CONTENTS

SUMMARY

The present study was carried out during the three successive seasons, i.e. 2011/2012, 2012/2013 and 2013/2014 at Shandaweel Agriculture research Station, Agriculture Research Center (ARC), Egypt. The objective of this study was to (1) Study the efficiency of pedigree selection in improving grain yield in durum wheat after two cycles of selection under normal and heat stress conditions. (2) Estimate phenotypic, genotypic coefficients of variation and heritability under normal and heat stress conditions. (3) Study the effect of selection on the correlated traits. (4) Estimate heat susceptibility index (HSI) and environmental sensitivity of the selected families to heat stress.

Two cycles of pedigree selection were completed under normal and heat stress conditions. Two durum wheat populations (*T. durum* Desf.) in the F_2, F_3 and F_4 -generations were used.

In 2011/2012 season: 1500 plants for each of F_2 population were grown in non replicated plots under heat stress conditions. Data collected on all the guarded plants of each population. At the end of the season fifty plant from each population under heat stress were selected for each selection criterion (grain yield and No. of spikes/plant) to be F3 families in the next season.

In 2012/2013 season: Eight field experiments were conducted to evaluate F_3 families selected from each treatment for each population was sown in same treatment. Each plant sowed in a separate row 2.5 m long, 30 cm. apart and 10 cm. between plants within row as F_3 families in Randomized complete design with three replications. Selection between and within families was practiced. The best 10 plants from best 10 families were selected from each experiment and retained to be raised as F_4 families in the next season.

In 2012/2013 season: Sixteen field experiments were conducted to evaluate F_4 families selected from each treatment for each population was sown in both environments. Each plant sowed in a separate row 2.5 m long, 30 cm. apart and 10

cm. between plants within row as F_4 families in Randomized complete design with three replications.

The studied traits were Days to heading (days), Number of spikes/plant, Plant height (cm), Biological yield/plant (gm), Grain yield/plant (gm), 100-kernel weight (gm) and Number of kernels/spike.

1- Base population:

The analysis of variance for all studied traits revealed highly significant differences among F3 families under normal and heat stress conditions.

In population 1: Under heat stress, for F_2 plants the average number of spikes/plant, plant height, biological yield, grain yield/plant, 100-kernel weight and number of kernels/ spike was 6.45 spikes, 102.9 cm, 54.14 gm, 12.95 gm, 5.42 gm and 36.75 kernels, respectively.

In population 2: Under heat stress, for F_2 plants the average number of spikes/plant, plant height, biological yield, grain yield/plant, 100-kernel weight and number of kernels/ spike was 8.89 spikes, 105.40 cm, 66.34 gm, 15.67 gm, 4.97 gm and 36.16 kernels, respectively,

2- Selection for grain yield/plant:

2-1-F_3 generation:

2 -1-1- Response to direct selection for grain yield under normal and heat stress conditions.

Analysis of variance revealed significant differences between F_3 families in all the studied traits except days to heading of populations 1 under normal condition was in significant.

The average grain yield/plant for selected families of population 1 was 24.37gm/plant with a range from 11.92 to 31.53 gm/plant under normal condition, while under heat stress conditions, it was 16.54 gm/plant with a range from 5.20 to 27.87 gm/plant. Meanwhile, average grain yield/plant for population 2 was 24.13 gm/plant with a range from 17.33 to 37.62 gm/plant under normal condition, while

under heat stress condition, it was 21.12 gm/plant with a range from 15.90 to 29.89 gm/plant.

The phenotypic coefficients of variability (pcv%) were 10.22% and 17.08% under normal and heat stress conditions, respectively in population 1, while they were 16.30% and 12.56% under normal and heat stress conditions, respectively in population 2. Genotypic coefficients of variability (gcv%) in population 1 were 9.46% and 16.36% under normal and heat stress conditions, respectively, while it was 15.89 and 11.57 under normal and heat stress conditions, respectively, in population 2. Estimates of (pcv%) and (gcv%) indicated the presence of variability in grain yield/plant. These variabilities suggest that selection among the F_3 families may produce change in grain yield/plant. In general, (pcv%) was relatively higher than (gcv%) under both environments. Heritability estimates in broad-sense (H) in population 1 were 85.62 and 91.67% under normal and heat stress, respectively. In population 2, it was 95.12 and 84.79 under normal and heat stress, respectively. In general, high estimates of broad sense heritability indicated that the environmental effects were small compared to the genetic effects.

2-1-2- Effect of selection for grain yield on the other traits under normal and heat stress conditions:

In population 1: Under normal condition, (pcv%) values ranged from 4.45% for no. of spikes/plant to 13.89% for biological yield/plant, (gcv%) values ranged from 1.45% for no. of spikes/plant to 11.41% for biological yield/plant, Broad sense heritability ranged from 10.69% for no. of spikes/plant to 96.08% for 100-kernel weight. While under heat stress condition, (pcv%) values ranged from 4.34% for days to heading to 17.08% for grain yield/plant, (gcv%) values ranged from 4.04% for days to heading to 16.36% for grain yield/plant, Broad sense heritability ranged from 72.64% for no. of kernel/spike to 94.39% for 100-kernel weight.

In population 2: Under normal condition, (pcv%) values ranged from 3.43% for days to heading to 20.50% for biological yield/plant, (gcv%) values ranged from 2.98% for days to heading to 18.40% for biological yield/plant, Broad sense heritability ranged from 75.43% for days to heading to 95.78% for 100-kernel weight. While under heat stress condition, (pcv%) values ranged from 3.59% for days to heading to 13.42% for biological yield/plant, (gcv%) values ranged from 3.16% for days to heading to 11.57% for grain yield/plant, Broad sense heritability ranged from 48.76% for biological yield/plant to 90.12% for 100-kernel weight.

2-2- Effect of selection for grain yield after the second cycle.

2-2-1- Analysis of variance for the studied traits:

The analysis of variance for the studied traits of the selected families in cycle 2 (F_4 generation) in populations 1 and 2 under the two environments showed that there were highly significant differences among selected families for grain yield and other related traits in F_4 generations under normal and heat stress conditions except days to heading in population 2 under normal condition, no. of spikes/plant, plant height and biological yield/plant under heat stress condition.

2-2-2-Phenotypic and genotypic coefficients of variability and heritability estimates:

The results indicated that phenotypic and genotypic coefficients of variability for grain yield/plant were (17.83 and 17.69%) and (11.86 and 11.51%) for F_4 selected families under normal and heat stress conditions, respectively, in population 1. In population 2, the above mentioned values were (10.87 and 10.50%) and (16.67 and 16.35%) for F_4 selected families under normal and heat stress conditions, respectively.

Heritability in broad sense values for grain yield/plant under normal and heat stress for F_4 selected families were 98.44 and 94.18%, respectively, in population 1. while in population 2 it were 93.45 and 96.19% under normal and heat stress conditions, respectively. Heritability for the other traits ranged from 73.66% for

plant height to 98.59% for 100-kernel weight under normal, and from 86.44 for plant height to 98.02% for 100-kernel weight under heat stress condition in population 1.While in population 2, heritability for the other traits ranged from 69.00% for biological yield/plant to 93.45% for grain yield/plant under normal, and from 49.70 for no. of spikes/plant to 96.19% for grain yield/plant under heat stress conditions.

2-2-3- Means, observed gain under normal:

Population 1: The results showed that average grain yield/plant under normal condition was 24.77 gm/plant and 18.60 gm/plant under heat stress. From these results it is clear that family no. 410 surpassed the best parent by 70.93% under normal condition and family no. 53 surpassed the better parent by 67.41% under heat stress conditions.

Average days to heading, no. of spikes/plant, plant height, biological yield, 100 kernel weight and no. of kernels/ spike for population 1 under normal condition was 103, 9.69, 111.37, 92.04, 6.09 and 42.31, respectively, while the average of these traits under heat stress were 91, 9.43, 114.25, 77.67, 6.06 and 31.94, respectively.

Population 2: The results showed that average grain yield/plant under normal was 29.21 gm/plant and 22.89 gm/plant under heat stress. It is clear that family no. 212 surpassed the best parent by 58.25% under normal and families no. 252 under heat stress conditions.

Average days to heading, no. of spikes/plant, plant height, biological yield, 100 kernel weight and no. of kernels/ spike for population 1 under normal were 103, 11.66, 114.79, 100.57, 5.58 and 45.45, respectively, while average these traits under heat stress were 91.40, 11.57, 106.40, 87.26, 4.60 and 39.64, respectively.

2-2-4- Means, observed gain of the selected families under heat stress:

Population 1: Average grain yield/plant under normal was 27.06 gm and 24.50 gm under heat stress. These results cleared that all families highly

significantly surpassed the best parent under normal condition except family no. 118 and all families under heat stress conditions.

Average days to heading, no. of spikes/plant, plant height, biological yield, 100 kernel weight and no. of kernels/ spike for population 1 under normal condition were 98, 10.52, 107.47, 93.87, 6.09 and 43.00, respectively, while average these traits under heat stress were 86, 10.24, 106.82, 86.43, 5.44 and 43.93, respectively.

Population 2: Average grain yield/plant under normal condition was 29.31 gm and 24.03 under heat stress. From these results it is clear that all families highly significantly surpassed the best parent under normal condition except family no. 235, while families no.40, 46, 67, 119, 371 and 430 under heat stress conditions were had average lower than the mean parent.

Average days to heading, no. of spikes/plant, plant height, biological yield, 100 kernel weight and no. of kernels/ spike for population 1 under normal were 101, 10.76, 112.00, 95.10, 5.72 and 48.06, respectively, while average these traits under heat stress were 91.03, 10.18, 105.17, 109.79, 5.63 and 33.77, respectively.

2-3-Average observed gain from selection in the two cycles:

In population 1: The observed gain for grain (OG%) yield/plant under normal was (71.98%) from the bulk sample and (26.20%) from the better parent in C_1. While under heat stress conditions it was (99.39%) from the bulk sample and was (34.62%) from the better parent in C_1. The observed gain for grain yield of the selected families under normal and evaluated under both environments in C_2 was (59.81 and 27.84%) and (44.26 and 37.78%) from bulk sample and the better parent, respectively. On the other hand, the observed gain (OG%) was (63.22 and 49.70%) and (37.59 and 76.43%) for families selected under heat stress and evaluated under normal and heat stress conditions, respectively. These results indicated that synergistic selection was better than antagonistic selection.

In population 2: The observed gain (OG%) for grain yield/plant under normal condition was (52.82%) from the bulk sample and was (39.72%) from the better parent in C_1. While under heat stress it was (51.07%) from the bulk sample and was (25.42%) from the better parent in C_1. The observed gain of the selected families under normal and evaluated under both conditions in C_2 was (27.95 and 40.69%) and (38.24 and 46.36%) from bulk sample and the better parent, respectively. While these gains were (27.82 and 40.28%) and (29.35 and 30.60%) for families selected under heat stress.

2-4-Heat susceptibility index and sensitivity to environments:

The results of population 1 showed that seven families of the selected families under normal and five families of the selected families under heat stress have heat susceptibility index (HSI) values less than one. While the results of population 2 showed that five families of the selected families under normal and five families of the selected families under heat stress have heat susceptibility index (HSI) values less than one. These families could be considered more tolerant to heat stress conditions and could be involved in wheat breeding programs for less favorable conditions.

2-5- Effect of heat stress on grain yield and other studied traits:

In population 1: the reduction in grain yield/plant was 32.13 and 0.28% in F_3 and F_4 generations, respectively. The reduction in no. of spikes/plant was 30.31 and 8.58% in F_3 and F_4 generations, respectively. The reduction in 100-kernel weight was 2.20 and 10.67% in F_3 and F_4 generations, respectively.

In population 2: the reduction in grain yield/plant was 12.47 and 17.73% in F_3 and F_4 generations, respectively. The reduction in no. of spikes/plant was 6.51 and 12.69% in F_3 and F_4 generations, respectively. The reduction in 100-kernel weight was 1.74 and 0.89% in F_3 and F_4 generations, respectively. These results showed that the maximum loss in grain yield/plant and the related traits was in F_3 generation and decreased with selection.

2-6- Phenotypic and genotypic correlations:

In populations 1 and 2 with selection under normal or heat stress conditions the highest estimates for both phenotypic and genotypic correlation were showed for the followed pairs of the studied traits: (grain yield/plant vs no. of kernel/spike), (grain yield/plant vs plant hight), (days to heading vs no. of kernel/spike), (biological yield/plant vs no. of spikes/plant), (no. of kernel/spike vs days to heading)), (biological yield/plant vs plant height), (grain yield/plant vs 100-kernel weight) and (biological yield/plant vs days to heading). While the phenotypic and genotypic correlation were high and negative for the followed pairs of the studied traits (no. of spikes/plant vs plant height), (biological yield/plant vs 100-kernel weight) and (grain yield/plant vs 100-kernel weight).

3- Selection for no. of spikes/plant:

3-1-F_3 generation:

3 -1-1- Response to direct selection for no. of spikes/plant under normal and heat stress conditions.

Analysis of variance revealed significant differences between F_3 families in all the studied traits under normal and heat stress of populations 1 and 2.

The average no. of spikes/plant for selected families of population 1 was 9.13 spikes with a range from 6.25 to 12.20 spikes/plant under normal, while under heat stress conditions, it ranged from 4.00 to 10.00 spikes/plant with average 6.24 spikes/plant. On the other hand, average no. of spikes/plant for population 2 was 9.24 with a range from 7.20 to 12.80 spikes under normal, while under heat stress conditions, it ranged from 7.00 to 11.50 spikes/plant with average 8.62 spikes/plant.

The phenotypic coefficients of variability (pcv%) were 9.51% and 13.12% under normal and heat stress conditions, respectively in population 1, while it were 11.57% and 7.37% under normal and heat stress conditions, respectively in population 2. Genotypic coefficients of variability (gcv%) in population 1 were

8.62% and 11.83% under normal and heat stress conditions, respectively, while it were 10.57 and 5.14 under normal and heat stress conditions, respectively, in population 2. Estimates of pcv and gcv indicated the presence of variability in no. of spikes/plant. These variabilities suggest that selection among the F_3 families may produce change in no. of spikes/plant. In general, (pcv%) was relatively higher than (gcv%) under both environments. Heritability estimates in broad-sense (H) in population 1 were 82.21 and 81.22% under normal and heat stress, respectively. In population 2, it was 83.38 and 85.87 under normal and heat stress, respectively. In general, high estimates of broad sense heritability indicated that the environmental effects were small compared to the genetic effects.

3-1-2- Effect of selection for no. of spikes/plant on the other traits under normal and heat stress conditions:

In population 1: Under normal, (pcv%) values ranged from 4.83% for days to heading to 14.44% for grain yield/plant, (gcv%) values ranged from 4.54% for days to heading to 13.99% for grain yield/plant, Broad sense heritability ranged from 59.51% for plant height to 95.83% for 100-kernel weight. While under heat stress conditions, (pcv%) values ranged from 4.28% for days to heading to 16.71% for grain yield/plant, (gcv%) values ranged from 3.95% for days to heading to 16.02% for grain yield/plant, Broad sense heritability ranged from 72.94% for biological yield/plant to 93.80% 100-kernel weight.

In population 2: Under normal, (pcv%) values ranged from 3.47% for days to heading to 19.87% for biological yield/plant, (gcv%) values ranged from 3.05% for days to heading to 18.07% for biological yield/plant, Broad sense heritability ranged from 76.19% for no. of kernel/spike to 95.83% for 100-kernel weight. While under heat stress conditions, (pcv%) values ranged from 3.94% for days to heading to 14.34% for biological yield/plant, (gcv%) values ranged from 2.05% for days to heading to 11.97% for grain yield/plant, Broad sense heritability ranged from 26.99% for days to heading to 91.38% for 100-kernel weight.

3-2-Effect of selection for no. of spikes/plant **after the second cycles.**

3-2-1- Analysis of variance for the studied traits:

The analysis of variance for the studied traits of the selected families in cycles 2 (F_4 generation) in populations 1 and 2 under the two environments showed that there were highly significant differences among selected families for no. of spikes/plant and other related traits in F_4 generations under normal and heat stress conditions with few exceptions.

3-2-2- Phenotypic, genotypic coefficients of variability and heritability estimates:

The results indicated that phenotypic and genotypic coefficients of variability for no. of spikes/plant were (12.94 and 11.52%) and (30.32 and 29.31%) for F_4 selected families under normal and heat stress conditions, respectively, in population 1. In population 2, the above mentioned values were (14.25 and 12.74%) and (12.82 and 11.15%) for F_4 selected families under normal and heat stress conditions, respectively.

Heritability in broad sense values for no. of spikes/plant under normal and heat stress for F_4 selected families were 79.30 and 93.46%, respectively, in population 1. While in population 2 it were 79.86 and 75.67% under normal and heat stress conditions, respectively. Heritability for the other traits ranged from 70.66% for no. of kernels/spike to 97.58% for grain yield/plant under normal, and from 65.33 for no. of kernels/spike to 97.62% for 100-kernel weight under heat stress conditions in population 1. In population 2, heritability for the other traits ranged from 78.56% for days to heading to 94.70% for 100-kernel weight under normal, and from 71.34 for days to heading to 96.59% for grain yield/plant under heat stress conditions.

3-2-3- Means, observed gain of the selected families under normal:

Population 1: The results showed that average no. of spikes/plant under normal condition was 10.12 spikes/plant and 9.75 spikes/plant under heat. It is

clear that families no. 92 and 486 highly significantly and surpassed the better parent under normal condition, and while the families no. 92, 214, 486 and 499 surpassed the better parent under heat stress conditions.

Average days to heading, 100-kernel weight, plant height, biological yield, grain yield/plant and no. of kernels/spike for population 1 under normal were 103, 5.92, 104.66, 81.36, 24.29 and 40.91, respectively, while average these traits under heat stress were 88.90, 5.90, 104.30, 75.83, 18.30 and 30.36, respectively.

Population 2: The results showed that average no. of spikes/plant under normal condition was 12.06 spikes/plant and 11.35 spikes/plant under heat stress. From these results it is clear that families no. 13, 126, 367 and 172 were highly significantly and surpassed the better parent under normal condition. While the families no. 13, 59 and 126 were surpassed the better parent under heat stress conditions.

Average days to heading, plant height, biological yield/plant, grain yield/plant, 100 kernel weight and no. of kernels/ spike for population 1 under normal were 103, 116.86, 30.30, 106.73, 5.64 and 44.99, respectively, while average these traits under heat stress were 91, 109.98, 89.35, 25.65, 4.74 and 42.04, respectively.

3-2-4- Means, observed gain of the selected families under heat stress:

Population 1: The results showed that average no. of spikes/plant under normal was 11.03 spikes and 10.66 spikes under heat. It is clear that all families highly significantly surpassed the better parent under normal except families no. 264 and 399 and all families under heat stress conditions except families no 264, 280 and 399.

Average days to heading, 100- kernel weight, plant height, biological yield, grain yield/plant and no. of kernels/spike for population 1 under normal were 100, 6.15, 103.50, 92.05, 29.25 and 44.31, respectively, while average these traits under heat stress were 89, 5.28, 102.84, 84.13, 23.89 and 40.47, respectively.

Population 2: The results show that average no. of spikes/plant under normal was 10.53 spikes and 10.18 spikes under heat stress. It is clear that families no. 34, 137, 169 and 245 highly significantly surpassed the better parent under normal and families no. 13, 34, 40, 137, 169 and 245 under heat stress conditions.

Average days to heading, 100- kernel weight, plant height, biological yield, grain yield/plant and no. of kernels/ spike for population 1 under normal were 100, 5.64, 106.20, 83.84, 26.83 and 47.92, respectively, while average these traits under heat stress were 91, 5.04, 101.85, 106.01, 24.56 and 34.19, respectively.

3-3-Average observed gain from selection in the two cycles:

In population 1: The observed gain for no. of spikes/plant under normal was (61.02 %) from the bulk sample and (17.96%) from the better parent in C_1. While under heat stress conditions it was (80.85%) from the bulk sample and was (23.46%) from the better parent in C_1. The observed gain for no. of spikes/plant of the selected families under normal and evaluated under both environments in C_2 was (21.14 and 36.17%) and (19.29 and 31.22%) from bulk sample and the better parent, respectively. Meanwhile, the gains for families selected under heat stress and evaluated under normal and heat stress conditions was (32.73 and 33.23%) and (35.17 and 33.28%) from the bulk sample and the better parent, respectively. These results indicated that synergistic selection was better than antagonistic selection.

In population 2: The observed gain for no. of spikes/plant under normal was (41.28%) from the bulk sample and was (23.69%) from the better parent in C_1. While it was (43.67%) from the bulk sample and was (11.51%) from the better parent in C_1. The observed gain of the selected families under normal and evaluated under both conditions in C_2 was (22.81 and 17.13%) and (34.01 and 12.93%) from bulk sample and the better parent, respectively. While these gains for families selected under heat stress and evaluated under normal and heat stress conditions was (22.58 and 19.20%) and (20.90 and 17.82%) from the bulk sample and the better parent, respectively.

3-4-Heat susceptibility index and sensitivity to environments:

The results of population 1 showed that five families of the selected families under normal and five families of the selected families under heat stress have heat susceptibility index (HSI) values less than one. The results of population 2 showed that seven families of the selected families under normal and six families of the selected families under heat stress have heat susceptibility index (HSI) values less than one. These families could be considered more tolerant to heat stress conditions and could be involved in wheat breeding programs for less favorable conditions.

3-5- Effect of heat stress on no. of spikes/plant and other studied traits:

In population 1: The reduction in no. of spikes/plant was 29.680 and 0.20% in F_3 and F_4 generations, respectively. The reduction in grain yield/plant was 26.22 and 1.65% in F_3 and F_4 generations, respectively. The reduction in 100-kernel weight was 84.08 and 10.81% in F_3 and F_4 generations, respectively.

In population 2: The reduction in no. of spikes /plant was 6.71 and 15.59% in F_3 and F_4 generations, respectively. The reduction in grain yield/plant was 10.46 and 18.94% in F_3 and F_4 generations, respectively. The reduction in 100-kernel weight was 1.90 and 10.64% in F_3 and F_4 generations, respectively.

3-6- Phenotypic and genotypic correlations:

In populations 1 and 2 with selection under normal or heat stress conditions the highest estimates for both phenotypic and genotypic correlation were showed for the followed pairs of the studied traits: (no. of kernels/spike vs grain yield yield/plant), (no. of spikes/plant vs grain yield yield/plant), (days to heading vs no. of kernels/spike), (biological yield/plant vs plant height), (plant height vs no. of kernels/spike) and (biological yield/plant vs no. of spikes/plant). While the phenotypic and genotypic correlation were high and negative between (days to heading vs no. of spikes/plant), (days to heading vs biological yield/plant) and (plant height vs no. of spikes/plant).

Recommendations:

From the previous results we can extract that direct selection for grain yield/plant was better than indirect selection for no. of spikes/plant. In the case of selection for grain yield/plant we obtained on three families from population 1 and three families from population 2 in the case of selection under normal condition and also we obtained three families from population 1 and three families from population 2 in the case of selection under heat stress condition. This families are promising to using its in the breeding programs in the future to obtain high yielding lines (or new variety) could be sown in the optimum environments.