Egypt. J. Plant Breed. 11(3): 55-68(2007)

SELECTION FOR DROUGHT TOLERANCE IN ADVANCED GENERATIONS OF SOME BREAD WHEAT CROSSES

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ABSTRACT

This study was carried out in 2001/2002, to 2005/2006 winter seasons at the experimental station of Nuclear Research Center, Inshas. The objective was to select wheat plants tolerant to drought. The first growing season was devoted to perform manual crossing between the high yielding varieties Sids 1, Gemmiza 7 and Giza 168 and the drought tolerant variety Sahel 1. Obtained hybrid seeds were sown in the second and third growing seasons under non-stressed conditions to raise F_1 and F_2 populations, respectively. All F_2 plants were screened to identify and select individuals with high yielding ability. In the growing season of 2004/2005 seeds of each F_2 selected plant were sown to raise F_3 progeny under non-stress (control), moderate drought stress (str.1) and severe drought stress (str.2) conditions. Phenotypic correlation coefficient between yield and its attributes were estimated for all F_3 progenies grown under normal and drought stressed conditions. Results revealed that both number of spikes/plant and number of grains/spike were the most important traits associated with grain yield/plant. On this basis, a considerable number of variants were selected and grown in the winter season of 2005/2006 as F_4 selected plant progenies. Obtained results also indicated that drought stress caused marked reductions in grain yield and most of its attributes.

Active rooting depth for the F_4 plant progenies increases with increasing soil moisture stress, where it reached to 45, 60 and 75 cm depth in February month and 60, 67.5 and 75 cm depth in April month for control, Str. 1 and Str. 2 treatments, respectively. As for actual water consumptive use of wheat, Str. 1 and Str. 2 treatments were less than control treatment with 19.5 and 49.59 %, respectively.

Key words : *Bread wheat – Crossing – Variation – Correlation – Selection – Drought tolerance.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most important and most widely grown cereal crop. Its importance is derived from many properties and uses of its grains which marks it as a stable food for more than one third of the world's population (Poehlman 1987).

Under dry areas the major limitation to cereal yields is the amount of available water (Auston 1987). Abiotic stresses limit crop productivity (Araus *et al* 2002 and Boyer 1982) and play a major role in determining the distribution of plant species across different types of environments.

Breeding for high yield potential under a biotic stresses especially drought and salinity is a major objective of most breeding programs. Several investigators such as Lal *et al* (1978), Clarke *et al* (1984), Chowdhury (1990), Boyadjieva (1996), Ahmed *et al* (1998) and Moussa and Abdel-Maksoud (2004) concluded that water stress caused marked reduction in wheat grain yield. Grain yield and its components remain a major selection criterion for improving adaptation to stress environments in many breeding programs, Ehdaie *et al* (1988). Yadav and Mishra (1993) found positive association between wheat grain yield/plant and number of tillers/plant, number of spikelets/spike and 100 grain weight. On the other hand, Sadiq *et al* (1994) concluded that high grain yield proved to be the best indicator of drought tolerance, meanwhile, Ginkel van *et al* (1998) declared that yield potential only partly explained the superior performance under drought.

The present study aimed to develop genetic variability and select drought tolerant genotypes in bread wheat populations following hybridization between a tolerant cultivar to drought and others possessing high yielding.

MATERIALS AND METHODS

A drought tolerant bread wheat variety namely Sahel 1 was crossed with the commercial high yielding varieties, Sids 1, Gemmiza 7 and Giza 168 in order to combine the drought resistance of Sahel 1 with the high yield potential of the other used varieties. Sahel 1 served as a male parent, while Sids 1, Gemmiza 7 and Giza 168 were used as females.

In 2001/2002 growing season, the four parents were grown at the experimental station belonging to the Nuclear Research Center, Inshas. The obtained hybrid seeds were planted under non-stress conditions in the two successive winter seasons of 2002/2003 and 2003/2004 to raise F_1 and F_2, respectively.

F_2 populations of the three crosses were screened to identify and select high yielding individual plants. Seeds of each F_2 selected plant were sown in the growing season of 2004/2005 as a single plant progeny under non-stress (0.4 bar), moderate drought stress (Str.1 = 0.8 bar) and severe drought stress (Str.2 = 1.2 bar) conditions. The detecting soil moisture stress was by using combination work between soil moisture retention curve (van Genuchten 1980) and neutron scattering method, (IAEA 1976). It is worth to mention that the best expression for drought stress is soil moisture suction (stress, bar) because the experiment based on soil moisture suction is valid to test at any region and under different air conditions. Here plant makes work (Joules) to obtain water from the soil against adsorptive force. The principal scale is number of Joules for water catching around the soil particle. As for irrigation intervals such as 2, 3, ..., 13 days is not constant for north delta or south Egypt because air temperature differs in both regions in the same time. Time to reach 1.2 bar in north delta need 20 days, whenever, in south of Egypt needs 5 days, for this reason soil moisture stress had been chosen.

At harvest, F_3 progenies grown under different drought treatments were screened to identify and select high yielding individuals *via* selection for traits of direct association with grain yield. In 2005/2006 winter season, three water treatments at 0.25, 0.8 and 1.2 bar soil matrix suction were chosen to get different drought stresses before the wilting point and represent control (normal irrigation), str. 1 and str. 2, respectively.

It is important to conclude that reduction soil matrix suction for control treatment to be approximately 0.25 bar instead of 0.40 bar as followed in 2004/2005 season, mainly aimed to keep the soil moisture content around the field capacity to insure normal growth for the developed plants under nonstress conditions. This would give a good indication concerning the effect of drought stresses on plant characteristics and help us to select outstanding variants showing grain yield close to that of the best plants grown under normal field conditions.

In 2005/2006 growing season, seeds of selected individuals derived from different progenies were sown to raise F_4 progenies under normal and drought conditions.

The field experiments were conducted using a split plot design with three replications either in F_3 or F_4. The whole plots were devoted to the drought treatments (control, str.1 and str.2), while the sub plots contained F_3 or F_4 progenies of different wheat crosses. In each plot, seeds were sown in two rows, 3 m long and 20 cm apart. Individual seeds were spaced 10 cm within rows. Consequently, the number of developed individual plants per each progeny was about 180.

Soil analysis

Mechanical and chemical analyses of the soil are presented in Tables (1 and 2) respectively. The analysis indicated that the soil has coarse particles and consequently macro-pores is the almost character, while the micro-pores are very low, so, the total porosity values are low and therefore, the soil water holding capacity is also low. The available nitrogen and potassium are generally low, while the available phosphorus is moderate.

Table 1. Soil physical properties of Inshas.

Soil depth (cm)	Particle size distribution (%)			Texture class	Total porosity	Soil bulk density g/cm^3	ECe dS/m	pH 1:2.5
	Sand	Silt	Clay					
0-15	94.2	3.2	2.6	Sandy	0.411	1.56	0.70	7.8
15-75	97.8	1.4	0.8	Sandy	0.366	1.75	0.75	7.8

Table 2. Soil chemical properties of Inshas.

Soluble cations (meq/L)				Soluble anions (meq/L)				Average nutrients (ppm)		
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO^{=}_3$	HCO^{-}_3	Cl^{-}	$SO^{=}_4$	N	P	K
4.00	4.00	2.47	0.33	-	4.00	5.00	1.80	3.90	9.06	54.60

Irrigation scheduling

Irrigation scheduling means how much is quantity of irrigation water? and when is irrigation process done ? the irrigation water quantity was to enough the plant requirements. Irrigation water quantity was measured using V-notch. Irrigation-process starts when the soil moisture suction reaches to 0.4, 08 and 1.2 bars for control. Str. 1 and Str. 2, respectively. These tensions were chosen according to the shape of soil moisture retention curve of Inshas sandy soil, where 0.8 and 1.2 represented medium and high soil water stress, respectively.

Soil moisture values were measured using neutron probe for the whole soil profile except 0-15 cm layer which measured by gravimetric method avoid neutron escape into the air (invalid determination).

Data recorded

The following traits were recorded for F_3 and F_4 wheat progenics

1- Plant height (cm).
2- Spike length (cm).
3- Number of spikes/plant.
4- Weight of grains/spike (gm).
5- Number of grains/spike.
6- 100-grain weight (gm).
7- Grain yield/plant (gm).

Reduction (%) in the mean of grain yield /plant due to drought stress was calculated as follows :

$$\text{Reduction (\%)} = \frac{\text{Mean under non-stress} - \text{Mean under stress}}{\text{Mean under non-stress}} \times 100$$

Statistical analysis

The obtained data were subjected to the proper statistical analysis of variance (Snedecor and Cochran 1969). The L.S.D. test was used for comparison between the means (Waller and Duncan 1969).

Correlation coefficient

Phenotypic correlation coefficients between yield and its components for F_3 progenies were calculated according to Leclerg (1962).

RESULTS AND DISCUSSION

Evaluation of F_3 progenies under stress and non-stress conditions

Effect of drought on yield and its components

The data given in Table (3) revealed that mean values of yield and its attributes for F_3 progenies derived from all the crosses and grown under str. 1 or str. 2 environments were generally less than means of the populations grown under normal irrigation. Average grain yield of F_3 progenies originated from Sahel 1 × Sids 1, Sahel 1 × Gemmiza 7 and Sahel 1 × Giza 168 crosses were less under Str. 1 conditions by 4.90, 15.45 and 19.35 %, respectively, as compared to the normal irrigated populations. Meanwhile, yield reductions reached 11.48, 23.17 and 30.34 %, respectively under str. 2 environment.

It is worthy to mention that progenies derived from the cross Sahel 1 × Giza 168 were influenced by stress treatments more than the progenies of Sahel 1 × Sids 1 or Sahel 1 × Gemmiza 7 crosses (Table 3). The differences among wheat genotypes in their relative tolerance to drought were previously reported by Bruckner and Frohberg (1987), Moustafa *et al* (1996), Sharma and Bhargava (1996) and Kinyua *et al* (2000).

Results in Table (3) also indicated that reduction in grain yield of all F_3 progenies due to drought stress was mainly accompanied by significant decreases in most of yield components, especially number of spikes/plant and number of grains/spike. In this respect, Mosaad *et al* (1995) evaluated a number of wheat cultivars under water stress conditions their, results revealed that the contribution of tillers to grain yield was higher in some tested cultivars. Ragab and Sobieh (2000) stated that longer irrigation interval significantly decreased plant height and number of grains/spike. Taghian and Abo El-Wafa (2003) attributed the decreases of final grain yield of wheat varieties grown under drought stress conditions to the marked reduction in all yield components.

Table 3. **Means of yield and yield attributes for F_3 progenies originated from Sahel 1 × Sids1, Sahel 1 × Gemmiza 7 and Sahel 1 × Giza 168.**

Treatment	Crosses	Plant height cm	Spike length cm	No. of spikes/ plant	No. of grains/ spike	100 - grain weight (g)	Grain yield/ plant (g)
Normal irrigation	Sahel 1 × Sids1	78.75	12.83	9.43	43.50	4.94	14.28
	Sahel 1 × Gemmiza 7	83.22	12.26	12.26	48.56	5.22	17.99
	Sahel 1 × Giza 168	73.97	11.90	9.93	48.40	4.19	14.83
Treatment mean		78.64	12.33	10.54	46.82	4.78	15.70
Moderate water stress (Str.1)	Sahel 1 × Sids1	73.76	12.33	8.96	37.93	4.41	13.57
	Sahel 1 × Gemmiza 7	82.30	11.55	9.23	43.50	4.55	15.21
	Sahel 1 × Giza 168	70.53	11.26	9.76	39.60	3.62	11.95
Treatment mean		75.53	11.71	9.32	40.34	4.19	13.58
Severe water stress (Str.2)	Sahel 1 × Sids1	72.06	12.20	7.16	36.53	4.33	12.63
	Sahel 1 × Gemmiza 7	79.73	11.36	7.33	41.90	4.46	13.39
	Sahel 1 × Giza 168	68.56	10.93	6.70	37.30	3.63	10.33
Treatment mean		73.45	11.50	7.06	38.57	4.14	12.12
LSD 5 % (treatments)		NS	0.428	1.68	3.98	0.379	2.09
LSD 5 % (crosses)		5.78	0.558	NS	3.99	0.229	1.11
LSD 5 % (interaction)		NS	NS	NS	NS	NS	NS

NS = not significant

Phenotypic correlation coefficients between yield and its contributing traits for F_3 progenies originated from different wheat crosses

Seed yield is the ultimate criterion which a plant breeder has always to keep in view in his attempts to evolve improved types of any crop plant. However, yield itself is not a unitary character but is the result of the interaction of a number of factors in the plant as well as in the environment in which the plant grows. It, therefore, becomes difficult to evaluate or select for this complex character directly. Accordingly, one may resort to more indirect methods such as determination of the association existing between other less variable characters and yield. Selection pressure may then be more easily exerted on any of the traits which show close and significant association with yield. On this basis, simple correlation coefficients (r) between yield and its effective traits were calculated for F_3 wheat progenies to detect the most important characters that correlate with grain yield/plant to be utilized as a selection criterion to pick out outstanding variants from different drought stress treatments. Obtained results revealed that number of spikes/plant and number of grains/spike were the most important components associated with grain yield/plant for the majority of F_3 wheat progenies grown in both drought-stressed and non-stressed environments (Table 4). Confirming results were obtained by Abd-El-Moneim (1993) who found positive and significant phenotypic and genotypic correlation coefficients between wheat grain yield and each of

Table 4. Phenotypic correlation coefficients between grain yield / plant and other studies of F_3 progenies of bread wheat under normal and drought conditions.

Treatments / Characters	Non-stress	Moderate water stress	Severe water stress
Sahel 1 × Sids1			
Plant height	0.343	0.400 *	-0.264
Spike length	0.599 **	-0.149	0.137
No. of spikes/plant	0.958 **	0.203	0.762**
No. of grains/spike	0.221	0.285	-0.030
100-grain weight	-0.133	0.319	0.079
Sahel 1 × Gemmiza 7			
Plant height	-0.070	0.089	0.255
Spike length	0.214	-0.296	0.472 **
No. of spikes/plant	0.762 **	0.101	0.516 **
No. of grains/spike	0.524 **	0.373 *	0.490 **
100-grain weight	-0.110	0.360	0.174
Sahel 1 × Giza 168			
Plant height	0.067	0.432 *	0.212
Spike length	0.096	0.209	0.043
No. of spikes/plant	0.854 **	0.489 **	0.455 *
No. of grains/spike	0.265	0.564 **	0.214
100-grain weight	0.242	-0.138	0.554 **

* and ** indicate significant and 0.05 and 0.01 probability level, respectively.

tillering capacity, number of spikes/plant and biological yield, while, Dhanda and Sethi (1996) stated that number of tillers/plant and biological yield were important for wheat grain yield improvement under normal and drought conditions. On the other hand, Afaf (2000) found significant relationship between grain yield/plant and each of heading date, plant height, spikes/plant and 100 kernel weight in some bread wheat genotypes. Meanwhile, Tammam *et al* (2000) reported that grain yield was positively and significantly associated at phenotypic and/or genotypic level with each of spikes/plant, grains/spike, 1000 kernel weight and spike length in bread wheat under varying environments.

Based on the results of the correlation studies, it was planned to consider number of spikes/plant and number of grains/spike as good selection criteria to screen the numerous number of plants derived from F_3 progenies in order to detect high yielding genotypes based on the above mentioned reliable traits. As a result, a considerable number of wheat promising plants from str. 1 and str. 2 treatments having grain yield equal to or more than that of the best normal irrigation (control) plants were selected and grown in 2005/2006 winter season to raise the F_4 individual plant progeny rows.

Evaluation of F_4 progenies under stress and non-stress conditions in 2005/2006 season.

1- Determination of the active rooting depth and the actual water consumption

The active rooting depth and the actual consumption use (Evapotranspiration, ET) for the F_4 wheat progenies of F_3 selected plants developed under control, str. 1 and str. 2 conditions were determined and illustrated in Figs. (4) and (5). Results revealed that rooting zone for wheat populations grown under str. 2 conditions extended downward more than control and str. 1 treatment, especially during February and March (Fig. 4). This gives an indication that wheat populations grown under str. 2 conditions were capable of with drawing water from the deeper soil to meet their requirements especially through the period expanded from the later vegetative growth up to grain filling.

It is worth mentioning that the actual water consumption for the F_4 progenies grown under str. 1 and str. 2 conditions were less than the consumption of control plant populations by 19.50 and 49.59 %, respectively (Fig. 5).

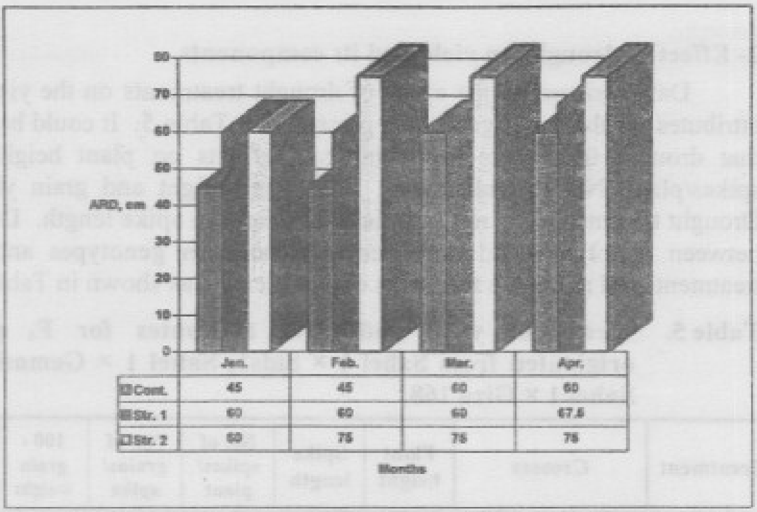

Fig. (4) : Active rooting depth (ARD) for F_4 wheat populations under different drought stress conditions.

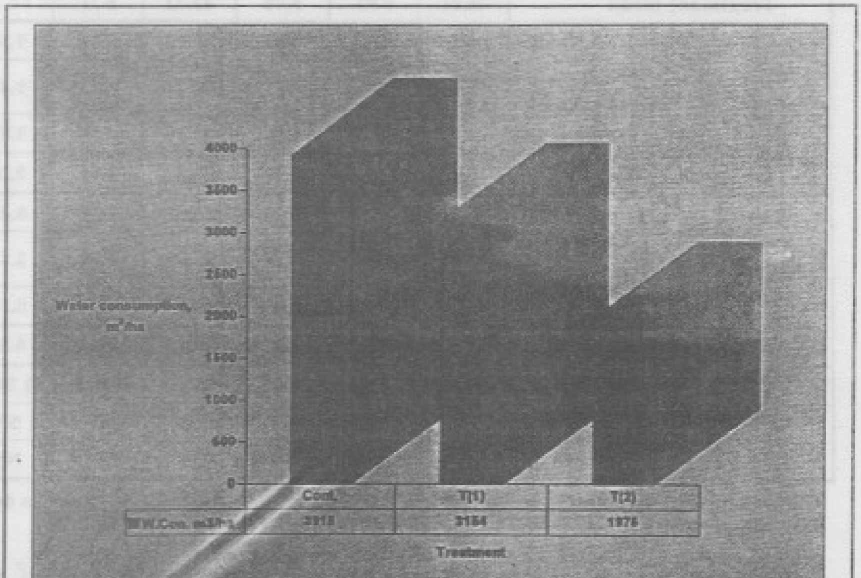

Fig. (5) : Water consumption (m^3/ha) for F_4 wheat populations under different drought stress conditions.

2- Effect of drought on yield and its components

Data concerning the effect of drought treatments on the yield and its attributes for the F_4 progenies are presented in Table 5. It could be observed that drought treatments had significant effects on plant height, No. of spikes/plant, No. of grain/spike, 100 grain weight and grain yield/plant. Drought treatments did not significantly affect the spike length. Differences between genotypes and the interaction between genotypes and drought treatments did not reach the limits of significance as shown in Table (5).

Table 5. Means of yield and yield attributes for F_4 progenies originated from Sahel 1 × Sids1, Sahel 1 × Gemmiza 7 and Sahel 1 × Giza 168.

Treatment	Crosses	Plant height	Spike length	No. of spikes/ plant	No. of grains/ spike	100 - grain weight	Grain yield/ plant
Normal irrigation	Sahel 1 × Sids1	72.56	10.42	5.02	43.91	5.59	11.67
	Sahel 1 × Gemmiza 7	78.27	9.66	5.05	43.99	5.26	12.34
	Sahel 1 × Giza 168	77.21	9.72	4.94	43.28	4.89	11.29
Treatment mean		76.01	9.93	5.00	43.72	5.21	11.76
Moderate water stress (Str.1)	Sahel 1 × Sids1	66.65	10.12	4.69	39.10	4.56	9.32
	Sahel 1 × Gemmiza 7	71.13	10.76	4.81	40.41	4.72	9.42
	Sahel 1 × Giza 168	64.64	11.21	4.15	39.10	4.65	8.85
Treatment mean		67.47	10.69	4.55	39.54	4.64	9.20
Severe water stress (Str.2	Sahel 1 × Sids1	58.75	10.16	4.08	36.03	4.44	8.45
	Sahel 1 × Gemmiza 7	62.93	10.10	4.18	37.09	4.60	8.52
	Sahel 1 × Giza 168	61.39	10.26	3.88	35.43	4.29	8.18
Treatment mean		61.02	10.17	4.05	36.18	4.44	8.38
LSD 5 % (treatments)		5.280	NS	0.536	7.26	0.536	1.740
LSD 5 % (crosses)		3.980	NS	NS	NS	NS	NS
LSD 5 % (interaction)		NS	NS	NS	NS	NS	NS

NS = not significant**Table 6. Average grain yield and water consumption of F_4 progenies derived from wheat crosses.**

Data given in Table (6) demonstrated that mean values of grain yield/plant for the F_4 progenies resulted from wheat crosses grown under str.2 were less than the average grain yield of progenies developed under str.1 by 8.90, but in the same time, the F_4 progenies under str. 2 treatment consumed less water by about 30.9 %. This suggests that enhancement drought tolerance, for breeding materials at hand, can be frequently

Table 6. Average grain yield and water consumption of F_4 progenies derived from wheat crosses.

F_4 progenies of wheat crosses	Control treatment		Str.1 treatment					Str.2 treatment				
	Average grain yield/plant (g)	Water consumption (m^3/ha)	No. of progenies derived from F_3 selected plants	Average grain yield/plant (g)	Reduction from control populations (%)	Water consumption (m^3/ha)	% Reduction from control populations	No. of progenies derived from F_3 selected plants	Average grain yield/plant (g)	Reduction from control populations (%)	Water consumption (m^3/ha)	% Reduction from control populations
Sahel 1 × Sids1	11.67		8	9.32	20.14			17	8.45	27.59		
Sahel 1 × Gemmiza 7	12.34		8	9.42	23.63			21	8.52	30.96		
Sahel 1 × Giza 168	11.29		8	8.85	21.61			18	8.18	27.54		
Mean	11.77	3918		9.20	21.79	3154	19.5		8.38	28.70	1975	49.59

accelerated *via* conducting selection under str. 2 compared to str. 1 drought conditions. Thus in the coming winter season, the F_5 plant progenies will be sown under str. 2 conditions only, while str. 1 treatment will be cancelled.

Acknowledgment

The authors are grateful to the International Atomic Energy Agency (IAEA) for financial support of this work which is a part of the project entitled "Identification and pyramiding of mutated genes: novel approaches for improving crop tolerance to salinity and drought". (Research Contract No. 12990).

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الانتخاب لتحمل الجفاف في الأجيال المتقدمة في بعض هجن قمح الخبز

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١-قسم البحوث النباتية وقسم بحوث الأراضي والمياه

٢- مركز البحوث النووية – هيئة الطاقة الذرية – أنشاص – مصر

أجريت هذه الدراسة خلال المواسم الشتوية : 2002/2001 ، 2003/2002 ، 2004/2003 ، 2005/2004 و 2006/2005 بالحقل التجريبي لمركز البحوث النووية – أنشاص. تم في الموسم الأول إجراء التهجين بين صنف متحمل الجفاف (ساحل I) وثلاث أصناف محلية عالية المحصول (سدس 1 ، جميزة 7 و جيزة 168).

زرعت البذور الهجينة المتحصل عليها من الموسم الأول في المواسم الزراعية الثانية والثالثة تحت ظروف الري الكامل (عدم الجفاف) وذلك للحصول على نباتات الأجيال الهجينية الأولى والثانية ، على التوالي. وتم غربلة جميع نباتات الجيل الثاني وانتخاب النباتات الفردية عالية المحصول. وفي الموسم الرابع زُرعت بذور كل نبات من النباتات المنتخبة على حدة لتنتج أنسال الجيل الثالث الهجيني تحت ظروف مستويين من الجفاف متوسط (0.8 بار) وعالي (1.2 بار) حددت من منحنى الشد الرطوبي الأرضي لأراضي أنشاص الرملية. أوضحت دراسة الارتباط وجود ارتباط قوي بين صفة المحصول وكلا من صفتي عدد السنابل بالنبات وعدد الحبوب بالسنبلة والتي استخدمتا كأساس غير مباشر للانتخاب للمحصول. وفي الموسم الخامس زُرعت بذور كل نبات من النباتات المنتخبة على حدة لتنتج أنسال الجيل الهجيني الرابع تحت نفس الظروف السابقة. وأظهرت النتائج أن معاملات الجفاف أدت الى نقص معنوى لمحصول النبات الفردى والذي كان مصحوبا بنقص معنوي لمعظم مكونات المحصول.

وقد دُرس كلاً من العمق الجذرى النشط والاستهلاك المائى الفعلى للمعاملات الثلاثة تحت الدراسة وقد وجد أن العمق الجذرى النشط لأنسال الجيل الهجيني الرابع يزداد بزيادة الإجهاد الرطوبى الأرضى حيث كان 45 ، 60 ، 75 سم فى شهر فبراير ، 60، 67.5 و 75 سم فى شهر أبريل وذلك لمعاملات عدم الجفاف والإجهاد المتوسط والعالى على الترتيب. أما عن قيم الاستهلاك المائى الفعلى فكانت معاملات الإجهاد الرطوبى المتوسط والعالى أقل من معاملة عدم الجفاف بنسبة 19.5 ، 49.59 % على الترتيب.