Parents’ Performance and F1 Crosses For Several Bread Wheat Cultivars Under Varying Levels of Nitrogen Fertilization

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Abstract. Six bread wheat varieties representing different traits were crossed in a half-diallel in 2017/2018 season. The 6 parents and its 15 F1 crosses were evaluated under normal and N-stress conditions in 2018/2019 season, to study the mean performance and the combining ability for earliness and morpho-physiological traits and biomass yield of wheat under normal and N-stress conditions.

Mean squares of genotypes, parents, crosses, and parents versus crosses were significant or highly significant for most of the studied traits and biological yield under both conditions, reflecting a sort of heterosis for these characters. Mean squares of GCA and SCA were significant or highly significant for most of the studied traits under both conditions, indicating the presence of both additive and non-additive types of genes in the genetic system controlling these traits. The best general combiners were P1 (Giza 168) and P2 (Sakha 94) at both conditions, P3 (Shandweel 1) at N-stress, and P4 (Gemmeiza 11) at normal condition for earliness and P6 (Mirs 1) at both conditions and P5 (Sids 12) at N-stress and P3 (Shandweel 1) at normal condition for biomass yield plant−1. The best cross combinations were crosses No.3 (P1xP4), No.5 (P1xP6), No.6 (P2xP3), No.7 (P1xP2), No.8 (P2xP5) and No.11 (P3xP5) under N-stress for earliness; and crosses No.3 (P1xP4), No.7 (P2xP4), No.8 (P2xP5), No.12 (P3xP6), No.14 (P4xP6) and No.15 (P5xP6) at both conditions, and cross No.2 (P1xP3) under N-stress for biomass yield plant−1.

1. Introduction
Wheat (*Triticum aestivum* L.) is one of the most important nutritional cereal crops in Egypt and all over the world. Wheat is the stable food crop of the urban areas; moreover, it is used widely in blending with maize flour in rural areas to make bread, macaroni, biscuit and sweets. It is also worth mentioning that wheat straw is a source of fodder for animals. It cultivated over a wide area all over the world; its cultivated area was 214 million hectares and produced about 734.05 million metric tons [1]. While, in Egypt, the total cultivated area of wheat reached about 3.17 million feddan and produced 8.5 million metric tons with an average of 17.88 ardah/feddan [2].

Thousands of modern wheat cultivars with high-yielding potential, highly responsive to nutrients, especially N, have been released for use in both favorable and marginal environments since the “Green Revolution” era in 1960s. It is generally thought that these modern high-yielding cultivars demand high N level to maximize their yield [3] and [4]. However, it would be economically and environmentally beneficial to have high-yielding genotype that could attain maximum yield at low N input especially in the light of global climate changes [5]. It has been reported that some modern cultivars out yielded both old tall and earlier semi dwarf cultivars at all nitrogen levels [6 and 7]. Plant growth is most critically limited by N due to its low availability in soil. Some important building blocks of life like nucleotide, cofactors, signaling molecules and protein contain nitrogen as their primary constituent. Therefore, quantitatively N is the most important nutrient and limiting factor for growth and development of plants [8]. Crop yield gets seriously affected by insufficient Nitrogen, but excess of it not significantly contributes to yield but cause N pollution...
by means of leaching, surface runoff, denitrification, and emission of greenhouse gases [9]. Intake of nitrate-contaminated water causes health hazard [10]. Increased cost of food production and the eutrophication of many natural aquatic and terrestrial ecosystems [11] is also the results of low recovery rate and high loss of fertilizer N.

Therefore, the objectives of this study were to determine the superior parents and cross combinations from a 6 X 6 diallel cross of bread wheat parental genotypes grown under normal and nitrogen-stress conditions and to estimate the combining ability and the mode of gene action in the inheritance of the studied traits under normal and nitrogen-stress conditions.

2. Materials and Methods

2.1. Materials

The genetic materials used in this investigation as parents included six bread wheat varieties (Triticum aestivum L.), representing a wide range of diversity for several agronomic characters. The names and pedigree of these parental genotypes are presented in Table 1.

Table 1. Parents names and pedigree of the parental genotypes

| No | Variety     | Pedigree          |
|----|-------------|-------------------|
| P1 | Giza 168    | MRL/BUE/SERI CM93046-8M-0Y-0M-2Y-0B |
| P2 | Sakha 94    | Opata / Rayon // Kauz |
| P3 | Shandweel 1 | SITE/MO4/NAC/THAC/3*PVN/3/MIRLO/BUC. |
| P4 | Gemmeiza 11 | BOW’S/KVZ’S’/7C/1SER182/3/GIZA168/SAKHA 61 |
| P5 | Sids 12     | BUC/7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLI/SCHAT’S’/6/MAYA/VU |
| P6 | Misr 1      | OASIS / SKAUZ // 4*BCN /3/ 2*PASTOR CMSS00Y01881T-050M-030Y- |

2.2. Methods

In 2017/2018 season, the parental varieties were sown at three various dates in order to overcome the differences in flowering time. All possible parental combinations excluding reciprocals were made among the six varieties, giving 15 F1 crosses. In 2018/2019 season, the twenty-one entries (6 parents and their 15 F1) were evaluated in two separate nitrogen fertilization regimes experiments. The first experiment (normal condition) was fertilized with 80 kg N/fed. The second experiment (N-stress condition) was fertilized with 40 kg N/fed. Each of the two experiments were fertilized with 15 kg P2O5/fad, in one dose during soil preparing. The nitrogen fertilizer in the form of ammonium nitrate (33.5% N) with the previous rates were added in two equal doses. The first dose was 30% with sowing and the second dose was 70% with the first irrigation. The two experiments were designed in a randomized complete block design (RCBD) with three replications in the Experimental Farm of Agronomy Department, Faculty of Agriculture, Mansoura University, Dakahlia Governorate, Egypt.

Each replicate consisted of 21 genotypes as well as two borders, each genotype was planted in one row, 4 m long and 25 cm apart with 20 cm between plants. Twenty grains were manually drilled in the rows on 10 November 2018, in each row. All other agricultural practices, except N-fertilization, were applied as recommended for wheat cultivation. The two outside plants from each row and the two external rows of each plot were excluded to avoid the border effect.

Data of the following characters were recorded for ten guarded plants chosen randomly per row in each replicate, except flag leaf area and total chlorophyll content which were recorded for five guarded plants for the two experiments. Earliness and morpho-physiological characters were recorded i.e. days to heading, number of tillers/ plant, plant height (cm), total chlorophyll content [chlorophyll meter (SPAD-502, Soil-Plant Analysis Development (SPAD) Section, Minolta Camera, Osaka, Japan) was used to measure flag leaf greenness in SPAD values according to [12], these values have been found to be linearly related to chlorophyll concentration in several situations [13], flag leaf area (cm²) according to [14], and biological yield plant¹ (g).

2.3. Statistical Analyses

The data were analyzed on plot mean basis. All obtained data were subjected to the statistical analysis of the randomized complete block design to test the differences among various genotypes under each nitrogen
regimes according to [15]. Treatments were compared using the least difference values (LSD) at 5% and 1% level of probability according to [16].

The data were analyzed using [17] method 2 model 1 to estimate general combining ability (GCA) and specific combining ability (SCA) effects. The parents were considered fixed. The relative importance of GCA to SCA were expressed as follows:

$$K^2_{GCA} / K^2_{SCA} = \frac{\text{Ms GCA} - \text{Ms e}}{(p+2)} / \frac{\text{Ms SCA} - \text{Ms e}}{(p+2)}$$

Where:

- Ms = mean squares,
- P = No. of parents, and
- $K^2$ is the average squares of the effects.

The analysis of variance for each trait is presented in Table 2.

### Table 2. Analysis of variance from method 2 model 1 and the expectation of mean square

| Source of variance | D.F | SS     | EMS     |
|--------------------|-----|--------|---------|
| General combining ability | P-1 | Sg Mg  | $\sigma^2 e + (P+2)(1/P-1)\sum g^2_i$ |
| Specific combining ability | P(P-1)/2 | Ss Ms  | $\sigma^2 e + 2/P(1-P)\sum \sum s^2_{ij}$ |
| Error              | (r-1)(c-1) | Se Me  | $\sigma^2 e$ |

Where: Me = The error mean squares of the main randomized complete block design divided by number of replications (Me = Me/r), and P = number of parents

3. Results and Discussion

Analysis of variance for flowering and vegetative traits are presented in Table 3. The results indicated clearly that mean squares of genotypes, parents, crosses and parents versus crosses were significant or highly significant for all studied earliness, morpho-physiological traits and biological yield under both normal and N-stress conditions, except each of; crosses for tillers no./plant at normal condition, parents for chlorophyll content under normal condition and flag leaf area under both conditions, and parents versus crosses for chlorophyll content under both conditions, reflecting a sort of heterosis for these characters. These results are confirmed by those obtained by [18 and 19], who revealed significant differences exist between various genotypes, parents, hybrids and parents versus hybrids for days to heading and days to maturity at normal and stress conditions. [20] show that mean squares of genotypes, parents, hybrids had highly significant for earliness components, except days to maturity and grain filling rate at normal condition.

### Table 3. Mean squares of wheat genotypes, parents, crosses and parents versus crosses for all earliness and morpho-physiological traits and biomass yield under normal and nitrogen stress conditions

| S. V. | D.F | Heading date (day) | Tillers number/ plant | Plant height (cm) |
|-------|-----|--------------------|-----------------------|-------------------|
|       |     | Normal             | N-Stress              | Normal            | N-Stress          |
| Genotypes | 20  | 75.62**            | 72.79**               | 6.55**            | 4.72**            | 79.56**           | 102.30**          |
| Parents    | 5   | 12.22**            | 16.46**               | 13.39**           | 8.93**            | 95.30**           | 150.77**          |
| Crosses     | 14  | 75.77**            | 90.02**               | 3.87              | 2.78*             | 64.36**           | 75.14**           |
| P. V Cross  | 1   | 390.50**           | 113.16**              | 9.91*             | 10.67**           | 213.79**          | 240.19**          |
| Error       | 40  | 0.54               | 0.53                  | 2.10              | 1.36              | 9.57              | 12.64             |

| S. V. | D.F | Chlorophyll content | Flag leaf area (cm²) | Biomass yield/plant (g) |
|-------|-----|---------------------|----------------------|------------------------|
|       |     | Normal              | N-Stress             | Normal                | N-Stress         |
| Genotypes | 20  | 12.03*              | 14.67**              | 99.81**               | 82.79*           | 3308.07**         | 1566.47**         |
| Parents    | 5   | 7.24                | 15.51**              | 30.18                 | 43.67            | 1124.30**         | 1836.42**         |
| Crosses     | 14  | 14.57*              | 15.42**              | 45.99*                | 92.64*           | 3231.25**         | 1118.49**         |
| P. V Cross  | 1   | 0.49                | 0.02                 | 1201.56**             | 140.53           | 15302.43**        | 6488.50**         |
| Error       | 40  | 5.92                | 4.40                 | 23.47                 | 39.97            | 371.31            | 163.10            |

*, ** significant at 0.05 and 0.01 level of probability, respectively.

3.1. Mean Performance of Parents and its F1 Crosses

For days to heading, the nitrogen stress treatment decreased the mean of days to heading for parents and their hybrids (Table 4). The parental P5 (Sids 12) under normal, P1 (Giza 168) under stress, and crosses; No.10(P3 x P4) under normal and crosses No. 7 (P2 x P4), No.8 (P2 x P5) under stress were the earliest parents and crosses for days to heading. Regarding to tillers number per plant, the nitrogen stress treatment decreased the mean of tillers number per plant for parents and their hybrids (Table 4). The parental P6 (Misr 1), cross No. 11
(P3 x P5) under normal, and the parental P5 (Sids 12) and crosses No. 7 (P2 X P4) and No. 9 (P2 X P6) under stress were the best genotypes for tillers number per plant. With respect to plant height, nitrogen stress treatment decreased the means of plant height for parents and their hybrids (Table 4). The results indicated highly significant different among genotypes. Among parents, the tallest parents were P5 (Sids 12) and P1 (Giza 168) under normal and N-stress conditions, respectively. Among crosses, the tallest plants were cross No. 1 (P1 x P2) under both conditions. As illustrated in Figure 3.

Table 4. Means of heading date (day), tillers No./p and plant height (cm), for wheat genotypes under normal and stress nitrogen conditions

| Genotypes   | Heading date (day) | Tillers No./ Plant | Plant height (cm) |
|-------------|-------------------|--------------------|------------------|
|             | Normal            | N-Stress           | Normal           | N-Stress         |
| Parents     |                   |                    |                  |
| P1-Giza 168 | 87.00             | 83.33              | 13.33            | 10.67            | 109.33          | 96.33           |
| P2-Sakha 94 | 85.67             | 85.00              | 10.67            | 8.00             | 116.33          | 110.00          |
| P3-Shandweel | 89.33             | 84.67              | 12.67            | 10.33            | 115.33          | 111.67          |
| P4-Gemmiza 11 | 84.67            | 89.00              | 12.00            | 10.00            | 107.00          | 102.00          |
| P5-Sids 12  | 84.33             | 88.33              | 15.33            | 13.00            | 121.00          | 112.67          |
| P6-Misr 1   | 88.33             | 88.00              | 16.33            | 12.00            | 120.00          | 114.33          |
| Means       | 86.56             | 86.39              | 13.39            | 10.67            | 114.83          | 107.83          |
| LSD 5%      | 0.38              | 0.38               | 0.76             | 0.61             | 1.61            | 1.86            |
| LSD 1%      | 0.51              | 0.51               | 1.01             | 0.81             | 2.16            | 2.48            |
| Crosses     |                   |                    |                  |
| 1-P1XP2     | 85.67             | 86.00              | 13.67            | 11.33            | 107.00          | 99.67           |
| 2-P1XP3     | 88.33             | 88.00              | 13.67            | 11.33            | 115.33          | 106.33          |
| 3-P1XP4     | 88.00             | 85.00              | 14.67            | 10.67            | 115.33          | 109.00          |
| 4-P1XP5     | 94.00             | 88.00              | 16.00            | 11.00            | 121.00          | 116.00          |
| 5-P1XP6     | 96.67             | 88.00              | 14.67            | 11.33            | 125.00          | 115.00          |
| 6-P2XP3     | 89.33             | 85.00              | 13.00            | 11.67            | 117.67          | 112.33          |
| 7-P2XP4     | 89.00             | 83.33              | 14.33            | 13.33            | 112.67          | 105.00          |
| 8-P2XP5     | 96.67             | 83.33              | 13.67            | 10.33            | 122.67          | 115.33          |
| 9-P2XP6     | 94.00             | 98.00              | 13.00            | 13.33            | 119.33          | 112.67          |
| 10-P3XP4    | 84.33             | 88.00              | 14.67            | 12.67            | 121.33          | 115.67          |
| 11-P3XP5    | 96.67             | 84.67              | 16.67            | 11.33            | 122.00          | 117.00          |
| 12-P3XP6    | 99.00             | 98.00              | 13.00            | 10.67            | 120.33          | 114.33          |
| 13-P4XP5    | 97.00             | 99.00              | 15.33            | 11.00            | 120.33          | 112.67          |
| 14-P4XP6    | 96.67             | 93.00              | 14.67            | 12.67            | 122.00          | 115.00          |
| 15-P5XP6    | 85.67             | 93.00              | 13.00            | 11.00            | 121.67          | 116.33          |
| Means       | 92.07             | 89.36              | 14.27            | 11.58            | 118.91          | 112.16          |
| LSD 5%      | 0.54              | 0.54               | 1.07             | 0.86             | 2.28            | 2.62            |
| LSD 1%      | 0.73              | 0.72               | 1.43             | 1.15             | 3.05            | 3.51            |

Results presented in Table 5 indicate clearly the total chlorophyll content means were decreased as affected by nitrogen stress. The results indicated highly significant different between genotypes. P3 (Shandweel 1) under normal and cross No. 4 (P1 x P5) under both conditions were the highest parent and cross in chlorophyll content, as shown in Figure 1. The flag leaf area means were decreased as affected by nitrogen stress (Table 5). P1 (Giza 168) and cross No.11 (P3 x P5) under normal and P5 (Sids 12) and cross No. 3 (P1 x P4) under N-stress were the highest parents and crosses for flag leaf area, as shown in Table 5 and Figure 2. It is clear from the data in Table 5 that, nitrogen stress condition decreased the means of biomass yield /plant for the parents and its crosses. With regard to parents, the highest biomass yield /plant was belonged to P5 (Sids 12) under both conditions. While, P4 (Gemmiza 11), under normal and P2 (Sakha 94) under N- stress, produced the lowest biomass yield /plant. These results indicated the different genetic background of the parents. Among crosses, cross No. 12(P3 x P6) showed the highest biomass yield plant \(^1\) under both conditions. While, the lowest biomass yield plant \(^1\) belonged to cross No. 1(P1 x P2) under both conditions, as illustrated in Figure 3.
Figure 1. Chlorophyll content in flag leaf (SPAD) as affected by the interaction between nitrogen fertilization treatments and wheat genotypes (parents and its crosses).

Figure 2. Flag leaf area (cm²) as affected by the interaction between nitrogen fertilization treatments and wheat genotypes (parents and its crosses).
Table 5. Means of chlorophyll content, flag leaf area (cm²) and biomass yield plant⁻¹ (g) for wheat genotypes under normal and nitrogen stress conditions

| Genotypes       | Chlorophyll content | Flag leaf area (cm²) | Biomass yield plant⁻¹ (g) |
|-----------------|---------------------|---------------------|---------------------------|
|                 | Normal | N-Stress | Normal | N-Stress | Normal | N-Stress |
| Parents         |        |          |        |          |        |          |
| P1-Giza 168     | 27.17  | 23.60    | 68.41  | 59.23    | 219.98 | 205.00   |
| P2-Sakha 94     | 24.37  | 22.13    | 58.58  | 54.16    | 202.00 | 175.67   |
| P3              | 27.40  | 22.00    | 63.97  | 59.10    | 231.53 | 195.35   |
| P4-Gemmiza      | 25.30  | 18.73    | 62.89  | 59.44    | 239.48 | 234.96   |
| P5-Sids 12      | 26.33  | 24.27    | 62.25  | 56.72    | 238.00 | 219.11   |
| P6-Misr 1       | 23.53  | 19.13    | 63.14  | 56.72    | 220.70 | 199.11   |
| Means           | 25.68  | 21.64    | 63.14  | 56.72    | 220.70 | 199.11   |
| LSD 5%          | 1.27   | 1.09     | 2.53   | 3.30     | 10.06  | 6.66     |
| LSD 1%          | 1.70   | 1.46     | 3.38   | 4.41     | 13.46  | 8.92     |
| Crosses         |        |          |        |          |        |          |
| 1- P1XP2        | 28.13  | 22.93    | 70.41  | 60.18    | 199.69 | 183.24   |
| 2- P1XP3        | 27.50  | 23.87    | 70.50  | 65.99    | 267.00 | 241.00   |
| 3- P1XP4        | 26.37  | 20.73    | 70.90  | 66.27    | 277.00 | 237.33   |
| 4- P1XP5        | 30.27  | 24.47    | 79.22  | 61.92    | 254.43 | 237.37   |
| 5- P1XP6        | 24.97  | 22.97    | 71.25  | 60.52    | 264.67 | 222.62   |
| 6- P2XP3        | 24.83  | 21.00    | 73.49  | 66.23    | 240.05 | 211.93   |
| 7- P2XP4        | 26.60  | 21.13    | 68.95  | 58.57    | 240.34 | 211.47   |
| 8- P2XP5        | 25.40  | 23.67    | 76.12  | 65.63    | 274.33 | 232.67   |
| 9- P2XP6        | 23.23  | 19.20    | 67.69  | 52.96    | 216.44 | 198.67   |
| 10- P3XP4       | 29.00  | 23.43    | 72.11  | 64.54    | 270.25 | 216.22   |
| 11- P3XP5       | 26.00  | 24.37    | 80.33  | 62.18    | 224.23 | 202.11   |
| 12- P3XP6       | 24.53  | 20.30    | 73.50  | 52.33    | 326.43 | 250.00   |
| 13- P4XP5       | 24.90  | 21.40    | 73.75  | 53.10    | 215.70 | 204.03   |
| 14- P4XP6       | 24.70  | 19.30    | 76.65  | 59.98    | 273.96 | 237.67   |
| 15- P5XP6       | 21.73  | 16.53    | 67.27  | 50.04    | 283.52 | 237.33   |
| Means           | 25.88  | 21.69    | 72.81  | 60.03    | 255.20 | 221.58   |
| LSD 5%          | 1.80   | 1.55     | 3.58   | 4.67     | 14.22  | 9.42     |
| LSD 1%          | 2.40   | 2.07     | 4.78   | 6.24     | 19.03  | 12.61    |

Figure 3. Biomass yield plant⁻¹ (g) as affected by the interaction between nitrogen fertilization treatments and wheat genotypes (parents and its crosses)
3.2. Yield Reduction Percentage and Susceptibility Index for N-Stress

A susceptibility index (SI) which provides a measure of stress resistance based on minimization of yield loss under stress as compared to optimum condition, rather than on yield level under stress, has been used to characterize relative stress tolerance of wheat genotypes [21]. This index was used to estimate relative stress injury because it accounted for variation in yield potential and stress intensity. Low stress susceptibility index (SI <1) mean higher stress tolerance, while high stress susceptibility index (SI >1) mean higher stress sensitivity. Also, the wheat genotypes that had the lowest values of yield reduction percentage and susceptibility index, indicating the tolerant wheat genotypes for stress.

Results in Table 6 clearly show values of yield reduction percentages (YR%) and means of susceptibility index for the studied parents and their F1 crosses. The results indicated that the lowest values of yield reduction% and susceptibility index (SI < 1) for parents were recorded by P5-Sids 12 (1.89 % and 0.15) and P1-Giza 168 (6.81 % and 0.55), followed by P6-Misr 1 (9.66 % and 0.79), indicating that the parents (P5-Sids 12 and P1-Giza 168) were higher tolerant to N-stress condition, and P6-Misr 1 was moderate tolerant to N-stress.

For crosses, the lowest values of yield reduction% and susceptibility index (SI < 1) were recorded by crosses No.13- P4XP5 (5.41 % and 0.44), 4- P1XP5 (6.71 % and 0.54), 9- P2XP6 (8.21 % and 0.67) and 1- P1XP2 (8.24 % and 0.67), indicating that these crosses were high to moderate tolerant to N-stress. While, the crosses No.; 2-1XP3 (9.74 % and 0.79), 11-3XP5 (9.86 % and 0.80), 6-2XP3 (11.71% and 0.95) and 7- P2XP4 (12.01 % and 0.98) were low tolerant to N-stress, where they recorded moderate values of yield reduction percentage and susceptibility index. However, the rest parents and crosses (P2-Sakha 94, P3-Shandweel 1, P4-Gemmiza 11, P5-Sids 12, P1-P2XP5, P2-XP5, P1- P2XP6, 10- P3XP4, 12- P3XP6, 14- P4XP6 and 15- P5XP6) are considered higher sensitive genotypes to N-stress condition, as they recorded the highest values of yield reduction percentage (more than 12.01 %) and susceptibility index (SI >1), as shown in Table 6, and Figure 4.

Table 6. Values of yield reduction percentages and stress susceptibility index for biomass yield of wheat genotypes

| Genotypes       | Yield reduction % | SI | Ranking |
|-----------------|------------------|----|---------|
| P1-Giza 168     | 6.81             | 0.55 | 4       |
| P2-Sakha 94     | 13.03            | 1.06 |         |
| P3-Shandweel 1  | 15.63            | 1.27 |         |
| P4-Gemmiza 11   | 12.69            | 1.03 |         |
| P5-Sids 12      | 1.89             | 0.15 | 1       |
| P6-Misr 1       | 9.66             | 0.79 | 8       |
| Crosses         |                   |     |         |
| 1-P1XP2         | 8.24             | 0.67 | 5       |
| 2- P1XP3        | 9.74             | 0.79 | 7       |
| 3- P1XP4        | 14.32            | 1.16 |         |
| 4- P1XP5        | 6.71             | 0.54 | 3       |
| 5- P1XP6        | 15.89            | 1.29 |         |
| 6- P2XP3        | 11.71            | 0.95 | 10      |
| 7- P2XP4        | 12.01            | 0.98 | 11      |
| 8- P2XP5        | 15.19            | 1.23 |         |
| 9- P2XP6        | 8.21             | 0.67 | 6       |
| 10- P3XP4       | 19.99            | 1.62 |         |
| 11- P3XP5       | 9.86             | 0.80 | 9       |
| 12- P3XP6       | 23.41            | 1.90 |         |
3.3. Analysis of Variance for Combining Ability

Mean squares of GCA and SCA were significant or highly significant for all the studied earliness and morpho-physiological traits and biomass yield, except GCA for flag leaf area under both conditions and SCA for tillers number/plant, chlorophyll content under both conditions, and for flag leaf area under N-stress condition. The significance of GCA and SCA indicate the presence of both additive and non-additive types of genes in the genetic system controlling these traits. The obtained results revealed that the ratios of GCA/SCA were less than unity for all earliness and morpho-physiological and biomass yield plant$^{-1}$ traits (Table 7), this means that these traits are predominantly controlled by non-additive gene action. It therefore could be concluded that selection procedures based on the accumulation of additive effect would be more effective in the lately segregated generations. These results are in accordance with those of [22, 23, 24, 25, 26, 27, 28 and 29] who reported that the magnitude of dominance variance in F$_2$’s for all studied traits was much greater than that of additive variance under both high N and low N, suggesting that selection should be postponed to later segregating generations in order to eliminate masking effects of dominance variance and take advantage of the additive variance for the improvement of nitrogen use efficiency and grain yield traits.

| S. V. | D.F | Heading date | Tillers number/ plant | Plant height |
|------|-----|--------------|-----------------------|--------------|
| GCA  | 5   | 11.29**      | 3.71**                | 55.28**      |
| SCA  | 15  | 29.84**      | 1.67                  | 16.93**      |
| Error| 40  | 0.18         | 0.70                  | 3.19         |
| GCA/SCA | - | 0.43         | 0.82                  | 0.87         |

Table 7. Mean squares of general (GCA) and (SCA) combining abilities, and GCA/SCA ratio for all the flowering and morpho-physiological, yield and its components traits under normal and nitrogen stress conditions.

| S. V. | D.F | Chlorophyll content | Flag leaf area | Biomass yield plant$^{-1}$ |
|------|-----|---------------------|----------------|-----------------------------|
| GCA  | 5   | Normal              | Normal         | Normal                      |
| SCA  | 15  | Normal              | Normal         | Normal                      |
| Error| 40  | Normal              | Normal         | Normal                      |

Figure 4. Yield reduction percentage (YR%) for wheat genotypes (parents and its crosses) as affected by N-stress condition.
3.3.1. General Combining Ability (GCA) Effects

Based on general combining ability estimates (Table 8), it could be concluded that the best general combiners were; P1 (Giza 168) and P2 (Sakha 94) at both conditions, P3 (Shandweel 1) at N-stress condition, and P4 (Gemmeiza 11) at normal condition for days to heading; P5 (Sides 12) at both conditions for tillers no./ plant; P1 (Giza 168), P2 (Sakha 94) and P4 (Gemmeiza 11) at both conditions for plant height (shortness); P1 (Giza 168) at both conditions and P5 (Sides 12) at N-stress condition for chlorophyll content; P1 (Giza 168) at N-stress condition for flag leaf area; and P6 (Misr 1) at both normal and N-stress conditions and P5 (Sids 12) at nitrogen stress condition and P3 (Shandweel 1) at normal condition for biomass yield per plant, as shown in Table 9.

Table 8. General combining ability effects of all the parental genotypes for heading date, tillers No./plant, plant height (cm) traits under normal and N-stress conditions

| Parents | Heading date | Tillers No./plant | Plant height |
|---------|--------------|------------------|--------------|
|         | Normal | N-Stress | Normal | N-Stress | Normal | N-Stress |
| P1 (Giza 168) | -0.85** | -2.24** | 0.15 | 0.06 | -2.74** | -4.72** |
| P2 (Sakha 94) | -0.93** | -1.74** | -1.14** | -1.11** | -1.53* | -1.43* |
| P3 (Shandweel 1) | 0.36* | -0.82** | -0.22 | -0.07 | 0.39 | 1.57* |
| P4 (Gemmeiza 11) | -1.14** | 0.85** | -0.06 | 0.01 | -2.32** | -1.89** |
| P5 (Sids 12) | 0.65** | 0.64** | 0.90** | 0.93** | 3.18** | 3.28** |
| P6 (Misr 1) | 1.90** | 3.31** | 0.36 | 0.18 | 3.01** | 3.19** |
| LSD 5% Gi | 0.28 | 0.27 | 0.55 | 0.44 | 1.17 | 1.34 |
| LSD 1% Gi | 0.37 | 0.37 | 0.73 | 0.59 | 1.56 | 1.79 |
| LSD 5% Gi-GJ | 0.76 | 0.75 | 1.50 | 1.21 | 3.20 | 3.68 |
| LSD 1% Gi-GJ | 1.01 | 1.01 | 2.00 | 1.62 | 4.28 | 4.92 |

*, ** significant at 0.05 and 0.01 level of probability, respectively.

Table 9. General combining ability effects of all the parental genotypes for chlorophyll content flag leaf area and biomass yield plant$^{-1}$ traits under normal and N-stress conditions.

| Parents | Chlorophyll content | Flag leaf area | Biomass yield plant$^{-1}$ |
|---------|---------------------|----------------|---------------------------|
|         | Normal | N-Stress | Normal | N-Stress | Normal | N-Stress |
| P1 (Giza 168) | 1.35** | 1.31** | 1.10 | 2.47* | -1.83 | 3.18 |
| P2 (Sakha 94) | -0.48 | 0.06 | -2.06* | -0.21 | -17.82** | -14.60** |
| P3 (Shandweel 1) | 0.74 | 0.66 | 0.94 | 1.98 | 9.20* | 0.73 |
| P4 (Gemmeiza 11) | 0.18 | -1.03* | -0.27 | -1.37 | -6.71 | -7.75** |
| P5 (Sids 12) | 0.03 | 0.91* | 1.36 | -0.23 | 1.72 | 9.66** |
| P6 (Misr 1) | -1.82** | -1.89** | -1.06 | -2.64* | 15.45** | 8.77** |
| LSD 5% Gi | 0.92 | 0.79 | 1.82 | 2.38 | 7.26 | 4.81 |
| LSD 1% Gi | 1.23 | 1.06 | 2.44 | 3.19 | 9.71 | 6.44 |
| LSD 5% Gi-GJ | 2.52 | 2.17 | 5.01 | 6.54 | 19.93 | 13.21 |
| LSD 1% Gi-GJ | 3.37 | 2.90 | 6.71 | 8.75 | 26.67 | 17.68 |

*, ** significant at 0.05 and 0.01 level of probability, respectively.
3.3.2. Specific Combining Ability (SCA) Effects

Based on specific combining ability estimates (Table 10), it could be concluded that the best cross combinations were; crosses No.1 (P1xP2), No.2 (P1xP3), No.10 (P3xP4) and No.15 (P5xP6) at normal condition, No.3 (P1xP4), No.5 (P1xP6), No.6 (P2xP3), No.7 (P1xP2), No.8 (P2xP5) and No.11 (P3xP5) under nitrogen stress for heading date (earliness); crosses No. 7 (P2xP4) and No.11 (P3xP5) at both conditions, and No. 1 (P1xP2), No. 4 (P1xP5) and No.14 (P4xP6) at nitrogen stress condition for tillers No. plant \(^1\); crosses No. 1 (P1xP2) and No. 15 (P5xP6) at both conditions for plant height (shortness); crosses No. 10 (P3xP4) at both condition, and No. 6 (P1xP5) at normal and cross No.5 (P1xP6) under nitrogen stress condition for chlorophyll content; crosses No.4 (P1xP5), No.6 (P2xP3), No. 8 (P2xP5), No. 11(P3xP5) and No.14(P4xP6) at normal condition, and No.3 (P1xP4) and No.8 (P2xP5) at nitrogen stress condition for flag leaf area; and crosses No.3 (P1xP4), No.7 (P2xP4), No.8 (P2xP5), No.12 (P3xP6), No.14 (P4xP6) and No.15 (P5xP6) at both conditions, cross No.10 (P3xP4) at normal condition, and cross No.2 (P1xP3) under nitrogen stress condition for biomass yield plant \(^1\), as shown in Table 11.

Table 10. Specific combining ability (SCA) effects for heading date, tillers No./ plant and plant height under normal and N-stress conditions.

| Crosses  | Heading date | Tillers No./plant | Plant height (cm) |
|----------|--------------|-------------------|-------------------|
|          | Normal | N-Stress | Normal | N-Stress | Normal | N-Stress |
| 1-P1xP2  | -3.05** | 1.46** | 0.64 | 1.07* | -6.48** | -5.10** |
| 2-P1xP3  | -1.67** | 2.55** | -0.28 | 0.03 | -0.07 | -1.43 |
| 3-P1xP4  | -0.51 | -2.12** | 0.55 | -0.39 | 2.64* | 4.69** |
| 4-P1xP5  | 3.70*** | 1.09** | 0.93 | 1.03* | 2.81 | 6.52** |
| 5-P1xP6  | 5.12*** | -1.58** | 0.14 | -0.22 | 6.98** | 5.61** |
| 6-P2xP3  | -0.59 | -0.95** | 0.35 | 0.53 | 1.06 | 1.27 |
| 7-P2xP4  | 0.58 | -4.29** | 1.51* | 1.11* | -1.23 | -2.60 |
| 8-P2xP5  | 6.45*** | -4.08** | -0.11 | -0.80 | 3.27* | 2.57 |
| 9-P2xP6  | 2.54** | 7.92** | -0.24 | 0.28 | 0.10 | -0.02 |
| 10-P3xP4 | -5.38** | -0.54 | 0.93 | 0.40 | 5.52** | 5.07** |
| 11-P3xP5 | 5.16*** | -3.66** | 1.97** | 1.15* | 0.68 | 1.23 |
| 12-P3xP6 | 6.24** | 7.01** | -1.15 | -0.43 | -0.82 | -1.35 |
| 13-P4xP5 | 6.99** | 9.01** | 0.47 | 0.40 | 1.73 | 0.36 |
| 14-P4xP6 | 5.41** | 0.34 | 0.35 | 1.15* | 3.56** | 2.77 |
| 15-P5xP6 | -7.38** | 0.55** | -2.28** | -1.43** | -2.27** | -1.06** |

LSD 5% \((S_{ij})\) 0.63 0.62 1.24 1.00 2.64 3.04
1% \((S_{ij})\) 0.84 0.83 1.65 1.33 3.54 4.06
LSD 5% \((S_{ik})\) 1.13 1.12 2.24 1.80 4.78 5.49
1% \((S_{ik})\) 1.51 1.50 2.99 2.41 6.39 7.34
LSD 5% \((S_{jl})\) 1.05 1.04 2.07 1.67 4.42 5.08
1% \((S_{jl})\) 1.40 1.39 2.77 2.23 5.92 6.80

*, ** significant at 0.05 and 0.01 level of probability, respectively.

Table 11. Specific combining ability (SCA) effects for, chlorophyll content, flag leaf area and biomass yield plant \(^1\) under normal and N-stress conditions.

| Crosses  | Chlorophyll content | Flag leaf area | Biomass yield plant \(^1\) |
|----------|---------------------|----------------|--------------------------|
|          | Normal | N-Stress | Normal | N-Stress | Normal | N-Stress |
| 1-P1xP2  | 1.44  | -0.11 | 1.33  | -1.16 | -26.00** | -20.50** |
| 2-P1xP3  | -0.41 | 0.23 | -1.59 | 2.45 | 14.29 | 21.93** |
| 3-P1xP4  | -0.98 | -1.21 | 0.03  | 6.10* | 40.20** | 26.74** |
| 4-P1xP5  | 3.07** | 0.58 | 6.72** | 0.60 | 9.20 | 9.37 |
| 5-P1xP6  | -0.39 | 1.88* | 1.17  | 1.61 | 5.70 | 4.49 |
| 6-P2xP3  | -1.25 | -1.39 | 4.56* | 5.37 | 3.32 | 10.64 |
| 7-P2xP4  | 1.08 | 0.43 | 1.24 | 1.07 | 19.53* | 18.66** |
| 8-P2xP5  | 0.03 | 1.03 | 6.78** | 6.99* | 45.09** | 22.44** |
| 9-P2xP6  | -0.30 | -0.64 | 0.77  | -3.27 | -26.53** | -10.66 |
| 10-P3xP4 | 2.26* | 2.14* | 1.40  | 4.84 | 22.42** | 8.08 |
| 11-P3xP5 | -0.59 | 1.13 | 7.99** | 1.34 | -32.03** | -23.45** |
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4. Conclusion

From the previous results, we can concluded that four crosses i.e. cross No. 3 (P1xP4), No. 7 (P2xP4), No. 8 (P2xP5) and No. 14 (P4xP6) were performed well for most of the studied traits under normal and N-stress conditions, as well as were the best cross combinations for biological yield and at least one or two other traits and earliness trait under both normal nitrogen fertilization and N-stress conditions, which can be subsequently utilized in future wheat breeding to develop high yielding new wheat cultivars from transgressive segregants recovered in latter generations. As, the ratios of GCA/SCA were less than unity for all earliness and morphophysiological and biomass yield plant-1 traits, therefore these traits are predominantly controlled by non-additive gene action, and therefore selection procedures based on the accumulation of additive effect would be more effective in the lately segregated generations.

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