*Egypt. J. Plant Breed. 27(2):289– 308(2023)*

# SELECTION BY INDEPENDENT CULLING LEVELS METHOD IN BREAD WHEAT UNDER NORMAL AND HEAT STRESS CONDITIONS

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## ABSTRACT

***Independent culling is useful when aimed to selecting for multiple traits. Thus, the present work aims to study the efficiency of selection by independent culling levels (ICL) for the three traits, No. of spikes/plant, 100-kernel weight and spike length under normal and late planting dates and to estimate observed and expected response to selection and genetic parameters after two cycles of phenotypic selection in the $F_2$ population. The $F_5$ selected families under normal and late planting were evaluated under both conditions. The genotypic variance was slightly less than the phenotypic one under both planting dates and generally decreased from the base population ($F_3$) to the $F_5$-generation. After the second cycle, heritability estimates were high, and reached 90.14, 81.22 and 85.71% under normal planting date, and 75.00, 78.97 and 85.71% under heat stress for No. of spikes/plant, 100-kernel weight and spike length, respectively. After the second cycles in the $F_5$-generation, evaluation under normal planting date showed observed gain of 0.57, 3.97 and 2.19% was achieved for the normal planting group, and 0.90, 22.21 and 4.85% for the late planting group, from the bulk sample, for number of spikes/plant, 100-kernel weight and spike length respectively, however, the observed gain was significant (P<0.01) increase for number of spikes/plant, 100-kernel weight and spike length under normal and late planting conditions from the better parent. Evaluation under late planting date, showed that the observed gain from the bulk sample was 1.69, 6.18 and 2.38% for normal group, and 7.55, 11.12 and 4.04% for the late planting conditions, for the same respective traits, respectively. The relative merits of selection under late planting to selection under normal planting conditions in changing the mean number of spikes/plant indicated that antagonistic selection was better than synergetic selection.***

Key words: ***Bread Wheat, Selection, Independent culling levels, Heritability, HIS***.

## INTRODUCTION

Crop breeding seeks to develop improved cultivars. Beside high yield levels, a successful cultivar in many crops must meet minimal standards for several other traits that are economically important, such as pest and disease resistance and product quality. Traits are often unfavorably correlated with each other. When traits are antagonistically correlated, selection for one trait causes an undesired economic response in the other trait (Bernardo 2010). This makes simultaneously breeding to improve multiple traits complicated.

Independent culling and the use of a selection index are two commonly used methods in plant breeding programs for selecting for multiple traits. Independent culling involves establishing minimum standards (i.e., culling levels) for each trait and selecting only individuals that meet these minimum standards. The thresholds can be set according to a specific selection intensity or a specific value, such as a value relative to an agronomic check. The independent culling can be applied to multiple traits simultaneously or to individual traits sequentially. The selection index method involves selection for all traits simultaneously based on a linear or nonlinear combination of individual traits weighted by their importance for the breeding objective (Lorena 2021). Independent culling, where "a certain level of merit is established for each trait, and all individuals below that level are discarded, regardless of the superiority or inferiority of their other traits (Hazel and Lush 1942). Heat sensitivity in grain crops could be considered as the basis of predictions that yield will decrease by 10% to 25% in the late 21$^{st}$ century due to higher global temperatures (Intergovernmental Panel on Climate Change 2014). Global average surface temperatures are predicted to increase from +1 to +4 °C in a range of climate change models by the end of the 21st century. Within a relatively short time period, breeders must improve breeding populations with adequate levels of heat stress tolerance (HST) to protect grain yield and other economic traits from rising global temperatures.

The objectives of this study were to estimate: (1) selection efficiency for independent culling levels including three traits, No. of spikes/plant, 100-kernel weight and spike length under normal and heat stress conditions, (2) genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PVC) and heritability under both conditions and (3) heat susceptibility index and sensitivity to environments.

## MATERIALS AND METHODS

This investigation was carried out at El-Mattana Agric. Res. Stn., (ARC), Ministry of Agric, Egypt, during the period from 2018/2019 to 2020/2021 growing seasons. The breeding material used in this study was 100 $F_3$-families traced back to random $F_2$ plants from the cross: {Giza 168 x Gemmeiza11} Table 1. Figure 1 shows the average temperature of crop duration for three growing seasons (2018/209, 2019/2020 and 2020/2021) according to Luxor Airport Station.

**Table 1. The pedigree, selection history and origin of the two parents used in this study.**

| Parents | Pedigree and selection history | Origin |
|---|---|---|
| **Giza 168** | **MRL/BUC //SERI. CM93046-8M-0Y-0M-2Y-0B-0SH.** | **Egypt** |
| **Gemmeiza11** | **Bow"s"/Kz"s"//7C/aeri 82/3/Giza 168/Sakha 61. GM78922-GM-1GM-2GM-1GM-0GM.** | **Egypt** |

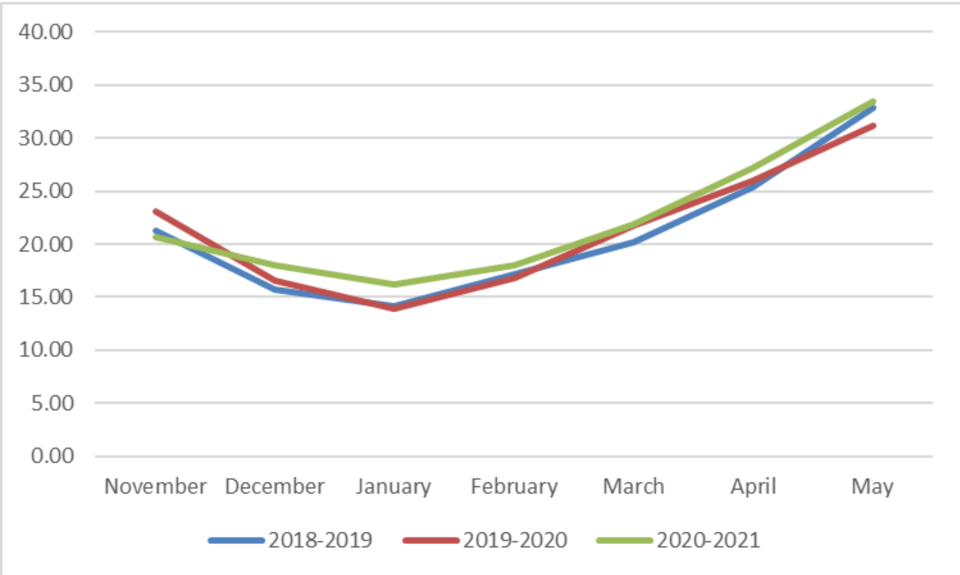


**Fig. 1. Average temperature of crop duration for three growing seasons**

2018/2019 season, ($F_3$ generation): Two field experiments were conducted to evaluate $F_3$ families selected from an $F_2$ population in a randomized complete block design of three replicates. The first experiment sown at normal date, while the other experiment sown at a late planting date. Each experiment comprised 100 $F_3$ families as well as the original parents, $F_3$ bulked random sample (a mixture of equal number of seeds from each plant to represent the generation mean for each date). Twenty families were selected on the basis of independent culling selection (No. of spikes/plant, 100- kernel weight and spike length). An equal number of grains composted from each $F_3$ plant to gave $F_4$ bulk progenies in addition to the parents and the check.

2019/2020 season, ($F_4$ generation): The 20-$F_4$-families selected via independent culling levels, that included the three traits , No. of spike/plant, 100-kernel weight and spike length with the parents and $F_3$ bulk sample were grown using randomized complete block design with three replications. Each family was a single row 3 m long, 30 cm apart and 10 cm between grains within row between plants. Data were recorded on 10 guarded plants from each family in each replicate at both sowing dates. At the end of the season, the best plant from each of the best 10 families' for independent culling levels (ICL) was saved to give the $F_5$ families.

2020/2021 season, ($F_5$ generation): The best ten families selected by ICL under each of normal, and late planting, the two parents and the bulk sample were evaluated under both sowing dates. Data were recorded for the aforementioned characters on ten guarded plants for each family.

**Statistical analysis**

Data were subjected to proper statistical analysis according to Steel *et al* (1997). Genotypes means were compared using Revised Least Significant Differences (RLSD) according to Gomez and Gomez (1984). The phenotypic ($\sigma^2p$), genotypic ($\sigma^2g$) variances, and heritability in broad sense (H) were calculated according to Walker (1960). Realized heritability ($h^2 = R / S$) was calculated according to Falconer (1989), where R = response to selection and S = selection differential. The phenotypic (PCV %) and genotypic (GCV %) coefficients of variability were calculated as outlined by Burton (1952). Heat susceptibility index (HSI) was calculated according to the method of Fischer and Maurer (1978). The sensitivity and relative merits of a selected line were assessed as described by Falconer (1990).

## RESULTS AND DISCUSSION

### 1- Description of the base population; season 2018/2019

The base population used in this study consisted of 100-$F_3$ families traced back to a random sample from $F_2$ single plants originated from the cross Giza 168 × Gemmeiza11. The analysis of variance revealed highly significant differences among $F_3$ families under normal and late planting dates, (Table 2). The average of characters was 84.05 and 74.22 for days to heading, 106.98 and 101.48 cm for plant height, 13.13 and 10.95 for number of spikes/plant, 69.23 and 67.97 for number of kernels/spike, 3.98 and 3.80 g for 100-kernel weight, 12.83 and 11.99 cm for spike length and 33.06 and 30.09 g for grain yield/plant under normal and late planting, respectively.

The GCV % was slightly less than PCV % under both environments, and decreased from C1 to C3, which is normal due to increasing homozygosity and decreasing heterozygosity of selected families. The high estimates of phenotypic and genotypic variability resulted in very high estimates of broad sense heritability in the two cycles of selection. These findings are in line with those reported by Salous *et al* (2014) and Mohiy (2015), who stated that selection reduces genotypic variance of the following generation. Abdelkader (2018), reported that the characteristics of the starting population have a significant effect on early generation selection. The slight difference between (GCV) and (PCV) resulted in high estimates of broad sense heritability for most studied characteristics.

Heritability estimates in broad sense were 94.06 and 95.67% for days to heading, 90.93 and 89.89% for plant height, 92.59 and 92.42% for number of spikes/plant, 95.23 and 92.41% for number of kernels/spike, 95.12 and 98.75% for 100-kernel weight, 91.67 and 92.28% for spike length and 94.72 and 93.63% for grain yield/plant under normal and late planting dates, respectively (Table 2). Similar results were found by Chander *et al (*1993) who sstated that broad sense heritability varied from 79 to 88% for grain yield/plant. Also, Zakaria (2004) reported that heritability values in broad sense were 85.2%, 59.4% and 54.5% for $F_3$ families ($C_0$), first cycle ($C_1$) and second cycle ($C_2$), respectively.

Heat stress reduced days to heading, plant height, no. of spikes/plant, no. of kernels/spike, 100-kernel weight, spike length and grain yield/plant by 11.69, 5.14, 16.60, 1.82, 4.52, 6.78 and 8.98, respectively, compared with the normal planting date, (Table 2). On the context, Poonam *et al* (2006) indicated that all their cultivars showed a decrease in yield due to late sowing and the loss was estimated by 30-40% compared with normal sowing. Besides, Tawfelis *et al* (2010) in Egypt, estimated the reduction by 36.2 %.

**Table 2. Means, mean squares, phenotypic (PCV) and genotypic (GCV) coefficients of variability and heritability ($h^2_{bs}$) values for all studied traits of the $F_3$ generation.**

| Date | Item | Heading date (day) | Plant height (cm) | No. of spikes/ plant | No. of kernels/ spike | 100-kernel weight (g) | Spike length (cm) | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|
| Normal planting date | $P_1$ | 84.05 | 111.67 | 12.67 | 66.00 | 3.76 | 11.00 | 23.12 |
| | $P_2$ | 82.33 | 100.00 | 12.33 | 67.00 | 3.58 | 12.33 | 26.53 |
| | $F_3$ families | 84.05 | 106.98 | 13.13 | 69.23 | 3.98 | 12.83 | 33.06 |
| | Rep. | 1.10 | 86.58 | 1.26 | 1.86 | 0.018 | 1.32 | 8.55 |
| | Families | 7.41** | 271.66** | 5.71** | 201.95** | 1.08** | 2.18** | 114.21** |
| | Error | 0.44 | 24.63 | 0.42 | 9.62 | 0.05 | 0.18 | 4.26 |
| | PCV% | 1.87 | 8.89 | 10.51 | 11.85 | 15.12 | 6.65 | 18.50 |
| | GCV% | 1.81 | 8.48 | 10.11 | 11.57 | 14.75 | 6.37 | 18.00 |
| | $h^2_b$ | 94.06 | 90.93 | 92.59 | 95.23 | 95.12 | 91.67 | 94.72 |
| Late planting date (heat stress) | $P_1$ | 76.67 | 105.00 | 9.33 | 65.33 | 3.75 | 10.33 | 22.36 |
| | $P_2$ | 77.67 | 98.33 | 8.33 | 67.00 | 3.67 | 11.67 | 23.61 |
| | $F_3$ families | 74.22 | 101.48 | 10.95 | 67.97 | 3.80 | 11.99 | 30.09 |
| | Rep. | 0.96 | 78.52 | 0.14 | 5.11 | 0.01 | 0.97 | 14.23 |
| | Families | 11.67** | 364.19** | 3.92** | 119.03** | 1.16** | 2.20** | 83.58** |
| | Error | 0.51 | 36.80 | 0.30 | 9.03 | 0.01 | 0.20 | 4.30 |
| | PCV% | 2.66 | 10.86 | 10.44 | 9.27 | 16.35 | 6.97 | 17.32 |
| | GCV% | 2.60 | 10.29 | 10.03 | 8.91 | 16.10 | 6.70 | 16.76 |
| | $h^2_b$ | 95.67 | 89.89 | 92.42 | 92.41 | 98.75 | 92.28 | 93.63 |
| | Reduction % | 11.69 | 5.14 | 16.60 | 1.82 | 4.52 | 6.78 | 8.98 |

**Reduction% = [(mean value of normal planting date - mean value of late planting date) × 100] /mean value of normal planting date ** = highly significant**

## 2- Response to direct selection using independent culling levels

## 2-1-Phenotypic and genotypic coefficients of variability and heritability estimates

The analysis of variances for the selection criterion and the other correlated traits revealed highly significant differences among genotypes in the $F_4$ and $F_5$-generation under normal and late planting dates as shown in Table (3). This indicated the presence of genetic variability for further cycles of selection by independent culling levels. The effect of selection for two cycles on the variability and heritability estimates for the selection criterion is presented in Table (4).

**Table 3. Mean squares for all studied traits in $F_4$ and $F_5$ generations for ICL selection method under normal (N) and heat stress (S) condition.**

| Generation | Dates | SOV | Mean Squares | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Selection criterion | | | Correlated traits | | | |
| | | | No. of spikes/plant | 100-kernel weight | Spike length | Days to heading | Plant height | No. of kernels/ spike | Grain yield /plant |
| $F_4$ | N | Rep | 4.87 | 0.07 | 3.02 | 13.82 | 48.75 | 26.25 | 82.88 |
| | | Families | 1.86** | 0.95** | 1.24** | 3.63** | 166.91** | 69.73** | 17.11** |
| | | Error | 0.13 | 0.02 | 0.18 | 1.06 | 22.44 | 8.62 | 2.70 |
| | S | Rep | 3.61 | 0.60 | 0.72 | 3.62 | 25.41 | 4.52 | 75.11 |
| | | Families | 2.03** | 0.33** | 1.67** | 11.48** | 56.67** | 77.41** | 30.48** |
| | | Error | 0.21 | 0.05 | 0.21 | 1.56 | 17.52 | 12.32 | 3.46 |
| $F_5$ | N | Rep | 1.30 | 1.08 | 0.40 | 3.33 | 32.50 | 10.30 | 29.90 |
| | | Families | 1.54** | 0.98** | 0.73** | 2.83** | 23.70** | 12.21** | 5.55** |
| | | Error | 0.15 | 0.08 | 0.10 | 0.74 | 5.65 | 1.49 | 1.04 |
| | S | Rep | 0.70 | 1.38 | 0.93 | 1.43 | 0.83 | 20.63 | 86.96 |
| | | Families | 0.73** | 0.48** | 0.83** | 0.77** | 21.85** | 10.46** | 10.19** |
| | | Error | 0.18 | 0.10 | 0.12 | 0.17 | 5.46 | 1.71 | 1.15 |

**Table 4. Phenotypic ($\sigma^2$ p), Genotypic ($\sigma^2$ g) variance and corresponding coefficients of variability for ICL in $F_3$ before and after two cycles of selection under normal (N) and heat stress (S) conditions.**

| Selection cycle | Selection criterion | $\sigma^2$ p | | $\sigma^2$ g | | PCV | | GCV | | $h^2_{bs}$% | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | S | N | S | N | S | N | S | N | S |
| $F_3$ Families ($C_0$) | No. of S/P | 1.90 | 1.30 | 1.76 | 1.21 | 10.51 | 10.44 | 10.11 | 10.03 | 92.59 | 92.42 |
| | 100-KW | 0.36 | 0.33 | 0.34 | 0.32 | 15.12 | 14.61 | 14.75 | 14.50 | 95.12 | 98.00 |
| | SL | 0.73 | 0.70 | 0.67 | 0.65 | 6.65 | 6.97 | 6.37 | 6.70 | 91.67 | 92.28 |
| $F_4$ selected families ($C_1$) | No. of S/P | 0.68 | 0.62 | 0.58 | 0.61 | 6.57 | 25.72 | 6.34 | 24.33 | 93.01 | 89.51 |
| | 100-KW | 0.33 | 0.11 | 0.30 | 0.09 | 15.71 | 14.17 | 15.08 | 13.04 | 92.05 | 84.64 |
| | SL | 0.56 | 0.41 | 0.49 | 0.36 | 5.16 | 8.88 | 4.77 | 8.31 | 85.62 | 87.52 |
| $F_5$ selected families ($C_2$) | No. of S/P | 0.24 | 0.51 | 0.46 | 0.18 | 5.78 | 4.73 | 5.49 | 4.10 | 90.14 | 75.00 |
| | 100-KW | 0.16 | 0.02 | 0.12 | 0.01 | 3.84 | 10.33 | 3.46 | 9.18 | 81.22 | 78.97 |
| | SL | 0.27 | 0.29 | 0.23 | 0.25 | 3.90 | 4.91 | 3.61 | 4.59 | 85.71 | 87.14 |

**$h^2_{bs}$ = Heritability in broad sense.**

The phenotypic ($\sigma^2$ph) and genotypic variances ($\sigma^2$g) were generally larger under normal planting date than under heat stress condition in $C_0$, $C_1$ and $C_2$. The PCV % of No. of spike/plant decreased from 10.51% in the base population to 5.78% after two cycles, and from 15.12 to 3.84% for 100-kernel weight, and from 6.65 to 3.90% for spike length, under normal planting date. The same trend of decrease in GCV % was also observed under both of normal and late planting date. Results indicated that small differences between PCV. % and GCV% for all generations were observed, indicating the importance of the genetic effects in controlling the inheritance for traits studied. The GCV % was slightly less than PCV % under both environments, and decreased from $C_0$ to $C_2$.

The close estimates of phenotypic and genotypic variability resulted in a high estimate of broad sense heritability in the two cycles of selection. Estimates of heritability in broad sense after two cycles of selection were high for No. of spikes/plant (90.14 and 75.0%), 100 kernel weight (81.22 and 78.97%) and spike length (85.71 and 87.14%) under normal and late planting, respectively. Another cause of high estimates of broad sense heritability which was calculated from the expected mean squares through the evaluation of the selected families at one site for one season. This in turn inflates families' mean squares by the confounding effects of the interactions of families, years and dates. normal and heat stress conditions, respectively. Similar results were reported in Assuit, Egypt by Kheiralla (1993), Najafian *et al* (2011) and also in Assuit, Egypt Ahmed *et al* (2014). Indirect selection based upon one or more of yield components, i.e., NS and SW might be more effective than direct selection for GY itself (Smith 1976). Mahdy *et al* (1996) found significant differences among selected lines in the $F_3$-$F_5$ lines, they also reported in Assuit, Egypt high estimates of phenotypic and genotypic coefficients of variability, and high broad sense heritability.

**2-2- Means and observed gain under normal planting date**

The two groups of families selected via selection criteria for two cycles, either under normal or heat stress evaluated in the $F_5$-generation under normal planting date are presented in Table (5). The first group selected under normal planting for ICL selection showed that No. of spikes/plant ranged from 11.33 to 13.33 with an average of 12.40 spikes/plant. Likewise, No. of spikes/plant in the second group, ranged from 10.00 to 12.00 with an average 10.70 spikes/plant, but the second trait included in the ICL, 100-kernel weight, under normal group ranged from 3.89 to 4.36 g with an average 4.06 g. Likewise, 100-kernel weight, of the late planting date ranged from 3.24 to 4.60 g with an average of 4.00 g. The third trait incorporated in the ICL, spike length in the normal group ranged from 12.00 to 13.33 with an average of 12.60 cm, while, spike length of the late planting group, ranged from 10.67 to 12.33 with an average of 11.53 cm.

**Table 5. Mean and observed gain from the bulk sample (OG%"Bulk") and from the better parent (OG%"BP") of the selected families for ICL method after two cycles of selection under normal planting date.**

| Item | Fam. No. | Evaluation under normal planting date | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | OG%(Bulk) | | | OG%(Bp) | | |
| | | No. of spikes /plant | 100-kernel weight (g) | Spike length (cm) | No. of spikes/ plant | 100-kernel weight (g) | Spike length (cm) | No. of spikes/ plant | 100-kernel weight (g) | Spike length (cm) |
| Normal selections | 8 | 13.33 | 4.00 | 12.00 | 8.11** | 2.56 | 2.68 | 17.65** | 17.30** | 2.83 |
| | 14 | 11.67 | 4.21 | 12.00 | 5.35* | 7.95** | 2.68 | 3.00 | 23.46** | 2.83 |
| | 22 | 13.00 | 3.89 | 13.00 | 5.43* | 0.26 | 5.43* | 14.74** | 14.08** | 11.40** |
| | 23 | 12.00 | 3.99 | 12.67 | 2.68 | 2.31 | 2.76 | 5.91* | 17.01** | 8.57** |
| | 30 | 12.67 | 4.08 | 12.67 | 2.76 | 4.62* | 2.76 | 11.83** | 19.65** | 8.57** |
| | 33 | 12.67 | 4.36 | 13.33 | 2.76 | 11.79** | 8.11** | 11.83** | 27.86** | 14.22** |
| | 35 | 11.33 | 3.94 | 13.00 | 8.11** | 1.03 | 5.43* | 0.00 | 15.54** | 11.40** |
| | 37 | 12.33 | 3.93 | 13.00 | 0.00 | 0.77 | 5.43* | 8.83** | 15.25** | 11.40** |
| | 40 | 11.67 | 4.21 | 12.33 | 5.35* | 7.95** | 0.00 | 3.00 | 23.46** | 5.66* |
| | 77 | 13.33 | 3.94 | 12.00 | 5.43* | 3.85 | 4.30 | 14.74** | 9.97** | 1.11 |
| | Average | 12.40 | 4.06 | 12.60 | 0.57 | 3.97 | 2.19 | 9.44** | 18.91** | 7.97** |
| Heat selections | 6 | 10.33 | 3.24 | 10.67 | 3.19 | -3.28 | -3.00 | 10.72** | 0.00 | 0.00 |
| | 31 | 10.33 | 4.42 | 11.67 | 3.19 | 31.94** | 6.09* | 10.72** | 36.42** | 9.37** |
| | 37 | 10.33 | 3.53 | 11.33 | 3.19 | 5.37 | 3.00 | 10.72** | 8.95** | 6.19* |
| | 50 | 10.00 | 4.04 | 12.00 | 6.28* | 20.60** | 9.09** | 7.18* | 24.69** | 12.46** |
| | 57 | 11.00 | 4.44 | 10.67 | 3.09 | 32.54** | 3.00 | 17.90** | 37.04** | 0.00 |
| | 60 | 10.67 | 4.27 | 11.33 | 0.00 | 27.46** | 3.00 | 14.36** | 31.79** | 6.19* |
| | 73 | 11.00 | 4.10 | 11.67 | 3.09 | 22.39** | 6.09** | 17.90** | 26.54** | 9.37** |
| | 80 | 12.00 | 4.20 | 12.33 | 12.46** | 25.37** | 12.09** | 28.62** | 29.63** | 15.56** |
| | 81 | 10.67 | 4.10 | 12.33 | 0.00 | 22.39** | 12.09** | 14.36** | 26.54** | 15.56** |
| | 82 | 11.33 | 4.60 | 11.33 | 6.19* | 37.31** | 3.00 | 21.44** | 41.98** | 6.19* |
| | Average | 10.70 | 4.00 | 11.53 | 0.90 | 22.21** | 4.85* | 15.39** | 26.36** | 8.09** |
| R.LSD$_{0.05}$ | | 0.66 | 0.19 | 0.55 | --- | --- | --- | --- | --- | --- |
| R.LSD$_{0.01}$ | | 0.91 | 0.27 | 0.75 | --- | --- | --- | ---- | ---- | ----- |

**---- = None significant, *= Significant and **= Highly significant.**

The average observed gain in percentage from the bulk sample and the best parent for the selected families in ICL method under normal or heat stress and were evaluated under normal planting date, are presented in Table (5). The observed gain under normal planting group reached 0.57, 3.97 and 2.19%. Likewise, under heat stress it reached 0.90, 22.21 and 4.85% from the bulk sample for no of spikes/plant, 100-kernel weight and spike length respectively. On the other hand, the observed gain under normal planting group from the better parent was significant (9.44, 18.91 and 7.97%). Likewise, under heat stress was significant (15.39, 26.36 and 8.09%, respectively) for the same above mentioned traits.

**2.3- Means and observed gains under late planting date**

The two groups of families selected for selection criteria for two cycles either under normal or under heat stress evaluated in the $F_5$-generation under heat stress conditions are presented in Table (6).

The first group wase selected under normal planting for ICL selection showed that No. of spikes/plant ranged from 11.00 to 12.67 with an average of 11.87 spikes/plant. Likewise, No. of spikes/plant in the second group, ranged from 9.67 to 11.00 with an average of 10.40 spikes/plant, but for the second trait included in the ICL, 100-kernel weight, under normal group ranged from 3.73 to 4.23 g with an average of 3.92 g. Likewise, 100-kernel weight, in the late planting date ranged from 3.06 to 4.20 with an average of 3.88 g. The third trait incorporated in the ICL, spike length in the normal group ranged from 10.67 to 12.33 with an average of 11.60 cm, while, spike length of the late planting group, ranged from 10.33 to 12.00 with an average of 11.10 cm.

The average observed gain in percentage from the bulk sample and the better parent for the selected families in ICL method under normal or heat stress evaluated under late planting date, and are presented in Table (6) . The average observed gain under normal planting group reached 1.69, 6.18 and 2.38%. Likewise, under heat stress it reached 7.55, 11.12 and 4.04% from the bulk sample for no of spikes/plant, 100-kernel weight and spike length, respectively. On the other hand, the observed gain under normal planting group from the better parent was significant (7.88, 22.44 and 5.45%).

**Table 6. Mean and observed gain from the bulk sample (OG%"Bulk") and from the better parent (OG%"BP") of the selected families for ICL method after two cycles of selection under late planting date.**

| Item | Fam. No. | Evaluation under late planting date | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | OG%(Bulk) | | | OG%(Bp) | | |
| | | No. of spikes /plant | 100-kernel weight | Spike length | No. of spikes/ plant | 100-kernel weight | Spike length | No. of spikes/ plant | 100-kernel weight | Spike length |
| Normal selections | 8 | 12.67 | 3.87 | 12.00 | 8.57** | 4.88 | 5.91* | 15.18** | 20.94** | 9.09** |
| | 14 | 11.67 | 4.08 | 12.00 | 0.00 | 10.57** | 5.91* | 6.09 | 27.50** | 9.09** |
| | 22 | 12.33 | 3.73 | 11.67 | 5.66* | 1.08 | 3.00 | 12.09** | 16.56** | 6.09* |
| | 23 | 12.00 | 3.87 | 11.67 | 2.83 | 4.88 | 3.00 | 9.09** | 20.94** | 6.09* |
| | 30 | 11.67 | 3.81 | 11.33 | 0.00 | 3.25 | 0.00 | 6.09 | 19.06** | 3.00 |
| | 33 | 12.00 | 4.23 | 12.00 | 2.83 | 14.63** | 5.91* | 9.09** | 32.19** | 9.09** |
| | 35 | 11.00 | 3.87 | 12.33 | 5.74* | 4.88 | 8.83* | 0.00 | 20.94** | 12.09** |
| | 37 | 12.00 | 3.87 | 11.33 | 2.83 | 4.88 | 0.00 | 9.09** | 20.94** | 3.00 |
| | 40 | 11.00 | 4.12 | 11.00 | 5.74* | 11.65** | -2.91 | 0.00 | 28.75** | 0.00 |
| | 77 | 12.33 | 3.73 | 10.67 | 5.66* | 1.08 | 5.83* | 12.09** | 16.56** | -3.00 |
| | Average | 11.87 | 3.92 | 11.60 | 1.69 | 6.18* | 2.38 | 7.88* | 22.44** | 5.45* |
| Heat selections | 6 | 10.00 | 3.06 | 10.67 | 3.41 | -12.32* | 0.00 | 15.34** | -2.24 | 3.29 |
| | 31 | 9.67 | 3.83 | 11.67 | 0.00 | 9.74 | 9.37** | 11.53** | 22.36** | 12.97** |
| | 37 | 10.33 | 3.27 | 10.67 | 6.83* | -6.30 | 0.00 | 19.15** | 4.47 | 3.29 |
| | 50 | 10.00 | 4.16 | 11.00 | 3.41 | 19.20** | 3.09 | 15.34** | 32.91** | 6.49* |
| | 57 | 10.00 | 4.08 | 10.33 | 3.41 | 16.91* | -3.19 | 15.34** | 30.35** | 0.00 |
| | 60 | 10.67 | 4.19 | 11.00 | 10.34** | 20.06** | 3.09 | 23.07** | 33.87** | 6.49* |
| | 73 | 11.00 | 3.84 | 11.33 | 13.75** | 10.03 | 6.19* | 26.87** | 22.68** | 9.68** |
| | 80 | 11.00 | 4.08 | 11.67 | 13.75** | 16.91* | 9.37** | 26.87** | 30.35** | 12.97** |
| | 81 | 10.33 | 4.07 | 12.00 | 6.83* | 16.62* | 12.46** | 19.15** | 30.03** | 16.17** |
| | 82 | 11.00 | 4.20 | 10.67 | 13.75** | 20.34** | 0.00 | 26.87** | 34.19** | 3.29 |
| | Average | 10.40 | 3.88 | 11.10 | 7.55* | 11.12* | 4.04* | 19.85** | 23.90** | 7.46* |
| $R.LSD_{0.05}$ | | 0.72 | 0.54 | 0.57 | ---- | --- | --- | --- | --- | --- |
| $R.LSD_{0.01}$ | | 0.99 | 0.74 | 0.79 | ------ | --- | --- | ---- | ---- | ----- |

**---- = None significant**, ***= Significant and **= Highly significant**.

Likewise, under heat stress, it was reached 19.85, 23.90 and 7.46% for the same above mentioned traits, respectively. Few researchers used independent culling levels method. Mahdy (1988) in Assuit, Egypt indicated that the ICL method of selection was inferior in improving grain yield/plant to desired gain index, Smith-Hazel index, and direct selection for grain yield/plant *Per se*. Ismail *et al* (1996) at Assuit, Egypt found that ICL method gave intermediate increase in grain yield and most of the involved traits. However, the genetic variance after using ICL method was larger than after single trait selection. Also, Mahdy (2012) found that using independent culling levels for three cycles to improve grain yield/plant under drought stress in their materials, was better than selection under normal irrigation, either evaluation conducted under drought stress or normal irrigation. Our results are in line with those reported by many investigators of them, Amin (2003) at Minia, Egypt and El-Morshidy *et al* (2010) at Assuit, Egypt.

**2.4-Average observed gain from selection using independent culling levels**

Means and observed gain from selection for three criteria incorporated in the ICL method for the two cycles of selection are presented in Table (7).

The observed gain from selection for no of spikes/plant under normal planting date was 3.63 and 2.57%, 100-kernel weight reached 5.85 and 6.74% and spike length was 4.05 and 4.00% from the better parent in $C_0$ and $C_1$, respectively. Likewise, from the bulk sample was (1.00 and -2.92%), (-2.68 and 1.96%) and (1.26 and 1.22%) for the above mentioned traits in $C_0$ and $C_1$, respectively. After two cycles of selection, the observed gain for no of spikes/plant of families selected under normal and evaluated under normal and heat stress was 9.44 and 14.68%, 100-kernel weight was 19.06 and 26.23% and spike length was 7.96 and 8.05% from the better parent, respectively. Likewise, from the bulk sample it was (0.57 and 3.58%), (4.10 and 22.08%) and (12.18 and 4.81%) for the above mentioned traits in $C_2$, respectively. On the other hand, the observed gains in the three selection criteria of families selected under late and evaluated under normal and heat stress were highly significant difference from the bulk sample or from the better parent.

**Table 7. Means and observed gain from selection for ICL method under normal and heat stress from the bulk sample and the better parent.**

| Item | Evaluation under normal planting date | | | | | | Evaluation under late planting date | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of spikes/ Plant | | 100-kernel weight (g) | | Spike length (cm) | | No. of spikes/ Plant | | 100-kernel weight (g) | | Spike length (cm) | |
| Cycle0: 2018/2019 | | | | | | | | | | | | |
| Families mean | 13.13 | | 3.98 | | 12.83 | | 10.95 | | 3.80 | | 12.00 | |
| OG% (Bulk) | 1.00 | | -2.68** | | 1.26* | | -16.17** | | -5.71** | | 2.82** | |
| OG %(Better parent | 3.63** | | 5.85** | | 4.05** | | 17.36** | | 1.33* | | 2.82** | |
| Cycle1: 2020/2021 | | | | | | | | | | | | |
| Families mean | 11.97 | | 3.64 | | 12.48 | | 9.63 | | 3.54 | | 10.80 | |
| OG% (Bulk) | 2.92** | | 1.96** | | 1.22** | | -3.70** | | 3.20** | | -1.82** | |
| OG %(Better parent | 2.57** | | 6.74** | | 4.00** | | 7.00** | | 16.06** | | 1.22** | |
| $F_5$-generation | N | S | N | S | N | S | N | S | N | S | N | S |
| Cycle2: 2021/2022 | | | | | | | | | | | | |
| Families mean | 12.40 | 10.70 | 4.06 | 4.09 | 12.60 | 11.53 | 11.87 | 10.40 | 3.92 | 3.88 | 11.60 | 11.10 |
| OG% (Bulk) | 0.57* | 3.58** | 4.10** | 22.08** | 12.18** | 4.81** | 1.71** | 7.54** | 6.23** | 11.17** | 2.38** | 4.03** |
| OG %(Better parent | 9.44** | | 19.06** | 26.23** | 7.96** | 8.05** | 7.91** | 11.46** | 22.50** | 23.96** | 5.45** | 7.45** |

*** and**, Significant at 0.05 and 0.01 levels of probability, respectively.**
**OG% (Bulk) = observed gain in percentage from the bulk sample.**
**OG% (BP) = observed gain in percentage from the best parent.**

**3- Heat susceptibility index, sensitivity to environment and correlation coefficients**

Heat susceptibility index, sensitivity to environment and correlation coefficients in $F_5$-generations are presented in Table (8). The results of the selected families for two cycles under normal planting date, and evaluated under both environments indicated that the five families no. 8, 23, 30, 33 and 37 showed heat susceptibility index (HSI) values less than one. Likewise, those selected under late planting date, and evaluated under both environments indicated that families no. 6, 37, 50, 57, 60 and 73 gave heat susceptibility index (HSI) values less than one. These families could be considered less susceptible to heat, indicating high plasticity to high temperature. The results obtained by Khanna-Chopra and Viswanath (1999) suggested that the yield under heat stress relative to control or optimum conditions is widely accepted as a gauge of heat-tolerance in wheat. Genotypes having HSI ≤ 0.500 were considered to be highly tolerant, HSI > 0.500 to ≤ 1.000 moderately tolerant and those having HSI > 1.000 were susceptible. Shenoda *et al* (2021) concluded that the smaller HIS values (<1.00) indicate better thermal tolerance, the genotypes which showed the lowest HSI values of $GY/m^2$, such as Masr 2, Giza171, Sids1 and line9, also indicated the highest $GY/m^2$ and had the best performance under heat stress conditions. In addition, this index may describe the stability in the yield under heat stress. Jinks and Connolly (1973 and 1975) concluded that environmental sensitivity was reduced if selection and environmental effects were in opposite directions, sensitivity was increased if selection and environmental effects were in the same direction.

A highly significant and positive correlation was observed between the mean grain yield/plant under normal and the same trait under heat stress ($r = 0.93^{**}$). On the other hand, correlation coefficients between HSI and grain yield/plant under normal and heat stress (table 8) were positive and non-significant, $r = 0.56$ and $r = 0.82$, respectively. By contrast, under late planting date the results showed that highly significant positive correlation was observed between the grain yield/plant under normal and the same trait under heat stress ($r = 0.90^{**}$).

**Table 8. Means of grain yield/plant, heat susceptibility index (HSI) and sensitivity under two dates after two cycles of selection in the F5-generations and correlations between them.**

| Item | Fam. No. | under normal date GY/P (g) | under heat stress GY/P (g) | HSI | Sensitivity |
|---|---|---|---|---|---|
| Normal planting date | 8 | 36.33 | 35.43 | 0.39 | 0.33 |
| | 14 | 32.96 | 30.10 | 1.36 | 1.04 |
| | 22 | 34.44 | 30.89 | 1.62 | 1.29 |
| | 23 | 33.45 | 31.54 | 0.90 | 0.69 |
| | 30 | 32.70 | 30.71 | 0.96 | 0.72 |
| | 33 | 35.81 | 33.65 | 0.95 | 0.79 |
| | 35 | 32.37 | 29.54 | 1.37 | 1.03 |
| | 37 | 33.76 | 32.27 | 0.69 | 0.54 |
| | 40 | 33.58 | 31.09 | 1.16 | 0.91 |
| | 77 | 35.35 | 33.84 | 0.67 | 0.55 |
| | Average | 34.08 | 31.91 | | 0.79 |
| Correlation | GY/P (Normal) | ----- | 0.93** | - 0.56 | |
| | GY/P (heat stress) | | | -0.82* | |
| | (HSI) | ---------- | -------- | ----- | |
| Late planting date (heat stress) | 6 | 33.43 | 32.04 | 0.77 | 0.62 |
| | 31 | 33.23 | 31.00 | 1.24 | 1.00 |
| | 37 | 28.54 | 27.48 | 0.69 | 0.48 |
| | 50 | 29.65 | 28.33 | 0.83 | 0.59 |
| | 57 | 29.52 | 30.33 | 0.51 | -0.36 |
| | 60 | 33.21 | 31.58 | 0.91 | 0.73 |
| | 73 | 32.18 | 31.16 | 0.59 | 0.46 |
| | 80 | 34.41 | 31.96 | 1.32 | 1.10 |
| | 81 | 35.03 | 31.06 | 2.10 | 1.78 |
| | 82 | 37.22 | 33.90 | 1.65 | 1.49 |
| | Average | 32.64 | 30.88 | | 0.79 |
| Correlation | GY/P (Normal) | ------- | 0.90** | 0.74* | |
| | GY/P (heat stress) | ------- | ---------- | 0.38 | |
| | (HSI) | ------- | ------ | ------- | |

**---- = None significant, *= Significant and **= Highly significant**.

Likewise, a positive correlation between HSI and grain yield/plant under normal and heat stress was r = 0.74 and r = 0.38, respectively. This would indicate that about 50% of the variation in heat susceptibility in this set of genotypes could be ascribed to variation in yield potential. Therefore, a stress tolerant genotype, as defined by (HSI), need not to have a high yield since (HSI) provides a measure of tolerance based on minimization of yield loss under stress, rather than no stress yield *per se* as pointed out by Bruckner and Frohberg (1987). These results are in harmony with the results of Salous *et al* (2014) who reported that a highly significant positive correlation was observed between mean grain yield/plant under normal planting and the heat susceptibility index (HSI) (r = 0.88**).

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# الإنتخاب بطريقة المستويات المستبعدة فى قمح الخبز
# تحت الظروف المثلي والاجهاد الحرارى

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***يهدف هذا البحث إلى دراسة كفاءة الانتخاب بالمستويات المستبعدة وشملت ثلاث صفات هى (عدد السنابل للنبات، وزن المائة حبة و طول السنبلة) تحت ظروف ميعادى الزراعة الأمثل والمتأخر وذلك بهدف تقدير الاستجابة المتوقعة بعد دورتين من الانتخاب للعشيرة الأساس الخاصة بالجيل الثانى. وتم تقييم منتخبات الجيل الخامس تحت ظروف الميعاد الأمثل والمتأخر. وكا ن مقدار التباين الوراثى أقل قليلا من التباين المظهرى تحت ظروف البيئتين، وانخفض تدريجيا من الجيل الثالث الى الجيل الخامس. وكانت كفاءة التوريث بالمعنى العريض ٩٠,١٤ ، ٨١,٢٢ و ٨٥,٧١% تحت ميعاد الزراعة الأمثل ، و ٧٥,٠٠، ٧٨,٩٧ و ٨٥,٧١% تحت ميعاد الزراعة المتاخر لصفات عدد السنابل للنبات، وزن المائة حبة و طول السنبلة على الترتيب. أظهرت منتخبات المجموعة الأولى (الميعاد الأمثل) والتى قيمت تحت ميعاد الزراعة الأمثل زيادة معنوية جدا بالنسبة للعينه العشوائية بمقدار ٠,٥٧، ٣,٩٧ و ٢,١٩ والمجموعة الثانية ( الميعاد المتأخر) والتى قيمت تحت ميعاد الزراعة الأمثل زيادة معنوية جدا بالنسبة للعينه العشوائية بمقدار ٠,٩٠، ٢٢,٢١ و ٤,٨٥% لصفات عدد السنابل للنبات، وزن المائة حبة و طول السنبلة على الترتيب. وعند تقييم المنتخبات تحت ميعاد الزراعة المتأخر أظهرت منتخبات المجموعة الأولى (الميعاد الأمثل) ١,٦٩، ٦,١٨ و ٢,٣٨% والمجموعة الثانية (الميعاد المتأخر) ٧,٥٥، ١١,١٢ و ٤,٠٤ زيادة معنويه لنفس الصفات السابقة بالترتيب بالنسبة للعينة العشوائية. وتشير النتائج إلي أن الانتخاب لمحصول الحبوب فى ميعاد الزراعة الأمثل أدى الى زيادة حساسية العائلات المنتخبة، بينما الإنتخاب فى ميعاد الزراعة المتأخر قلل الحساسية.***

***المجلة المصرية لتربية النبات ٢٧(٢): ٢٨٩– ٣٠٨ (٢٠٢٣)***