.24*), flag leaf width (0.40**), biomass/plant (0.96**), protein content (0.51**) and grain yield/plant (0.49**), while, highly significant and negative association with number of grains/spike (-0.22*) and hectoliter weight (-0.34**). Spike length showed significant positive correlation with number of tillers (0.26**), flag leaf length (0.48**), flag leaf width (0.37**), number of grains/spike (0.36**), biomass/plant (0.80**), potassium content (0.26**) and grain yield/plant (0.44**), while highly significant and negative association with hectoliter weight (-0.48**). Number of tillers showed significant positive association with flag leaf length (0.26*), and biomass/plant (0.40**), while highly significant and negative correlation with number of grains/spike (-0.21*), hectoliter weight (-0.22*) and phosphorus content (-0.21*). Flag leaf length showed positive and significant association with flag leaf width (0.26**), biomass/plant (0.64**) and grain yield/plant (0.32**), while highly significant and negative association with hectoliter weight (-0.31**) and carotene content (-0.26**). Flag leaf width showed positive and significant association with biomass/plant (0.57**), protein content (0.37**) and grain yield/plant (0.28**), while, highly significant and negative association with hectoliter weight (-0.31**). Number of grains/spike showed positive and highly significant association with biomass/plant (0.38**), harvest index (0.35**), hectoliter weight (0.27**), sedimentation value (0.26**), carotene content (0.29**) and grain yield/plant (0.43**); while, negative and highly significant association with protein content (-0.41**). Biomass/plant showed positive and highly significant correlation with harvest index (0.30**), 1000 grain weight (0.57**), protein content (0.46**), potassium content (0.63**), phytic acid (0.31**) and grain yield/plant (0.74**), while negative and highly significant correlation with hectoliter weight (-0.64**) and phosphorus content (-0.26**). Harvest index showed positive and significant association with 1000 grain weight (0.21*), phosphorus content (0.44**) and grain yield/plant (0.86**), while highly significant and negative correlation with carotene content (-0.21*) and protein content (-0.40**). 1000 grain weight showed positive and highly significant correlation with grain yield/plant (0.43**). Hectoliter weight showed positive and significant association with sedimentation value (0.20*), carotene content (0.35**) and grain yield/plant (0.36**), while, highly significant negative correlation was observed with protein content (-0.39**). Sedimentation value showed positive and significant association with grain yield/plant (0.19*). Carotene content showed significant and positive correlation with grain yield/plant (0.20**), while, negative and highly significant correlation with protein content (-0.26**) and phosphorus
content (-0.19*). Protein content showed positive and significant association with grain yield/plant (0.19*), whereas potassium content showed positive association with grain yield/plant (0.33**).

**Under pooled analysis (Rainfed and restricted irrigation conditions):** Grain yield/plant showed highly significant positive (Table 4.67) correlation with plant height (0.31**), spike length (0.31**), number of tillers (0.34**), flag leaf length (0.35**), flag leaf width (0.22**), number of grains/spike (0.29**), biomass/plant (0.85**), harvest index (0.30**), 1000 grain weight (0.17*), hectolitre weight (0.23**), sedimentation value (0.24**), carotene content (0.19**) and protein content as shown in Fig. 4.1 to 4.10.
Days to flowering showed highly significant positive correlation with days to maturity (0.61**), plant height (0.15*) and carotene content (0.23**), while, highly significant and negative correlation was observed with 1000 grain weight (-0.22**) and grain yield/plant (-0.21**). Days to maturity showed highly significant positive correlation with carotene content.
(0.24**), while, significant negative correlation was observed with and 1000 grain weight (-0.26**) and grain yield/plant (-0.30**). Plant height showed significant positive correlation with spike length (0.20**), number of tillers (0.33**), flag leaf length (0.54**), flag leaf width (0.57**), number of grains/spike (0.24**), biomass/plant (0.32**), sedimentation value (0.34**), protein content (0.30**) and grain yield/plant (0.31**), while significant negative association with hecoliter weight (-0.31**). Spike length showed significant positive correlation with number of tillers (0.23**), flag leaf length (0.36**), flag leaf width (0.17*), number of grains/spike (0.14*), biomass/plant (0.38**), sedimentation value (0.16*) and grain yield/plant (0.31**), while significant negative association with hecoliter weight (-0.16*). Number of tillers showed significant positive association with flag leaf length (0.41**), flag leaf width (0.21**), number of grains/spike (0.20**), biomass/plant (0.37**), sedimentation value (0.21**) and grain yield/plant (0.34**). Flag leaf length showed positive and significant association with flag leaf width (0.58**), number of grains/spike (0.23**), biomass/plant (0.33**), 1000 grain weight (0.16*), sedimentation value (0.32**), phosphorus content (0.14*) and grain yield/plant (0.35**), while, significant negative association with hecoliter weight (-0.19**). Flag leaf width showed positive and significant association with number of grains/spike (0.28**), biomass/plant (0.18**), sedimentation value (0.25**), protein content (0.35**) and grain yield/plant (0.22**) while, significant negative association with hecoliter weight (-0.27**). Number of grains/spike showed positive and highly significant association with biomass/plant (0.25**), sedimentation value (0.29**) and grain yield/plant (0.29**). Biomass/plant showed significant positive correlation with sedimentation value (0.25**) and grain yield/plant (0.85**), while significant negative with harvest index (-0.22**). Harvest index showed positive and significant association with grain yield/plant (0.30**), while, 1000 grain weight showed significant positive correlation with grain yield/plant (0.17*). Hectoliter weight showed significant positive association with carotene content (0.16*) and grain yield/plant (0.23**), while, significant negative correlation with protein content (-0.32**). Sedimentation value showed positive and significant association with grain yield/plant (0.24**). Carotene content showed positive and significant association with grain yield/plant (0.19**). Protein content showed positive and significant association with grain yield/plant (0.17*).
Correlation co-efficient of 102 durum wheat genotypes for physiological traits

Coefficient of correlation among 11 characters including grain yield, yield contributing and physiological traits worked out for durum wheat genotypes have been presented in Table 4.68.

**Rainfed conditions**: Grain yield/plant showed highly significant positive correlation with stem weight (0.22*), chlorophyll content I (0.36**), chlorophyll content II (0.43**) and chlorophyll content III (0.28**); while, it showed significant and negative correlation with canopy temperature I (-0.22*), canopy temperature II (-0.24*), canopy temperature III (-0.23*) and number of effective spikes (-0.61**). Among the genotypes, canopy temperature I showed highly significant positive correlation with stem weight (0.62**), number of effective spikes (0.20*), chlorophyll content II (0.20*) and chlorophyll content III (0.23*) while, highly significant and negative correlation was observed with canopy temperature II (-0.24*), canopy temperature III (-0.56**), flag leaf area/plant (-0.28**) and grain yield/plant (-0.22*) while, rest of the traits show independent association. Among the genotypes, canopy temperature II showed highly significant positive correlation with leaf weight (0.29**), stem weight (0.52**), chlorophyll content I (0.25**), chlorophyll content II (0.27**) and chlorophyll content III (0.24*), while, highly significant and negative correlation was observed with canopy temperature III (-0.43**) and grain yield/plant (-0.24*). Canopy temperature III showed significant positive correlation with leaf weight (0.35**), stem weight (0.75**), number of effective spikes (0.30**), chlorophyll content I (0.23*), chlorophyll content II (0.37**) and chlorophyll content III (0.36**), while, it showed highly significant and negative association with flag leaf area/plant (-0.27**) and grain yield/plant (-0.23*). Flag leaf area/plant showed significant negative correlation with chlorophyll content I (-0.51**), chlorophyll content II (-0.47**) and chlorophyll content III (-0.47**). Leaf weight showed significant and positive correlation with stem weight (0.47**) while, significant and negative correlation with chlorophyll content II (-0.19*) and chlorophyll content III (-0.20*). Stem weight showed significant and positive correlation with grain yield/plant (0.22*). Number of effective spikes showed negative and significant association with grain yield/plant (-0.61**); whereas, among the genotypes chlorophyll content I showed positive and significant association with chlorophyll content II (0.72**), chlorophyll content III (0.60**) and grain yield/plant (0.36**), while rest of the traits show independent association; similarly, chlorophyll content II showed positive and highly significant association with
chlorophyll content III (0.75**) and grain yield/plant (0.43**); among the genotypes chlorophyll content III showed positive and highly significant correlation with grain yield/plant (0.28**).

**Restricted irrigation conditions:** Grain yield/plant showed highly significant positive correlation with flag leaf area (0.37**), leaf weight (0.41**) and stem weight (0.43**), chlorophyll content I (0.20*), chlorophyll content II (0.23*) and chlorophyll content III (0.24*), while highly significant and negative correlation was observed with canopy temperature I (-0.37**), canopy temperature II (-0.19*) and canopy temperature III (-0.33**). Among the genotypes, canopy temperature I showed highly significant positive correlation with leaf weight (0.25**), stem weight (0.61**), chlorophyll content I (0.19*), chlorophyll content II (0.20*) and chlorophyll content III (0.19*) while, highly significant and negative correlation was observed with canopy temperature III (-0.38**) and flag leaf area (-0.37**) and grain yield/plant (-0.37**) and rest of the traits show independent association. Among the genotypes, canopy temperature II showed significant negative correlation with grain yield/plant (-0.19*). Among the genotypes, canopy temperature III showed highly significant positive correlation with stem weight (0.44**), chlorophyll content I (0.29**), chlorophyll content II (0.34**), chlorophyll content III (0.31**) and leaf weight (0.21*), while, highly significant and negative correlation was observed with flag leaf area/plant (-0.24*) and grain yield/plant (-0.33**). Flag leaf area/plant showed significant positive correlation with grain yield/plant (0.37**), while showed highly significant and negative association with chlorophyll content II (-0.31**), chlorophyll content III (-0.30**) and chlorophyll content I (-0.22*). Leaf weight showed significant and positive correlation was observed with stem weight (0.36**) and grain yield/plant (0.41**) while, negative and significant association with chlorophyll content II (-0.37**); whereas, among the genotypes, stem weight showed positive and significant correlation with grain yield/plant (0.43**), chlorophyll content I showed positive and significant association with chlorophyll content II (0.72**), chlorophyll content III (0.68**) and grain yield/plant (0.20*), while, rest of the traits show independent association; similarly, chlorophyll content II showed positive and highly significant association with chlorophyll content III (0.83**) and grain yield/plant (0.23*); among the genotypes chlorophyll content III showed positive and highly significant correlation with grain yield/plant (0.24*).
Under pooled analysis (Rainfed and restricted irrigation conditions): Grain yield/plant showed highly significant positive correlation with flag leaf area/plant (0.33**), leaf weight (0.33**), stem weight (0.27**), number of effective spikes (0.32**), chlorophyll content I (0.28**), chlorophyll content II (0.21*) and chlorophyll content III (0.37**); while, it showed highly significant and negative association with canopy temperature I (-0.19*), canopy temperature II (-0.26**) and canopy temperature III (-0.25**). Among the genotypes, canopy temperature I showed highly significant positive correlation with canopy temperature II (0.67**) and canopy temperature III (0.51**) while, highly significant and negative correlation was observed with flag leaf area/plant (-0.31**), number of effective spikes (-0.31**), leaf weight (-0.19**) and grain yield/plant (-0.19*) and rest of the traits show independent association.

Among the genotypes, canopy temperature II showed highly significant positive correlation with canopy temperature III (0.76**), chlorophyll content I (0.32**), chlorophyll content II (0.30**) and chlorophyll content III (0.27**) while, highly significant and negative correlation was observed with number of effective spikes (-0.42**), flag leaf area/plant (-0.19**) and grain yield/plant (-0.26**). Canopy temperature III showed significant and positive correlation with chlorophyll content I (0.42**), chlorophyll content II (0.36**) and chlorophyll content (0.36**) while, negative and significant association with flag leaf area (-0.31**), stem weight (-0.22**), number of effective spikes (-0.53**) and grain yield/plant (-0.25**); whereas, among the genotypes, flag leaf area/plant showed positive and significant correlation with leaf weight (0.52**), stem weight (0.18**), number of effective spikes (0.36**) and grain yield/plant (0.33**). Leaf weight showed positive and significant correlation with stem weight (0.49**), number of effective spikes (0.24**), chlorophyll content III and grain yield/plant (0.33**). Stem weight showed positive and significant correlation with number of effective spikes (0.28**) and grain yield/plant (0.27**) while, negative and significant correlation with chlorophyll content I (-0.20**) and chlorophyll content II (-0.15*). Number of effective spikes showed positive and significant association with grain yield/plant (0.32**) while, negative and significant correlation with chlorophyll content I (-0.22**), chlorophyll content II (-0.19**) and chlorophyll content (-0.20**). Chlorophyll content I showed positive and significant association with chlorophyll content II (0.79**), chlorophyll content III (0.66**) and grain yield/plant (0.28**), while, rest of the traits showed independent association; similarly, chlorophyll content II showed positive and highly significant association with chlorophyll content III (0.79**) and grain yield/plant (0.21*).
Chlorophyll content III showed positive and significant association with grain yield/plant (0.37**).

**Correlation co-efficient of 12 heat tolerance durum wheat genotypes for morphological, quality and biochemical traits**

Coefficient of correlation among 19 characters involving grain yield, yield contributing, biochemical and quality traits worked out for durum wheat genotypes have been presented in Table 4.69.

**Under pooled analysis (Rainfed and restricted irrigation conditions):** Grain yield/plant showed highly significant positive correlation with spike length (0.54**), number of tillers (0.53**), flag leaf length (0.79**), number of grains/spike (0.53**), biomass/plant (0.85**), harvest index (0.99**), 1000 grain weight (0.86**), hectolitre weight (0.59**), sedimentation value (0.91**), carotene content (0.57**), protein content (0.45**) and potassium content (0.63**), while negative correlation with days flowering (-0.48*) and days to maturity (-0.52**) as shown in Fig. 4.11 to 4.14.
Days to flowering showed highly significant positive correlation with days to maturity (0.84**), flag leaf length (0.42*) and biomass/plant (0.48*), while, highly significant and negative correlation was observed with harvest index (-0.75**), 1000 grain weight (-0.53**), protein content (-0.53**) and grain yield/plant (-0.48*). Days to maturity showed highly significant negative correlation was observed with harvest index (-0.78**), 1000 grain weight (-0.75**), protein content (-0.61*) and grain yield/plant (-0.52**). Plant height showed significant positive correlation with spike length (0.66**) and biomass/plant (1.06**), while, significant negative association with flag leaf length (-0.53**), harvest index (-0.79**), 1000 grain weight (-0.51**), potassium content (-0.54**) and phytic acid content (-0.66**). Spike length showed significant positive correlation with number of tillers (0.52**), number of grains/spike (0.48*), biomass/plant (0.60**), sedimentation value (0.67**) and grain yield/plant (0.54**), while significant negative association with flag leaf length (-0.55**), harvest index (-0.50**), 1000 grain weight (-0.46*) and phosphorus content (-0.48*). Number of tillers showed significant positive association with flag leaf length (0.42*), number of grains/spike (1.03**), biomass/plant (0.53**) and grain yield/plant (0.53**), while significant and negative association with hectolitre weight (-0.64**). Flag leaf length showed positive and significant association with flag leaf width (0.44*), number of grains/spike (0.65**), harvest index (0.60**), 1000 grain weight (0.54**), carotene content (0.48*), phosphorus content (0.75**), potassium content (1.06**), phytic acid (0.70**) and grain yield/plant (0.79**), while, significant negative association with sedimentation value (-1.04**). Flag leaf width showed positive and significant association with number of grains/spike (0.84**) and potassium content (0.42*). Number of grains/spike showed positive and highly significant association with biomass/plant (0.51**), potassium content (0.45*), phytic acid (0.43*) and grain yield/plant (0.53**). Biomass/plant showed significant
positive correlation with sedimentation value (0.50**), carotene content (0.64*) and grain yield/plant (0.85**), while, significant negative with harvest index (-1.10**). Harvest index showed positive and significant association with protein content (0.76**), phosphorus content (1.06**), phytic acid content (0.78**) and grain yield/plant (0.99**), while, significant negative correlation with hectolitre weight (-0.59**) and sedimentation value (-0.47**). 1000 grain weight showed positive and significant association with phytic acid content (0.66**) and grain yield/plant (0.86**), while significant and negative association with sedimentation value (-0.61**). Hectolitre weight showed positive and significant association with grain yield/plant (0.59**). Sedimentation value showed significant positive association with carotene content (0.47*) and grain yield/plant (0.91**), while, significant negative correlation with protein content (-0.41*), potassium content (-0.66**) and phytic acid content (-0.55**). Carotene content showed positive and significant association with grain yield/plant (0.57**). Protein content showed significant positive association with phytic acid content (0.63**) and grain yield/plant (0.45*). Potassium content showed positive and significant association with grain yield/plant (0.63**).

**Correlation co-efficient of 12 heat tolerance durum wheat genotypes for physiological traits**

Coefficient of correlation among 11 characters involving grain yield, yield contributing, physiological traits worked out for durum wheat genotypes have been presented in Table 4.70.

**Under pooled analysis (Rainfed and restricted irrigation conditions):** Grain yield/plant showed highly significant positive correlation with flag leaf area (0.80**), chlorophyll content at vegetative state (0.87**), chlorophyll content at flowering stage (0.62**) and chlorophyll content at grain filling stage (0.56**); while, it showed significant and negative correlation with canopy temperature at vegetative stage (-0.48*), canopy temperature at flowering stage (-0.53**), canopy temperature at grain filling stage (-0.61**) and number of effective spikes (-0.49*) as shown in Fig. 4.15 to 4.18.
Canopy temperature at vegetative stage showed highly significant positive correlation with flag leaf area/plant (0.71**) and stem weight (1.04**); while, it showed significant and negative correlation with grain yield/plant (-0.48*). Canopy temperature at flowering stage showed highly significant negative correlation with stem weight (-0.55**) and grain yield/plant (-0.53**). Canopy temperature at grain filling stage showed significant and negative correlation with stem weight (-1.07**) and grain yield/plant (-0.61**). Flag leaf area/plant showed positive and significant correlation with leaf weight (0.87**), stem weight (0.94**), chlorophyll content at vegetative stage (0.69**), chlorophyll content at flowering stage (0.72**), chlorophyll content at grain filling stage (0.61**) and grain yield/plant (0.80**). Stem weight showed positive and significant correlation with number of effective spikes (3.36**) while, negative and significant correlation with chlorophyll content at flowering stage (-0.90**) and chlorophyll content at grain filling stage (-1.22**). Number of effective spikes showed negative and significant correlation
with chlorophyll content at vegetative stage (-0.45**), chlorophyll content at flowering stage (-0.57**), chlorophyll content at grain filling stage (-0.43**) and grain yield/plant (-0.49**). Chlorophyll content at vegetative stage showed positive and significant association with Canopy temperature at flowering stage (0.54**), chlorophyll content at grain filling state (0.47*) and grain yield/plant (0.87**). Chlorophyll content at flowering stage showed positive and highly significant association with chlorophyll content at grain filling stage (0.80**) and grain yield/plant (0.62**). Chlorophyll content at grain filling stage showed significant and positive association with grain yield/plant (0.56**).

4.5 Path coefficient analysis

The correlation coefficients do not project the complete picture, especially when the casual factors are interrelated. Hence, they are partitioned into corresponding direct and indirect effects through path coefficient analysis, carried out taking grain yield/plant as a dependent variable under rainfed and restricted irrigation conditions over three years presented in the Table 4.71 to 4.72.

Rainfed condition:

Under rainfed condition, out of all yield contributing traits, biomass and harvest index and days to flowering proved to be the major direct components of grain yield compared to other characters (Table: 4.71). Biomass (0.876) and harvest index (0.289) exhibited a high positive direct contribution to grain yield. Biomass/plant exhibited negative indirect effect on grain yield through harvest index (-0.123). Plant height showed high positive direct contribution to grain yield (0.146), while, negative indirect effect via harvest index (-0.166) and protein content (-0.126); and positive indirect effect through biomass/plant (0.583) and flag leaf length (0.018). Spike length showed high negative direct contribution to grain yield (-0.210), while, positive indirect effect via biomass/plant (0.312) and plant height (0.056); and negative indirect effect via hectolitre weight (-0.086) and harvest index (-0.077). Number of tillers showed high positive direct contribution to grain yield (0.114), while, negative indirect effect through harvest index (-0.122) and positive indirect effect through spike length (0.098) and biomass/plant (0.215). Biomass/plant showed high positive direct contribution to grain yield (0.876), while, negative indirect effect via. Harvest index (-0.123) and hectoliter weight (-0.079) while, positive indirect
effect through plant height (0.097) and 1000 grain weight (0.027). Harvest index showed high positive direct contribution to grain yield (0.289), while, negative indirect effect via biomass/plant (-0.372) and plant height (-0.084); and positive indirect effect through protein content (0.163) and hectoliter weight (0.124). 1000 grain weight showed high positive direct contribution to grain yield (0.190) while, negative indirect effect via carotene content (-0.028) while, positive indirect effect through biomass/plant (0.125) and harvest index (0.080). Hectoliter weight showed high positive direct contribution to grain yield (0.191), while, negative indirect effect via biomass/plant (-0.361) and plant height (-0.066) while, positive indirect effect through harvest index (0.187) and spike length (0.095). Carotene content showed high positive direct contribution to grain yield (0.156) and negative indirect effect via biomass/plant (-0.177) and flag leaf length (-0.053) while, positive indirect effect through harvest index (0.139) and hectolitre weight (0.058). Protein content showed high negative direct contribution to grain yield (-0.263), while, negative indirect effect via harvest index (-0.179) and hectoliter weight (-0.063) while, positive indirect effect through biomass/plant (0.205) and plant height (0.070). Potassium content showed high positive direct contribution to grain yield (0.207) and positive indirect effect through harvest index (0.087) and protein content (0.023).

**Restricted irrigation condition:**

Under restricted irrigation condition, out of all the yield contributing traits, biomass and harvest index and days to flowering proved to be the major direct components of grain yield compared to other characters. Biomass (0.542) and harvest index (0.748) exhibited a high positive direct contribution to grain yield (Table 4.72). Biomass/plant exhibited positive indirect effect on grain yield through harvest index (0.223). Harvest index showed positive indirect effect via biomass/plant (0.161). Flag leaf width showed negative direct effect to grain yield (-0.077); while positive indirect effect on grain yield through biomass/plant (0.307). Protein content showed positive direct effect on grain yield/plant (0.072); while, negative indirect effect through harvest index (-0.302) and positive indirect effect through biomass/plant (0.251). Phosphorus content showed positive direct effect on grain yield/plant (0.072); while, negative indirect effect through harvest index (-0.302) and positive indirect effect through biomass/plant (0.251).
Potassium content showed negative direct effect to grain yield (-0.078) while, positive indirect effect through biomass/plant (0.342).

4.6 Line x Tester analysis

Analysis of variance and performance of cross combinations

Morphological, quality and biochemical traits

Ten high yielding early heat tolerant parents were taken to develop crosses in a line x tester fashion and to estimate their combining ability for yield and its contributing traits. Six lines *i.e.*, HD 4672, GW 1225, HI 8550, MACS 9, HI 8638 and HI 8627 were crossed with four testers namely A9-30-I, Sarangpur local, Meghdoot and MACS 1967 to develop 24 F1s. The analysis of variance for line x tester for various morphological, quality and biochemical traits are given in Table: 4.73. The ANOVA for combining ability of grain yield and its contributing characters showed that mean sum of square was found significant for all the traits. The *per se* performance of all the 24 crosses and their parents have been presented in Tables 4.74 and 4.75.

**Days to flowering:** Among parents, MACS 9 (61 days), HD 4672 (65 days) and MACS 1967 (66 days) were early to flower, while, Sarangpur local (78 days) and HI 8627 (82 days) were late to flower. Among cross combinations, MACS 9/ Sarangpur local (61 days), HD 4672/ MACS 1967(62 days), MACS 9/ A 9-30-I (62 days) and HI 8550/ MACS 1967 (64 days) were early to flower, while, HI 8638/ MACS 1967 (79 days) and HI 8627/ A 9-30-1 (82 days) were late to flower.

**Days to maturity:** Among parents, MACS 9 (117 days), A 9-30-1 (119 days), HD 4672 (120 days) and MACS 1967 (120 days) were early to mature, while, HI 8550 (128 days) and HI 8627 (130 days) were late to mature. Among cross combinations, HD 4672/ MACS 1967(117 days), MACS 9/ A 9-30-1 (118 days), HI 8550/ MACS 1967 (119 days) and MACS 9/ Sarangpur local (119 days) were early to mature, while, HI 8627/ A 9-30-1 (139 days) and HI 8638/ MACS 1967 (142 days) were late to mature.

**Plant height (cm):** Among parents, HD 4672 (73.0 cm), MACS 1967 (79.0 cm), and A 9-30-1 (84.0 cm) showed dwarf plant type, while, GW 1225 (94.0 cm), Meghdoot (94.0 cm) and
Sarangpur local (97.0 cm) showed tall plant type. Among cross combinations, MACS 9/ Meghdoot (83.0 cm), HD 4672/ MACS 1967 (84.0 cm), HI 8550/ Meghdoot (86.0 cm) and HI 8627/ MACS 1967 (86.0 cm) showed dwarf plant type, while, GW 1225/ A 9-30-1 (105.0 cm) and GW 1225/ Sarangpur local (108.0 cm) showed tall plant type.

**Spike length (cm):** Among parents, MACS 9 (7.9 cm), HI 8550 (7.7 cm), HI 8638 (7.5 cm) and HI 8627 (7.5 cm) showed long spike length, while, GW 1225 (6.7 cm) and HD 4672 (6.8 cm) showed short spike length. Among cross combinations, HD 4672/ Meghdoot (8.2 cm), HI 8627/ Sarangpur local (8.2 cm), HI 8550/ A 9-30-1 (8.0 cm), GW 1225/ Meghdoot (7.9 cm) and HI 8550/ MACS 1967 (7.9 cm) showed long spike length, while, HI 8638/ Meghdoot (7.0 cm) and HI 8638/ A 9-30-1 (7.1 cm) showed short spike length.

**Number of tillers/plant:** Among parents, HI 8627 (8.0), A 9-30-1 (6.5) and Sarangpur local (6.5) showed high tillering, while, HI 8638 (4.2), MACS 9 (5.2) and MACS 1967 (5.2) showed less tillering. Among cross combinations, HI 8627/ A 9-30-1 (8.5), HD 4672/ A 9-30-1 (8.2), HI 8550/ Meghdoot (7.4) and HI 8627/ MACS 1967 (7.4) showed high tillering, while, HI 8638/ Meghdoot (4.0) and MACS 9/ MACS 1967 (4.2) showed low number of tillers/plant.

**Flag leaf length (cm):** Among parents, HI 8627 (21.1 cm), MACS 1967 (20.6 cm) and Meghdoot (20.2 cm) showed high flag leaf length, while, HD 4672 (18.5 cm) and MACS 9 (18.6 cm) showed low flag leaf length. Among cross combinations, HD 4672/ Meghdoot (21.5 cm), MACS 9/ A 9-30-1 (21.1 cm), HI 8638/ MACS 1967 (21.1 cm) and HI 8627/ A 9-30-1 (21.0 cm) showed high flag leaf length, while, MACS 9/ Meghdoot (15.7 cm) and HD 4672/ MACS 1967 (18.4 cm) showed low flag leaf length.

**Number of grains/spike:** Among parents, HI 8550 (61.7), HI 8627 (56.5) and Sarangpur local (51.2) showed more number of grains/spike, while, GW 1225 (33.5) and A 9-30-1 (39.5) showed less number of grains/spike. Among cross combinations, HI 8627/ Meghdoot (55.5), MACS 9/ Sarangpur local (52.5), HI 8550/ A 9-30-1 (51.7) and HI 8627/ Sarangpur local (50.5) showed more number of grains/spike, while, GW 1225/ MACS 1967 (32.7) and GW 1225/ Meghdoot (34.8) showed less number of grains/spike.
**Biomass/plant (g):** Among parents, HI 8638 (45.0 g), HI 8627 (42.1 g) and A 9-30-1 (37.9 g) showed more biomass/plant, while, GW 1225 (29.0 g) and MACS 9 (32.5 g) showed less biomass/plant. Among cross combinations, MACS 9/ Sarangpur local (58.7 g), HD 4672/ MACS 1967 (55.7 g), MACS 9/ A 9-30-1 (50.9 g), HI 8550/ Meghdoot (50.4 g) and HI 8627/ MACS 1967 (50.4 g) showed more biomass/plant, while, GW 1225/ A 9-30-1 (31.5 g) and GW 1225/ Sarangpur local (34.8 g) showed less biomass/plant.

**Harvest index (%):** Among parents, GW 1225 (39.6 %), MACS 9 (38.7 %) and HI 8627 (36.3 %) showed high harvest index, while, MACS 1967 (32.6 %) and A 9-30-1 (32.7 %) showed low harvest index. Among cross combinations, HI 8638/ Meghdoot (41.6 %), GW 1225/ Sarangpur local (40.2 %), MACS 9/ A 9-30-1 (39.6 %) and HI 8638/ A 9-30-1 (36.5 %) showed high harvest index, while, HI 8638/ MACS 1967 (32.4 %) and HD 4672/ Meghdoot (33.0 %) showed low harvest index.

**1000 grain weight (g):** Among parents, MACS 9 (60.2 g), HI 8638 (56.5 g) and HD 4672 (53.4 g) showed high 1000 grain weight, while, HI 8550 (41.7 g) and MACS 1967 (42.9 g) showed low 1000 grain weight. Among cross combinations, MACS 9/ A 9-30-1 (61.4 g), MACS 9/ MACS 1967 (61.3 g), MACS 9/ Sarangpur local (60.3 g) and MACS 9/ MACS 1967 (60.3 g) showed high 1000 grain weight, while, HI 8627/ MACS 1967 (48.1 g) and GW 1225/ Meghdoot (50.8 g) showed low 1000 grain weight.

**Hectoliter weight (kg/l):** Among parents, HD 4672 (80.4 kg/l), HI 8638 (79.5 kg/l) and HI 8550 (79.0 kg/l) showed high hectoliter weight, while, A 9-30-1 (76.7 kg/l), Meghdoot (76.7 kg/l) and MACS 1967 (76.7 kg/l) showed low hectoliter weight. Among cross combinations, HI 8627/ A 9-30-1 (80.5 kg/l), HI 8638/ Meghdoot (79.7 kg/l) and HD 4672/ MACS 1967 (79.3 kg/l) showed high hectoliter weight, while, HI 8550/ Meghdoot (76.8 kg/l) and HI 8627/ MACS 1967 (76.8 kg/l) showed low hectoliter weight.

**Sedimentation value (ml):** Among parents, HI 8550 (38.9 ml), HI 8638 (37.5 ml) and A 9-30-1 (37.0 ml) showed high sedimentation value, while, HI 8627 (21.7 ml) and GW 1225 (23.4 ml) showed low sedimentation value. Among cross combinations, HI 8550/ A 9-30-1 (40.2 ml), MACS 9/ MACS 1967 (37.4 ml), HI 8638/ A 9-30-1 (36.9 ml) and GW 1225/ A 9-30-1 (36.4
ml) showed high sedimentation value, while, GW 1225/ Meghdoot (23.8 ml) and HD 4672/ Meghdoot (24.2 ml) showed low sedimentation value.

**Carotene content (ppm):** Among parents, A 9-30-1 (4.9 ppm), Sarangpur local (4.7 ppm) and MACS 9 (4.6 ppm) showed high carotene content, while, GW 1225 (3.1 ppm) and HI 8638 (3.7 ppm) showed low carotene content. Among cross combinations, HI 8627/ Sarangpur local (4.7 ppm), HI 8627/ A 9-30-1 (4.6 ppm), HI 8627/ Meghdoot (4.5 ppm), HI 8550/ Meghdoot (4.3 ppm) and HI 8627/ MACS 1967 (4.3 ppm) show high carotene content, while, GW 1225/ Sarangpur local (2.6 ppm) and GW 1225/ A 9-30-1 (2.7 ppm) showed low carotene content.

**Protein content (%):** Among parents, MACS 1967 (17.8 %), MACS 9 (16.2 %) and Meghdoot (15.1 %) showed high protein content, while, HI 8627 (12.5 %) and HD 4672 (12.6 %) showed low protein content. Among cross combinations, GW 1225/ Meghdoot (16.3 %), MACS 9/ A 9-30-1 (16.3 %), GW 1225/ MACS 1967 (15.5 %) and MACS 9/ Meghdoot (15.3 %) show high protein content, while, HI 8627/ Sarangpur local (12.0 %) and HD 4672/ Meghdoot (12.5 %) showed low protein content.

**Phosphorus content (g):** Among parents, HI 8627 (7.3 g), MACS 9 (7.2 g) and MACS 1967 (6.5 g) showed high phosphorus content, while, HI 8550 (4.2 g) and A 9-30-1 (4.3 g) showed low phosphorus content. Among cross combinations, HI 8550/ Meghdoot (7.3 g), HI 8627/ MACS 1967 (7.3 g), MACS 9/ Meghdoot (6.5 g)and MACS 9/ A 9-30-1 (6.4 g) show high phosphorus content, while, GW 1225/ Meghdoot (4.2 g) and HI 8638/ A 9-30-1 (4.2 g) showed low phosphorus content.

**Potassium content (g):** Among parents, A 9-30-1 (45.5 g), MACS 9 (45.3 g) and HI 8627 (44.3 g) showed high potassium content, while, GW 1225 (41.7 g), HD 4672 (41.8 g) and HI 8550 (41.8 g) showed low potassium content. Among cross combinations, HI 8550/ MACS 1967 (43.8 g), GW 1225/ A 9-30-1 (43.6 g) and HI 8627/ Meghdoot (43.2 g) show high potassium content, while, HI 8638/ A 9-30-1 (40.0 g) and MACS 9/ Sarangpur local (40.1 g) showed low potassium content.

**Phytic acid content (g):** Among parents, A 9-30-1 (35.1 g), HD 4672 (32.8 g) and Sarangpur local (32.3 g) showed high phytic acid content, while, HI 8550 (28.7 g) and MACS 9 (30.0 g)
showed low phytic acid content. Among cross combinations, HI 8627/ Meghdoot (35.4 g), GW 1225/ Sarangpur local (34.1 g), HI 8550/ Meghdoot (33.9 g) and HI 8627/ MACS 1967 (33.9 g) show high phytic acid content, while, HI 8638/ Sarangpur local (28.2 g) and HI 8638/ A 9-30-1 (28.3 g) showed low phytic acid content.

**Grain yield/plant (g):** Among parents, HI 8627 (15.4 g), HI 8638 (15.3 g) and HD 4672 (13.1 g) showed high grain yield/plant, while, MACS 1967 (10.9 g) and Meghdoot (11.4 g) showed low grain yield/plant. Among cross combinations, MACS 9/ Sarangpur local (21.6 g), HD 4672/ MACS 1967 (20.4 g), MACS 9/ A 9-30-1 (19.9 g), HI 8550/ Meghdoot (18.8 g) and HI 8627/ MACS 1967 (18.8 g) showed high grain yield/plant, while, HI 8550/ Meghdoot (10.8 g), GW 1225/ Meghdoot (11.9 g) and MACS 9/ Meghdoot (11.9 g) showed low grain yield/plant.

**Physiological traits**

The ANOVA for 24 crosses (F₁s) obtained through Line x Tester fashion showed significant variability for 11 physiological traits. All the 11 traits except leaf weight had shown presence of variability among lines, testers and parents and also the presence of significant interaction among line x tester (Table 4.76). The per se performance of 24 crosses and their parents of physiological traits has been presented in Table 4.77.

**Per se performance of cross combinations**

**Canopy temperature I (vegetative stage) (°C):** Among parents, GW 1225 (17.7 °C), MACS 9 (18.0 °C) and Sarangpur local (18.1 °C) showed low canopy temperature, while, Meghdoot (19.7 °C) and A 9-30-1 (19.5 °C) showed high canopy temperature. Among cross combinations, HI 8550/ Meghdoot (17.0 °C), HI 8627/ MACS 1967 (17.0 °C), MACS 9/ MACS 1967 (17.6 °C) and GW 1225/ Sarangpur local (17.7 °C) showed low canopy temperature, while, HI 8627/ MACS 1967 (19.8 °C) and HD 4672/ Sarangpur local (19.5 °C) showed high canopy temperature.

**Canopy temperature II (flowering stage) (°C):** Among parents, GW 1225 (21.1 °C), HI 8550 (21.4 °C) and MACS 9 (21.7 °C) showed low canopy temperature, while, HI 8638 (22.6 °C) and MACS 1967 (22.6 °C) showed high canopy temperature. Among cross combinations, GW 1225/ Sarangpur local (20.5 °C), HI 8550/ Meghdoot (20.9°C) and MACS 9/ Meghdoot (21.0 °C)
showed low canopy temperature, while, MACS 9/ A 9-30-1 (23.7 °C) and MACS 9/ Sarangpur local (23.7 °C) showed high canopy temperature.

**Canopy temperature III (grain filling stage) (°C):** Among parents, A 9-30-1 (24.4 °C), HI 8550 (24.6 °C) and Sarangpur local (24.8 °C) showed low canopy temperature, while, MACS 9 (26.5 °C) and HD 4672 (26.2 °C) showed high canopy temperature. Among cross combinations, HI 8638/ MACS 1967 (24.0 °C), HI 8627/ MACS 1967 (24.3 °C), HI 8627/ Meghdoot (24.5 °C) and HI 8550/ Sarangpur local (24.8 °C) showed low canopy temperature, while, MACS 9/A 9-30-1 (27.8 °C) and MACS 9/ Sarangpur local (27.9 °C) showed high canopy temperature.

**Flag leaf area/plant (cm):** Among parents, Sarangpur local (23.2 cm), Meghdoot (22.9 cm) and HI 8627 (22.5 cm) showed maximum flag leaf area/plant, while, HD 4672 (15.1 cm) and A 9-30-1 (18.7 cm) showed minimum flag leaf area. Among cross combinations, MACS 9/ A 9-30-1 (25.1 cm), HI 8627/ A 9-30-1 (24.3 cm), GW 1225/ Sarangpur local (22.6 cm) and MACS 9/ Sarangpur local (22.3 cm) showed maximum flag leaf area, while, MACS 9/ Meghdoot (15.9 cm) and HD 4672/ MACS 1967 (17.8 cm) showed minimum flag leaf area.

**Leaf weight/plant (g):** Among parents, A 9-30-1 (1.6 g), Sarangpur local (1.6 g) and HI 8627 (1.5 g) showed high leaf weight, while, MACS 9 (1.2 g), GW 1225 (1.3 g) and Meghdoot (1.3 g) showed low leaf weight. Among cross combinations, MACS 9/ A 9-30-1 (1.8 g), MACS 9/ Sarangpur local (1.8 g), HD 4672/ A 9-30-1 (1.7 g) and HI 8627/ A 9-30-1 (1.7 g) showed high leaf weight, while, HD 4672/ Sarangpur local (1.2 g), MACS 9/ Meghdoot (1.2 g) and HI 8638/ Meghdoot (1.2 g) showed low leaf weight.

**Stem weight/plant (g):** Among parents, A 9-30-1 (34.5 g), HI 8627 (32.2 g) and HI 8550 (29.4 g) showed high stem weight, while, MACS 9 (22.6 cm) and HI 8638 (24.9 g) showed low stem weight. Among cross combinations, HI 8627/ Meghdoot (40.5 g), GW 1225/ Meghdoot (36.4 g), MACS 9/ A 9-30-1 (34.8 g) and GW 1225/ MACS 1967 (33.8 g) showed high stem weight, while, HD 4672/ Sarangpur local (19.3 g) and HI 8638/ Meghdoot (19.4 g) showed low stem weight.

**Number of effective spikes/plant:** Among parents, HI 8627 (7.5), A 9-30-1 (5.5) and Sarangpur local (5.5) showed more number of effective spikes, while, HI 8638 (3.3) and HD 4672 (4.2)
showed less number of effective spikes. Among cross combinations, HI 8627/ A 9-30-1 (7.8), HD 4672/ A 9-30-1 (7.5), HI 8638/ MACS 1967 (6.3) and GW 1225/ Meghdoot (6.2) showed more number of effective spikes, while, HI 8638/ A 9-30-1 (3.0) and HI 8638/ Sarangpur local (3.0) showed less number of effective spikes.

**Chlorophyll content I (vegetative stage) (%)**: Among parents, HI 8638 (62.0 %), MACS 9 (60.6 %) and HI 8627 (60.6 %) showed more chl. I, while, A 9-30-1 (56.0 %) and MACS 1967 (56.1 %) showed less chl. I. Among cross combinations, HI 8638/ A 9-30-1 (60.8 %), HI 8638/ Sarangpur local (60.5 %), MACS 9/ A 9-30-1 (60.4 %) and MACS 9/ MACS 1967 (60.0 %) showed more chl. I, while, HI 8550/ Meghdoot (53.9 %) and HI 8627/ MACS 1967 (53.9 %) showed less chl. I.

**Chlorophyll content II (flowering stage) (%)**: Among parents, HI 8627 (56.2 %), HD 4672 (55.0 %) and MACS 9 (54.6 %) showed more chl. II, while, A 9-30-1 (50.2 %) and HI 8550 (51.3 %) showed less chl. II. Among cross combinations, HI 8550/ Sarangpur local (55.1 %), HI 8638/ A 9-30-1 (55.0 %), HD 4672/ A 9-30-1 (54.9 %) and MACS 9/ A 9-30-1 (54.8 %) showed more chl. II, while, HI 8550/ Meghdoot (50.6 %) and HI 8627/ MACS 1967 (50.6 %) showed less chl. II.

**Chlorophyll content III (grain filling stage) (%)**: Among parents, HI 8627 (52.8 %), MACS 9 (50.4 %) and HI 8638 (50.4 %) showed more chl. III, while, HI 8550 (47.6 %) and A 9-30-1 (47.9 %) showed less chl. III. Among cross combinations, MACS 9/ A 9-30-1(53.6 %), HI 8638/ Meghdoot (52.3 %), HD 4672/ A 9-30-1 (52.0 %) and MACS 9/ MACS 1967 (51.6 %) showed more chl. III, while, HI 8550/ Meghdoot (46.9 %) and HI 8627/ MACS 1967 (46.9 %) showed less chl III.

**Combining ability analysis**

**Morphological, quality and biochemical traits**: The estimates of general combining ability (\(\sigma^2_{gca}\)) for parents and specific combining ability (\(\sigma^2_{sca}\)) for crosses were estimated (Table 4.78). The estimates of \(\sigma^2_{gca}\) for lines and testers were calculated as the mean sum of squares for lines and testers. The \(\sigma^2_{gca}\) was relatively more than the estimate of \(\sigma^2_{sca}\) for the characters viz., days to flowering, days to maturity, plant height, number of grains/spike, while \(\sigma^2_{sca}\) was more for
characters viz., plant height, number of tillers/plant, spike length, grain yield/plant, 1000 grain weight, hectolitre weight, sedimentation value, carotene content, protein content, phosphorus content, potassium content and phytic acid.

For days to 50% flowering, only lines contributed to $\sigma^2_{gca}$. The magnitude of $\sigma^2_{gca}$ for lines was greater than the $\sigma^2_{sca}$. It infers that the additive genetic variance was important for these attributes. In case of days to maturity, the variance due to $\sigma^2_{gca}$ (average) was considerably larger in magnitude than that of $\sigma^2_{sca}$, which suggested the pre-dominance of additive genetic variance. The lines mainly contributed to the $\sigma^2_{gca}$ in case of plant height. However, the magnitude of $\sigma^2_{gca}$ was larger than $\sigma^2_{sca}$ in lines, suggesting importance of additive genetic variance in the inheritance of this trait. Number of tillers/plant, only lines contributed to $\sigma^2_{gca}$. The magnitude of $\sigma^2_{gca}$ for lines was found higher than the value of $\sigma^2_{sca}$ in this character. It infers that the additive genetic variance is of greater importance for this attribute. The variance due to $\sigma^2_{sca}$ was found greater over $\sigma^2_{gca}$ (average), which indicated that the non-additive gene action for the expression of spike length. For number of grains/spike, $\sigma^2_{gca}$ for lines was found larger in magnitude for tester; the average estimates of $\sigma^2_{gca}$ was larger than the $\sigma^2_{sca}$. It infers that the additive genetic variance is of greater importance for this attribute. 1000 grain weight, carotene content, protein content, phosphorus content, potassium content and phytic acid showed only testers contributed to $\sigma^2_{gca}$ and magnitude of $\sigma^2_{gca}$ for testers was found greater than the $\sigma^2_{sca}$, suggesting importance of additive genetic variance in the inheritance of these attributes. For grain yield/plant, only $\sigma^2_{gca}$ (average) contributed and magnitude of $\sigma^2_{gca}$ for lines was found greater than $\sigma^2_{sca}$. It infers that the additive genetic variance is of greater importance for this attribute.

**Physiological traits:** The estimates of general combining ability ($\sigma^2_{gca}$) for parents and specific combining ability ($\sigma^2_{sca}$) for crosses were estimated (Table 4.79). The estimates of $\sigma^2_{gca}$ for lines and testers were calculated when the mean squares for lines and testers were significant. The $\sigma^2_{gca}$ was relatively more than the estimate of $\sigma^2_{sca}$ for the characters viz., canopy temperature at vegetative stage, canopy temperature at flowering stage and canopy temperature at grain filling stage, while of $\sigma^2_{sca}$ was more for characters viz., flag leaf area/plant, leaf weight,
stem weight, number of effective spikes, chlorophyll content at vegetative stage, chlorophyll content at flowering stage and chlorophyll content at grain filling stage.

The magnitude of general combining ability ($\sigma^2_{gca}$) for flag leaf area/plant, stem weight, chlorophyll content at vegetative stage, chlorophyll content at flowering stage and grain yield/plant was considerably larger than that of specific combining ability ($\sigma^2_{sca}$), which suggested that pre-dominance of additive genetic action in controlling these traits, Whereas, magnitude of specific combining ability ($\sigma^2_{sca}$) for canopy temperature at vegetative stage, canopy temperature at flowering stage and number of effective spikes/plant was considerably larger in magnitude than that of general combining ability ($\sigma^2_{gca}$), suggesting the importance of non-additive gene action in the inheritance of the traits. General combining ability ($\sigma^2_{gca}$) was 13.22 times more than the specific combining ability ($\sigma^2_{sca}$) for flag leaf area/plant, which infers that the additive genetic variance is of greater importance for this attribute, and direct selection can be practiced.

**Components of genetic variation**

**Morphological, quality and biochemical traits:** The estimates of additive genetic variance ($\sigma^2_A$) and dominance genetic variance ($\sigma^2_D$) have been presented in Table 4.80. In days to flowering, the additive genetic variance (40.12) was about 1.45 times larger than the dominance genetic variance (27.66); and the ratio of $\sigma^2_D/\sigma^2_A$ was 0.69 which indicated partial dominance for this character. The additive genetic variance (15.90) for days to maturity was about 0.16 times of the dominance genetic variance (99.54), and the ratio of $\sigma^2_D/\sigma^2_A$ was 6.26, which indicated over dominance for this attribute. In plant height, additive genetic variance (82.73) was found 1.9 times larger than dominance genetic variance (43.17), and the ratio of $\sigma^2_D/\sigma^2_A$ was 0.52, which indicated partial dominance for this character. For spike length, the additive genetic variance (0.07) was about 0.2 times of the dominance genetic variance (0.33), and the ratio of $\sigma^2_D/\sigma^2_A$ was 4.71, which indicated over dominance for this character. The dominance genetic variance (3.43) for number of tillers/plant was considerably larger than the additive genetic variance (1.41), and the ratio of $\sigma^2_D/\sigma^2_A$ was 2.43, which indicated over dominance for this character. For flag leaf length, the additive genetic variance (0.73) was found 0.12 times of the dominance genetic variance (6.19); and the ratio of $\sigma^2_D/\sigma^2_A$ was 8.48, which indicated over
dominance for this character. In number of grains/spike, the additive genetic variance (29.95) was found lesser than the dominance genetic variance (113.28); and the ratio of $\sigma^2_D/\sigma^2_A$ was 3.78, which indicated over dominance for this character. For biomass/plant, the additive genetic variance (2.39) was found lesser than the dominance genetic variance (194.57); and the ratio of $\sigma^2_D/\sigma^2_A$ was 81.41, which indicated over dominance for this character. For harvest index, the additive genetic variance (13.43) was found lesser than the dominance genetic variance (28.07) and the ratio of $\sigma^2_D/\sigma^2_A$ was 2.09, which indicated over dominance for this character. For 1000 grain weight, the additive genetic variance (9.09) was found lesser than the dominance genetic variance (30.99), and the ratio of $\sigma^2_D/\sigma^2_A$ was 3.41, which indicated over dominance for this character. For hectolitre weight, the additive genetic variance (0.13) was found lesser than the dominance genetic variance (2.06), and the ratio of $\sigma^2_D/\sigma^2_A$ was 15.85, which indicated over dominance for this character.

In sedimentation value, the additive genetic variance (33.91) was about 1.3 times larger than the dominance genetic variance (26.04), and the ratio of $\sigma^2_A/\sigma^2_D$ was 0.77, which indicated partial dominance for this character. For carotene content, the additive genetic variance (0.62) was found lesser than the dominance genetic variance (0.94) and the ratio of $\sigma^2_D/\sigma^2_A$ was 1.52, which indicated over dominance for this character. For protein content, the additive genetic variance (0.55) was lesser than the dominance genetic variance (3.79), and the ratio of $\sigma^2_A/\sigma^2_D$ was 6.89, which indicated over dominance for this character. For phosphorus content, the additive genetic variance (0.94) was lesser than the dominance genetic variance (1.45), and the ratio of $\sigma^2_A/\sigma^2_D$ was 1.54, which indicated over dominance for this character. For potassium content, the additive genetic variance (0.47) was lesser than the dominance genetic variance (2.64), and the ratio of $\sigma^2_A/\sigma^2_D$ was 5.62, which indicated over dominance for this character. For phytic acid content, the additive genetic variance (2.60) was lesser than the dominance genetic variance (8.44), and the ratio of $\sigma^2_A/\sigma^2_D$ was 3.25, which indicated over dominance for this character. For grain yield/plant, the $\sigma^2_A$ and $\sigma^2_D$ were almost of similar magnitude. The value of $\sigma^2_D/\sigma^2_A$ is found to be 1.02, which is approximately equal to unity, indicating complete dominance.

**Physiological traits:** The estimates of additive genetic variance ($\sigma^2_A$) and dominance variance ($\sigma^2_D$) have been presented in Table 4.81. In canopy temperature at vegetative stage, the additive
genetic variance (-0.45) was about -0.27 times of the dominance variance (1.66), and the ratio of $\sigma^2_A/\sigma^2_D$ was -3.67, which indicated partial dominance for this character. The additive genetic variance (0.25) for canopy temperature at flowering stage was about 0.12 times of dominance variance (2.00), and the ratio of $\sigma^2_D/\sigma^2_A$ was 8.00, which indicated over dominance for this attribute. In canopy temperature at grain filling stage, the additive genetic variance (1.21) was found larger than the dominance variance (0.57), and the ratio of $\sigma^2_D/\sigma^2_A$ was 0.47, which indicated partial dominance for this character. For flag leaf area/plant, the additive genetic variance (4.40) was about 0.37 times of the dominance variance (11.79), and the ratio of $\sigma^2_D/\sigma^2_A$ was 2.68, which indicated over dominance for this character. The additive variance (-0.02) for leaf weight was considerably lesser than the dominant genetic variance (0.16), and the ratio of $\sigma^2_D/\sigma^2_A$ was -8.00, which indicated over dominance for this character. For stem weight, the additive genetic variance (-34.17) was found lesser than the dominance variance (140.94), and the ratio of $\sigma^2_D/\sigma^2_A$ was -4.12, which indicated over dominance for this character. For number of effective spikes, the additive variance (1.34) was found lesser than the dominance genetic variance (2.77), and the ratio of $\sigma^2_D/\sigma^2_A$ was 2.07, which indicated over dominance for this character. For chlorophyll content at vegetative stage, the additive variance (3.26) was found lesser than the dominance genetic variance (5.52), and the ratio of $\sigma^2_D/\sigma^2_A$ was 1.69, which indicated over dominance for this character. For chlorophyll content at flowering stage, the additive variance (-1.40) was found lesser than the dominance genetic variance (11.14), and the ratio of $\sigma^2_D/\sigma^2_A$ was -7.96, which indicated over dominance for this character.

**General and specific combining ability effects:** The estimates of general combining ability (gca) effects of parents in line x testers have been presented in Tables 4.82 and 4.83 and estimates of specific combining ability (sca) effects for F$_1$s have been given in Tables 4.84 to 4.86.
General combining ability (gca) effect of morphological, quality and biochemical traits

The estimates of general combining ability (gca) effects of parents have been presented in Table 4.82.

**Days to flowering:** General combining ability (GCA) effects of all the ten genotypes were significant for this trait. Among the genotypes, gca effects of HD 4672 (-5.21**) and MACS 9 (-6.00**) were highly significant and negative in direction. These genotypes can be regarded as desirable combiners for early flowering. The gca effects of HI 8550 (2.42*) and HI 8627 (7.75**) were significant but positive in direction, and hence, these were undesirable combiners for early flowering, while, they can be used for developing medium late flowering genotypes.

**Days to maturity:** General combining ability effects of HD 4672, MACS 9 and HI 8627 were significant for this trait. Among the genotypes, gca effects of HD 4672 (-3.58**) and MACS 9 (-4.12**) were highly significant and negative in direction. These genotypes can, therefore be regarded as desirable combiners for early maturity. The gca effect of HI 8627 (6.96**) was significant but positive in direction, and hence, these were undesirable combiners for early maturity, while, they can be used for developing medium late maturing genotypes.

**Plant height (cm):** Among the genotypes, gca effects of HD 4672 (-5.38**), HI 8627 (-2.89**) and MACS 1967 (-7.06**) were highly significant and negative in direction. These genotypes can, therefore be regarded as best combiners for developing dwarf plant types. The gca effects of GW 1225 (6.58**) and A 9-30-1 (4.14**) were significant but positive in direction, and hence, these were poor combiners for dwarf plant types.

**Spike length (cm):** General combining ability effects of HI 8550 and HI 8638 were significant for this trait. Among the genotypes, gca effect of HI 8550 (3.58**) was significant and positive in direction. These genotypes can, therefore be regarded as good combiners for increasing the spike length. The gca effects of HI 8638 (-2.42**) were highly significant but negative in direction, and hence, these were undesirable combiners for spike length.

**Number of tillers/plant:** General combining ability effects of HD 4672 and HI 8627 were significant for this trait. Among the genotypes, gca effects of HD 4672 (5.89**) and HI 8627
were significant and positive in direction. These genotypes can, therefore be considered as desirable combiners for improving the number of effective tillers.

**Flag leaf length (cm):** General combining ability effects of A 9-30-1 and HI 8638 were significant for this trait. Among the genotypes, gca effects of A 9-30-1 (3.33**) were significant and positive in direction. This genotype can, therefore be regarded as desirable combiner for increasing flag leaf length. The gca effect of HI 8638 (-4.89**) was highly significant but negative in direction, hence, this is undesirable combiner for flag leaf length.

**Number of grains/spike:** General combining ability effect of GW 1225, HI 8550, HI 8638 and HI 8627 were significant for this trait. Among the genotypes, gca effects of HI 8550 (3.20*) and HI 8627 (6.12**) were significant and positive in direction. These genotypes can, therefore be regarded as desirable combiners for increasing the number of grains/spike. The gca effects of GW 1225 (-6.59*) and HI 8638 (-2.97*) were highly significant but negative in direction, and hence, these are undesirable combiners for number of grains/spike.

**Biomass/plant (g):** Among the genotypes, gca effect of MACS 9 (5.14**) was significant and positive in direction. This genotype can, therefore be regarded as desirable combiner for improving the biomass. The gca effects of GW 1225 (-7.22**) and HI 8638 (-2.47*) was highly significant but negative in direction and hence these are undesirable combiners for biomass/plant.

**Harvest index (%):** Among the genotypes, gca effect of HI 8638 (2.51*) was significant and positive in direction. This genotypes can, therefore be regarded as desirable combiner for increasing the flag leaf length. The gca effect of HI 8627 (-2.32*) was highly significant but negative in direction, and hence, this is an undesirable combiner for harvest index.

**1000 grain weight (g):** Among the genotypes, gca effects of MACS 9 (3.10*) and HI 8638 (2.34*) were highly significant and positive in direction. These genotypes can, therefore be regarded as desirable combiners for improving the 1000 grain weight. The gca effect of HI 8550 (-4.22**) was highly significant but negative in direction, and hence, this is an undesirable combiner for 1000 grain weight.

**Hectoliter weight (kg/l):** Among the genotypes, gca effect of HD 4672 (5.86**) was highly significant and positive in direction. This genotype can, therefore be regarded as desirable
combiners for improving the hectoliter weight. The gca effects of MACS 1967 (-3.21**) was highly significant but negative in direction, and hence, this is an undesirable combiner for hectoliter weight.

**Sedimentation value (ml):** General combining ability effects of all the genotypes were significant for this trait except GW 1225 and MACS 9. Among the genotypes, gca effects of HI 8550 (4.97**), HI 8638 (3.17*), A 9-30-1 (3.06*) and Sarangpur local (2.40*) were highly significant and positive in direction. These genotypes can, therefore be regarded as desirable combiners for increasing the sedimentation value. The gca effects of HD 4672 (-3.24*), HI 8627 (-3.33**), Meghdoot (-2.44*) and MACS 1967 (-3.02*) were highly significant but negative in direction, and hence, these were undesirable combiners for sedimentation value.

**Carotene content (ppm):** Among the genotypes, gca effect of HI 8627 (3.89**) was highly significant and positive in direction making this a desirable combiner for increasing the carotene content. The gca effect of GW 1225 (-2.89*) was significant but negative in direction, and hence, this is an undesirable combiners for carotene content.

**Protein content (%):** Among the genotypes, gca effect of GW 1225 (6.12**) was highly significant and positive in direction making this a desirable combiner for increasing the protein content. The gca effects of HI 8627 (-4.06**) were highly significant but negative in direction, and hence, this is an undesirable combiners for protein content.

**Phosphorus content (g):** Among the genotypes, gca effect of HI 8550 (3.25**) was highly significant and positive in direction making it a desirable combiner for increasing the phosphorus content. Other genotypes were undesirable combiners for phosphorus content.

**Potassium content (g):** Among the genotypes, gca effects of HI 8638 (-5.23**) were highly significant but negative in direction, and hence, these were undesirable combiners for potassium content. Other genotypes were desirable combiners for potassium content.

**Phytic acid content (g):** Among the genotypes, gca effect of HI 8638 (-6.12**) was highly significant but negative in direction making it a desirable combiner for phytic acid content. Other genotypes were undesirable combiners for phytic acid content.
Grain yield/plant (g): General combining ability effects of GW 1225, MACS 9, HI 8638 and A 9-30-1 were significant for this trait. Among the genotypes, gca effects of MACS 9 (6.93**) and HI 8638 (4.07**) were significant and positive in direction. These genotypes can, therefore, be regarded as desirable combiners for improving the grain yield/plant of the genotypes. The gca effects of GW 1225 (-2.71*) and A 9-30-1 (-4.25**) were highly significant but negative in direction, and hence, these were undesirable combiners for grain yield/plant.

General combining ability (gca) effect of physiological traits

The estimates of general combining ability (gca) effects of parents have been presented in Table 4.83.

Canopy temperature I (vegetative stage) (ºC): Among the genotypes, gca effects of HI 8550 (-3.17**) and A 9-30-1 (-2.43*) were significant and negative in direction. These genotypes can, therefore, be regarded as desirable combiners for reducing the canopy temperature of the genotypes.

Canopy temperature II (flowering stage) (ºC): Among the genotypes, gca effects of HI 8550 (-2.48*) and HI 8638 (-3.32**) were significant and negative in direction. These genotypes can, therefore, be regarded as desirable combiners for reducing the canopy temperature of the genotypes.

Canopy temperature III (grain filling stage) (ºC): Among the genotypes, gca effects of MACS 9 (-2.31*) and HI 8627 (-2.28*) were significant and negative in direction. These genotypes can, therefore, be regarded as desirable combiners for reducing the canopy temperature of the genotypes.

Flag leaf area/plant (cm): Among the genotypes, gca effects of HI 8627 (3.41**) and Sarangpur local (3.71**) were significant and positive in direction. These genotypes can, therefore, be regarded as good combiners for increasing the flag leaf area. The gca effects of HI 8638 (-3.45**) and MACS 1967 (-3.30**) were highly significant but negative in direction, and hence, these were undesirable combiners for flag leaf area.
**Stem weight (g):** Among the genotypes, gca effects of GW 1225 (2.79*), HI 8627(3.53**) and Meghdoot (3.41**) were significant and positive in direction. These genotypes can, therefore be consider as desirable combiners for improving the number of effective tillers. The gca effects of HI 8638 (-3.54**) were highly significant but negative in direction, and hence, these were undesirable combiners for stem weight.

**Number of effective spikes/plant:** Among the genotypes, gca effects of HI 8627 (2.37*) were significant and positive in direction. These genotypes can, therefore be regarded as desirable combiners for increasing the flag leaf length. The gca effects of HI 8638 (-2.47*) were highly significant but negative in direction, and hence, these were undesirable combiners for number of effective spikes/plant.

**Chlorophyll content I (vegetative stage) (%)** Among the genotypes, gca effect of HI 8638 (3.31**) was significant and positive in direction. This genotype can, therefore be regarded as desirable combiner for increasing the chlorophyll content at vegetative stage. The gca effects of GW 1225 (-2.34*) was highly significant but negative in direction, and hence, this is an undesirable combiner for chlorophyll content at vegetative stage.

**Chlorophyll content II (flowering stage) (%)**: Among the genotypes, gca effects of HI 8638 (2.41*) was significant and positive in direction. This genotype can, therefore be regarded as desirable combiner for increasing the chlorophyll content at flowering stage. The gca effects of GW 1225 (-3.41**) was highly significant but negative in direction, and hence, this is an undesirable combiner for chlorophyll content at flowering stage.

**Chlorophyll content III (grain filling stage) (%)**: Among the genotypes, gca effects of HI 8638 (3.65**) was significant and positive in direction. This genotype can, therefore be regarded as desirable combiner for increasing the chlorophyll content at grain filling stage. The gca effects of HI 8550 (-2.37*) was significant but negative in direction, and hence, this is undesirable combiner for chlorophyll content at grain filling stage.

**Specific combining ability effects of morphological, quality and biochemical traits:** The specific combining ability effects of 24 cross combinations are presented in Table 4.84 and 4.85.
**Days to flowering:** Six cross combinations had significant specific combining ability effect. Among these, two cross combination showed negative and four cross combination showed positive significant specific combining ability effect. Crosses GW 1225/ MACS 1967 (-3.88**) and MACS 9/ Sarangpur local (-2.89**) appeared as desirable for early flowering as they showed negative specific combining ability. Therefore, early flowering segregants can be selected from this cross combinations. On the other hand, significant cross combinations with positive sca effects were identified as undesirable cross combinations for early maturity. However, these crosses can be utilized for selecting segregants with medium late flowering.

**Days to maturity:** Eleven cross combination showed significant specific combining ability effect. Among these, five cross combinations showed negative and six cross combinations showed positive significant specific combining ability. Crosses GW 1225/A 9-30-1 (-4.88**), MACS 9/ A 9-30-1 (-2.21*), MACS 9/ Sarangpur local (-2.79*), HI 8627/ Meghdoot (-9.46**) and HI 8627/ MACS 1967 (-6.88**) appeared as desirable for early maturity as they showed negative specific combination ability effect; while, significant cross combinations with positive sca effects were identified as undesirable cross combinations for early maturity.

**Plant height (cm):** Cross combination with negative specific combining ability effect was considered desirable for this character. Thirteen cross combinations showed significant specific combining ability effect. Among these, seven combinations showed negative and six cross combinations showed positive significant specific combining ability effect. Crosses HD4672/ Sarangpur local (-3.49**), GW 1225/ Meghdoot (-3.14**), HI 8550/ MACS 1967 (-3.24**), MACS 9/ MACS 1967 (-4.11**), HI 8638/ Sarangpur local (-3.78**), HI 8627/ A 9-30-1 (-2.56*) and HI 8627/ Meghdoot (-2.81**) were desirable for plant height as they showed negative specific combinations ability effect.

**Spike length (cm):** Cross combinations with positive sca effects were considered as desirable for this character. Out of twenty four cross combinations; ten showed significant sca effects *i.e.*, 5 and 5 with positive and negative sca effects, respectively. Crosses GW 1225/ Sarangpur local (2.78**), HI 8550/ A 9-30-1 (4.32**), MACS 9/ A 9-30-1 (3.28**), HI 8638/ MACS 1967 (3.52**) and HI 8627/ MACS 1967 (2.89**) were desirable for increasing spike length as they showed positive significant sca effect.
**Number of tillers/plant:** Cross combination with positive sca effect were considered as desirable for this character. Out of twenty four cross combinations, eight showed significant sca effect \(i.e.,\) 5 and 4 with positive and negative sca effects, respectively. Crosses HD 4672/ A 9-30-1 (4.21**), HD 4672/ Meghdoot (3.81**), HI 8550/ MACS 1967 (2.63**), MACS 9/ Sarangpur local (2.08*) and HI 8627/ Sarangpur local (2.84**) were desirable for number of tillers/plant as they showed positive significant sca effect.

**Flag leaf length (cm):** Cross combinations with positive sca effects were considered as desirable for this character. Eleven cross combination showed significant sca effects, \(i.e.,\) 6 and 5 with positive and negative sca effects, respectively. Crosses HD 4672/ Meghdoot (2.47*), GW 1225/ MACS 1967 (3.78**), HI 8550/MACS 1967 (3.81**), MACS 9/ Sarangpur local (2.89**), HI 8627/ A 9-30-1 (3.58**) and HI 8627/ MACS 1967 (3.09**) were desirable for increasing flag leaf length as they showed positive significant sca effect.

**Number of grains/spike:** Cross combinations with positive sca effects were considered as desirable for this character. Thirteen cross combinations showed significant sca effects, \(i.e.,\) 7 and 6 with positive and negative sca effects, respectively. Crosses HD 4672/ MACS 1967 (4.63**), GW 1225/ Sarangpur local (10.95**), HI 8550/ A 9-30-1 (4.58**), HI 8550/ Meghdoot (5.80**), MACS 9/ Meghdoot (3.97**), HI 8638/ MACS 1967 (2.47*) and HI 8627/ MACS 1967 (3.22**) were desirable for improving number of grains/ spike as they showed positive significant sca effect.

**Biomass/plant (g):** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Sixteen cross combinations showed significant specific combining ability, \(i.e.,\) 9 and 7 with positive and negative sca effects, respectively. Crosses HD4672/ MACS 1967 (9.57**), GW 1225/ Sarangpur local (2.32*), HI 8550/ A 9-30-1 (3.31**), HI 8550/ MACS 1967 (6.10**), MACS 9/ Sarangpur local (5.99**), MACS 9/ Meghdoot (9.66**), HI 8638/ Meghdoot (3.89**), HI 8627/ Sarangpur local (4.19**) and HI 8627/ MACS 1967 (3.18**) were desirable for improving biomass/plant as they showed positive significant sca effect.

**Harvest index (%):** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Eight cross combinations showed significant specific
combining ability, *i.e.*, 4 and 4 with positive and negative sca effects, respectively. Crosses GW 1225/ A 9-30-1 (2.20*), GW 1225/ Sarangpur local (2.46*), HI 8550/ Meghdoot (5.58**) and HI 8638/ MACS 1967 (2.55*) were desirable for increasing harvest index as they showed positive significant specific combining ability effect.

1000 grain weight (g): Cross combinations with positive specific combining ability effects were considered as desirable for this character. Eight cross combinations showed significant specific combining ability, *i.e.*, 3 and 5 with positive and negative sca effects, respectively. Crosses HD 4672/ MACS 1967 (2.42*), GW 1225/ MACS 1967 (3.37**) and HI 8550/ Sarangpur local (3.42**) were desirable for increasing 1000 grain weight as they showed positive significant sca effect.

Hectoliter weight (kg/l): Out of twenty four cross combinations, ten crosses showed significant specific combining ability, while, five cross HD 4672/ MACS 1967 (3.58**), GW 1225/ Sarangpur local (3.69**), MACS 9/ MACS 1967 (2.46*), HI 8638/ MACS 1967 (3.79**) and HI 8627/ Sarangpur local (3.53**) showed positive significant specific combining ability and considered desirable cross combinations for this trait.

Sedimentation value (ml): Ten cross combinations showed significant sca effect for this trait, *i.e.*, 5 and 5 with positive and negative sca effects, respectively. Crosses GW 1225/A 9-30-1(3.35**), GW 1225/ Sarangpur local (2.19*), HI 8550/ MACS 1967 (2.06*), HI 8638/ Meghdoot (2.27*) and HI 8627/ Meghdoot (3.10**) were considered as most desirable cross combinations as they showed significant and positive sca effects.

Carotene content (ppm): Ten cross combinations showed significant specific combining ability effects, *i.e.*, 5 and 5 with positive and negative sca effects, respectively. Crosses HD 4672/ MACS 1967 (4.14**), GW 1225/ Meghdoot (3.70**), HI 8550/ MACS 1967 (2.42*), MACS 9/ MACS 1967 (3.27**) and HI 8627/ A 9-30-1 (3.07**) were considered as desirable cross combinations as they showed significant and positive sca effects.

Protein content (%): Cross combinations with positive sca effects were considered as desirable for this character. Nine cross combinations showed significant sca effects, *i.e.*, 4 and 5 with positive and negative sca effects, respectively. Crosses GW 1225/ Meghdoot (2.56*), HI 8550/
A9 30-1 (3.76**), MACS 9/ Sarangpur local (3.23**) and HI 8638/ A9 30-1 (2.69**) were desirable for improving protein content as they showed positive significant sca effect.

**Phosphorus content (g):** Cross combinations with positive sca effects were considered as desirable for this character. Six cross combination showed significant sca effects, *i.e.*, 2 and 4 with positive and negative sca effects, respectively. Crosses HD 4672/ Meghdoot (2.33*) and HI 8627/ A 9 30-1 (3.45**) were desirable for improving phosphorus content as they showed positive significant sca effect.

**Potassium content (g):** Cross combinations with positive sca effects were considered as desirable for this character. Four cross combination showed significant sca effects, *i.e.*, 3 and 1 with positive and negative sca effects, respectively. Crosses GW 1225/A 9-30-1 (2.95**), HI 8550/ MACS 1967 (3.56**) and HI 8627/ MACS 1967 (4.77**) were desirable for improving potassium content as they showed positive significant sca effect.

**Phytic acid content (g):** Cross combination with negative specific combining ability effect was considered desirable for this character. Eleven cross combinations showed significant specific combining ability effect. Among these, six combinations showed negative and five cross combinations showed positive significant specific combining ability effect. Crosses HD 4672/ A 9-30-1 (-2.85**), HD 4672/ Sarangpur local (-3.77**), GW 1225/A 9-30-1 (-2.12*), HI 8550/A 9-30-1 (-2.37**), MACS 9/ Meghdoot (-3.37**) and HI 8627/ A 9-30-1 (-2.19*) were desirable for phytic acid content as they showed negative specific combinations ability effect.

**Grain yield/plant (g):** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Thirteen cross combinations showed significant sca effects, *i.e.*, 7 and 6 with positive and negative sca effects, respectively. Crosses HD 4672/ Sarangpur local (3.09**), HD 4672/ MACS 1967 (4.30**), GW 1225/ Sarangpur local (2.79**), HI 8550/ Meghdoot (2.20*), MACS 9/ Sarangpur local (2.88**), MACS 9/ Meghdoot (3.39**) and HI 8627/ Sarangpur local (2.76**) were desirable for grain yield/plant as they showed significant positive specific combining ability effects.
Specific combining ability effects of physiological traits

The specific combining ability effects of 24 cross combinations were presented in Table 4.86.

Canopy temperature I (vegetative stage) (ºC): Three cross combinations had significant specific combining ability effect. Among these, two cross combination showed negative and one cross combination showed positive significant specific combining ability effect. Crosses GW 1225/ Sarangpur local (-2.98**) and HI 8550/ MACS 1967 (-2.10*) appeared as desirable for canopy temperature as they showed negative specific combining ability. Therefore, lower canopy temperature segregants can be selected from this cross combinations. On the other hand, significant cross combinations with positive sca effects were identified as undesirable cross combinations for canopy temperature.

Canopy temperature II (flowering stage) (ºC): Three cross combinations had significant specific combining ability effect. Among these, two cross combination showed negative and one cross combination showed positive significant specific combining ability effect. Crosses GW 1225/ Sarangpur local (-2.18*) and MACS 9/ MACS 1967 (-2.50*) appeared as desirable for canopy temperature as they showed negative specific combining ability. Therefore, lower canopy temperature segregants can be selected from this cross combinations. On the other hand, significant cross combinations with positive sca effects were identified as undesirable cross combinations for canopy temperature.

Canopy temperature III (grain filling stage) (ºC): Two cross combinations had significant specific combining ability effect. Crosses GW 1225/ Sarangpur local (-2.22*) and HI 8550/ Sarangpur local (-2.08*) appeared as desirable for canopy temperature as they showed negative specific combining ability. Therefore, lower canopy temperature segregants can be selected from this cross combinations.

Flag leaf area/plant(cm): Cross combinations with positive sca effects were considered as desirable for this character. Out of twenty four cross combinations; five showed significant sca effect i.e., 2 and 3 with positive and negative sca effects, respectively. Crosses HD 4672/ Meghdoot (2.86**) and MACS 9/ Sarangpur local (3.12**) were desirable for increasing flag leaf area as they showed positive significant sca effect.
**Leaf weight (g):** Cross combination with positive sca effect were considered as desirable for this character. Cross HI 8627/ Meghdoot (-2.14*) were undesirable for leaf weight.

**Stem weight (g):** Cross combinations with positive sca effects were considered as desirable for this character. Seventeen cross combinations showed significant sca effects, *i.e.*, 9 and 8 with positive and negative sca effects, respectively. Crosses HD 4672/ A 9-30-1 (8.12**), GW 1225/ Meghdoot (3.23**), GW 1225/ MACS 1967 (3.07**), HI 8550/ Meghdoot (3.19**), MACS 9/ Sarangpur local (6.17**), MACS 9/ Meghdoot (2.36*), HI 8638/ Sarangpur local (3.08**), HI 8638/ Meghdoot (4.54**) and HI 8627/ MACS 1967 (9.43**) were desirable for stem weight, as they showed positive significant sca effect.

**Number of effective spikes/plant:** Cross combinations with positive sca effects were considered as desirable for this character. Three cross combination showed positive significant sca effects. Crosses HD 4672/ A 9-30-1 (3.30**), HI 8550/ MACS 1967 (2.13*) and HI 8627/ Sarangpur local(2.41*) were desirable for improving number of effective spikes/plant as they showed positive significant sca effect.

**Chlorophyll content I (vegetative stage) (%)** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Five cross combinations showed significant specific combining ability, *i.e.*, 4 and 1 with positive and negative sca effects, respectively. Crosses HD 4672/ Sarangpur local (2.08*), GW 1225/ Sarangpur local (2.87**), HI 8550/ Sarangpur local (2.14*) and HI 8627/ MACS 1967 (2.88**) were desirable for improving Chlorophyll content as they showed positive significant sca effect.

**Chlorophyll content II (flowering stage) (%)** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Four cross combinations showed positive significant specific combining ability. Crosses HD 4672/ A 9-30-1 (3.09**), HD 4672/ Sarangpur local (2.45*), HI 8550/ Sarangpur local (2.31*) and HI 8550/ MACS 1967 (3.54**) were desirable for improving Chlorophyll content as they showed positive significant sca effect.

**Chlorophyll content III (grain filling stage) (%)** Cross combinations with positive specific combining ability effects were considered as desirable for this character. Five cross combinations
showed significant specific combining ability, \textit{i.e.}, 3 and 2 with positive and negative \textit{sca} effects, respectively. Crosses HD 4672/ A 9-30-1 (3.08**), MACS 9/ Sarangpur local (2.85**) and HI 8627/ A 9-30-1 (2.56*) were desirable for improving Chlorophyll content as they showed positive significant \textit{sca} effect.

**Heterosis of morphological, quality and biochemical traits**

The magnitude of heterosis (\textit{i.e.,} extent of superiority of \textit{F}_1s over the better parent) was calculated for 24 cross combinations and tested for its significance. The heterosis for 19 characters has been presented in Tables 4.87 and 4.88.

**Days to flowering:** Earliness in flowering in wheat genotypes is a desirable attribute; and hence, heterosis in negative direction is considered advantageous. Crosses HD 4672/ MACS 1967 (-6.09**), HI 8550/ Sarangpur local (-8.10**), MACS 9/ Meghdoot (-14.05**), HI 8638/ A 9-30-1 (-2.78*), HI 8638/ Sarangpur local (-8.96**) and HI 8638/ Meghdoot (-7.01**) showed significant negative heterosis, while, GW 1225/ Meghdoot (3.75**), HI 8550/ A 9-30-1 (4.18**), HI 8550/ MACS 1967 (8.12**), MACS 9/ A 9-30-1 (4.08**), MACS 9/ MACS 1967 (11.68**), HI 8638/ MACS 1967 (10.21**), HI 8627/ Sarangpur local (4.69**), HI 8627/ Meghdoot (4.92**) and HI 8627/ MACS 1967 (14.21**) showed significant positive heterosis for this trait. Heterobeltiosis ranged from 0.51\% to 14.21\%.

**Day to maturity:** Earliness in maturity in wheat genotypes is a desirable attribute; and hence, heterosis in negative direction is considered advantageous. Fifteen cross combinations showed significant heterosis, in which six crosses showed significant negative heterosis \textit{viz.,} HD 4672/ MACS 1967 (-2.50*), HI 8550/ Sarangpur local (-2.47*), HI 8638/ Sarangpur local (-4.18**), HI 8638/ Meghdoot (-2.41*), HI 8627/ Meghdoot (-8.31**) and HI 8627/ MACS 1967 (-6.78**) found desirable for this trait. Heterosis over better parent ranged from 0.28\% to 18.72\%.

**Plant height (cm):** Twenty four cross combinations showed significant heterosis for this trait, of which three of them showed significant and negative heterosis. Crosses GW 1225/ Meghdoot (-6.60**), MACS 9/ MACS 1967 (-4.63**) and HI 8638/ Sarangpur local (-2.55*) showed
significant and negative heterosis, hence, considered desirable cross combinations for this trait. Heterosis over better parent ranged from -2.55 % to 28.18 %.

**Spike length (cm):** Twenty four cross combinations showed significant heterosis for this trait, of which four of them showed significant and negative heterosis. HD 4672/ A 9-30-1 (7.18**), HD4672/ Sarangpur local (3.47**), HD 4672/ Meghdoot (20.54**), HD 4672/ MACS 1967 (8.66**), GW 1225/ A 9-30-1 (13.72**), GW 1225/ Sarangpur local (13.97**), GW 1225/ Meghdoot (18.45**), GW 1225/ MACS 1967 (8.48**), HI 8550/A 9-30-1 (8.64**), HI 8550/ Sarangpur local (5.18**), HI 8550/ Meghdoot (10.16**), HI 8550/ MACS 1967 (4.68**), MACS 9/ A 9-30-1 (7.73**), MACS 9/ Sarangpur local (3.38**), MACS 9/ Meghdoot (5.64**), HI 8638/ MACS 1967 (6.09**), HI 8627/ A 9-30-1 (3.86**), HI 8627/ Sarangpur local (5.18**), HI 8627/ Meghdoot (10.16**), and HI 8627/ MACS 1967 (9.37**) were considered as desirable combinations as they showed significant and positive heterosis. Heterosis over better parent ranged from 3.38 % to 20.54 %.

**Number of tillers/plant:** Twenty four cross combinations showed significant heterosis for this trait, of which nine of them showed significant and negative heterosis. HD 4672/ A 9-30-1 (40.00**), HD 4672/ Sarangpur local (11.43**), HD 4672/ Meghdoot (9.09**), HD 4672/ MACS 1967 (6.45**), GW 1225/ Sarangpur local (5.41**), GW 1225/ Meghdoot (30.30**), GW 1225/ MACS 1967 (6.45**), HI 8550/ Meghdoot (15.15**), HI 8550/MACS 1967 (41.94**), MACS 9/ A 9-30-1 (12.90**), MACS 9/ Sarangpur local (22.58**), HI 8627/ A 9-30-1 (7.29**), HI 8627/ Sarangpur local (30.77**), HI 8627/ Meghdoot (12.12**), and HI 8627/ MACS 1967 (16.13**) with positive significant heterosis making them desirable combinations for this trait. Heterosis over better parent ranged from 5.41 % to 41.94 %.

**Flag leaf length (cm):** Eleven crosses viz., HD 4672/ A 9-30-1 (6.78**), HD 4672/ Sarangpur local (3.98**), HD 4672/ Meghdoot (16.55**), GW 1225/ A 9-30-1 (8.70**), HI 8550/ A 9-30-1 (2.96**), HI 8550/ Meghdoot (4.75**), MACS 9/ A 9-30-1 (7.25**), MACS 9/ Sarangpur local (13.07**), MACS 9/ Meghdoot (5.46**), HI 8627/ A 9-30-1 (9.91**) and HI 8627/ Sarangpur local (6.00**) were considered as desirable combinations as they showed significant and positive heterosis. Heterosis over better parent ranged from 1.27 % to -18.59 %.
Flag leaf width (cm): Eighteen crosses viz., HD 4672/ A 9-30-1 (13.51**), HD 4672/ Sarangpur local (52.70**), HD 4672/ Meghdoot (27.03**), HD 4672/ MACS 1967 (16.22**), GW 1225/ A 9-30-1 (8.14**), GW 1225/ Sarangpur local (24.42**), GW 1225/ Meghdoot (12.79**), GW 1225/ MACS 1967 (4.65**), HI 8550/ A 9-30-1 (10.34**), HI 8550/ Sarangpur local (6.67**), HI 8550/ Meghdoot (8.89**), MACS 9/ A 9-30-1 (3.45**), MACS 9/ Sarangpur local (18.68**), MACS 9/ Meghdoot (12.09**), HI 8627/ A 9-30-1 (9.20**), HI 8627/ A 9-30-1 (9.20**), HI 8627/ Sarangpur local (6.25**), and HI 8627/ Meghdoot (2.08*) with significant positive heterosis making them desirable combinations for this trait. Heterosis over better parent ranged from 1.04 % to 52.70 %.

Number of grains/spike: Fifteen cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (2.11*), HD 4672/ MACS 1967 (17.67**), GW 1225/ A 9-30-1 (13.93**), GW 1225/ Sarangpur local (42.29**), GW 1225/ Meghdoot (3.98**), HI 8550/ A 9-30-1 (30.80**), HI 8550/ Meghdoot (16.49**), HI 8550/ MACS 1967 (15.54**), MACS 9/ A 9-30-1 (15.61**), MACS 9/ Meghdoot (11.70**), MACS 9/ MACS 1967 (9.16**), HI 8638/ MACS 1967 (9.16**), HI 8627/ A 9-30-1 (21.10**), HI 8627/ Meghdoot (6.32**) and HI 8627/ MACS 1967 (32.67**) were considered as desirable cross combinations for this attribute. Range of heterosis is from 0.42 % to 42.29 %.

Biomass/plant (g): Twenty one cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (20.63**), HD 4672/ Sarangpur local (5.96**), HD 4672/ Meghdoot (9.99**), HD 4672/ MACS 1967 (66.35**), GW 1225/ A 9-30-1 (8.68**), GW 1225/ Sarangpur local (20.07**), GW 1225/ Meghdoot (23.63**), GW 1225/ MACS 1967 (25.99**), HI 8550/ A 9-30-1 (27.90**), HI 8550/ Meghdoot (29.12**), HI 8550/ MACS 1967 (50.80**), MACS 9/ A 9-30-1 (34.60**), MACS 9/ Sarangpur local (56.57**), MACS 9/ Meghdoot (80.75**), MACS 9/ MACS 1967 (7.44**), HI 8638/ Meghdoot (31.18**), HI 8638/ MACS 1967 (10.77**), HI 8627/ A 9-30-1 (3.79**), HI 8627/ Sarangpur local (25.31**), HI 8627/ Meghdoot (19.84**) and HI 8627/ MACS 1967 (47.16**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 0.44 % to 66.35 %.

Harvest index (%): Twenty two cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (8.51**), HD 4672/ Sarangpur local (7.20**), HD 4672/ MACS 1967 (13.12**), GW 1225/ A 9-30-1 (18.14**), GW 1225/ Sarangpur local (18.02**), GW 1225/
MACS 1967 (8.51**), HI 8550/ A 9-30-1 (14.06**), HI 8550/ Sarangpur local (2.94*), HI 8550/ Meghdoot (33.25**), HI 8550/ MACS 1967 (14.92**), MACS 9/ A 9-30-1 (12.07**), MACS 9/ Sarangpur local (16.16**), MACS 9/ Meghdoot (12.64**), MACS 9/ MACS 1967 (4.87**), HI 8638/ A 9-30-1 (18.70**), HI 8638/ Sarangpur local (19.75**), HI 8638/ Meghdoot (14.87**), HI 8638/ MACS 1967 (27.88**), HI 8627/ Sarangpur local (6.22**), HI 8627/ Meghdoot (8.98**) and HI 8627/ MACS 1967 (4.61**). were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 0.25 % to 33.25 %.

**1000 grain weight (g):** All twenty four cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (21.64**), HD 4672/ Sarangpur local (18.42**), HD 4672/ Meghdoot (25.56**), HD 4672/ MACS 1967 (35.61**), GW 1225/ A 9-30-1 (16.12**), GW 1225/ Sarangpur local (28.74**), GW 1225/ Meghdoot (11.94**), GW 1225/ MACS 1967 (38.58**), HI 8550/ A 9-30-1 (21.95**), HI 8550/ Sarangpur local (38.39**), HI 8550/ Meghdoot (26.60**), HI 8550/ MACS 1967 (15.18**), MACS 9/ A 9-30-1 (16.94**), MACS 9/ Sarangpur local (31.41**), MACS 9/ Meghdoot (32.86**), MACS 9/ MACS 1967 (42.45**), HI 8638/ A 9-30-1 (26.01**), HI 8638/ Sarangpur local (27.03**), HI 8638/ Meghdoot (27.52**), HI 8638/ MACS 1967 (35.66**), HI 8627/ A 9-30-1 (16.91**), HI 8627/ Sarangpur local (22.16**), HI 8627/ Meghdoot (20.24**) and HI 8627/ MACS 1967 (21.21**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 11.94% to 42.45 %.

**Hectoliter weight (kg/l):** Nine cross combinations showed significant positive heterosis i.e., HD 4672/ Meghdoot (3.04**), HD 4672/ MACS 1967 (3.48**), MACS 9/ Meghdoot (2.17*), MACS 9/ MACS 1967 (2.17*), HI 8638/ A 9-30-1 (3.04**), HI 8638/ Meghdoot (2.39*), HI 8638/ MACS 1967 (3.91**), HI 8627/ A 9-30-1 (2.61*) and HI 8627/ Sarangpur local (2.77*) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 0.22 % to 3.91 %.

**Sedimentation value (ml):** Twenty three cross combinations showed significant heterosis i.e., 19 and 4 crosses showed significant positive and negative heterosis respectively viz., HD 4672/ A 9-30-1 (21.57**), HD 4672/ Sarangpur local (19.61**), GW 1225/ A 9-30-1 (55.71**), GW 1225/ Sarangpur local (47.86**), GW 1225/ Meghdoot (2.14*), GW 1225/ MACS 1967 (7.14**), HI 8550/ A 9-30-1 (8.56**), HI 8550/ Meghdoot (38.78**), HI 8550/ MACS 1967 (25.75**), MACS 9/ A 9-30-1 (9.44**), MACS 9/ Sarangpur local (15.56**), MACS 9/ Meghdoot
(10.20**), HI 8638/ Sarangpur local (3.76**), HI 8638/ Meghdoot (38.78**), HI 8638/ MACS 1967 (2.40*), HI 8627/ A 9-30-1 (23.08**), HI 8627/ Sarangpur local (34.62**), HI 8627/ Meghdoot (30.77**) and HI 8627/ MACS 1967 (22.31**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 0.90 % to 55.71 %.

**Carotene content (ppm):** Nine cross combinations showed significant positive heterosis viz., GW 1225/ Meghdoot (20.67**), HI 8550/ A 9-30-1 (5.89**), HI 8550/ MACS 1967 (11.05**), HI 8638/ A 9-30-1 (11.88**), HI 8638/ Meghdoot (7.73**), HI 8627/ A 9-30-1 (62.18**), HI 8627/ Sarangpur local (17.94**), HI 8627/ Meghdoot (19.10**) and HI 8627/ MACS 1967 (16.47**) were considered as most desirable cross combinations for this trait. The range of heterosis was from 5.89 % to 62.18 %.

**Protein content (%):** Eleven cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (12.93**), HD 4672/ Sarangpur local (9.76**), HD 4672/ MACS 1967 (5.54**), GW 1225/ Meghdoot (14.55**), GW 1225/ MACS 1967 (9.36**), HI 8550/ A 9-30-1 (6.75**), HI 8550/ Sarangpur local (4.50**), MACS 9/ Sarangpur local (14.62**), HI 8627/ A 9-30-1 (5.61**), HI 8627/ Sarangpur local (4.81**), and HI 8627/ MACS 1967 (4.55**) were considered as most desirable cross combinations for this trait. The range of heterosis was from 1.16 % to 29.03 %.

**Phosphorus content (g):** Thirteen cross combinations showed significant positive heterosis viz., HD 4672/ MACS 1967 (20.67**), GW 1225/ A 9-30-1 (21.32**), GW 1225/ Sarangpur local (3.50**), HI 8550/ A 9-30-1 (30.74**), HI 8550/ Sarangpur local (22.02**), HI 8550/ MACS 1967 (72.49**), MACS 9/ A 9-30-1 (45.18**), MACS 9/ Sarangpur local (9.51**), MACS 9/ Meghdoot (20.05**), HI 8638/ A 9-30-1 (12.11**), HI 8638/ Meghdoot (20.95**), HI 8627/ A 9-30-1 (40.60**), and HI 8627/ Meghdoot (2.93**) were considered as most desirable cross combinations for this trait. The range of heterosis was from 0.78 % to 45.18 %.

**Potassium content (g):** Three cross combinations showed significant positive heterosis viz., HD 4672/ Meghdoot (2.69*), GW 1225/ A 9-30-1 (4.49**) and HI 8550/ MACS 1967 (2.47*) were considered as most desirable cross combinations for this trait. The range of heterosis was from 0.02 % to -11.60 %.
Phytic acid content (g): Heterosis in negative direction is considered in these traits. Eleven cross combinations showed significant heterosis, in which twelve crosses showed significant negative heterosis viz., HD 4672/ A 9-30-1 (-11.71**), HD 4672/ Sarangpur local (-10.54**), HD 4672/ Meghdoot (-2.58*), HD 4672/ MACS 1967 (-3.96**), GW 1225/ A 9-30-1 (-14.32**), MACS 9/ Meghdoot (-11.11**), HI 8638/ A 9-30-1 (-14.35**), HI 8638/ Sarangpur local (-12.43**), HI 8638/ Meghdoot (-12.28**), HI 8638/ MACS 1967 (-2.27*), HI 8627/ A 9-30-1 (-15.54**) and HI 8627/ Meghdoot (-7.28**) found desirable for this trait. The range of heterosis was from 1.71 % to 18.10 %.

Grain yield/plant (g): Twenty three cross combinations showed significant positive heterosis viz., HD 4672/ A 9-30-1 (23.45**), HD 4672/ Sarangpur local (12.53**), HD 4672/ Meghdoot (10.59**), HD 4672/ MACS 1967 (87.60**), GW 1225/ A 9-30-1 (4.00**), GW 1225/ Sarangpur local (21.14**), GW 1225/ Meghdoot (5.00**), GW 1225/ MACS 1967 (18.38**), HI 8550/ A 9-30-1 (36.59**), HI 8550/ Meghdoot (69.71**), HI 8550/ MACS 1967 (72.43**), MACS 9/ A 9-30-1 (31.81**), MACS 9/ Sarangpur local (58.93**), MACS 9/ Meghdoot (90.15**), MACS 9/ MACS 1967 (9.34**), HI 8638/ A 9-30-1 (18.73**), HI 8638/ Sarangpur local(18.53**), HI 8638/ Meghdoot (52.50**), HI 8638/ MACS 1967 (41.50**), HI 8627/ A 9-30-1 (4.31**), HI 8627/ Sarangpur local (32.93**), HI 8627/ Meghdoot (31.03**), HI 8627/ MACS 1967 (53.60**) were considered as desirable cross combinations. Range of heterosis over better parent is from 4.00 % to 87.60 %.

Heterosis of physiological traits

The magnitude of heterosis (i.e., extent of superiority of F₁s over the better parent) was calculated for 24 cross combinations and tested for its significance. Inbreeding depression refers to reduced fitness of progenies resulting from inbreeding. The heterosis for 11 physiological characters has been presented in Table 4.89.

Canopy temperature I (vegetative stage) (ºC): Lower canopy temperature is considered as desirable trait in wheat crop under early sown conditions, hence, heterosis in negative direction is considered advantageous. Crosses HI 4672/ Meghdoot (-5.33**), HD 4672/ MACS 1967 (-5.45**), GW 1225/ A 9-30-1 (-5.64**),GW 1225/ Meghdoot (-6.68**), HI 8550/ A 9-30-1 (-8.20**), HI 8550/ Meghdoot (-6.76**), HI 8550/ MACS 1967 (-11.30**), MACS 9/ A 9-30-1
(-5.64**), MACS 9/ MACS 1967 (-6.70**), HI 8638/ A 9-30-1 (-9.99**), HI 8638/ Sarangpur local (-5.58**), HI 8638/ Meghdoot (-5.24**), HI 8638/ MACS 1967 (-2.92**) and HI 8627/ Meghdoot (-4.99**) showed significant negative heterosis for this trait. Heterosis ranged from 1.88 % to -11.30 %.

**Canopy temperature II (flowering stage) (ºC):** Lower canopy temperature is considered as desirable trait in wheat crop under early sown conditions, hence, heterosis in negative direction is considered advantageous. Crosses HD 4672/ MACS 1967 (-4.57**), GW 1225/ Sarangpur local (-6.19**), HI 8550/ A 9-30-1 (-5.50**), HI 8550/ Meghdoot (-5.07**), HI 8550/ MACS 1967 (-6.63**), MACS 9/ MACS 1967 (-7.00**), HI 8638/ A 9-30-1 (-5.16**), HI 8638/ Sarangpur local (-5.53**), HI 8638/ Meghdoot (-4.06**) and HI 8638/ MACS 1967 (-3.54**) showed significant negative heterosis. Heterosis ranged from 1.13 % to -15.19 %.

**Canopy temperature III (grain filling stage) (ºC):** Crosses GW 1225/ MACS 1967 (-3.27**), HI 8550/ MACS 1967 (-3.08**), HI 8638/ MACS 1967 (-3.85**), HI 8627/ A 9-30-1 (-4.13**), HI 8627/ Meghdoot (-4.14**) and HI 8627/ MACS 1967 (-5.71**) showed significant negative heterosis for this trait. Heterosis ranged from 0.81 % to 12.01 %.

**Flag leaf area/plant (cm):** Thirteen cross combinations showed positive significant heterosis for this trait, *i.e.*, HD 4672/ A 9-30-1 (23.18**), HD 4672/ Sarangpur local (30.02**), HD 4672/ Meghdoot (46.80**), GW 1225/ A 9-30-1 (16.81**), GW 1225/Sarangpur local (18.48**), GW 1225/ Meghdoot (13.84**), HI 8550/A 9-30-1 (12.01**), HI 8550/ Meghdoot (12.45**), MACS 9/A 9-30-1 (8.01**), MACS 9/ Sarangpur local (31.87**), MACS 9/Meghdoot (16.37**), HI 8638/ A 9-30-1 (10.59**), HI 8627/ A 9-30-1 (21.26**) and HI 8627/ Sarangpur local (7.93**). Heterosis over better parent ranged from 4.52 % to 46.80 %.

**Leaf weight/plant (g):** Twenty four cross combinations showed significant heterosis for this trait, of which nine of them showed significant and negative heterosis. HD 4672/ A 9-30-1(17.86**), HD 4672/ Meghdoot (2.50*), HD 4672/ MACS 1967 (4.88**), GW 1225/ A 9-30-1 (11.54**), GW 1225/ Sarangpur local (25.64**), GW 1225/ Meghdoot (34.62**), GW 1225/ MACS 1967 (5.13**), HI 8550/ Meghdoot (18.75**), MACS 9/ A 9-30-1 (21.62**), MACS 9/ Sarangpur local (41.89**), MACS 9/ Meghdoot (44.59**), HI 8638/ Meghdoot (22.50**), HI 8627/ A 9-30-1 (7.69**), HI 8627/ Sarangpur local (14.29**), and HI 8627/ MACS 1967 (35.37**) were
considered as desirable combinations as they had showed significant and positive heterosis. Heterosis over better parent ranged from 2.50 % to 44.59 %.

**Stem weight/plant (g):** Eleven crosses *viz.* HD 4672/ A 9-30-1 (18.61**), GW 1225/ Sarangpur local (40.29**), GW 1225/ Meghdoot (73.89**), GW 1225/ MACS 1967 (61.62**), HI 8550/ Meghdoot (14.93**), MACS 9/ Sarangpur local (53.83**), MACS 9/ Meghdoot (44.69**), HI 8638/ Sarangpur local (16.05**), HI 8638/ Meghdoot (30.88**), HI 8627/ Sarangpur local (16.46**), and HI 8627/ MACS 1967 (53.22**) were considered as desirable combinations as they had showed significant and positive heterosis. Heterosis over better parent ranged from 1.95 % to 73.89 %.

**Number of effective spikes/plant:** Thirteen cross combinations showed significant positive heterosis *viz.* HD 4672/ A 9-30-1 (80.00**), HD 4672/ Sarangpur local (32.00**), HD 4672/ Meghdoot (20.00**), HD 4672/ MACS 1967 (16.00**), GW 1225/ A 9-30-1 (10.00**), GW 1225/ Sarangpur local (10.00**), GW 1225/ Meghdoot (32.14**), GW 1225/ MACS 1967 (11.11**), HI 8550/ A 9-30-1 (13.79**), HI 8550/ Meghdoot (3.57**), HI 8550/ MACS 1967 (33.33**), MACS 9/ Sarangpur local (10.00**) and HI 8627/ Sarangpur local (42.42**) were desirable cross combinations for this attribute. Range of heterosis is from 3.57 % to 80.00 %.

**Chlorophyll content I (vegetative stage) (%):** Twelve cross combinations showed significant positive heterosis *viz.* HD 4672/ A 9-30-1 (3.06**), HD 4672/ MACS 1967 (3.66**), HI 8550/ A 9-30-1 (2.71*), HI 8550/ Sarangpur local (4.95**), HI 8550/ Meghdoot (3.02**), MACS 9/ Sarangpur local (3.49**), MACS 9/ MACS 1967 (4.28**), HI 8638/ A 9-30-1 (7.05**), HI 8638/ Sarangpur local (4.17**), HI 8638/ MACS 1967 (6.15**), and HI 8627/ MACS 1967 (5.41**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 1.11 % to 7.05 %.

**Chlorophyll content II (flowering stage) (%):** Twelve cross combinations showed significant positive heterosis *viz.* HD 4672/ A 9-30-1 (9.43**), HD 4672/ Meghdoot (5.38**), HI 8550/ A 9-30-1 (4.25**), HI 8550/ Sarangpur local (7.41**), HI 8550/ Meghdoot (5.20**), MACS 9/ Sarangpur local (4.85**), MACS 9/ MACS 1967 (3.21**), HI 8638/ A 9-30-1 (7.84**), HI 8638/ Sarangpur local (5.26**), HI 8638/ Meghdoot (6.49**), HI 8638/ MACS 1967 (4.39**)
and HI 8627/ Meghdoot (5.06**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 1.12 % to 7.84 %.

**Chlorophyll content III (grain filling stage) (%):** Twelve cross combinations showed significant positive heterosis *viz.*, HD 4672/ A 9-30-1 (8.52**), HD 4672/ Meghdoot (3.48**), GW 1225/ Sarangpur local (2.43*), GW 1225/ MACS 1967 (2.13*), HI 8550/ Sarangpur local (5.53**), HI 8550/ Meghdoot (2.38*), MACS 9/ Sarangpur local (8.69**), MACS 9/ MACS 1967 (3.91**), HI 8638/ A 9-30-1 (7.72**), HI 8638/ Sarangpur local (3.28**), HI 8638/ Meghdoot (6.06**) and HI 8638/ MACS 1967 (7.72**) were considered as desirable cross combinations for this trait. Range of heterosis over better parent is from 1.19 % to -10.29 %.

**4.7 Generation mean analysis of significant superior crosses:**

Among 24 crosses evaluated, based on the heterosis, combining ability and *per se* performance, six top crosses were selected and further generations (F₂, F₃, BC₁, BC₂) were developed and evaluated by applying six parameter model of generation mean analysis. The mean performance of all the six generations of six crosses for 20 yield traits, morphological, quality and physiological traits are presented in Tables 4.90 to 4.92. The adequacy of simple additive-dominance model, (without non-allelic interactions) was tested by estimation of the scales A, B, C and D with their respective standard errors (Table 4.93 to 4.96). Scaling test reveals the presence of non-allelic interactions tends to bias estimates of A (or d) and D (or H) components to an unknown extent, attests to the need for detecting its presence in the parents involved in a cross. If all the 4 scales are significant, that means interactions are present (also in case of F₃ is used). Individually, they signify that Significant A component indicates the presence of *J* (additive x dominance interaction), significant B indicates the presence of *J* (additive x dominance interaction), significant C indicates the presence of *I* (dominance x dominance interaction) and significant D indicates the presence of *I* (additive x additive interaction). Significance of even one of the 4 scales necessitates or marks adequacy to components of means of genes effects by 6-parameters model (with BC) or 5-parameters model (with F₃) depending on the case. The scaling tests, indicated inadequacy of the data to fit into simple additive dominance model for all the characters. So the genetic components m, d, h, i, j, l. were estimated with an assumption of an additive dominance model with digenic interactions and presented in Tables 4.97 to 4.102.
At least one of the scaling tests in most of the crosses was found significant for the characters like grain yield per plant, spike length, number of tillers/plant, flag leaf length, number of grains/spike, biomass/plant, hectoliter weight and thousand grain weight indicating pre-dominance of epistatic (non-allelic) gene effect or complex inheritance for these traits.

**Spike length (cm):** Scaling test A was found significant and positive for the cross combinations víz., HI 8550/ A 9-30-1 (3.92**), MACS 9/ MACS 1967 (1.08**) and HI 8627/ Sarangpur local (1.23**) while, significant negative for HD 4672/ MACS 1967 (-3.83**), GW 1225/ Sarangpur local (-3.02**) and HI 8550/ MACS 1967 (-0.80**). Scaling test B was found significant positive for cross combinations víz., HD 4672/ MACS 1967 (2.19**), HI 8550/ MACS 1967 (0.61**) and MACS 9/ MACS 1967 (0.97**) while, significant negative for GW 1225/ Sarangpur local (-1.11**), HI 8550/ A 9-30-1 (-1.46**) and HI 8627/ Sarangpur local (-0.69*). Scaling test C was found significant positive for the cross combinations víz., GW 1225/ Sarangpur local (2.39**) and MACS 9/ MACS 1967(4.47**) while, significant negative for HI 8550/ A 9-30-1 (-4.44**) and HI 8550/ MACS 1967 (-3.13**). Scaling test D was found significant positive for crosses víz., GW 1225/ Sarangpur local (3.26**) and MACS 9/ MACS 1967 (1.21**) while, significant negative for HI 8550/ A 9-30-1 (-3.45**) and HI 8550/ MACS 1967 (-1.47**).

**Number of tillers/plant:** Scaling test A was found significant and positive for the cross combinations víz., GW 1225/ Sarangpur local (2.30**), HI 8550/ MACS 1967 (3.00**) and HI 8627/ Sarangpur local (3.00**) while, significant negative for HD 4672/ MACS 1967 (-2.90**) and HI 8550/ A 9-30-1 (-2.90**). Scaling test B was found significant positive for cross combinations víz., GW 1225/ Sarangpur local (8.40**), HI 8550/ A 9-30-1 (2.50*), HI 8550/ MACS 1967 (4.60**) and MACS 9/ MACS 1967 (6.00**). Scaling test C was found significant positive for the cross combinations víz., HD 4672/ MACS 1967 (9.70**), GW 1225/ Sarangpur local (5.50**), HI 8550/ A 9-30-1 (8.60**), HI 8550/ MACS 1967 (13.60**) and MACS 9/ MACS 1967 (5.40**). Scaling test D was found significant positive for crosses víz., HD 4672/ MACS 1967 (7.00**), HI 8550/ A 9-30-1 (4.50**) and HI 8550/ MACS 1967 (3.00**) while, significant negative for GW 1225/ Sarangpur local (-2.60**).

**Flag leaf length (cm):** Scaling test A was found significant and positive for the cross combinations víz., HI 8550/ MACS 1967 (4.13**), MACS 9/ MACS 1967 (8.11**) and HI 8627/
Sarangpur local (8.18**) while, significant negative for HD 4672/ MACS 1967 (-4.34**) and GW 1225/ Sarangpur local (-6.70**). Scaling test B was found significant positive for cross combinations viz., HD 4672/ MACS 1967 (13.70**), HI 8550/ A 9-30-1 (7.42**), HI 8550/ MACS 1967 (9.55**), MACS 9/ MACS 1967 (6.88**) and HI 8627/ Sarangpur local (7.71**) while, significant negative for GW 1225/ Sarangpur local (-6.50**). Scaling test C was found significant positive for the cross combinations viz., HI 8550/ MACS 1967 (13.46**) while, significant negative for GW 1225/ Sarangpur local (-23.78**), HI 8550/ A 9-30-1 (-9.44**) and MACS 9/ MACS 1967 (-8.57**). Scaling test D was found significant negative for cross combinations viz., HD 4672/ MACS 1967 (-5.54**) and HI 8550/ A 9-30-1 (-7.74**), MACS 9/ MACS 1967 (-11.78**) and HI 8627/ Sarangpur local (-10.02**).

**Number of grains/spike:** Scaling test A was found significant and positive for the cross combinations viz., HD 4672/ MACS 1967 (15.10**) and HI 8627/ Sarangpur local (25.40**) while, significant negative for GW 1225/ Sarangpur local (-2.30*), HI 8550/ A 9-30-1 (-34.20**), HI 8550/ MACS 1967 (-45.70**) and MACS 9/ MACS 1967 (-15.10**). Scaling test B was found significant positive for cross combinations viz., HD 4672/ MACS 1967 (20.50**), MACS 9/ MACS 1967 (9.50**) and HI 8627/ Sarangpur local (22.80**), while, significant negative for HI 8550/ MACS 1967 (-4.70**). Scaling test C was found significant positive for the cross combinations viz., HD 4672/ MACS 1967 (34.20**) and HI 8627/ Sarangpur local (40.80**), while, significant negative for GW 1225/ Sarangpur local (-19.60**), HI 8550/ A 9-30-1 (-81.30**), HI 8550/ MACS 1967 (-16.00**) and MACS 9/ MACS 1967 (-16.80**). Scaling test D was found significant positive for cross combinations viz., GW 1225/ Sarangpur local (11.00**) and HI 8550/ MACS 1967 (17.20**) while, significant negative for HI 8550/ A 9-30-1 (-22.30**) and MACS 9/ MACS 1967 (-5.60**).

**Biomass/plant (g):** Scaling test A was found significant and positive for the cross combinations viz., HD 4672/ MACS 1967 (5.51**) and HI 8627/ Sarangpur local (3.74**), while, significant negative for HI 8550/ A 9-30-1 (-11.29**). Scaling test B was found significant positive for cross combinations viz., HD 4672/ MACS 1967 (8.48**), GW 1225/ Sarangpur local (14.07**), HI 8550/ A 9-30-1 (4.08**), HI 8550/ MACS 1967 (9.30**), MACS 9/ MACS 1967 (11.40**) and HI 8627/ Sarangpur local (4.85**). Scaling test C was found significant positive for the
cross combinations *viz.*, HD 4672/ MACS 1967 (8.15**), GW 1225/ Sarangpur local (13.70**), HI 8550/ MACS 1967 (23.21**), MACS 9/ MACS 1967 (11.84**) and HI 8627/ Sarangpur local (20.57**). Scaling test D was found significant positive for cross combinations *viz.*, HI 8550/ A 9-30-1 (4.21**), HI 8550/ MACS 1967 (6.27**) and HI 8627/ Sarangpur local (5.99**) while, significant negative for HD 4672/ MACS 1967 (-2.92**).

**Harvest index (%)**: Scaling test A was found significant and positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (2.91**) and HI 8627/ Sarangpur local (6.80**), while, significant negative for GW 1225/ Sarangpur local (-7.69**), HI 8550/ A 9-30-1 (-10.22**) and HI 8550/ MACS 1967 (-11.01**). Scaling test B was found significant positive for cross combinations *viz.*, GW 1225/ Sarangpur local (16.96**) and HI 8550/ A 9-30-1 (11.14**), while, significant negative for HD 4672/ MACS 1967 (-11.03**) and HI 8550/ MACS 1967 (-9.80**). Scaling test C was found significant positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (36.16**), GW 1225/ Sarangpur local (6.81**) and HI 8627/ Sarangpur local (27.68**). Scaling test D was found significant positive for cross combinations *viz.*, HD 4672/ MACS 1967 (22.14**), HI 8550/ MACS 1967 (11.02**) and HI 8627/ Sarangpur local (10.32**).

**1000 grain weight (g)**: Scaling test A was found significant and positive for the cross combinations *viz.*, GW 1225/ Sarangpur local (9.85**), HI 8550/ A 9-30-1 (8.82**) and HI 8550/ MACS 1967 (12.30**), while, significant negative for MACS 9/ MACS 1967 (-5.60**). Scaling test B was found significant positive for cross combinations *viz.*, HD 4672/ MACS 1967 (11.08**), GW 1225/ Sarangpur local (7.16**), HI 8550/ A 9-30-1 (5.37**), HI 8550/ MACS 1967 (12.21**), MACS 9/ MACS 1967 (10.57**) and HI 8627/ Sarangpur local (9.13**). Scaling test C was found significant positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (11.86**), GW 1225/ Sarangpur local (15.11**), HI 8550/ A 9-30-1 (15.77**), HI 8550/ MACS 1967 (27.91**), MACS 9/ MACS 1967 (8.41**) and HI 8627/ Sarangpur local (11.56**). Scaling test D was found non-significant for all test crosses.

**Sedimentation value (ml)**: Scaling test A was found significant and positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (4.40**), GW 1225/ Sarangpur local (2.60**), HI 8550/ A 9-30-1 (5.60**) and HI 8627/ Sarangpur local (4.30**), while, significant negative for HI 8550/ MACS 1967 (-4.50**). Scaling test B was found significant positive for cross combinations *viz.*, HD 4672/ MACS 1967 (7.00**), HI 8550/ A 9-30-1 (5.50**), and HI 8627/
Sarangpur local (6.20**). Scaling test C was found significant negative for the cross combinations *viz.*, HI 8550/ MACS 1967 (-7.10**). Scaling test D was found significant and negative for cross combinations *viz.*, HD 4672/ MACS 1967 (-3.90**), HI 8550/ A 9-30-1 (-6.80**) and HI 8627/ Sarangpur local (-6.30**).

**Carotene content (ppm):** Scaling test A was found significant and positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (1.23*) and GW 1225/ Sarangpur local (1.21*). Scaling test B was found non-significant for all test crosses. Scaling test C was found significant positive for the cross combinations *viz.*, GW 1225/ Sarangpur local (2.41**) while, significant negative for HI 8550/ A 9-30-1 (-2.40**) and HI 8627/ Sarangpur local (-1.79*). Scaling test D was found significant and negative for HI 8550/ A 9-30-1 (-1.42**).

**Protein content (%):** Scaling test A was found significant and positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (1.92**) and HI 8550/ A 9-30-1 (3.30**), while, significant negative for HI 8550/ MACS 1967 (-1.75*). Scaling test B was found significant positive for cross combinations *viz.*, HI 8550/ A 9-30-1 (2.99**). Scaling test C was found significant positive for the cross combinations *viz.*, HD 4672/ MACS 1967 (3.49**), HI 8550/A 9-30-1 (3.56**) and MACS 9/ MACS 1967 (2.69*). Scaling test D was found significant positive for HI 8550/ MACS 1967 (2.13**), while, significant negative for HI 8550/ A 9-30-1 (-1.38*).

**Phosphorus content (g):** Scaling test A was found significant and positive for the cross HI 8550/ MACS 1967 (1.35*). Scaling test B was found significant positive for the cross HI 8627/ Sarangpur local (1.85*), while, significant negative for HD 4672/ MACS 1967 (-1.47*). Scaling test C and D were found non-significant for all test crosses.

**Potassium content (g):** Scaling test A was found significant and positive for the cross combinations *viz.*, MACS 9/ MACS 1967 (2.78*), while, significant negative for HI 8550/ A 9-30-1 (-2.22*) and HI 8550/ MACS 1967 (-4.07**). Scaling test B was found significant positive for cross combinations *viz.*, GW 1225/ Sarangpur local (2.56*) and MACS 9/ MACS 1967 (5.23**), while, significant negative for HI 8550/ A 9-30-1 (-2.33*) and HI 8550/ MACS 1967 (-3.14*). Scaling test C was found significant positive for the cross HD 4672/ MACS 1967 (16.68**), while, significant negative for HI 8550/ A 9-30-1 (-4.66**). Scaling test D was found
significant positive for cross combinations viz., HD 4672/ MACS 1967 (8.03**) and HI 8550/ MACS 1967 (4.67**), while, significant negative for GW 1225/ Sarangpur local (-1.98*) and MACS 9/ MACS 1967 (-2.57**).

**Phytic acid content (g):** Scaling test A was found significant and positive for the cross combinations viz., MACS 9/ MACS 1967 (23.09**), while significant negative for HI 8550/ A 9-30-1 (-10.44**) and HI 8550/ MACS 1967 (-4.07**). Scaling test B was found significant positive for cross combinations viz., HD 4672/ MACS 1967 (3.27*), GW 1225/ Sarangpur local (8.90**) and MACS 9/ MACS 1967 (20.28**), while, significant negative for HI 8550/ MACS 1967 (-12.31**). Scaling test C was found significant positive for the cross combinations viz., GW 1225/ Sarangpur local (10.03**), MACS 9/ MACS 1967 (52.17**) and HI 8627/ Sarangpur local (10.18**), while, significant negative for HD 4672/ MACS 1967 (-12.35**). Scaling test D was found significant positive for cross combinations viz., HI 8550/ A 9-30-1 (5.75**), HI 8550/ MACS 1967 (13.39**) and MACS 9/ MACS 1967 (4.40**) while, significant negative for HD 4672/ MACS 1967 (-7.59**).

**Grain yield/plant (g):** Scaling test A was found significant and positive for the cross combinations viz., HD 4672/ MACS 1967 (2.86**) and HI 8627/ Sarangpur local (3.60**), while, significant negative for GW 1225/ Sarangpur local (-2.45*), HI 8550/ A 9-30-1 (-6.16**) and HI 8550/ MACS 1967 (-3.85**). Scaling test B was found significant positive for cross combinations viz., GW 1225/ Sarangpur local (11.07**), HI 8550/ A 9-30-1 (4.78**) and MACS 9/ MACS 1967 (2.71*). Scaling test C was found significant positive for the cross combinations viz., HD 4672/ MACS 1967 (14.70**), GW 1225/ Sarangpur local (6.90**), HI 8550/ MACS 1967 (8.12**) and HI 8627/ Sarangpur local (17.15**). Scaling test D was found significant positive for crosses viz., HD 4672/ MACS 1967 (6.28**), HI 8550/ A 9-30-1 (1.64*), HI 8550/ MACS 1967 (6.28**) and HI 8627/ Sarangpur local (6.01**).

**Canopy temperature I (vegetative stage) (°C):** Scaling test A was found significant and negative for the crosses viz., MACS 9/ MACS 1967 (-1.71*) and HI 8627/ Sarangpur local (-1.55*). Scaling test B was found significant negative for cross MACS 9/ MACS 1967 (-4.48**), scaling test C was found significant negative for HI 8627/ Sarangpur local (-3.10*) and scaling test D was found significant positive for MACS 9/ MACS 1967 (2.11*).
Canopy temperature II (flowering stage) (°C): Scaling test A was found significant and negative for the cross MACS 9/ MACS 1967 (-2.91**), and Scaling test B was found significant negative for crosses viz., HI 8550/ A 9-30-1 (-1.47**) and MACS 9/ MACS 1967 (-5.78**). Scaling test C was found significant positive for the cross HI 8550/ MACS 1967 (3.10**) while, significant negative for MACS 9/ MACS 1967 (-3.93**). Scaling test D was found significant positive for cross MACS 9/ MACS 1967 (2.00**).

Canopy temperature III (grain filling stage) (°C): Scaling test A was found significant and negative for the cross MACS 9/ MACS 1967 (-3.81**). Scaling test B was found significant negative for crosses HI 8550/ A 9-30-1 (-1.37**) and MACS 9/ MACS 1967 (-6.58**). Scaling test C was found significant positive for the cross HI 8550/ MACS 1967 (3.11*), while, significant negative for crosses viz., MACS 9/ MACS 1967 (-5.63**) and HI 8627/ Sarangpur local (-2.00*). Scaling test D was found significant positive for MACS 9/ MACS 1967 (2.38**).

Chlorophyll content I (vegetative stage) (%): Scaling test A was found significant and positive for the cross combinations viz., GW 1225/ Sarangpur local (2.64*), HI 8550/ A 9-30-1 (7.91**), HI 8550/ MACS 1967 (9.81**) and HI 8627/ Sarangpur local (5.87**), while, significant negative for HD 4672/ MACS 1967 (-16.87**) and MACS 9/ MACS 1967 (-3.65**). Scaling test B was found significant positive for cross combinations viz., HI 8550/ A 9-30-1 (3.94**) and HI 8627/ Sarangpur local (11.01**), while, significant negative for GW 1225/ Sarangpur local (-15.00**). Scaling test C was found significant positive for the cross combinations viz., HI 8550/ MACS 1967 (8.95**), MACS 9/ MACS 1967 (11.90**) and HI 8627/ Sarangpur local (10.88**), while, significant negative for HD 4672/ MACS 1967 (-25.11**), GW 1225/ Sarangpur local (-13.63**) and HI 8550/ A 9-30-1 (-16.95**). Scaling test D was found significant positive for cross MACS 9/ MACS 1967 (8.52**), while, significant negative for crosses viz., HD 4672/ MACS 1967 (-3.07*), HI 8550/ A 9-30-1 (-11.41**) and HI 8627/ Sarangpur local (-3.00*).

Chlorophyll content II (flowering stage) (%): Scaling test A was found significant and positive for the cross combinations viz., GW 1225/ Sarangpur local (2.85**), HI 8550/ A 9-30-1 (3.45**) and HI 8550/ MACS 1967 (9.01**) while, significant negative for crosses viz., HD 4672/ MACS 1967 (-17.07**) and MACS 9/ MACS 1967 (-4.45**). Scaling test B was found significant positive for cross combinations viz., HI 8550/ A 9-30-1 (3.54**) and HI 8627/
Sarangpur local (10.41**) while, significant negative for crosses viz., GW 1225/ Sarangpur local (-15.71**) and MACS 9/ MACS 1967 (-1.69*). Scaling test C was found significant positive for the cross combinations HI 8550/ MACS 1967 (8.35**), MACS 9/ MACS 1967 (10.90**) and HI 8627/ Sarangpur local (10.28**) while, significant negative for HD 4672/ MACS 1967 (-25.31**), GW 1225/ Sarangpur local (-13.00**) and HI 8550/ A 9-30-1 (-17.31**). Scaling test D was found significant positive for cross MACS 9/ MACS 1967 (5.12*) while, significant negative for crosses viz., HD 4672/ MACS 1967 (-3.51**) and HI 8550/ A 9-30-1 (-14.40**).

**Chlorophyll content III (grain filling stage)** (%): Scaling test A was found significant and positive for the cross combinations viz., GW 1225/ Sarangpur local (2.84*) and HI 8550/ MACS 1967 (8.91**) while, significant negative for crosses viz., HD 4672/ MACS 1967 (-12.89**) and MACS 9/ MACS 1967 (-4.45**). Scaling test B was found significant positive for cross combinations viz., HI 8550/ A 9-30-1 (3.34**) and HI 8627/ Sarangpur local (12.81**) while, significant negative for cross GW 1225/ Sarangpur local (-14.21**). Scaling test C was found significant positive for the cross combinations viz., HI 8550/ MACS 1967 (7.85**), MACS 9/ MACS 1967 (13.50**) and HI 8627/ Sarangpur local (12.68**) while, significant negative for crosses viz., HD 4672/ MACS 1967 (-23.14**), GW 1225/ Sarangpur local (-12.12**) and HI 8550/ A 9-30-1 (-17.54**). Scaling test D was found significant positive for cross MACS 9/ MACS 1967 (7.23**) while, significant negative for crosses viz., HD 4672/ MACS 1967 (-1.89*) and HI 8550/ A 9-30-1 (-13.23**).

**Estimation of genes effects**

The estimation of gene effect for all the twenty characters in all the crosses is presented in Table 4.97 to 4.102.

**Spike length (cm):** Significant positive additive effect (d) was found in the crosses viz., HI 8550/ A 9-30-1 (2.35**) and HI 8627/ Sarangpur local (1.29**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-2.96**), GW 1225/ Sarangpur local (-1.47**) and HI 8550 / MACS 1967 (-0.69**) while, dominant gene effect (h) was found significant and positive in crosses viz., HI 8550/ A 9-30-1 (7.38**) and HI 8550/ MACS 1967 (3.92**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-6.21**) and MACS 9/ MACS 1967 (-2.20**). Significant positive additive x additive (i) effect was found in crosses viz., HI 8550/ A
9-30-1 (6.90**) and HI 8550/ MACS 1967 (2.93**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-6.52**) and MACS 9/ MACS 1967 (-2.40**). Significant positive additive x dominance (j) effect was found in the cross HI 8550/ A 9-30-1 (2.69**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-3.01**), GW 1225/ Sarangpur local (-0.95**) and HI 8550 / MACS 1967 (-0.70**). Significant positive dominance x dominance effect (l) was found in cross GW 1225/ Sarangpur local (10.65**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-9.36**) and HI 8550/ MACS 1967 (-2.74**).

**Number of tillers/plant:** Significant positive additive effect (d) was found in the cross HI 8627/ Sarangpur local (1.40*); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-2.09**), HI 8550/ A 9-30-1(-3.30**) and MACS 9/ MACS 1967 (-2.70**) while, dominant gene effect (h) was found significant and negative in crosses viz., HD 4672/ MACS 1967 (-14.45**), HI 8550/ A 9-30-1 (-8.89**) and HI 8550/ MACS 1967 (-6.50**). Significant positive additive x additive (i) effect was found in cross GW 1225/ Sarangpur local (5.19**); and significant negative in crosses viz., HD 4672/ MACS 1967 (-14.00**), HI 8550/ A 9-30-1 (-8.99**) and HI 8550/ MACS 1967 (-6.00**). Significant negative additive x dominance (j) effect was found in the crosses viz., GW 1225/ Sarangpur local (-3.04**), HI 8550/ A 9-30-1 (-2.70**) and MACS 9/ MACS 1967 (-2.90**). Significant positive dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 267 (18.30**) and HI 8550/ A 9-30-1 (9.39**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-15.90**) and MACS 9/ MACS 1967 (-7.04*).

**Flag leaf length (cm):** Significant positive additive effect (d) was found in the cross MACS 9/ MACS 1967 (1.54**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-7.31**), GW 1225/ Sarangpur local (-2.98**) and HI 8550 / A 9-30-1 (-3.05**). Dominant gene effect (h) was found significant and positive in crosses viz., HD 4672/ MACS 1967 (12.55**), GW 1225/ Sarangpur local (17.38**), HI 8550/ A 9-30-1 (19.92**), MACS 9/ MACS 1967 (21.25**) and HI 8627/ Sarangpur local (16.09**). Significant positive additive x additive (i) effect was found in crosses viz., HD 4672/ MACS 1967 (11.08**), GW 1225/ Sarangpur local (10.58**), HI 8550/ A 9-30-1 (15.48**), MACS 9/ MACS 1967 (23.56**) and HI 8627/ Sarangpur local (20.04**). Significant negative additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (-9.02**), GW 1225/ Sarangpur local (-10.00**), HI 8550/
A 9-30-1 (-4.39**) and HI 8550/ MACS 1967 (-2.71*). Significant negative dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (-20.44**), HI 8550/ A 9-30-1 (-21.51**), HI 8550/ MACS 1967 (-13.89**), MACS 9/ MACS 1967 (-38.60**) and HI 8627/ Sarangpur local (-35.93**).

**Number of grains/spike:** Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-7.00**), HI 8550/ A 9-30-1 (-1.90**), HI 8550/ MACS 1967 (-7.30**) and MACS 9/ MACS 1967 (-9.60**) while, dominant gene effect (h) was found significant and positive in crosses viz., HI 8550/ A 9-30-1 (38.55**) and MACS 9/ MACS 1967 (16.40**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-38.09**) and HI 8550/ MACS 1967 (-34.90**). Significant positive additive x additive (i) effect was found in crosses viz., HI 8550/ A 9-30-1 (44.60**) and MACS 9/ MACS 1967 (11.20**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-21.99**) and HI 8550/ MACS 1967 (-34.40**). Significant negative additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (-2.70**), HI 8550/ A 9-30-1 (-15.85**), HI 8550/ MACS 1967 (-20.50**) and MACS 9/ MACS 1967 (-12.30**). Significant positive dominance x dominance effect (l) was found in crosses viz., GW 1225/ Sarangpur local (63.59**) and HI 8550/ MACS 1967 (84.80**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-37.00**), HI 8550/ A 9-30-1 (-7.90**) and HI 8627/ Sarangpur local (-55.60**).

**Biomass/plant (g):** Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-5.27**), HI 8550/ A 9-30-1 (-6.52**) and MACS 9/ MACS 1967 (-1.87**). Dominant gene effect (h) was found significant and positive in crosses viz., HD 4672/ MACS 1967 (3.45*) and MACS 9/ MACS 1967 (6.11**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-10.50**) and HI 8627/ Sarangpur local (-9.80**). Significant positive additive x additive (i) effect was found in cross HD 4672/ MACS 1967 (5.83**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-8.42**), HI 8550/ MACS 1967 (-12.50**) and HI 8627/ Sarangpur local (-11.98**). Significant negative additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (-1.48**), GW 1225/ Sarangpur local (-6.35**), HI 8550/ A 9-30-1 (-7.68**), HI 8550/ MACS 1967 (-3.96**) and MACS 9/ MACS 1967 (-5.92**). Significant positive dominance x dominance effect (l) was found in cross HI 8550/
MACS 1967 (15.63**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-19.82**), GW 1225/ Sarangpur local (-17.14**) and MACS 9/ MACS 1967 (-10.00**).

**Harvest index (%)**: Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-9.17**), HI 8550/ A 9-30-1 (-7.91**) and MACS 9/ MACS 1967 (-3.54*). Dominant gene effect (h) was found significant and negative in crosses viz., HD 4672/ MACS 1967 (-39.21**), HI 8550/ A 9-30-1 (-7.91**), HI 8550/ MACS 1967 (-25.67**) and HI 8627/ Sarangpur local (-21.10**). Significant negative additive x additive (i) effect was found in crosses viz., HD 4672/ MACS 1967 (-44.28**) and HI 8550/ MACS 1967 (-22.03**). Significant positive additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (6.96**) and HI 8627/ Sarangpur local (3.27*); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-12.32**) and HI 8550/ A 9-30-1 (-10.68**). Significant positive dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (52.40**), HI 8550/ MACS 1967 (42.84**) and HI 8627/ Sarangpur local (13.59**); and significant and negative in cross GW 1225/ Sarangpur local (-11.73**).

**1000 grain weight (g)**: Significant positive additive effect (d) was found in the cross GW 1225/ Sarangpur local (2.41**). Dominant gene effect (h) was found significant and positive in crosses viz., HD 4672/ MACS 1967 (8.79**), GW 1225/ Sarangpur local (17.12**), HI 8550/ A 9-30-1 (6.65**), HI 8550/ MACS 1967 (5.69**) and MACS 9/ MACS 1967 (4.33*). Significant negative additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (-5.60**), MACS 9/ MACS 1967 (-8.08**) and HI 8627/ Sarangpur local (-4.68**). Significant negative dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (-10.00**), GW 1225/ Sarangpur local (-18.90**), HI 8550/ A 9-30-1 (-12.61**) and HI 8550/ MACS 1967 (-21.11**).

**Sedimentation value (ml)**: Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-3.50**) and HI 8627/ Sarangpur local (-2.50*). Dominant gene effect (h) was found significant and positive in crosses viz., HI 8550/ A 9-30-1 (13.25**) and HI 8627/ Sarangpur local (9.95**). Significant positive additive x additive (i) effect was found in crosses viz., HD 4672/ MACS 1967 (7.79**), HI 8550/ A 9-30-1 (13.60**) and HI 8627/ Sarangpur local (12.60**). Significant positive additive x dominance (j) effect was found in the cross GW 1225/ Sarangpur local (3.20**). Significant negative dominance x dominance effect (l)
was found in crosses viz., HD 4672/ MACS 1967 (-19.19**), HI 8550/ A 9-30-1 (-24.70**) and HI 8627/ Sarangpur local (-23.10**).

**Carotene content (ppm):** Dominant gene effect (h) was found significant and positive in cross viz., HI 8550/ A 9-30-1 (4.19**), and significant positive additive x additive (i) effect was found in cross viz., HI 8550/ A 9-30-1 (2.83**). Significant negative dominance x dominance effect (l) was found in cross viz., HI 8550/ A 9-30-1 (-3.27**).

**Protein content (%)**: Significant negative additive effect (d) was found in the cross viz., HI 8550/ MACS 1967 (-1.25**). Dominant gene effect (h) was found significant and positive in cross viz., HI 8550/ A 9-30-1 (4.38**); and significant negative in crosses viz., HD 4672/ MACS 1967 (-9.49**); and HI 8550/ MACS 1967 (-3.12**). Significant positive additive x additive (i) effect was found in cross viz., HI 8550/ A 9-30-1 (2.76*); and significant and negative in cross viz., HI 8550/ MACS 1967 (-4.25**). Significant negative additive x dominance (j) effect was found in the cross viz., HI 8550/ MACS 1967 (-0.59**). Significant positive dominance x dominance effect (l) was found in cross HI 8550/ MACS 1967 (6.58**); and significant and negative in cross viz., HI 8550/ A 9-30-1 (-9.08**).

**Phosphorus content (g)**: Significant negative additive effect (d) was found in the cross viz., HI 8627/ Sarangpur local (-1.12**). Significant negative additive x dominance (j) effect was found in the cross viz., HI 8627/ Sarangpur local (-1.45**).

**Potassium content (g)**: Significant negative additive effect (d) was found in the cross viz., MACS 9/ MACS 1967 (-1.45*). Dominant gene effect (h) was found significant and positive in crosses viz., GW 1225/ Sarangpur local (3.73*) and MACS 9/ MACS 1967 (5.71**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-15.64**) and HI 8550/ MACS 1967 (-7.36**). Significant positive additive x additive (i) effect was found in crosses viz., GW 1225/ Sarangpur local (3.95*) and MACS 9/ MACS 1967 (5.14**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-16.06**) and HI 8550/ MACS 1967 (-9.33**). Significant positive dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (15.44**) and HI 8550/ MACS 1967 (16.55**); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-7.18**) and MACS 9/ MACS 1967 (-13.20**).
Phytic acid content (g): Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-2.61**), HI 8550/ A 9-30-1 (-4.41**) and HI 8627/ Sarangpur local (-1.71*). Dominant gene effect (h) was found significant and positive in cross viz., HD 4672/ MACS 1967 (18.33**); and significant and negative in crosses viz., HI 8550/ MACS 1967 (-19.50**) and MACS 9/ MACS 1967 (-6.17**). Significant positive additive x additive (i) effect was found in cross viz., HD 4672/ MACS 1967 (15.18**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-11.50**), HI 8550/ MACS 1967 (-24.70**) and MACS 9/ MACS 1967 (-8.79**). Significant negative additive x dominance (j) effect was found in the crosses viz., HD 4672/ MACS 1967 (-1.85*), GW 1225/ Sarangpur local (-3.24**) and HI 8550/ A 9-30-1 (-4.79**). Significant positive dominance x dominance effect (l) was found in crosses viz., HI 8550/ A 9-30-1 (22.80**) and HI 8550/ MACS 1967 (50.81**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-18.01**), GW 1225/ Sarangpur local (-12.78**) and MACS 9/ MACS 1967 (-34.60**).

Grain yield/plant (g): Significant negative additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (-5.28**), HI 8550/ A 9-30-1 (-3.96**) and MACS 9/ MACS 1967 (-1.88*). Dominant gene effect (h) was found significant and negative in crosses viz., HD 4672/ MACS 1967 (-11.67**), HI 8550/ A 9-30-1 (-4.99**), HI 8550/ MACS 1967 (-10.90**) and HI 8627/ Sarangpur local (-11.50**). Significant negative additive x additive (i) effect was found in crosses viz., HD 4672/ MACS 1967 (-12.56**), HI 8550/ A 9-30-1 (-3.28*), HI 8550/ MACS 1967 (-12.60**) and HI 8627/ Sarangpur local (-12.00**). Significant positive additive x dominance (j) effect was found in the cross viz., HD 4672/ MACS 1967 (1.78*); and significant and negative in crosses viz., GW 1225/ Sarangpur local (-6.76**), HI 8550/ A 9-30-1 (-5.47**) and HI 8550/ MACS 1967 (-1.62*). Significant positive dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (10.42**), HI 8550/ MACS 1967 (17.00**) and HI 8627/ Sarangpur local (6.89*); and significant and negative in cross viz., GW 1225/ Sarangpur local.

Canopy temperature I (vegetative stage) (°C): Dominant gene effect (h) was found significant and negative in cross viz., MACS 9/MACS 1967 (-4.75**), while, significant negative additive x additive (i) effect was found in cross viz., MACS 9/MACS 1967 (-4.75**). Significant positive additive x dominance (j) effect was found in the cross viz., MACS 9/MACS 1967 (1.38*) and
significant positive dominance x dominance effect (l) was found in cross \textit{viz.}, MACS 9/MACS 1967 (10.94**).

**Canopy temperature II (flowering stage) (**C):** Significant positive additive effect (d) was found in the cross \textit{viz.}, HD 4672/ MACS 1967 (1.24*); and significant and negative in cross \textit{viz.}, HI 8550/ MACS 1967 (-2.31**). Dominant gene effect (h) was found significant and negative in crosses \textit{viz.}, HI 8550/ A 9-30-1 (-1.77**) and MACS 9/ MACS 1967 (-4.96**). Significant positive additive x additive (i) effect was found in cross \textit{viz.}, HD 4672/ MACS 1967 (3.99**); and significant and negative in cross \textit{viz.}, MACS 9/ MACS 1967 (-4.76**). Significant positive dominance x dominance effect (l) was found in crosses \textit{viz.}, HI 8550/ A 9-30-1 (4.74*) and MACS 9/ MACS 1967 (13.45**).

**Canopy temperature III (grain filling) (**C):** Dominant gene effect (h) was found significant and negative in cross namely MACS 9/ MACS 1967 (-5.81*). Significant negative additive x additive (i) effect was found in cross namely MACS 9/ MACS 1967 (-5.64**). Significant positive dominance x dominance effect (l) was found in cross namely MACS 9/ MACS 1967 (15.15**).

**Chlorophyll content I (vegetative stage) (**):** Significant positive additive effect (d) was found in the crosses \textit{viz.}, GW 1225/ Sarangpur local (7.54**) and HI 8550/ A 9-30-1 (4.99**); and significant and negative in crosses \textit{viz.}, HD 4672/ MACS 1967 (-7.00**) and HI 8627/ Sarangpur local (-2.69**). Dominant gene effect (h) was found significant and positive in crosses \textit{viz.}, HD 4672/ MACS 1967 (12.19**) and HI 8550/ A 9-30-1 (29.23**); and significant and negative in cross namely MACS 9/ MACS 1967 (-21.80**). Significant positive additive x additive (i) effect was found in crosses \textit{viz.}, HD 4672/ MACS 1967 (7.02**), HI 8550/ A 9-30-1 (28.80**) and HI 8627/ Sarangpur local (6.00**); and significant and negative in cross namely MACS 9/ MACS 1967 (-17.00**). Significant positive additive x dominance (j) effect was found in the crosses \textit{viz.}, GW 1225/Sarangpur local (9.07**), HI 8550/ A 9-30-1 (1.98*) and HI 8550/ MACS 1967 (4.30**); and significant and negative in crosses \textit{viz.}, HD 4672/ MACS 1967 (-7.82**) and HI 8627/ Sarangpur local (-2.56**). Significant positive dominance x dominance effect (l) was found in crosses \textit{viz.}, HD 4672/ MACS 1967 (11.06**), GW 1225/ Sarangpur local (12.10**) and MACS 9/ MACS 1967 (22.17**); and significant and negative in crosses \textit{viz.}, HI 8550/ MACS 1967 (-13.10**) and HI 8627/ Sarangpur local (-22.90**).
Chlorophyll content II (flowering stage) (%): Significant positive additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (4.23**) and HI 8550/ MACS 1967 (3.25**); and significant and negative in cross namely HD 4672/ MACS 1967 (-4.00**). Dominant gene effect (h) was found significant and positive in crosses viz., HD 4672/ MACS 1967 (8.49**), HI 8550/ A 9-30-1 (20.03**) and HI 8550/ MACS 1967 (4.47**); and significant and negative in crosses viz., MACS 9/ MACS 1967 (-22.30**) and HI 8627/ Sarangpur local (-3.79**). Significant positive additive x additive (i) effect was found in crosses viz., HI 8550/ A 9-30-1 (28.00**) and HI 8627/ Sarangpur local (5.12**); and significant and negative in cross namely MACS 9/ MACS 1967 (-9.24**). Significant positive additive x dominance (j) effect was found in the crosses viz., GW 1225/ Sarangpur local (9.27**) and HI 8550/ MACS 1967 (3.80**); and significant and negative in cross namely HD 4672/ MACS 1967 (1.92**). Significant positive dominance x dominance effect (l) was found in crosses viz., HD 4672/ MACS 1967 (11.26**), GW 1225/ Sarangpur local (12.09**) and MACS 9/ MACS 1967 (23.18**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-40.30**), HI 8550/ MACS 1967 (-12.50**) and HI 8627/ Sarangpur local (-21.20**).

Chlorophyll content III (grain filling stage) (%): Significant positive additive effect (d) was found in the crosses viz., GW 1225/ Sarangpur local (7.55**), HI 8550/ A 9-30-1 (1.22*) and HI 8550/ MACS 1967 (4.12*); and significant and negative in cross namely HI 8627/ Sarangpur local (-2.70**). Dominant gene effect (h) was found significant and positive in crosses viz., GW 1225/ Sarangpur local (4.68*), HI 8550/ A 9-30-1 (28.93**) and HI 8550/ MACS 1967 (4.22**); and significant and negative in cross namely MACS 9/ MACS 1967 (-21.10**). Significant positive additive x additive (i) effect was found in crosses viz., HD 4672/ MACS 1967 (4.32*), HI 8550/ A 9-30-1 (21.80**) and HI 8627/ Sarangpur local (5.99**); and significant and negative in cross namely MACS 9/ MACS 1967 (-6.24**). Significant positive additive x dominance (j) effect was found in the crosses viz., GW 1225/ Sarangpur local (8.52**), HI 8550/ A 9-30-1 (2.28**) and HI 8550/ MACS 1967 (3.95**); and significant and negative in crosses viz., HD 4672/ MACS 1967 (-9.23**) and HI 8627/ Sarangpur local (-3.47**). Significant positive dominance x dominance effect (l) was found in crosses viz., GW 1225/ Sarangpur local (10.61**) and MACS 9/ MACS 1967 (20.58**); and significant and negative in crosses viz., HI 8550/ A 9-30-1 (-50.05**), HI 8550/ MACS 1967 (-11.97**) and HI 8627/ Sarangpur local (-24.67**).