Egypt. J. Plant Breed. 8: 353-370 (2004)

NEW GENETIC VARIATION IN DROUGHT TOLERANCE INDUCED VIA IRRADIATION AND HYBRIDIZATION OF EGYPTIAN CULTIVARS OF BREAD WHEAT

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ABSTRACT

This study was carried out during four seasons from 1999/2000 through 2002/03 at the Experimental field of the Atomic Energy Authority, Inchas, Egypt. The main objective was to create genetic variation in 6 Egyptian wheat (Triticum aestivum) cultivars via gamma irradiation in M1 and M2 generations and segregation of their crosses in the F2 and F2M2 generations to obtain drought tolerant genotypes. It was found that both drought and/or irradiation caused a decrease in grain yield and most studied traits, while irradiation caused an increase in yield in the 2nd mutated generation of crosses under drought stress. Significant differences were observed among parents and crosses in all generations for most studied traits under both well watered and stress conditions. The most tolerant genotypes in the field were the cultivars Gemmieza 5 and Sids 1, the F2 cross Sakha 8 X Gemmeiza 5 and the F_2M_2 Sids 1 X Giza 164 . Estimates of PCV and GCV were high for grain yield especially in the 2nd mutated generation of F_2 crosses (F_2M_2), assuring the important role of hybridization and irradiation in inducing new variation under water stress. The best 3 drought tolerant selections and their 3 original parents were assessed in the field. They proved superiority in performance under water stress conditions as well as earliness. They might be of great value in breeding programs for developing drought tolerant cultivars. Variant (1) a glaucousness mutation was selected from irradiated Sids 1 in the M1, variant (2) from irradiated cross Sids 1 X Giza 164 in the F_2M_2, and variant (3) from the non-irradiated cross Sakha 8 X Giza 164 in the F_2.

Key words: ***Bread wheat, Triticum aestivum, Hybridization, Gamma radiation, Mutations, Drought tolerance.***

INTRODUCTION

Wheat, *Triticum aestivum* L. is one of the major food crops in the world supplying nearly 55% of the carbohydrates consumed worldwide. The total consumption of wheat grains in Egypt is about 12.0 million tons, so Egypt imports about 5.15 million tons annually (i.e. 43% of total local consumption). To satisfy the increasing demands of wheat grains, one of the main solutions is to expand growing wheat in the desert land, which represents about 96% of the entire area of Egypt. Low water holding capacity of the sandy soils of the new reclaimed lands and insufficiency of irrigation water devoted to those lands necessitate wheat breeders to develop drought tolerant cultivars of wheat to be used under such water stress conditions.

The success in developing improved varieties of crop plants through conventional breeding programs depends on the existence of genetic variation amenable for selection. Two conventional breeding procedures are mainly used to create new genetic variations; the first is hybridization procedure followed by generating of recombinations in the segregating generations and the second is the mutation breeding procedure.

During the past seventy years, more than 2,252 mutant varieties have been officially released (Maluzynki *et al* 2000). Many induced mutants were released directly as new varieties; others were used as parents to derive new varieties. Mutation induction with radiation was the most frequently used method to develop direct mutant varieties (89%) (Ahloowalia *et al* 2004). Gamma rays were employed to develop 64% of the radiation-induced mutant varieties, followed by X-rays (22%). Success has been achieved in wheat breeding for drought tolerance by mutation breeding (Siddiqui 1990).

The main objective of the present investigation was to create new genetic variations for the purpose of selecting desirable variants characterized with increased drought tolerance in the Egyptian bread wheat cultivars using gamma radiation and hybridization. The secondary objective was to evaluate the field performance of the studied wheat crosses and their parents (whether were irradiated or not) as well as the best new variants (whether were transgressive segregants or mutations) developed via irradiation and/or hybridization under stress and non-stress conditions.

MATERIALS AND METHODS

Materials

Seeds of six bread wheat (*Triticum aestivum* L.) cultivars, viz. Sahel 1 (drought tolerant), Sids 1(heat tolerant), Sakha 8 (salt tolerant), Gemmeiza 5 (rust resistant), Giza 164 (heat tolerant) and Giza 168 (high yielding and yellow rust resistant) used in this study as parents, were obtained from Wheat Research Section, Field Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt.

In 1999/2000 and 2000/2001 seasons the 6 parents were grown at the experimental fields of Plant Research Dept., Nuclear Research Center, Atomic Energy Authority, Inshas, for making F_1 crosses. The three cultivars, Sahel 1, Sids 1 and Sakha 8 were used as females and the 3 cultivars Gemmeiza 5, Giza 164 and Giza 168, were used as males according to the mating design II of Comstock and Robinson (1952). The six parents and the produced nine crosses were used as the genetic material of the present study.

Laboratory testing of radiosensitivity of the wheat genotypes

Fresh air-dried seeds with 12% of water content from each of the six wheat cultivars used in the present study were treated with ten different doses of gamma rays i.e. 0, 10, 15, 20, 25, 30, 35, 40, 45, and 50 Krad in order to identify the proper radiation dose for useful mutation induction. Irradiation treatments were achieved by a Co-60 Gamma unit which delivered 7.5 KGy (750 Krad) per hour. Exposure times were equivalent to achieve the previous doses. The effect of different doses of gamma irradiation on the mean seedling height of all the six genotypes grown in three replicates in glass containers with 75 grains per treatment was studied after 6 days of sowing.

Field experiments

Season 2001 / 2002

According to the previous laboratory experiment, seeds of the 15 wheat genotypes (the six parents and their nine F_1's) were irradiated with 30 Krad of gamma rays dose and planted in the field (Experiment 1) at location I on the 17th of November 2001, where the soil is loamy sand at the experimental fields of Plant Research Dept., Nuclear Research center, Inshas, Al-Sharkia Governorate under full irrigation regime (surface irrigation every ten days). Individual seeds were planted in a 3-meter rows, at 20-cm space between plants and 30 cm between rows in blocks (each block contains 30 rows). The non-irradiated (control) 15 genotypes (the six parents and their nine F_1's) were planted in an adjacent field at the same location under two irrigation regimes i.e. under full irrigation (irrigation every ten days) (Experiment 2) and under water stress conditions (irrigation every twenty days) (Experiment 3). The experimental design used in each of these three experiments was a randomized complete block design (RCBD) with three replications. Beside P's, PM_1's, F_1's and F_1M_1's evaluation, seeds of PM_2's, F_2's and F_2M_2's were collected separately from PM_1, F_1 and F_1M_1 plants, respectively.

Season 2002 / 2003

In 2002/2003 season four field experiments were carried out at location II on 17 November, 2002 where the soil is sandy. The six parents (P's) and their F_2's were planted under water non-stress (Experiment 4) and stress (Experiment 5). Moreover, the 6 parents in PM2 generation and their 9 F2M2 crosses were planted under non-stress (Experiment 6) and water stress conditions (Experiment 7). Individual seeds were planted in a 3-meter rows, at 20-cm space between plants and 30 cm between rows in blocks (each block contains 60 rows). These experiments were conducted at the same experimental farm under the same irrigation regimes, viz. non-stress (irrigation every ten days) and water stress conditions (irrigation every 20 days) in a RCBD with three replications.

Data recorded

In both seasons (2001/2002 and 2002/2003) data were recorded on days to 50 % flowering, plant height (cm), number of fertile spikes per plant, number of grains per spike, 100-grain weight (g) and grain yield per plant (g). Ten guarded plants from each plot were used for data recording.

Data analysis

Normal analysis of variance of the data was performed according to Gomez and Gomez (1984). Genotypic (GCV) and phenotypic (PCV) coefficients of variation were estimated too.

RESULTS AND DISCUSSION

1. Laboratory experiment

Data on laboratory testing (not presented) indicated that the seedling height decreased gradually with the increasing of gamma ray dose for all cultivars as compared with zero dose Krad (non-irradiated). Accordingly, the percentage of reduction in seedling height was increased with each increase in gamma ray dose.

It was observed that the 30 Krad dose caused growth reductions in seedling height ranged from 32.67% in Gemmeiza 5 to 38.75% in Sakha 8. The growth reduction resulted from 10, 15, 20 and 25 Krad doses were below 30%. However, the growth reduction caused by 40 and 45 Krad ranged from 45.65 to 57.50. Whereas, the 50 Krad dose caused a growth reduction above 50% for all cultivars. Konzak and Mikaelsen (1995) advised that the selected doses of sparsely ionizing radiations (e.g. gamma rays) for mutation breeding of cereals are those which cause 30-50% reduction in seedling growth in laboratory tests. Accordingly, we selected the 30 Krad dose to irradiate the six wheat parents and their nine F_1 crosses as an attempt for obtaining useful gene mutations. This dose (30 Krad) of gamma irradiation was also preferred by many other investigators in wheat seeds (Wang *et al* 1986 and Ragab and Sobieh 2000) who selected mutant varieties by irradiation of wheat cultivars and hybrids by 30 Krad of gamma rays.

2. Field Experiments

Analysis of variance

Data on analysis of variance of the seven experiments conducted in 2001/02 and 2002/03 seasons (not presented) indicated that the tested genotypes differed significantly for grain yield and most studied traits under both irrigation regimes.

Mean squares due to parental cultivars in 2001/02 season (non-irradiated parents (P's) under both stressed and non-stressed environments and irradiated parents in the M1 generation (PM_1's) under full irrigation) were significant. Mean squares due to non-irradiated parents (P's) in 2002/03 season for days to flowering and spikes/plant under stress conditions and due to irradiated parents in the M2 generation (PM_2's) for days to flowering and grains/spike under both stress and non-stress conditions and for plant height and grain yield under non-stress conditions were also significant.

Mean squares due to irradiated F_1M_1 and non-irradiated F_1 crosses were significant for all studied traits under both stress and non-stress conditions. Variances due to unirradiated crosses in the F_2 generation (F_2's) were significant for days to flowering, plant height and grain yield/plant under both irrigation regimes and spikes/plant under full irrigation. Irradiated crosses in the F_2 generation (F_2M_2's) differed significantly for all studied traits under both irrigation regimes, except for spikes/plant and 100-grain weight under full irrigation.

Mean squares due to parents vs. F_1 crosses (heterosis) whether were irradiated or not were significant for all studied traits under both stress and non-stress except for days to flowering under non-stress conditions.

Mean Performance

Water stress effect:

Water stress caused obvious reductions in wheat grain yield/plant (Table 1) amounted for the non-irradiated parents (44.6% in 2001/02 and 56.1% in 2002/03 season), F_1's (57.4%) and F_2's (72.7%) and for the M2 generation of parents (PM_2) 72.6% and of F_2's (F_2M_2's) (60.5%). Amongst the grain yield components, the reductions due to water stress were more pronounced in spikes/plant (which reached to 57.1, 61.6, 39.5, 52.1 and 47.1% in P's, PM_2's, F_1's, F_2's and F_2M_2's, respectively) followed by grains/spike (which reached to 36.6, 27.8 and 19.3% in P_2's, PM_2's and F_2M_2's, respectively) and were least pronounced in spikelets/spike (from 2.6% in F_1's to 12.1% in P's). Moreover, drought stress in wheat caused shortening in plant height which was between 12.4 and 29.4% for P's and averaged 21.4, 15.1, 19.1 and 26.3% for F_1's, F_2's, F_2M_2's and PM_2's, respectively. Water stress did not change date of flowering in some material (P_2's and PM_2's) and caused delay by 3.3, 2 and 1 day in F_1's, F_2's and F_2M_2's, respectively.

Our results about the reduction in wheat grain yield due to drought stress are also consistent with those reported by many other investigators (Moustafa *et al* 1996, Kheiralla *et al* 1997 and Ragab and Sobieh 2000).

Several investigators also reported that water stress had a strong negative effect on spikes/plant in wheat (Jat *et al* 1990, Mosaad *et al* 1995 and Kheiralla *et al* 1997), grains/spike (Day and Intalp 1970, Sharma and Bhargava 1996, Kheiralla *et al* 1997 and Ragab and Sobieh 2000), grain weight (Fisher and Maurer 1978) and plant height (Jat *et al* 1990, Sharma and Bhargava 1996 and Ragab and Sobieh 2000).

Irradiation effect

Irradiation caused different degrees of reductions in grain yield (41.8% in PM_2's vs. P's, 11.7% in F_1M_1's vs. F_1's and 17.7% in F_2M_2's vs. F_2's under non-stress and 28.4% in PM_2's vs. P's under stress) while it caused grain yield increase (favorable) of 14.6% in PM_2's vs. P's under non-stress and 19.1% in F_2M_2's vs. F_2's, under stress conditions. However, irradiation caused favorable effects in increasing grains/spike for F_2M_2's vs. F_2 by 3.9% under non-stress, weight of 100 grains for PM_2's vs. P's by 11.1% and F_2M_2's vs. F_2's by 2.2%, in earliness for PM_2's vs. P's by 7 and 8 days under non-stress and stress, respectively and in shortening of plant

Table 1. Means and ranges (Min. and Max.) of wheat parents (P's), F_1's and F_2's (irradiated and non-irradiated) grown under water stress (S) and non-stress (NS) conditions in 2001/02 and 2002/03 seasons.

Trait	Stress	Mean & range	2001/02				2002/03			
			P	PM1	F1	F1M1	P	PM2	F2	F2M2
Grain yield /plant (g)	NS	Mean	35.2	20.5	61.7	54.5	32.8	37.6	59.4	48.9
		Min.	28.1	15.8	39.2	40.1	23.3	32.3	37.1	32.6
			(3)	(4)	(3x6)	(2x6)	(4)	(2)	(1x4)	(3x5)
		Max.	54.3	28.9	94.0	69.8	45.2	42.5	68.9	62.7
			(2)	(1)	(2x4)	(2x5)	(2)	(4)	(1x6)	(2x4)
	S	Mean	19.5	-	26.3	-	14.4	10.3	16.2	19.3
		Min.	12.0	-	15.5	-	10.8	8.2	11.7	10.4
			(3)		(3x6)		(3)	(1)	(1x5)	(3x6)
		Max.	24.2	-	31.6	-	17.5	12.7	22.8	33.1
			(4)		(2x4)		(4)	(5,6)	(3x4)	(2x5)
	Reduction %		44.6	-	57.4	-	56.1	72.6	72.7	60.5
Spikes/plant	NS	Mean	13.2	11.0	18.2	16.0	9.1	8.6	11.9	10.6
		Min.	10.3	7.3	12.6	11.3	8.0	7.0	9.3	8.6
			(6)	(6)	(1x4)	(3x6)	(4)	(1)	(1x4)	(3x5)
		Max.	18.8	13.0	24.7	19.0	10.6	10.0	15.0	12.0
			(2)	(1)	(2x4)	(1x6)	(2)	(2)	(2x4)	(3x6)
	S	Mean	9.5	-	11.0	-	3.9	3.3	5.7	5.6
		Min.	7.0	-	8.8	-	3.0	3.0	5.0	4.7
			(5)		(3x4)		(4)	(1)	(1x4)	(2x6)
		Max.	11.7	-	13.2	-	5.3	4.0	6.3	6.7
			(2)		(1x6)		(2)	(6)	(2x5)	(2x5)
	Reduction %		28.0	-	39.5	-	57.1	61.6	52.1	47.1
Grains/spike	NS	Mean	76.0	67.7	97.8	87.6	87.7	77.6	87.7	91.1
		Min.	66.8	61.0	92.6	81.2	71.3	67.6	75.3	79.0
			(3)	(4)	(3x5)	(3x4)	(4)	(2)	(3x4)	(3x5)
		Max.	87.7	74.4	102.5	94.7	96.3	88.3	100.6	101.0
			(2)	(1)	(1x4)	(2x6)	(3)	(6)	(1x6)	(2x6)
	S	Mean	76.0	-	84.3	-	55.6	56.0	77.8	73.5
		Min.	57.7	-	78.3	-	41.6	44.6	71.3	58.3
			(3)		(2x6)		(3)	(3)	(2x4)	(3x6)
		Max.	88.3	-	90.7	-	61.6	70.6	92.0	85.0
			(6)		(3x4)		(6)	(6)	(2x6)	(2x5)
	Reduction %		0.0	-	13.8	-	36.6	56.0	11.3	19.3
100-grain weight (g)	NS	Mean	4.5	4.2	5.2	5.0	4.8	5.0	5.3	5.3
		Min.	4.1	3.0	4.7	4.6	4.3	4.5	4.8	4.6
			(1)	(5)	(2x6)	(3x6)	(3)	(6)	(1x6)	(2x6)
		Max.	4.9	5.1	5.6	5.3	5.0	5.3	5.6	5.9
			(4)	(4)	(3x4)	(2x5)	(1)	(3)	(1x4)	(2x4)
	S	Mean	3.8	-	3.6	-	4.3	4.6	4.5	4.6
		Min.	3.3	-	3.0	-	3.6	4.2	3.8	3.8
			(6)		(3x6)		(3)	(6)	(1x6)	(2x6)
		Max.	4.3	-	4.2	-	4.8	5.0	5.0	5.3
			(5)		(2x5)		(5)	(4)	(3x4)	(3x4)
	Reduction %		15.5	-	30.7	-	10.4	8.0	15.1	13.2
Days to 50 % flowering	NS	Mean	88.0	91.0	89.0	90.0	81.0	81.0	75.0	79.0
		Min.	78.0	82.0	86.0	88.0	70.0	70.0	72.0	72.0
			(6)	(6)	(1x6)	(1x6)	(6)	(6)	(2x6)	(2x4)
		Max.	92.0	94.0	92.0	95.0	86.0	87.0	84.0	86.0
			(5)	(2,3)	(3x5)	(3x6)	(5)	(5)	(3x5)	(3x5)
	S	Mean	89.0	-	86.0	-	81.0	81.0	75.0	80.0
		Min.	80.0	-	84.0	-	70.0	70.0	72.0	75.0
			(6)		(3x6)		(6)	(6)	(2x6)	(1x6)
		Max.	93.0	-	88.0	-	86.0	85.0	86.0	86.0
			(5)		(1x5)		(5)	(5)	(3x5)	(3x5)
	Reduction %		-1.1	-	3.3	-	0.0	0.0	-2.6	-1.2
Plant height (cm)	NS	Mean	95.1	89.2	103.5	96.4	98.3	89.7	95.3	100.7
		Min.	84.9	76.4	97.0	92.8	90.0	73.3	81.6	91.6
			(6)	(6)	(1x5)	(1x4)	(6)	(1)	(3x6)	(1x4)
		Max.	108.5	97.2	108.2	102.5	108.3	98.3	106.6	121.6
			(2)	(2)	(2x5)	(3x5)	(2)	(2)	(1x6)	(2x6)
	S	Mean	83.3	-	82.1	-	69.4	66.1	80.2	81.6
		Min.	78.3	-	72.6	-	61.6	60.0	66.6	68.3
			(3)		(3x5)		(1)	(4)	(2x6)	(1x6)
		Max.	89.5	-	91.0	-	73.3	73.3	100.0	90.0
			(2)		(1x4)		(3)	(5)	(3x5)	(2x5)
	Reduction %		12.4	-	20.7	-	29.4	26.3	15.8	18.9

1 = Sahel 1, 2 = Sids 1, 3 = Sakha 8, 4 = Gemmeiza 5, 5 = Giza 164, 6 = Giza 168.

P's, PM_1's and PM_2's = non-irradiated parents, irradiated parents in M1 and M2, respectively.

F_1 and F_2 = non-irradiated crosses in the F1 and F2 generations, respectively.

F_1M_1 and F_2M_2 = irradiated crosses in the (F_1M_1) and (F_2M_2) generations, respectively.

Reduction%=100(Mean of NS-Mean of S)/Mean of NS.

height by 5.7 and 20.6% for PM_2's vs. P's under non-stress and stress, respectively, and 6.9% for F_1M_1's vs. F_1's under non-stress.

Singh and Kumar (1974) found that the mean grain yield per plant of the M_2 was 22.27 gm, whereas, the parental mean was 12.32 gm. They also found an increase in 100-grain weight of wheat as a result of gamma irradiation.

Khanna *et al* (1986) found that wheat plant height was increased by increasing gamma ray doses up to 7.5 Krad, but it decreased with increasing gamma ray doses above that. Moreover, Sobieh (2002) found significant decreases in plant height due to gamma irradiation in Sids 5, Sids 6 and Sids 7 wheat cultivars. He was able to select short culm mutants from such cultivars; the internode length of all short culm mutants was significantly reduced as compared to their parents.

Genotypic differences

Genotypic differences were found for all studied traits either under drought stress or non-stress conditions. The highest yielders under non stress conditions were Sids 1 and Sids 1 X Gemmeiza 5 for non-irradiated genotypes. Under stress Gemmeiza 5, the F_1 cross Sids 1 X Gemmeiza 5, the F_2 cross Sakha 8 X Gemmeiza 5 and the F_2M_2 Sids 1 X Giza 164 were the best yielders. On the contrary, the lowest grain yield under both stress and non-stress was obtained from the non-irradiated parents Sakha 8 and Giza 168 and from the irradiated parents Sahel 1 in the M_2 generation (PM2). For crosses, under non-stress the lowest yield was exhibited by the F_1 Sakha 8 X Giza 168, and the F_2 Sahel 1 X Giza 164 and under stress the worst F_2M_2 cross for grain yield Sakha 8 X Giza 168.

The superiority of genotypes in grain yield/plant was accompanied by superiority in one or more yield components. For parents, superiority of Sids 1 in grain yield was accompanied by superiority in spikes/plant under both stress and non-stress conditions, and by superiority in grains/spike in P's and PM_1's under no-stress. Beside the superiority of some crosses in grain yield, they were superior in spikes/plant (Sids 1 X Gemmeiza 5 and Sahel 1 X Giza 168), grains/spike (Sakha 8 X Giza 164) and 100-grain weight (Sakha 8 x Gemmeiza 5).

The earliest and shortest parent was Giza 168 (whether irradiated or not in M1 or M2) under both water stress and non-stress conditions. Sahel 1 X Giza 168 was the earliest and shortest F_1 and the shortest F_2M_2 under non-stress and the earliest F_2M_2 under stress conditions.

Many studies have also indicated that there is a genotypic variation in drought tolerance of wheat (Fischer and Maurer 1978). Genotypic differences in grain yield of wheat under water stress and non-stress conditions were reported by Musick and Dusek (1980), Rab *et al* (1984), Chowdhury (1990), Jat *et al* (1990), Clarke *et al* (1992), Mosaad *et al* (1995), Boyadjieva (1996), Moustafa *et al* (1996) Sharma and Bhargava (1996), Kheiralla *et al* (1997) and Ragab and Sobieh (2000).

Several workers reported also wheat genotypic differences under both drought stress and non-stress conditions in number of spikes per plant (Jat *et al* 1990, Mosaad *et al* 1995, Moustafa *et al* 1996, Kheiralla *et al* 1997, Ahmad *et al* 1998), grains per spike (Sharma and Bhargava, 1996, Kheiralla *et al* 1997 and Ragab and Sobieh 2000), 100-grain weight (Day and Intalap 1970, Fisher and Maurer 1978 and Kheiralla *et al* 1997) and plant height (Jat *et al* 1990, Sharma and Bhargava 1996 and Ragab and Sobieh 2000).

It is worthy to note that under drought stress, the highest heterobeltiosis estimates for grain yield per plant were obtained from Sakha 8 X Giza 164 (52.96%), Sids 1 X Giza 164 (37.75%), Sids 1 X Gemmeiza 5 (30.81%) and Sahel 1 X Giza 164 (24.05%). Each of these F_1 crosses was characterized by high estimate of heterobeltiosis for at least one yield component. The F_1 cross Sakha 8 X Giza 164 showed the highest heterobeltiosis estimates for grain yield under both stress (100.98%) and non-stress (52.96%) conditions. Moreover, the F_1 cross Sids 1 X Gemmeiza 5 was amongst the best four crosses for grain yield heterobeltiosis under both stress and non-stress. The later crosses had, as well, the highest absolute yield under both stress and non-stress and could be of value for drought tolerance.

Coefficients of Variation

The estimates of genotypic (GCV) and phenotypic (PCV) coefficients of variation were calculated (Table 2) to study the efficiency of irradiation in increasing variability that can help wheat breeder in the improvement process *via* selection either under water stress or non-stress conditions.

Genotypic and phenotypic coefficients of variation exhibited the highest estimates in grain yield trait followed by spikes/plant, while the lowest were for days to 50% flowering. Both GCV and PCV estimates were generally higher in the F_1 than F_2 and under water stress than non-stress conditions.

Table 2. Estimates of genotypic (GCV) and phenotypic (PCV) coefficients (%) of variation of the studied crosses of wheat under water stress and non stress

Water stress	Generation	Days to flowering	Plant height (cm)	No spikes/ plants	No. Spikelets/ spike	No. grains/spike	100- grian weight (g)	Grain yield/ plant (g)
				GCV				
Non –stress	F_1	3.85	7.12	25.03	4.74	13.53	8.83	38.69
	F_1M_1	3.31	6.76	24.46	5.51	14.01	12.53	46.35
	F_2	6.84	8.29	19.20	4.90	9.97	7.08	31.32
	F_2M_2	6.18	9.35	12.30	4.14	9.75	5.81	20.59
Stress	F_2	6.63	11.89	22.18	1.57	17.49	5.57	15.10
	F_2M_2	5.77	10.92	26.22	5.84	16.63	7.24	43.65
				PCV				
Non-stress	F_1	3.97	7.21	25.59	4.80	16.62	9.05	39.04
	F_1M_1	3.52	6.80	24.65	5.68	14.26	12.71	46.54
	F_2	6.93	8.29	19.20	4.90	9.97	7.08	31.32
	F_2M_2	6.19	11.10	14.83	5.33	11.50	7.50	24.17
Stress	F_2	6.66	12.97	24.25	5.51	18.88	8.19	23.10
	F_2M_2	5.79	13.93	27.35	6.95	18.74	9.00	47.61

Irradiated F_1 crosses (F_1M_1) showed higher GCV and PCV estimates than non-irradiated ones (F_1) under water non-stress for grain yield/plant, grains/spike and 100-grain weight traits.

Moreover, F_2M_2 crosses under water stress exhibited higher estimates of GCV and PCV than their corresponding non-irradiated ones (F_2) for grain yield, spikes/plant and 100-grain weight (Table 13).

In addition, under no stress the F_2M_2 had higher PCV estimates than F_2 for plant height, grains/spike and 100-grain weight and higher GCV estimates for plant height only.

It is worthy to note that for days to flowering the irradiated populations exhibited smaller magnitudes of both GCV and PCV estimates than non-irradiated ones.

It could be concluded from these results that for most studied traits especially grain yield and its components and especially under water stress conditions of the F_2 generation of the crosses; irradiation causes increase in the magnitudes of both GCV and PCV. This might be attributed to the creation of new variation *via* irradiation, which can help in increasing the efficiency of selection for drought tolerance.

Characterization of selected variants in the field

In the present experiment, many variants with desired morphological traits related to drought tolerance were selected (Fig. 1 and 2). The agronomic and morphological performances of the three most important of these variants as compared with their parents are shown in Tables (3 and 4). These variants exhibited a good performance under drought stress conditions, and have adaptive traits related to drought tolerance such as earliness in flowering, glaucousness (waxyness) and productiveness.

Table 3. Agronomic and morphological traits of the first selected variant (V1) as compared to its original parent Sids 1 (selection and evaluation were done under water non-stress conditions).

Trait	2001/02 season		2002/03 season	
	V1 (M_1)	Sids 1	V1 (M_2)	Sids 1
Grain yield/plant (g)	35.2	54.3	54.2	45.2
No. spikes/plant	7.0	18.1	7.0	10.6
No. grains/spike	90.0	87.7	130.0	93.6
100-grain weight (g)	4.5	4.7	4.6	4.7
Days to flowering	90.0	91.0	85.0	84.0
Plant height (cm)	85.0	108.5	85.0	108.3

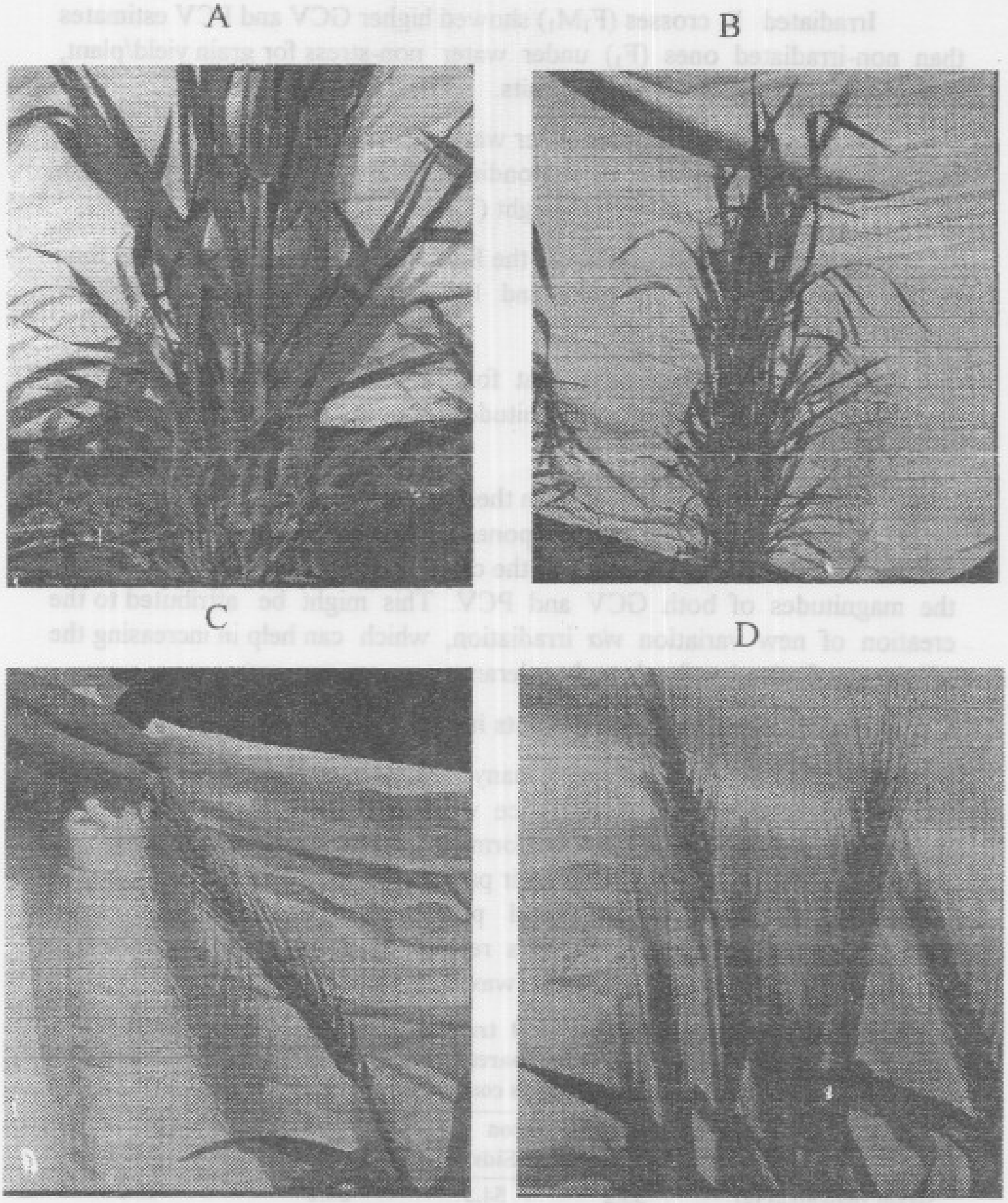

Fig.1. A: Wheat waxy variant (V1) selected from Sids 1 cultivar irradiated with 30 Krad (300 Gy) of gamma rays. B: non-waxy plant of Sids 1. C: Long spike contains 32 spikelet of the waxy variant V1. D: Sids 1 spike with 22 spikelets.

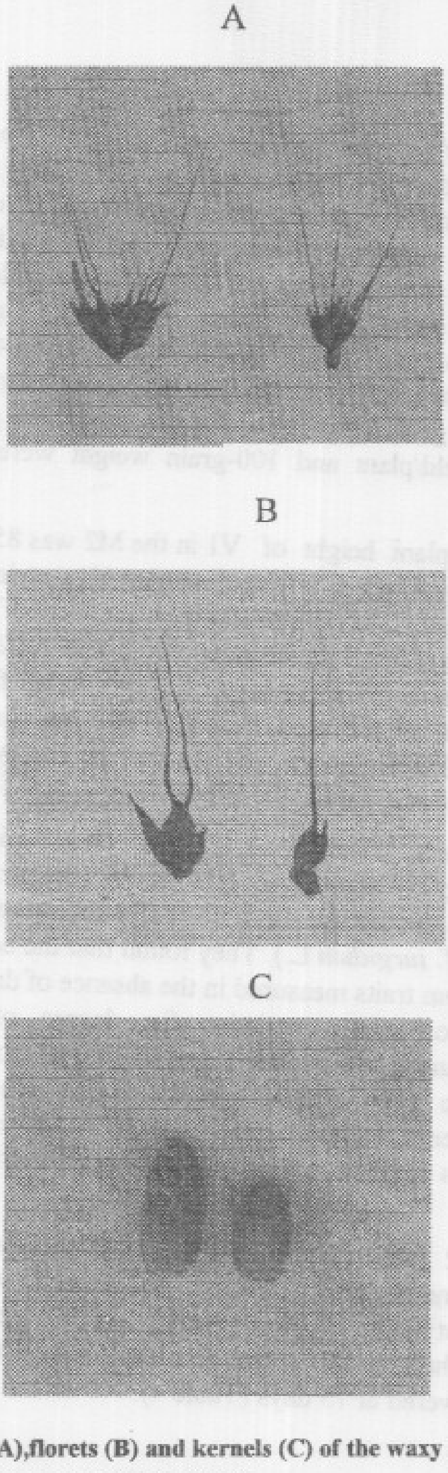

Fig. 2. Spikelets (A),florets (B) and kernels (C) of the waxy mutant, V1 (left) and the original parent, Sids 1 (right).

Variant 1 (V1) which is a glaucousness mutation was selected from Sids 1 cultivar irradiated with gamma rays (30 Krad) in the first mutated generation (M_1) under water non-stress conditions and evaluated in the M_1 and M_2 under the same conditions. It is characterized by a waxy layer covering the whole stems, leaves and spikes. It had 7 tillers bearing 7 fertile spikes; each spike contained 90 grains. Estimates of grain yield/plant and 100-grain weight of this variant in M_1 were 35.3 and 4.5 gm, respectively (Table 3). Its plant height was 85 cm and it flowered after 90 days from planting. In the M_2 generation, it had 7 spikes/plant, 130 grains/spike and the means of grain yield/plant and 100-grain weight were 54.2 and 4.6 gm, respectively.

The mean plant height of V1 in the M2 was 85 cm and the days to 50% flowering were 85 days. It is obvious that V1 outyielded its parent (Sids 1) in 2002/03 season and exhibited higher numbers of grains per spike and shorter plants than Sids 1 in both 2001/02 and 2002/03 seasons. Further investigation concerning superiority of V1 over Sids 1 for drought tolerance will be carried out in the next seasons. Figures (1 and 2) show the whole plants, spikes, spikelets, florets and kernels of the waxy variant (V1) in comparison with its original parent Sids 1.

Glaucousness (waxyness) is one characteristic that has been considered as a plant adaptation to drought (Shantz 1927). Fischer and Wood (1979) suggested the importance of glaucousness in wheat (*Triticum aestivum* L. and *T. turgidum* L.). They found that the best prediction of yield under drought from traits measured in the absence of drought was given by a linear model containing an index for degree of leaf waxyness or glaucousness. Johnson *et al* (1983) found that the glaucous selections yielded significantly more grain and dry matter than non-glaucous selections in two higher yielding environments. Glaucousness (waxyness) of wheat leaves, stems and spikes may be a positive attribute for yield in drought stress conditions.

Variant 2 (V2) was selected from the irradiated cross Sids 1 X Giza 164 in the second mutated generation (F_2M_2) under water stress conditions. Grain yield/plant and 100-grain weight of V2 were 41.5 and 4.5 gm, respectively. It had 8 spikes/plant and 108 grains/spike. Its plant height was 90 cm and it flowered at 75 days (Table 4).

Table 4. Agronomic and morphological traits of the selected variants (V2 and V3) as compared to their original populations from which they were selected (evaluation and selection were done in 2002/03 season under water stress conditions).

Trait	V_2 (M_2)	F_2M_2 of Sids 1x Giza 164	Sids 1	Giza 164	V3	F2 of Sakha 8 x Giza 164	Sakha 8
Grain yield/plant (g)	41.5	33.1	13.6	15.0	30.2	21.6	10.8
No. spikes/plant	8.0	6.7	5.3	3.0	8.0	6.0	3.3
No. grains/spike	108.0	85.0	58.6	54.3	91.0	81.3	41.6
100-grain weight (g)	4.5	4.9	4.2	4.8	5.5	4.4	3.6
Days to flowering	75.0	79.0	86.0	86.0	85.0	86.0	84.0
Plant height (cm)	90.0	90.0	65.0	73.3	100.0	100.0	73.3

It is clear from the results that the V2 had higher grain yield/plant, higher number of spikes/plant, grains/spike and 100-grain weight (i.e. all studied yield components) than its original F2M2 cross population (Sids 1 X Giza 164), and than the parental cultivars Sids 1 and Giza 164 under water stress conditions. Moreover, this variant (V2) exhibited earliness. It flowered 11 days earlier than both of its parents as well as its original F_2M_2 cross population. On the other hand, it showed taller plants than its original parents. This variant (V2) could therefore be considered of great value for drought tolerance and will further be tested for its superiority under water stress conditions.

If its superiority is repeatedly exhibited, it could be offered to the wheat breeder as a new genotype for future use under drought conditions.

Variant 3 (V3) was selected from the non-irradiated cross Sakha 8 X Giza 164 in the first segregating generation (i.e. F_2) under water stress conditions. Means of grain yield/plant and 100-grain weight of this variant were 30.2 and 5.5 gm, respectively. It had 8 spikes/plant and 91 grains/spike. The plant height of V3 was 100 cm and it flowered after 85 days from planting. This new variant (V3) is more drought tolerant than its origin (F_2 generation of the cross Sakha 8 X Giza 164) and its parents (Sakha 8 and Giza 164), since its grain yield/plant and all yield components are clearly higher than those of its origins under water stress conditions. The plants of V3 are obviously taller than those of its parental origin. Further testing of this variant (V3) will be carried out to assure its superiority in drought tolerance.

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تباين وراثى جديد متحمل للجفاف مستحدث عن طريق التشعيع والتهجين لأصناف مصريه من قمح الخبز

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أجريت هذه الدراسة خلال الأربعة مواسم من ١٩٩٩/٢٠٠٠ حتى ٢٠٠٢/٢٠٠٣ في حقل التجارب ومعامل هيئة الطاقة الذرية بأنشاص واستهدفت الحصول على تراكيب وراثية من قمح الخبز تتحمل الجفاف بالانتخاب في الحقل في ستة أصناف مصرية و هجنها التسعة في الجيل الثانى F_2 وفي أجيالها الطفرية M_1 و M_2 التالية لتعريض بذورها لأشعة جاما. وجد أن كلا من الجفاف و الإشعاع تسببا بصفة عامة في نقص المحصول ومعظم الصفات فيما عدا أن الإشعاع تسبب في زيادة محصول النبات في الجيل الثاني للهجن المشععة (F_2M_2) تحت ظروف الجفاف. وجدت اختلافات معنوية بين الأباء وبين الهجن في كل الأجيال المدروسة بالنسبة لمعظم الصفات المدروسة تحت ظروف الجفاف والرى الكامل. وتم تحديد الآباء والهجن الأكثر تحملاً للجفاف بناءاً على آدائها المحصولى في الحقل وهى الصنف جميزه ٥ والصنف سدس ١ والهجين سدس ١ × جميزه ٥ فى الجيل الأول والهجين سخا ٨ × جميزه ٥ والهجين سدس ١ × جيزه ١٦٤ فى الجيل الثانى بعد التشعيع. كانت قيم معامل التباين الوراثى والمظهري لصفة المحصول عالية وخصوصاً في الجيل الثاني للهجن المشععه مما يؤكد على دور التهجين والإشعاع في استحداث التباينات الوراثية الجديدة تحت ظروف الجفاف. وقد تم انتخاب العديد من التراكيب الوراثية المتحملة للجفاف وتم توصيف أهم ثلاث منها من حيث سلوكها في الحقل مقارنة بآبائها الثلاثة المشتقة منها. حيث ثبت تفوقها في المحصول تحت ظروف الجفاف وتبكيرها في النضج. ويعتقد أنها ذات قيمة عالية لبرامج التربية التى تستهدف استنباط أصناف قمح متحملة للجفاف. كان المنتخب الأول عبارة عن طفرة مكسوة بالشمع منتخبة من الصنف سدس ١ المشعع فى الجيل الأول M_1 والمنتخب الثانى مأخوذ من الهجين سدس ١ × جيزه ١٦٤ فى الجيل الثانى بعد التشعيع (F_2M_2) والمنتخب الثالث تم الحصول عليه من الهجين سخا ٨ × جيزه ١٦٤ فى الجيل الثانى (F_2) بدون تشعيع.

المجلة المصرية لتربية النبات ٨: ٣٥٣-٣٧٠ (٢٠٠٤)