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Selection Efficiency and Environmental Sensitivity for Agronomic Traits in A Bread Wheat Population under Normal and Late Sowing Dates Conditions

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ABSTRACT

The present study was carried out during seasons, i.e. 2017/18 to 2019/20 at Shandaweel Agric. Res. Stat., Sohag Governorate, Egypt. Two cycles of pedigree selection for grain yield plant⁻¹ and number of spikes plant⁻¹ from F₂ to F₄ generations were practiced under normal and late sowing dates. The genotypic variance was slightly less than the phenotypic variance under both environments and generally decreased from (F₂) to F₄ generation. After two cycles of pedigree selection, broad sense heritability estimates were 90.27% and 73.83% for grain yield plant⁻¹ and 88.21% and 82.47% for no. of spikes plant⁻¹ under normal and late sowing dates, respectively. Evaluation of the selected families for high grain yield plant⁻¹ under normal sowing date showed significant differences 18.33% and 9.31% when selection was practiced under normal sowing date, and 20.60% and 11.83% when selection was under late sowing date from the bulk sample and the better parent, respectively. The average observed gains of the selected families for high no. of pikes plant⁻¹ under normal sowing date and evaluated under both conditions were 13.53% and 17.74% from the bulk sample and 9.67% and 11.51% from the better parent under normal and late sowing dates, respectively. While when selection was under late sowing date were 12.68% and 17.80% from the bulk sample and 8.78% and 11.57% from the better parent under normal and late sowing dates, respectively. The antagonistic and the synergistic selection nearly have the same effect on the sensitivity to heat stress under the two selection criteria.

Keywords: Heat stress, genetic gain, heritability, heat susceptibility index, phenotypic and genotypic coefficient of variation.

INTRODUCTION

Wheat is the most important grain crop in the world. It provides food to 36% of the global population, (Singh and Chaudhary, 2006). In Egypt, wheat crop is considered as the essential strategic cereal crop for thousands of years. In Egypt, the cultivated area of wheat was 3.26 million feddan produce about 8.77 million tones while wheat annual consumption is about 20.4 million ton, (USDA GAIN Report. 2019). Many of the world's wheat areas (especially in the Arab countries) are exposed to terminal heat stress. One of the important objectives in many wheat breeding programs is to develop heat tolerant cultivars. The ability of wheat to adapt to a wide range of ecological conditions has made it one of the most important crops worldwide, but heat stress has a negative effects on yield. Heat stress frequently affects wheat plants during heading or in the grain-filling period, making it essential to intensify research on the effects of heat stress (Wahid *et al* 2007 and Rezaei *et al* 2015). The damage is greatly influenced by the growth stage which the plants are subjected to stress (Porter and Gawith 1999). The flowering stage has generally been found to be the most sensitive to heat stress (Ferris 1998) because both meiosis and pollen growth are negatively affected. Selection for stress tolerance in breeding programs has

been impeded by lack of genotypes that show clear differences in response at specific growth stages to well define environmental stress (Hanson and Nelson, 1980). Pedigree selection method has become the most effective method for selection in breeding wheat crop (Mahdy, 1988; Kheiralla *et al.*, 1993 and Ali, 2011). Several workers indicated that pedigree selection is effective in improving grain yield (Abdel-Karim, 1991; Omara *et al.*, 2004; Ahmed, 2006 and El-Morshidy *et al.*, 2010). Kheiralla *et al* (1993) showed that direct selection for 1000-kernel weight, grains/spike and spikes plant⁻¹ was accompanied by an increase in grain yield which accounted 5.90, 6.93 and 7.50%, respectively, after two cycles of selection calculated as a deviation from the best parent mean.

The objectives of this study were to 1) study the efficiency of pedigree selection in improving grain yield plant⁻¹ using grain yield plant⁻¹ and number of spikes plant⁻¹ as selection criterion under normal and late sowing dates conditions. 2) study the sensitivity of the selected lines to terminal heat stress conditions.

MATERIALS AND METHODS

The present study was carried out through the three successive seasons, i.e. 2017/18 to 2019/20 at Shandaweel Agricultural Research Station, Sohag

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Governorate, Agricultural Research Center (ARC), Egypt. The genetic materials chosen for this study included one F₂ bread wheat population. The pedigree and origin of the parents are presented in Table 1.

Table 1. The parents pedigree, selection history and origin of the population under study.

| Parents | Pedigree | Origin |
|------------------------------|-----------------|--------|
| Parent ₁ (Misr2) | SKAUZ/BAV92 | Egypt |
| Parent ₂ (HD2501) | HD 2189/HD 2160 | India |

This population was grown under two sowing dates, the normal sowing date (20th November) and (20th December) as late sowing date, and all the other recommended agricultural practices have been applied to both planting dates. Min., max. and mean monthly temperature on Celsius for the three growing seasons 2017/18 to 2019/20 are presented in table 2.

Table 2. Min., max. and mean monthly temperature on Celsius for the three growing seasons 2017/18 to 2019/20.

| Season | Month | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 2017/ 2018 | Min. | 10.07 | 9.10 | 6.65 | 11.32 | 14.35 | 16.50 | 21.97 |
| | Max. | 24.27 | 23.10 | 19.84 | 26.11 | 30.55 | 32.20 | 37.71 |
| | Mean | 17.17 | 16.10 | 13.24 | 18.71 | 22.45 | 24.35 | 29.84 |
| 2018/ 2019 | Min. | 11.71 | 8.06 | 5.77 | 7.68 | 10.00 | 14.00 | 22.55 |
| | Max. | 25.50 | 20.55 | 19.39 | 21.75 | 24.65 | 29.60 | 38.81 |
| | Mean | 18.61 | 14.31 | 12.58 | 14.71 | 17.32 | 21.80 | 30.36 |
| 2019/ 2020 | Min. | 13.73 | 8.41 | 5.45 | 7.45 | 11.19 | 14.87 | 19.52 |
| | Max. | 28.30 | 21.69 | 18.23 | 21.48 | 26.19 | 30.63 | 35.45 |
| | Mean | 21.02 | 15.05 | 11.84 | 14.47 | 18.69 | 22.75 | 27.48 |

In the season of 2017/18, 500 plants of F₂ population were grown in non replicated plots under each of normal (20th November) and late (20th December) sowing dates. The plot consisted of 20 rows, 2.5 m. long, 30 cm apart and 10 cm between plants within rows. Also, the parents of the population were grown. After maturity, plants were individually harvested and threshed. Data collected on all the guarded plants. Twenty plants from each treatment were selected for each selection criterion to be raised as F₃ families.

In the season of 2018/19 (F₃ generation) the 20 F₃ families were evaluated under the same environment of selection. The best 10 plants from the best 10 families were selected from each experiment and retained to be raised as F₄ families in the next season.

In the season of 2019/20 (F₄ generation) four field experiments were conducted to evaluate F₄ families selected from each treatment was sown in both conditions (the plants selected under normal or late sowing dates were evaluated under both conditions).

In the F₃ and F₄ generations, each family was planted in a separate row 2.5 m long, 30 cm apart and 10 cm between plants within row in a Randomized Complete Block Design (RCBD) with three replications. Parents and unselected bulk were grown in each replicate. Selection between and within families was practiced.

The studied traits:

Days to heading (DH), number of spikes plant⁻¹ (S/plant), biological yield plant⁻¹ (BY), 100-kernel weight (100-KW), number of kernels spike⁻¹ (K/S) and grain yield plant⁻¹ (GY).

Statistical analysis:

Analysis of variance and combined analysis were performed according to Snedecor and Cochran (1980) using MSTAT-C computer program in randomized complete blocks design (RCBD). Estimates of phenotypic and genotypic variances, as well as heritability estimates were calculated from EMS of the variance and covariance components of the selected families. Genotypes means were compared using Revised Least Significant Difference (RLSD) according to El-Rawi and Khalafalla (1980). The phenotypic (σ^2_p) and genotypic (σ^2_g) variances and heritability in broad sense were calculated according to the following formula:

$$\text{The genotypic variance } \sigma^2_g = (\text{MS}_{\text{Treat}} - \text{MS}_{\text{Error}}) / r.$$

$$\text{The phenotypic variance } \sigma^2_p = \sigma^2_g + \sigma^2_e / r.$$

Heritability in broad sense " H^2_{bs} " was estimated as the ratio of genotypic (σ^2_g) to the phenotypic (σ^2_p) variance according to Walker (1960). Realized heritability (h^2) was calculated as: $h^2 = R/S$ (Falconer, 1989), where R = response to selection and S = selection differential. The phenotypic (pcv%) and genotypic (gcv%) coefficients of variability were estimated using the formula developed by Burton (1952). Heat susceptibility index (HSI) was calculated according to the method of Fischer and Maurer (1978).

The phenotypic correlation coefficients via base population (F₂) and the second cycle of selection (F₄) were calculated among the studied traits as outlined by Al-Jibouri *et al.* (1958), as follows: Phenotypic correlation $rp_{xy} = \text{cov } p_{xy} / (\sigma p_x \cdot \sigma p_y)$. The sensitivity and relative merits of selected families were assessed as described by Falconer (1990). The relative merits of the two types of selection in changing the mean is expressed as the ratio:

$$\frac{(\text{Change of mean by antagonistic selection})}{(\text{Change of mean by synergistic selection})}$$

Synergistic selection: selection and environment acted in the same direction.

Antagonistic selection: selection and environment acted in opposite direction.

RESULTS AND DISCUSSION

1- Description of the base population; season 2017/2018

The studied traits of the two parents and the F₂ generation under both conditions are shown in Table 3. The first parent was higher than the second parent in all the studied traits under normal and late sowing dates conditions. In F₂ population, heat stress conditions caused a reduction in number of spikes plant⁻¹, 100-kernel weight, number of kernels spike⁻¹, biological yield plant⁻¹ and grain yield plant⁻¹ by an average of 18.41, 5.63, 2.37, 10.20 and 26.82%, respectively. Abdelghani *et al.* (1994) reported that grain yield, 1000-grain weight and number of spikes/m² were reduced due to late sowing. Tammam and Tawfiles (2004) stated that days to heading, number of spikes plant⁻¹, number of kernels/spike, 1000-kernel weight, biological yield plant⁻¹ and grain yield plant⁻¹ were significantly increased in the recommended sowing compared to the late sowing date. Soliman (2009) found that delaying sowing date significantly decreased days to heading, no. of spikes plant⁻¹, no. of kernels/spike, biological yield and grain yield.

The coefficient of variability ranged from 7.51 and 11.42% for 100-kernel weight to 40.42 and 41.86% for grain yield under normal and late sowing date, respectively. Same results have been stated by Ismail (1995), Amin (2003), El-Morshidy *et al.* (2010) and Ali (2011). Broad sense heritability ranged from 50.85% for biological yield to 76.47% for no. of spikes plant⁻¹ under

normal sowing date, and from 28.13% for grain yield to 69.21% for 100-kw under late sowing date. The expected genetic advance ranged from 0.50 for 100-kernel weight to 23.28 for biological yield under normal sowing date, and from 0.73 for 100-kernel weight to 23.16 for biological yield under late sowing date. Similar results have been found by Zakaria *et al.* (2008).

Table 3. Means, reduction%, coefficient of variability (CV), broad sense heritability (H_b) and $\Delta G/\text{mean}\%$ of the base population (F₂ generation) under normal and late sowing dates.

| base population (F ₂ generation) under normal and late sowing dates. | | | | | | | | | | | |
|---|--------------------|--------|-------|--------|--------|------------------|--------|-------|--------|--------|--------|
| Item | Normal sowing date | | | | | Late sowing date | | | | | |
| | S/plant | 100-KW | K/S | BY | GY | S/plant | 100-KW | K/S | BY | GY | |
| F ₂ Population | Means±SE | 9.36± | 4.63± | 35.08± | 50.66± | 15.25± | 7.64± | 4.37± | 34.26± | 45.49± | 11.16± |
| | | 0.175 | 0.020 | 0.453 | 1.068 | 0.353 | 0.164 | 0.033 | 0.663 | 1.041 | 0.304 |
| | Reduction% | | | | | | 18.41 | 5.63 | 2.37 | 10.20 | 26.82 |
| | CV % | 32.66 | 7.51 | 22.55 | 36.82 | 40.42 | 32.94 | 11.42 | 29.72 | 35.16 | 41.86 |
| | H (b) % | 76.47 | 68.21 | 73.68 | 50.85 | 69.92 | 66.84 | 69.21 | 53.06 | 68.48 | 28.13 |
| ΔG/mean% | 4.68 | 0.50 | 11.88 | 23.28 | 9.02 | 3.60 | 0.73 | 12.98 | 23.16 | 4.34 | |
| Parent 1 | Means±SE | 11.2± | 4.86± | 26.82± | 50.56± | 14.59± | 11.00± | 4.69± | 27.56± | 43.84± | 14.25± |
| | | 0.58 | 0.074 | 1.71 | 7.46 | 1.27 | 0.84 | 0.126 | 3.85 | 5.58 | 2.22 |
| | Reduction% | | | | | | 1.79 | 3.54 | 12.89 | 13.29 | 2.37 |
| Parent 2 | CV % | 11.64 | 3.42 | 14.28 | 32.99 | 19.42 | 17.01 | 5.99 | 3.13 | 28.46 | 34.81 |
| | Means±SE | 10.8± | 4.77± | 23.42± | 42.72± | 13.34± | 10.20± | 4.81± | 25.64± | 37.92± | 12.55± |
| | | 0.73 | 0.099 | 1.91 | 3.57 | 1.72 | 0.374 | 0.122 | 2.146 | 1.06 | 1.164 |
| | Reduction% | | | | | | 5.56 | 1.03 | 4.41 | 11.24 | 5.94 |
| | CV % | 15.21 | 4.65 | 18.26 | 18.71 | 28.86 | 8.20 | 5.68 | 18.71 | 6.26 | 20.75 |

The phenotypic correlation (Table, 4) showed that grain yield plant⁻¹ under normal sowing date had highly significant correlation values (0.77, 0.59 and 0.87) with no. of spikes plant⁻¹, no. of kernels/spike and biological yield plant⁻¹, respectively. While, under late sowing date grain yield plant⁻¹ had highly significant correlation values (0.65, 0.19, 0.46 and 0.77) with no. of spikes plant⁻¹, 100-wernel weight, no. of kernels/spike and biological yield plant⁻¹, respectively.

Table 4. Phenotypic correlation between the studied traits for the base population (F₂) under normal and late sowing dates.

| Normal and late sowing dates. | | | | | | |
|-------------------------------|--------------------------|----------|----------|--------|--------|--------|
| Under Late Sowing Date | Under Normal Sowing Date | | | | | |
| | Treat. | S/plant | 100-KW | K/S | BY | GY |
| | S/plant | | - 0.17** | 0.06 | 0.87** | 0.77** |
| | 100-KW | - 0.08 | | - 0.04 | 0.02 | 0.02 |
| | K/S | - 0.18** | - 0.06 | | 0.34** | 0.59** |
| | BY | 0.83** | 0.03 | 0.08 | | 0.87** |
| | GY | 0.65** | 0.19** | 0.46** | 0.77** | |

2 – Selection for high grain yield plant⁻¹.

Variability and heritability estimates.

The phenotypic variance σ^2_p and the genotypic variance σ^2_g were larger under normal sowing date for all the selection cycles than that under late sowing date and decreased with selection, Table 5. The phenotypic was generally larger than the genotypic coefficient of

variability. The phenotypic coefficient of variability (pcv%) for grain yield plant⁻¹ in the F₂ generation was 40.42% under normal sowing date and decreased to 9.73 and 11.95% in F₃ and F₄ generations, respectively. While, under late sowing date, it was 41.83, 12.57 and 6.00% for cycles C₀, C₁ and C₂, respectively. The genotypic coefficient of variability (gcv%) for grain yield plant⁻¹ under normal sowing date was 33.79, 9.22 and 11.36% in cycles C₀, C₁ and C₂, respectively. While, under late sowing date, it was 22.20, 12.09 and 5.15% for cycles C₀, C₁ and C₂, respectively. The heritability generally increased from C₀ to C₂ under normal sowing date and it was 69.92, 93.18 and 90.27% for cycles C₀, C₁ and C₂, respectively. On the other hand, under late sowing date it was 28.13, 92.51 and 66.76% for cycles C₀, C₁ and C₂, respectively. The realized heritability increased from C₁ to C₂ under normal sowing date and it was 20.83 and 28.05% for cycles C₁ and C₂, respectively. On the other hand, under late sowing date it was 24.66 and 66.76% for cycles C₁ and C₂, respectively. These results are in agreement with those of Ahmed (2006), Ali (2011) and Mahdy *et al.* (2012). Abd El-Rady (2017) stated that the realized heritability was 40.08 and 67.40% under normal compared to 40.19 and 78.47% under stress conditions after cycle1 and 2, respectively.

Table 5. Variability and heritability estimates of grain yield plant⁻¹ after two cycles of selection under normal (N) and late sowing date (H).

| Selection cycle | σ^2_p | | σ^2_g | | P.C.V. % | | G.C.V. % | | H % | | R heritability | |
|-------------------|--------------|-------|--------------|-------|----------|-------|----------|-------|-------|-------|----------------|-------|
| | N | H | N | H | N | H | N | H | N | H | N | H |
| (C ₀) | 37.98 | 21.82 | 26.56 | 6.14 | 40.42 | 41.83 | 33.79 | 22.20 | 69.92 | 28.13 | -- | -- |
| (C ₁) | 4.801 | 2.444 | 4.307 | 2.261 | 9.73 | 12.57 | 9.22 | 12.09 | 93.18 | 92.51 | 20.83 | 24.66 |
| (C ₂) | 5.190 | 0.511 | 4.685 | 0.377 | 11.95 | 6.00 | 11.36 | 5.15 | 90.27 | 73.83 | 28.05 | 66.76 |

Means and observed gains in grain yield plant⁻¹ under normal sowing date:

The group of families which selected for grain yield plant⁻¹ under normal sowing date was evaluated under both sowing dates, in case of normal sowing date, it ranged from 16.73 g for family no. 256 to 24.99 g for family no. 7 with an average of 18.84 g, (Table 6). The average observed gain under normal irrigation was insignificant 7.31 and 6.73% from the bulk sample and the better parent, respectively. Two of the selected families i.e., No. 7 and 104 showed highly significant observed gain (30.12 and 29.68%) for family no. 7 and (14.52 and 13.98%) for family no. 104 compared to the bulk sample and the better parent, respectively. On the other hand, when the selected families were evaluated under late sowing date it ranged from 10.67 g for family no. 145 to 13.08 g for family no. 113 with an average of 11.75 g. The average observed gain was highly significant (18.33%) from the bulk sample and significant (9.31%) from the better parent. Furthermore, all the selected families showed significant or highly significant observed gain from the bulk sample ranged from 10.00 for family no. 145 to 26.62% for family no. 113, six of them showed significant or highly significant observed gain from the better parent ranged from 11.36 for family no. 55 to 18.52% for family no. 113. Abd El-Rady (2017) reported that the average observed gains of normal conditions selections were 19.58 and 23.66% from bulk sample and 7.93 and 8.73% from the better parent when evaluation practiced under normal and stress conditions, respectively.

Means and observed gains grain yield plant⁻¹ under late sowing date selection:

The group of families selected for grain yield plant⁻¹ under late sowing date was evaluated under both conditions, in case of normal sowing date, it ranged from 17.44 g for family no. 120 to 24.55 g for family no. 45 with an average of 19.29 g, (Table 6). The average observed gain under normal sowing date was (9.49 and 8.92%) from the bulk sample and the better parent, respectively. The selected families no. 11, 45 and 88 were highly significant surpassed the better parent and the bulk sample. On the other hand, when the selected families were evaluated under late sowing date it ranged from 11.23 g for family no. 88 to 13.03 g for family no. 170 with an average of 12.09 g. The average observed gain significantly ($P < 0.01$) out yielded the bulk sample and the better parent by (20.60 and 11.83%), respectively, it ranged from (14.52 and 5.09%) for family no. 88 to (26.31 and 18.17%) for family no. 170 compared to the bulk sample and the better parent, respectively. The selected families no. 11, 19, 102, 120 and 170 highly significant surpassed the bulk sample and the better parent. Abd El-Rady (2017) found that the average observed gains of stress selections were 26.44 and 32.57% from bulk sample and 14.12 and

16.57% from the better parent, when evaluation practiced under normal and stress conditions, respectively.

Generally we can state that selection for high grain yield plant⁻¹ for two cycles under late sowing date in our study was better than selection under normal sowing date. Ismail (1995) found that genetic gains in grain yield over the bulk sample and the better parent was (8.47 and 4.86%) and (6.96 and 6.41%) in two populations. Kheiralla *et al.* (2006) reported that two cycles of selection for grain yield increased grain yield by 20.2 and 7.6% from the bulk sample and the better parent, respectively. Similar results have also been found by Ali (2011) and Mahdy *et al.* (2012).

Average observed gain after two cycles of selection for high grain yield plant⁻¹:

Means and observed gain from selection for high grain yield plant⁻¹ are shown in Table 7. The observed gain from selection for high grain yield plant⁻¹ under normal sowing date in C₁ was 14.13 and 11.28% from the bulk sample and the better parent, respectively. While, in C₂ it was 6.73 and 9.31% from the better parent and 7.31 and 18.33% from the bulk sample under normal and late sowing dates, respectively. On the other hand, the observed gain from selection for high grain yield plant⁻¹ under late sowing date in C₁ was 16.08 and 20.58% from the better parent and the bulk sample, respectively. While, in C₂ it was 8.92 and 11.83% from the better parent and 9.49 and 20.60% from the bulk sample under normal and late sowing date, respectively. It is obvious that selection under late sowing was better than selection under normal sowing. In the other wards, antagonistic selection for grain yield was better than synergistic selection.

Heat susceptibility index and sensitivity to environments:

Among the families which selected under normal sowing date and evaluated under both conditions, five families no. 55, 61, 113, 186 and 256 showed (HSI) values less than unit and gave lower values of sensitivity. These families are less susceptible to heat and more stable under various conditions, while family no. 7 had good performance under normal sowing date and it had HSI more than unit, so it can be used under normal sowing date (Table 8).

The results of the heat stress conditions group showed that six families no. 19, 62, 102, 120, 170 and 203 showed (HSI) values less than unit and gave lower values of sensitivity. These families were less susceptible to heat stress and more stable under various conditions. While the family no. 45 had high grain yield plant⁻¹ under normal sowing date, so it can be sown under normal sowing date. The two parents were slightly similar in tolerance to heat stress than the unselected bulk.

Table 6. Means of grain yield plant⁻¹ and the observed gain from the bulk sample (OG% Bulk) and from the better parent (OG% BP) for the high grain yield plant⁻¹ selected families after two cycles of selection under normal and late sowing dates.

| Item | Fam. No. | Evaluation under normal sowing date | | | Evaluation under late sowing date | | |
|------------------------------------|----------|-------------------------------------|------------|---------|-----------------------------------|------------|---------|
| | | Mean | OG% Bulk | OG% BP | Mean | OG% Bulk | OG% BP |
| Selection under normal sowing date | 7 | 24.99 | 30.12** | 29.68** | 12.16 | 21.03** | 12.31** |
| | 28 | 17.68 | 1.24 | 0.62 | 10.76 | 10.78* | 0.93 |
| | 55 | 17.40 | -0.34 | -0.98 | 12.03 | 20.18** | 11.36** |
| | 61 | 17.61 | 0.84 | 0.22 | 11.59 | 17.19** | 8.05 |
| | 73 | 18.95 | 7.86 | 7.28 | 10.93 | 12.17* | 2.47 |
| | 104 | 20.43 | 14.52** | 13.98** | 11.40 | 15.76** | 6.46 |
| | 113 | 18.89 | 7.59 | 7.01 | 13.08 | 26.62** | 18.52** |
| | 145 | 18.46 | 5.42 | 4.82 | 10.67 | 10.00* | 0.06 |
| | 186 | 17.24 | -1.30 | -1.93 | 12.10 | 20.64** | 11.88** |
| | 256 | 16.73 | -4.36 | -5.02 | 12.83 | 25.19** | 16.94** |
| | Mean | 18.84 | 7.31 | 6.73 | 11.75 | 18.33** | 9.31* |
| Selection under late sowing date | 11 | 20.72 | 15.74** | 15.21** | 11.94 | 19.58** | 10.70* |
| | 19 | 17.96 | 2.76 | 2.14 | 12.29 | 21.89** | 13.26** |
| | 45 | 24.55 | 28.89** | 28.44** | 11.57 | 17.05** | 7.89 |
| | 62 | 18.41 | 5.16 | 4.56 | 11.92 | 19.44** | 10.55* |
| | 88 | 20.45 | 14.62** | 14.08** | 11.23 | 14.52** | 5.09 |
| | 102 | 17.50 | 0.25 | -0.38 | 12.80 | 24.98** | 16.70** |
| | 120 | 17.44 | -0.10 | -0.73 | 12.54 | 23.44** | 14.99** |
| | 144 | 20.16 | 13.38** | 12.83* | 11.81 | 18.74** | 9.76* |
| | 170 | 17.72 | 1.45 | 0.83 | 13.03 | 26.31** | 18.17** |
| | 203 | 17.99 | 2.96 | 2.35 | 11.78 | 18.53** | 9.53* |
| | Mean | 19.29 | 9.49 | 8.92 | 12.09 | 20.60** | 11.83** |
| Parent 1 | | 16.72 | | | 10.47 | | |
| Parent 2 | | 17.57 | | | 10.66 | | |
| Bulk | | 17.46 | | | 9.60 | | |
| R.L.S.D. | | 0.05: 1.96 | 0.01: 2.62 | | 0.05: 1.00 | 0.01: 1.34 | |

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

Table 7. Means and observed gain from selection for high grain yield plant⁻¹ after two cycles of selection under normal and late sowing dates from the bulk sample and the better parent.

| Cycle | Mean | grain yield plant ⁻¹ | | | |
|----------------|---------------|---------------------------------|---------|--------|---------|
| | | Normal | | Heat | |
| Cycle (1) | Families mean | 22.51 | 12.44 | | |
| | Parent (1) | 19.27 | 10.44 | | |
| | Parent (2) | 19.97 | 10.13 | | |
| | Bulk sample | 19.33 | 9.88 | | |
| | OG % (Bulk) | 14.13** | 20.58** | | |
| | OG% (B. P.) | 11.28* | 16.08** | | |
| R. L.S.D. 0.05 | | 2.01 | 1.22 | | |
| R. L.S.D. 0.01 | | 2.69 | 1.64 | | |
| Cycle (2) | | Normal | Heat | Normal | Heat |
| | Families mean | 18.84 | 11.75 | 19.29 | 12.09 |
| | Parent (1) | 16.72 | 10.47 | 16.72 | 10.47 |
| | Parent (2) | 17.57 | 10.66 | 17.57 | 10.66 |
| | Bulk sample | 17.46 | 9.60 | 17.46 | 9.60 |
| | OG % (Bulk) | 7.31 | 18.33** | 9.49 | 20.60** |
| | OG% (B. P.) | 6.73 | 9.31* | 8.92 | 11.83** |
| R. L.S.D. 0.05 | | 1.96 | 1.00 | 1.96 | 1.00 |
| R. L.S.D. 0.01 | | 2.62 | 1.34 | 2.62 | 1.34 |

In the F₄-generation after two cycles of selection for high grain yield plant⁻¹ under heat stress (heat group) and under normal sowing date (normal group), the two groups of families were evaluated under both conditions. The relative merits were 1.56 and 0.74 when evaluation was made under normal and late sowing dates, respectively. These results indicated that the antagonistic selection was better than the synergistic selection to increase grain yield plant⁻¹ in these materials, whether evaluation made under normal or late sowing dates. Mohamed (2001) stated that

the antagonistic selection reduced sensitivity of the intermated families and the synergistic selection increased it. Kheiralla *et al.* (2006) found that selection under early planting (the synergistic selection) increased sensitivity of the selected families, while selection under late planting (the antagonistic selection) decreased it.

Table 8. Means of grain yield plant⁻¹, heat susceptibility index (HSI) and sensitivity (S) of the selected families under normal (N) and late sowing date (H) and evaluated under both conditions after two cycles of selection (F₄ generation).

| Item | Selection under normal sowing date | | | | | Selection under late sowing date | | | | |
|----------------------------------|------------------------------------|-------|-------|------|------|----------------------------------|-------|-------|------|------|
| | Fam. No. | N | H | HSI | S | Fam. No. | N | H | HSI | S |
| F ₄ selected families | 7 | 24.99 | 12.16 | 1.37 | 1.63 | 11 | 20.72 | 11.94 | 1.14 | 1.12 |
| | 28 | 17.68 | 10.76 | 1.04 | 0.88 | 19 | 17.96 | 12.29 | 0.85 | 0.72 |
| | 55 | 17.40 | 12.03 | 0.82 | 0.68 | 45 | 24.55 | 11.57 | 1.42 | 1.65 |
| | 61 | 17.61 | 11.59 | 0.91 | 0.77 | 62 | 18.41 | 11.92 | 0.95 | 0.83 |
| | 73 | 18.95 | 10.93 | 1.13 | 1.02 | 88 | 20.45 | 11.23 | 1.21 | 1.17 |
| | 104 | 20.43 | 11.40 | 1.18 | 1.15 | 102 | 17.50 | 12.80 | 0.72 | 0.60 |
| | 113 | 18.89 | 13.08 | 0.82 | 0.74 | 120 | 17.44 | 12.54 | 0.75 | 0.62 |
| | 145 | 18.46 | 10.67 | 1.12 | 0.99 | 144 | 20.16 | 11.81 | 1.11 | 1.06 |
| | 186 | 17.24 | 12.10 | 0.79 | 0.65 | 170 | 17.72 | 13.03 | 0.71 | 0.60 |
| | 256 | 16.73 | 12.83 | 0.62 | 0.50 | 203 | 17.99 | 11.78 | 0.92 | 0.79 |
| | Mean | 18.84 | 11.75 | | 0.90 | Mean | 19.29 | 12.09 | | 0.92 |
| Parent (1) | | 16.72 | 10.47 | 0.99 | 0.80 | | 16.72 | 10.47 | 1.00 | 0.80 |
| Parent (2) | | 17.57 | 10.66 | 1.05 | 0.88 | | 17.57 | 10.66 | 1.05 | 0.88 |
| Bulk | | 17.46 | 9.60 | 1.20 | 1.00 | | 17.46 | 9.60 | 1.21 | 1.00 |

Correlation

The results in Table 9 revealed that grain yield plant⁻¹ under normal sowing date have positive and highly significant correlation with each of no. of spikes plant⁻¹,

100-kernel weight, number of kernels spike⁻¹ and biological yield plant⁻¹ (0.68, 0.45, 0.51 and 0.86, respectively). While, under late sowing date grain yield plant⁻¹ have significant correlation with number of spikes plant⁻¹ (0.32) and highly significant correlation with number of kernels spike⁻¹ and biological yield plant⁻¹ (0.46 and 0.52, respectively).

Table 9. Phenotypic correlation between the studied traits for the selected families in (F4 generation) for grain yield plant⁻¹ under normal and late sowing dates.

| Treat. | Evaluation under normal sowing date | | | | |
|-----------------------------------|-------------------------------------|---------|---------|--------|--------|
| | S/plant | 100-KW | K/S | BY | GY |
| Evaluation under late sowing date | S/plant | 0.22 | -0.10 | 0.68** | 0.68** |
| | 100-KW | 0.13 | -0.23 | 0.55** | 0.45** |
| | K/S | -0.60** | -0.46** | 0.24 | 0.51** |
| | BY | 0.42** | 0.04 | 0.03 | 0.86** |
| | GY | 0.32* | 0.02 | 0.46** | 0.52** |

3 – Selection for high no. of spikes plant⁻¹.

Variability and heritability estimates.

The phenotypic variance σ^2_p and the genotypic variance σ^2_g were larger under normal sowing date for the two selection cycles than that under late sowing date, (Table 10). The phenotypic coefficient of variability was generally larger than the genotypic coefficient of variability. The phenotypic coefficient of variability (pcv%) under normal sowing date for no. of spikes plant⁻¹ were 32.66, 9.17 and 9.24% for cycles of C₀, C₁ and C₂, respectively. While, under late sowing date, it were 32.94, 15.01 and 5.73% for cycles of C₀, C₁ and C₂, respectively. The genotypic coefficient of variability (gcv%) for no. of spikes plant⁻¹ under normal sowing date were 28.56, 8.86 and 9.15% for cycles of C₀, C₁ and C₂, respectively. While, under late sowing date, it were 26.93, 14.43 and 5.21% for cycles of C₀, C₁ and C₂, respectively. The heritability under normal sowing date were 76.47, 93.18 and 88.21% for cycles of C₀, C₁ and C₂, respectively. While, under late sowing date, it were 66.84, 92.41 and 82.47% for cycles of C₀, C₁ and C₂, respectively. The realized heritability increased from C₁ to C₂ under normal sowing date and it were 34.75 and 40.11% for cycles C₁ and C₂, respectively.

While, under late sowing date it was 39.43 and 55.52% for cycles C₁ and C₂, respectively. These results are in agreement with those of El-Morshidy *et al.* (2010). Taha *et al.* (2011) reported that broad sense heritability after two cycles of selection for no. of spikes plant⁻¹ were (73.19 and 78.4%) for the two populations.

Means and observed gains under normal sowing date selection:

The two groups of families selected for high no. of spikes plant⁻¹ for two cycles, either under normal or late sowing dates, were evaluated in the F4 generation under both environments and presented in Table 11. The group of families selected and evaluated for no. of spikes plant⁻¹

under normal sowing date ranged from 8.93 spikes for family no. 94 to 12.15 spikes for family no. 123 with an average of 10.63 spikes. The average observed gain under normal sowing date was highly significant 13.53% and 9.66% from the bulk sample and the better parent, respectively, and it ranged from -2.91% and -7.50% for family no. 94 to 24.36% and 20.99% for family no. 123 compared to the bulk sample and the better parent, respectively. Eight of the selected families significantly surpassed the bulk sample and five of them highly significant surpassed the better parent. On the other hand, when the selected families were evaluated under late sowing date, it ranged from 8.54 spikes for family no. 94 to 10.77 spikes for family no. 123 with an average of 9.628 spikes. The average observed gain was highly significant (17.74%) from the bulk sample and significant (11.51%) from the better parent, and it ranged from 7.26% and 0.23% for family no. 94 to 26.46% and 20.89% for family no. 123 compared to the bulk sample and the better parent, respectively. All the selected families significantly surpassed the bulk sample except family no. 94 and four of them highly significant surpassed the better parent.

Means and observed gains under late sowing date selection:

The group of families which selected for no. of spikes plant⁻¹ under late sowing date was evaluated under both conditions. In case of normal sowing date, it ranged from 9.97 spikes for family no. 29 to 11.48 spikes for family no. 75 with an average of 10.52 spikes, (Table 11).

The average observed gain under normal sowing date was 12.68% and 8.78% from the bulk sample and the better parent, respectively, and it ranged from 7.79% and 3.68% for family no. 29 to 19.92% and 16.35% for family no. 75 compared to the bulk sample and the better parent, respectively. All the selected families significantly or highly significant surpassed the bulk sample and five of them surpassed the better parent. On the other hand, when the selected families were evaluated under late sowing date it ranged from 8.84 spikes for family no. 13 to 10.33 spikes for family no. 75 with an average of 9.635 spikes. The average observed gain was 17.80% and 11.57% from the bulk sample and the better parent, respectively, and it ranged from 10.37% and 3.58% for family no. 13 to 23.33% and 17.52% for family no. 75 compared to the bulk sample and the better parent, respectively. All the selected families significantly or highly significant surpassed the bulk sample except family no. 13 and six of them surpassed the better parent.

Generally we can state that selection for high no. of spikes plant⁻¹ for two cycles under normal or late sowing dates nearly have the equal effect. Zakaria (2004) found that no. of spikes plant⁻¹ increased after two cycles of selection by 15.52% and 19.79% compared to the bulk sample and the better parent, respectively.

Table 10. Variability and heritability estimates of no. of spikes plant⁻¹ after two cycles of selection under normal (N) and late sowing date (H).

| Selection cycle | σ^2_p | | σ^2_g | | P.C.V. % | | G.C.V. % | | H % | | R heritability | |
|-------------------|--------------|-------|--------------|-------|----------|-------|----------|-------|-------|-------|----------------|-------|
| | N | H | N | H | N | H | N | H | N | H | N | H |
| (C ₀) | 9.35 | 6.33 | 7.15 | 4.23 | 32.66 | 32.94 | 28.56 | 26.93 | 76.47 | 66.84 | -- | -- |
| (C ₁) | 3.987 | 3.185 | 3.647 | 2.944 | 9.17 | 15.01 | 8.86 | 14.43 | 93.18 | 92.41 | 34.75 | 39.43 |
| (C ₂) | 3.320 | 0.472 | 2.929 | 0.389 | 9.74 | 5.73 | 9.15 | 5.21 | 88.21 | 82.47 | 40.11 | 55.52 |

Table 11. Means of no. of spikes plant⁻¹ and the observed gain from the bulk sample (OG% Bulk) and from the better parent (OG% BP) for the high no. of spikes plant⁻¹ selected families after two cycles of selection under normal and late sowing dates.

| Item | Fam. No. | Evaluation under normal sowing date | | | Evaluation under late sowing date | | |
|------------------------------------|----------|-------------------------------------|------------|---------|-----------------------------------|------------|---------|
| | | Mean | OG% Bulk | OG% BP | Mean | OG% Bulk | OG% BP |
| Selection under normal sowing date | 22 | 10.00 | 8.10* | 4.00 | 9.11 | 13.06* | 6.48 |
| | 39 | 9.93 | 7.45* | 3.32 | 9.28 | 14.66** | 8.19 |
| | 73 | 9.73 | 5.55 | 1.34 | 9.39 | 15.65** | 9.27 |
| | 94 | 8.93 | -2.91 | -7.50 | 8.54 | 7.26 | 0.23 |
| | 104 | 11.12 | 17.36** | 13.67** | 10.00 | 20.80** | 14.80** |
| | 123 | 12.15 | 24.36** | 20.99** | 10.77 | 26.46** | 20.89** |
| | 152 | 11.03 | 16.68** | 12.96** | 9.35 | 15.29** | 8.88 |
| | 186 | 11.67 | 21.25** | 17.74** | 10.45 | 24.21** | 18.47** |
| | 234 | 11.60 | 20.78** | 17.24** | 10.24 | 22.66** | 16.80** |
| | 287 | 10.11 | 9.10* | 5.04 | 9.13 | 13.25* | 6.68 |
| | Mean | 10.63 | 13.53** | 9.66** | 9.628 | 17.74** | 11.51* |
| Selection under late sowing date | 13 | 11.07 | 16.96** | 13.25** | 8.84 | 10.37 | 3.58 |
| | 21 | 10.58 | 13.14** | 9.26* | 9.93 | 20.21** | 14.17** |
| | 29 | 9.97 | 7.79* | 3.68 | 9.73 | 18.63** | 12.47* |
| | 45 | 10.04 | 8.47* | 4.38 | 9.43 | 16.01** | 9.65 |
| | 75 | 11.48 | 19.92** | 16.35** | 10.33 | 23.33** | 17.52** |
| | 89 | 10.23 | 10.17** | 6.16 | 9.43 | 15.98** | 9.62 |
| | 114 | 10.17 | 9.61* | 5.57 | 10.04 | 21.12** | 15.14** |
| | 144 | 10.91 | 15.74** | 11.98** | 9.12 | 13.16* | 6.58 |
| | 135 | 10.69 | 14.03** | 10.20** | 9.89 | 19.89** | 13.82** |
| | 192 | 10.12 | 9.16* | 5.11 | 9.62 | 17.64** | 11.40* |
| | Mean | 10.52 | 12.68** | 8.78* | 9.635 | 17.80** | 11.57* |
| Parent 1 | | 9.60 | | | 8.52 | | |
| Parent 2 | | 9.24 | | | 8.32 | | |
| Bulk | | 9.19 | | | 7.92 | | |
| R.L.S.D. | | 0.05: 0.75 | 0.01: 1.00 | | 0.05: 0.96 | 0.01: 1.29 | |

Average observed gain after two cycles of selection for high no. of spikes plant⁻¹:

The observed gain from selection for high no. of spikes plant⁻¹ under normal sowing date in C₁ was 15.87 and 21.75% from the better parent and the bulk sample, respectively. While in C₂ it was 9.67 and 11.51% from the better parent and 13.53 and 17.74% from the bulk sample under normal and late sowing date, respectively. The observed gain from selection for high no. of spikes plant⁻¹ under late sowing date in C₁ was 16.12 and 24.12% from the better parent and the bulk sample, respectively. While in C₂ it was 8.78 and 11.57% from the better parent and 12.68 and 17.80% from the bulk sample under normal and late sowing date, respectively. (Table 12).

Table 12. Means and observed gain from selection for high no. of spikes plant⁻¹ after two cycles of selection under normal and late sowing dates from the bulk sample and the better parent.

| Cycle | Mean | no. of spikes plant ⁻¹ | |
|----------------|---------------|-----------------------------------|---------------------|
| | | Normal | Heat |
| Cycle (1) | Families mean | 12.60 | 8.50 |
| | Parent (1) | 10.60 | 7.13 |
| | Parent (2) | 10.43 | 7.05 |
| | Bulk sample | 9.86 | 6.45 |
| | OG % (Bulk) | 21.75** | 24.12** |
| | OG% (B. P.) | 15.87* | 16.12 ^{ns} |
| R. L.S.D. 0.05 | | 1.74 | 1.40 |
| R. L.S.D. 0.01 | | 2.32 | 1.88 |
| Cycle (2) | Families mean | 10.63 | 9.628 |
| | Parent (1) | 9.60 | 8.52 |
| | Parent (2) | 9.24 | 8.32 |
| | Bulk sample | 9.19 | 7.92 |
| | OG % (Bulk) | 13.53** | 17.74** |
| | OG% (B. P.) | 9.67** | 11.51* |
| R. L.S.D. 0.05 | | 0.75 | 0.96 |
| R. L.S.D. 0.01 | | 1.00 | 1.29 |

Heat susceptibility index and sensitivity to environments:

Among the families which selected under normal sowing date and evaluated under both conditions, four families no. 22, 39, 73 and 94 showed (HSI) values less than unit and gave lower values of sensitivity. These families are less susceptible to heat and more stable under various conditions. The results of the families which selected under late sowing date and evaluated under both conditions showed that seven families no. 21, 29, 45, 89, 114, 135 and 192 showed (HSI) values less than unit and gave lower values of sensitivity (especially families no. 29 and 114). These families were less susceptible to heat stress and more stable under various conditions. The second parent was more tolerant to heat stress than the first parent and the unselected bulk, (Table 13). Falconer (1990) stated that, when selection and environment change the character in opposite direction this is antagonistic selection, i.e. selection upwards in a low environment or downwards in a high environment. Synergistic selection, upwards in a high environment or downwards in a low environment when selection and environment change the character in the same direction. The relative merits of the two types of selection in changing the mean is according to (Falconer 1990). A ratio over 1.0 means that antagonistic selection is better, and a ratio less than 1.0 means that synergistic selection is better.

In the F₄-generation after two cycles of selection for high no. of spikes plant⁻¹ under late sowing date (heat group) and under normal sowing date (normal group), the two groups of families were evaluated under both environments. The relative merits were 1 and 0.924 when selections were evaluated under heat stress and normal conditions, respectively. These results indicated that the synergistic selection and the antagonistic nearly have the same effect in improve no. of spikes plant⁻¹ in these

materials, whether for evaluation made under normal under heat stress conditions. Similar results have been found by Falconer (1990) who reported that to increase the mean performance, selection should to be made upwards in a bad environment, and conversely, to decrease mean performance downwards selection should be made in a good environment.

Table 13. Means of no. of spikes plant⁻¹, heat susceptibility index (HSI) and sensitivity (S) of the selected families under normal (N) and late sowing date (H) and evaluated under both conditions after two cycles of selection (F₄ generation).

| Item | Selection under normal sowing date | | | | | Selection under late sowing date | | | | |
|----------------------------------|------------------------------------|-------|-------|------|------|----------------------------------|-------|-------|------|------|
| | Fam. No. | N | H | HSI | S | Fam. No. | N | H | HSI | S |
| F ₄ selected families | 22 | 1000 | 9.11 | 0.94 | 0.70 | 13 | 11.07 | 884 | 238 | 1.76 |
| | 39 | 993 | 9.28 | 0.69 | 0.51 | 21 | 10.58 | 993 | 0.73 | 0.51 |
| | 73 | 9.73 | 9.39 | 0.37 | 0.27 | 29 | 9.97 | 9.73 | 0.28 | 0.18 |
| | 94 | 8.93 | 8.54 | 0.46 | 0.31 | 45 | 10.04 | 9.43 | 0.72 | 0.48 |
| | 104 | 11.12 | 10.00 | 1.07 | 0.88 | 75 | 11.48 | 10.33 | 1.18 | 0.90 |
| | 123 | 12.15 | 10.77 | 1.21 | 1.09 | 89 | 10.23 | 9.43 | 0.93 | 0.63 |
| | 152 | 11.03 | 9.35 | 1.62 | 1.32 | 114 | 10.17 | 10.04 | 0.15 | 0.10 |
| | 186 | 11.67 | 10.45 | 1.11 | 0.96 | 144 | 10.91 | 9.12 | 1.94 | 1.41 |
| | 234 | 11.60 | 10.24 | 1.24 | 1.07 | 135 | 10.69 | 9.89 | 0.89 | 0.63 |
| | 287 | 10.11 | 9.13 | 1.03 | 0.77 | 192 | 10.12 | 9.62 | 0.58 | 0.39 |
| | Mean | 10.63 | 9.628 | | 0.79 | Mean | 10.52 | 9.635 | | 0.70 |
| Parent (1) | 9.60 | 8.52 | 1.19 | 0.85 | | 9.60 | 8.52 | 1.33 | 0.85 | |
| Parent (2) | 9.24 | 8.32 | 1.05 | 0.72 | | 9.24 | 8.32 | 1.17 | 0.72 | |
| Bulk | 9.19 | 7.92 | 1.47 | 1.00 | | 9.19 | 7.92 | 1.64 | 1.00 | |

Correlation

The results in Table 14 revealed that no. of spikes plant⁻¹ under normal sowing date have positive and highly significant correlation with biological yield plant⁻¹ and grain yield plant⁻¹ (0.54 and 0.74, respectively). While, under late sowing date no. of spikes plant⁻¹ have significant correlation with 100-kernel weight (0.29), highly significant negative correlation with number of kernels spike⁻¹ (-0.64) and highly significant correlation with biological yield plant⁻¹ and grain yield plant⁻¹ (0.47 and 0.46, respectively).

Table 14. Phenotypic correlation between the studied traits for the selected families in (F₄ generation) for no. of spikes plant⁻¹ under normal and late sowing dates.

| Treat. | Evaluation under normal sowing date | | | | |
|-----------------------------------|-------------------------------------|---------|---------|--------|--------|
| | S/plant | 100-KW | K/S | BY | GY |
| Evaluation under late sowing date | S/plant | 0.13 | -0.18 | 0.54** | 0.74** |
| | 100-KW | 0.29* | -0.47** | 0.50** | 0.30* |
| | K/S | -0.64** | -0.59** | 0.09 | 0.33** |
| | BY | 0.47** | 0.19 | -0.12 | 0.77** |
| | GY | 0.46** | 0.20 | 0.23 | 0.52** |

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كفاءة الانتخاب والحساسية للبيئة للصفات المحصولية في عشيرة من قمح الخبز تحت ظروف ميعادي الزراعة العادي والمتأخر

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تم إجراء هذه الدراسة خلال المواسم من 2018/2017 إلى 2020/2019 في محطة البحوث الزراعية بشندويل - محافظة سوهاج - مصر. تم تنفيذ دورتين من الانتخاب المنسب لمحصول الحبوب للنبات وعدد السنايل للنبات من الجيل الثاني إلى الجيل الرابع تحت ميعادي الزراعة العادي والمتأخر. وكان مقدار التباين الوراثي أقل قليلاً من التباين المظهري تحت كلا البيئتين وانخفض عموماً من الجيل الثاني إلى الجيل الرابع. كانت درجة التوريث بالمعنى الواسع المقدرة لصفة محصول الحبوب للنبات 90.27% و 73.83% و لصفة عدد السنايل للنبات 88.21% و 82.47% تحت ميعاد الزراعة العادي والمتأخر على الترتيب بعد دورتين من الانتخاب المنسب. أظهرت السلالات المنتخبة لمحصول الحبوب العالي للنبات والمقيمة تحت ميعاد الزراعة العادي فروق معنوية 18.33% و 9.31% عندما تم الانتخاب تحت ميعاد الزراعة العادي، و 20.60% و 11.83% من مخلوط العشيرة والأب الأفضل على الترتيب عندما تم الانتخاب تحت ميعاد الزراعة المتأخر. كان متوسط التقدم المشاهد للعائلات المنتخبة لعدد السنايل العالي للنبات تحت ميعاد الزراعة العادي والمقيمة تحت كلا البيئتين 13.53% و 17.74% من مخلوط العشيرة و 9.67% و 11.51% من الأب الأفضل تحت ميعادي الزراعة العادي والمتأخر على الترتيب، بينما عندما تم الانتخاب تحت ميعاد الزراعة المتأخر والتقييم تحت كلا البيئتين كان 12.68% و 17.80% من مخلوط العشيرة و 8.78% و 11.57% من الأب الأفضل تحت ميعادي الزراعة العادي والمتأخر على الترتيب. كان الانتخاب المتضاد والانتخاب المتوافق تقريباً لهما تأثير متساوي على الحساسية للحرارة تحت الانتخاب لمحصول الحبوب العالي للنبات وعدد السنايل المرتفع للنبات.