Egypt. J. Plant Breed. 11(3): 135-165(2007)

GAMMA RAYS AND EMS INDUCED DROUGHT TOLERANT MUTANTS IN BREAD WHEAT

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ABSTRACT

This study was carried out in 2002/2003, 2003/2004 and 2004/2005 seasons at the fields and laboratories of Nuclear Research Center, Inshas, Egypt in an attempt to induce drought tolerant mutants in the Egyptian bread wheat cultivars Sids1 and Sakha 93 via gamma rays and EMS mutagens. Variability parameters, heritability and genetic advance from selection in M_2 ***and*** M_3 ***bulks derived via these mutagens were estimated and yield superiority of the new induced mutants over parent cultivars and*** M_2 ***bulks were evaluated under water-stress and non-stress conditions. Significant differences were observed among*** M_2 ***and among*** M_3 ***bulks as well as among*** M_3 ***families selected under water stress or non-stress for all studied traits. Irradiation and EMS mutagens succeeded to induce new variability measured by increases in means, ranges, PCV and GCV parameters in many*** M_2 ***and*** M_3 ***bulks under stress and non-stress. Comparing induced*** M_2 ***with*** M_3 ***bulks, for superiority in studied genetic parameters including heritability in broad sense (***h_b^2***) and expected genetic advance (GA) from selection indicated that there were 3 common superior bulks in both*** M_2 ***and*** M_3 ***generations (Sd-RAD-1, Sd-RAD-3 and Sd-EMS-1) under non-stress, while under water stress there were two common superior bulks (Sd-EMS-3 and Sk-RAD-2). Superiority of these induced bulks qualified them for predicting to achieve genetic improvement in grain yield via selection under drought stress and non-stress conditions. A total of 101 putative induced mutants were selected for grain yield in*** M_2 ***generation; out of them 37 were selected under non-stress and 64 under water stress. Their*** M_3 ***families were evaluated along with their parents. Out of these 101 mutants, 22 showed significant superiority in grain yield over their parent cultivars under water stress. Out of these 22 mutants, 9 resulted from selection under non-stress (6 from Sids1 and 3 from Sakha 93) and 13 were a result of selection under water stress (all of them were from Sakha 93). The most superior induced mutants selected under non-stress and evaluated under water stress Sd-RAD-1-7, Sk-RAD-1-3, and Sd-RAD-2-3 exhibited superiority in grain yield over the respective parent cultivar by 13.3, 10.4 and 9.3%, respectively. However, the superior mutants selected and evaluated under water-stress exhibited high superiority in grain yield over their respective parent cultivar by 34.8% (Sk-EMS-4-8), 34.7% (Sk-EMS-5-2), 26.4% (Sk-EMS-5-3), 23.6% (Sk-EMS-5-6), 21.5% (Sk-EMS-3-1) and 20.1% (Sk-RAD-1-4). These superior induced mutants should be subjected to further evaluation and selection to assure their superiority in drought tolerance. Higher actual selection gain could be realized by practicing selection in drought rather than in non-drought environment.***

Key words: ***Wheat, Triticum aestivum, Drought, EMS, Gamma rays, Mutants, Mutagens, Induced variation***

INTRODUCTION

Increasing genetic variability in wheat populations could be achieved *via* hybridization and / or mutation breeding procedures. Physical and chemical mutagens are efficient tools for increasing genetic variability. The most important mutagens are X-rays, gamma rays, fast neutrons and a variety of chemicals (ethylmethane sulphonate (EMS), sodium azide, etc.). During the past seventy years, more than 2252 mutant varieties have been officially released (Maluszynski *et al* 2000). Most of induced mutants (70%) were released directly as new varieties; others were used as parents to derive new varieties. A wide range of characters have been improved by mutation breeding, including tolerance to biotic and abiotic stresses, early maturity and other yield contributing characters. Mutation induction with radiation was the most frequently used method to develop direct mutant varieties (89%); the use of chemical mutagens was relatively infrequent (Ahloowalia *et al* 2004). Gamma rays and EMS mutagens were effective in broadening genetic variability and increasing means of wheat cultivars for grain yield and its components, helping plant breeders to practice an efficient selection in the M_2 and next mutated generations following treatments with these mutagens (Khanna *et al* 1986, Salam 1986, Savov 1989, Sobieh and Ragab 2000, Sobieh 2002 and Al-Naggar *et al* 2004 using gamma rays and Sandhu and Gupta 1983, Reddy and Revathi 1992 and Kalia *et al* 2000 using EMS).

Improving qualitative characters *via* conventional breeding methods is simple and quick but that for quantitative characters such as drought tolerance is often difficult and time consuming .However, induced mutants *via* gamma rays have been obtained in bread wheat for resistance to drought leading to the release of 16 varieties (FAO/IAEA 1996). Induced mutants *via* gamma rays have also been obtained for increased glaucousness of spikes, stems and leaves, which proved useful for drought tolerance (Konzak 1984, Al-Naggar *et al* 2004 and Al-Bakry 2007).

The present investigation was conducted in an attempt to induce drought tolerant mutants in the Egyptian bread wheat cultivars Sids1 and Sakha 93 *via* gamma rays and EMS mutagens. The parameters of variability (means, ranges, phenotypic (PCV) and genotypic (GCV) coefficients of variation), heritability and expected genetic advance from selection in the M_2 and M_3 bulks derived *via* these mutagens were estimated. The superiority in grain yield of the new induced mutants over their respective parent cultivars and M_2 bulks was evaluated under water stress and non-stress conditions.

MATERIALS AND METHODS

This investigation was carried out at the Experimental Farm of the Plant Research Department, Nuclear Research Center, Inshas, Sharkyia Governorate during the three successive growing seasons 2002 / 2003, 2003 / 2004 and 2004 / 2005. Grains of the two commercial Egyptian cultivars of bread wheat (*Triticum aestivum* L.), *i.e.* Sakha 93 and Sids1, bred by Agric. Res. Center, Egypt to be drought tolerant cultivars, were subjected to two types of mutagens, *i.e.* gamma rays and ethyl methane sulphonate (EMS). Dry grains of the two commercial cultivars were exposed to three gamma ray doses (15, 25 and 35 Krad, where 1 K Gy = 100 Krad). The source of irradiation is installed at the Nuclear Research Center, Inshas, Egypt. Irradiation treatments were achieved by a Co^{60} gamma unit which delivered 7.5 K Gy (750 Krad) per hour. Exposure times were equivalent to achieve previous doses. Grains from the same wheat cultivars (Sakha93 and Sids1) were soaked in five different concentrations of EMS (0.1, 0.2, 0.3, 0.4 and 0.5 %) at laboratory temperature for three hours after which the seeds were dried with filter paper according to FAO/IAEA (1977). Sixteen bulks were therefore produced; eight were derived from Sids 1 which included 3 bulks *via* 15, 25, and 35 Krad gamma rays (Sd – RAD - 1, Sd – RAD - 2 and Sd – RAD – 3, respectively) and 5 bulks *via* 0.1, 0.2, 0.3, 0.4, and 0.5% EMS (Sd – EMS - 1, Sd – EMS - 2, Sd – EMS - 3, Sd – EMS – 4 and Sd – EMS – 5, respectively) and eight were derived from Sakha 93 which included 3 bulks *via* 15, 25, and 35 Krad gamma rays (Sk– RAD - 1, Sk – RAD - 2 and Sk – RAD – 3, respectively) and 5 bulks *via* 0.1, 0.2, 0.3, 0.4, and 0.5% EMS (Sk – EMS - 1, Sk – EMS - 2, Sk – EMS - 3, Sk – EMS - 4 and Sk– EMS – 5, respectively).

First season (2002 / 2003) (M_1 generation)

Wheat grains of the 16 M_1 bulks treated with gamma rays and EMS mutagens as well as the two non-treated parent cultivars Sakha93 and Sids1 were sown on 28 Nov.,2002 in separate plots to obtain M_1 plants of each bulk. The distance between rows were 30 cm and between plants were 10 cm in each row. The plants were left for natural self pollination. At harvest, twenty grains were taken randomly from each M_1 plant (M_2 seed). Equal M_2 seeds harvested from plants of each bulk were mixed to represent seed of the respective M_2 bulk. These seeds of M_2 bulks were kept to be used in experiments of the second (2003/2004) and third (2004/2005) seasons. The recommended cultural practices for wheat production at Inshas were followed, in M_1 generation.

Second season (2003 / 2004) (M_2 generation)

Grains of M_2 generation representing the 16 M_2 bulks as well as grains of non- treated parent wheat cultivars (*i.e.* a total of 18 entries) were sown on November 30, 2003 to obtain plants of M_2 bulks and to evaluate these bulks and parent cultivars under water stress and non-stress conditions. Two irrigation intervals, starting 21 days after sowing, were used *i.e.* irrigation every 11 days (non-stress) and irrigation every 22 days (drought stress) using the drip irrigation system. A split-plot design with three replications was used where the two irrigation regimes were assigned to the main plots, and the 18 wheat entries (genotypes) were devoted to the sub plots (two untreated parent cultivars + 6 bulks derived *via* irradiation + 10 bulks derived *via* EMS). In each plot, grains were individually sown in hills at 10 cm space between plants. Each plot consisted of 12 rows; each row was 2.5 m long and 25 cm wide, making a plot area of 7.5 m^2. At harvest, ten plants were taken at random from each plot in M_2 generation for recording data. At harvest, ten grains were taken randomly from each M_2 plant (M_3 seed) grown under non-stress and mixed to represent seed of the respective M_3 bulk. Selection was practiced for high-yielding individual plants in each M_2 bulk under stress and non-stress conditions, separately. Grain yield/plant of the selected variants should significantly exceed the average of the control (of each respective parent cultivar) by 50 % or more. Seeds of the selected variants as well as those representing bulks (M_3 seed) and control from each cultivar were kept separately in paper bags for sowing in the next season (M_3 generation). Number of these variants (putative mutants) was 23 and 30 from Sids 1 and 41 and 7 from Sakha 93 selected under stress and non-stress conditions, respectively, making a total of 101 putative mutants (Table 1). Out of these 101 mutants, 29 and 16 mutants were derived from gamma radiation treatments and 24 and 32 mutants were derived from EMS treatments for Sids1 and Sakha 93, respectively. The name of each selected variant was designated with the corresponding bulk from which it was selected followed by a different number.

Table 1. Number of high yielding putative mutants derived from M_2 populations as a result of different mutagen treatments in Sids 1 and Sakha 93 wheat cultivars selected under drought stress and non-stress conditions.

Mutagenic treatment	Non-Stress		Stress		Total		Grand Total
	Sids1	Sakha93	Sids1	Sakha93	Sids1	Sakha93	
Gamma rays	**17**	**5**	**12**	**11**	**29**	**16**	**45**
15 Krad	**8**	**3**	**6**	**6**	**14**	**9**	**23**
25 Krad	**3**	**-**	**4**	**1**	**7**	**1**	**8**
35 Krad	**6**	**2**	**2**	**4**	**8**	**6**	**14**
EMS	**13**	**2**	**11**	**30**	**24**	**32**	**56**
0.10%	**3**	**-**	**-**	**1**	**3**	**1**	**4**
0.20%	**3**	**2**	**7**	**4**	**10**	**6**	**16**
0.30%	**1**	**-**	**1**	**10**	**2**	**10**	**12**
0.40%	**-**	**-**	**-**	**9**	**-**	**9**	**9**
0.50%	**6**	**-**	**3**	**6**	**9**	**6**	**15**
Total	**30**	**7**	**23**	**41**	**53**	**48**	**101**

Third season (2004 / 2005) (M_3 generation)

Three field experiments were conducted in 2004/2005 season. The 1st experiment was carried out to evaluate the 16 M_3 bulks and the two parent cultivars (Sids 1 and Sakha 93) under drought stress and non stress conditions. The 2nd experiment was carried out to evaluate 55 genotypes (37 M_3 families as putative mutants selected under non-stress conditions + 16 M_2 bulks + the two parent cultivars; Sids 1, Sakha 93) under water stress and non stress conditions. A split-plot design with three replicates was used in both experiments, where the two irrigation regimes were assigned to the main plots, and the genotypes (18 for 1st and 55 for 2nd experiment) were devoted to the sub plots. The 3rd experiment was conducted to evaluate 82 genotypes (64 M_3 families as putative mutants selected under water stress + 16 M_2 bulks + the two parent cultivars) under water stress conditions only. A randomized complete blocks design with 3 replications was used for the3rd experiment. For all three experiments conducted in 2004/2005 season, the experimental plot consisted of four rows of 2 m long and 25 cm wide, *i.e.* plot area was 2 m^2. The space between each two plants in each row was 10 cm.

For recording data in all M_2 and M_3 experiments, 10 plants from each experimental plot were used. The following data were measured: (1) plant height (cm), (2) number of spikes/ plant, (3) number of grains/ spike, (4) 100-grain weight (g) and (5) grain yield/ plant (g). Data of all experiments on M_2 and M_3 generations were subjected to the proper statistical analysis of variance for the corresponding experimental design according to Gomez and Gomez (1984). The LSD test was used to verify the differences between means. Genotypic and phenotypic variances of each bulk (either in M_2 or M_3 generation) were estimated separately. Phenotypic variance (σ_{ph}^2 of untreated plants of each cultivar was considered as environmental variance ,σ_e^2, while that of each treated bulk was considered to include both genetic ,σ_g^2, and environmental ,σ_e^2, variances (Shin 1968). Therefore, σ_g^2 of each bulk was calculated using the formula: $\sigma_g^2 = \sigma_{ph}^2 - \sigma_e^2$. The following equations were used to estimate genotypic (GCV) and phenotypic (PCV) coefficient of variations as follows: GCV= (σ_g/x) 100, PCV= (σ_{ph}/x) 100, where: σ_g = genetic standard deviation, σ_{ph} = phenotypic standard deviation, and x= mean of the respective population (bulk). Broad-sense heritability (h_b^2) was estimated using the following formula: $h^2_b\% = 100\sigma_g^2/\sigma_{ph}^2$. The predicted genetic advance (GA) from selection using 10% selection intensity was estimated according to the following formula: $GA\ \% = 100h^2_b k\sigma_{ph}/x$, where: k = a selection differential of a value of 1.76 for 10% selection intensity.

RESULTS AND DISCUSSION

Experiment one (M_2 bulks)

Analysis of variance of M_2 bulks (not presented) indicated that mean squares due to irrigation regimes and those due to genotypes (M_2 bulks and parents) were significant or highly significant for all studied traits. Mean squares due to genotypes X irrigation regimes interaction were significant or highly significant for all studied traits, confirming results of previous researchers (Fischer and Maurer 1978, Sharma and Bharagava 1996, Ragab and Sobieh 2000 and Al-Naggar *et al* 2004).

Water stress effect on M_2 bulks

Water stress caused a significant reduction in mean grain yield/plant (Table 2) across all mutated and non-mutated M_2 bulks from 19.91 g under non-stress to 15.73 g under drought stress conditions (20.68% reduction). Reduction in grain yield due to water stress across Sakha 93- M_2 bulks (24.29%) was greater than that across Sids1-M_2 bulks (18.03%). Moreover, reduction in grain yield due to water stress across M_2 bulks derived from EMS treated Sakha 93 cultivar was much higher (24.29%) than that across M_2 bulks derived from EMS treated Sids 1 cultivars (15.42%).

Table 2. Means of studied traits in wheat M_2 bulks derived *via* gamma rays and EMS from Sids 1 and Sakha 93 cultivars under drought stress (S) and non-stress (NS) conditions (Inshas, 2003/2004).

M_2 bulks and parents	Plant height (cm)			Spikes/ plant (No.)			Grains/ spike (No.)			100-grain weight (g)			Grain yield/plant (g)		
	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)
Sids 1	90.1	69.3	23.1	6.4	6.3	1.6	62.8	59.4	5.4	5.2	5.0	4.1	19.0	15.0	21.1
Sd - RAD - 1	94.2	70.0	26.1	9.2	6.0	34.7	62.1	60.7	2.2	5.0	4.7	5.3	22.3	13.8	38.4
Sd - RAD - 2	94.3	71.3	24.4	9.0	7.0	22.6	62.1	59.9	3.4	5.0	4.9	1.8	20.7	15.8	23.3
Sd - RAD - 3	86.1	72.3	16.1	7.9	8.2	-3.4	60.6	61.8	-2.0	5.2	4.5	13.3	19.9	18.3	8.0
Sd - EMS - 1	84.2	74.1	12.1	7.5	8.0	-7.1	62.6	59.6	4.9	4.8	4.9	-2.2	20.5	18.3	11.0
Sd - EMS - 2	84.2	73.9	12.2	7.1	7.9	10.6	61.4	61.4	0.0	5.0	4.9	3.6	18.0	19.5	-8.1
Sd - EMS - 3	92.7	72.7	21.6	8.2	6.4	22.3	63.3	59.9	5.3	4.8	4.7	1.4	19.1	14.8	22.3
Sd - EMS - 4	91.7	78.4	14.5	7.5	6.7	10.7	62.7	61.0	2.7	4.7	5.0	-5.4	18.9	14.6	22.8
Sd - EMS - 5	93.7	73.4	21.7	7.8	7.4	5.5	61.8	59.6	3.6	4.6	5.0	10.4	20.3	15.6	23.4
Sakha 93	81.7	71.6	12.3	7.1	6.6	6.1	61.7	62.8	-1.7	4.8	4.7	2.1	19.0	15.2	20.1
Sk - RAD - 1	81.7	70.3	14.0	7.6	6.2	17.6	60.8	61.1	-0.6	5.0	4.7	5.9	19.1	16.2	14.8
Sk - RAD - 2	78.6	72.2	8.1	7.5	6.1	19.0	60.9	59.7	2.0	5.1	4.7	7.7	19.2	15.3	20.3
Sk -RAD - 3	78.8	69.2	12.1	8.6	5.3	38.4	60.1	59.9	0.2	5.3	4.7	11.5	20.8	14.7	29.1
Sk - EMS - 1	74.9	71.2	5.0	7.5	6.8	10.2	61.5	61.5	0.1	5.1	4.2	16.8	19.5	14.6	25.4
Sk - EMS - 2	89.6	73.0	18.5	9.0	7.2	20.4	63.3	62.8	0.9	4.6	4.4	4.4	21.4	17.3	19.1
Sk - EMS - 3	77.0	67.4	12.5	7.8	7.0	10.6	59.8	59.5	0.4	5.4	4.9	8.8	20.7	15.6	24.8
Sk - EMS - 4	88.6	71.8	19.0	8.9	7.1	20.6	63.3	59.4	6.2	4.6	5.1	-9.1	21.2	14.4	32.2
Sk - EMS - 5	87.1	72.2	17.1	7.5	6.5	13.4	62.7	60.2	4.0	4.8	4.8	0.3	18.7	14.2	24.2
Over all average	86.1	71.9	16.5	7.9	6.8	12.9	61.9	60.6	2.1	5.0	4.8	3.3	19.9	15.7	20.7
LSD 0.05:															
Irrigations (I)	1.7				0.7			0.5			0.0			1.5	
Genotypes (G)	2.2				0.5			0.7			0.1			0.9	
G x I	3.1				0.8			1.0			0.2			1.3	

Red. = reduction.

Reduction in grain yield of M_2 bulks due to water stress was associated with significant reductions in all other studied traits. These reductions due to drought stress were relatively high in magnitude for plant height (16.47%) followed by spikes/plant (12.93) and were low but significant for other traits, *i.e.* grains/spike (2.07%), and 100-grain weight (3.33%) (Table 2). These results are consistent with those reported by Chowdhury (1990), Jat *et al* (1990), Clarke *et al* (1992), Mosaad *et al* (1995), Sharma and Bharagava (1996), Sobieh and Ragab (2000) and Al-Naggar *et al* (2004).

Irradiation and EMS effects on M_2 generation

In the M_2 generation, there was a significant increase in grain yield/plant as a result of some gamma ray and/or EMS treatments as compared to non-treated wheat cultivars Sids 1 and Sakha 93. The highest significant increase in grain yield under water stress conditions ocurred due to the effect of 0.2 % concentration EMS on Sids 1 (29.8%) and Sakha 93 (14.1%). Under non-stress conditions, the highest increase in grain yield was a result of gamma radiation of 15 Krad on Sids 1 cultivar (17.2%) and EMS treatment of 0.2% concentration on Sakha 93 cultivar (12.7%). Other significant increases in grain yield occurred in M_2 following gamma radiation of 25 Krad (8.6%), 35 Krad (4.7%) under non-stress and 35 Krad (22.0%) under stress for Sids 1 cultivar and 15 Krad (7.2%) under stress conditions for Sakha 93. More significant increases in grain yield exhibited in M_2 generation following EMS treatments of 0.1% (7.9%) and 0.5% (6.7%) on Sids 1 and 0.3% (9.3%) and 0.4% (11.9%) on Sakha 93 under non-stress and 0.1% (21.7%) on Sids 1 under stress conditions. On the other hand, significant reductions occurred in grain yield/plant of Sids 1 in M_2 generation following treatment with 15 Krad gamma radiations (8.5%) under stress and 0.2% EMS (5.3%) under non-stress conditions.

It is worthy to note that using the treatment of 0.2% EMS on both cultivars significantly increased the grain yield of their M_2 bulks under water stress and non-stress conditions. This treatment caused significant increases in M_2 of Sakha 93 for 4 traits (plant height, spikes/plant, grains/spike and grain yield) under non-stress and for 2 traits (spikes/plant and grain yield) under water stress and in M_2 of Sids 1 for spikes/plant under non-stress and for 4 traits (plant height, spikes/plant, grains/spike and grain yield) under stress conditions.

For gamma radiation, the treatment of 15 Krad increased significantly the M_2 of Sids 1 for 3 traits (plant height, spikes/plant and grain yield) under non-stress and M_2 of Sakha 93 for grain yield under water stress. The treatment with a dose of 35 Krad increased significantly the M_2 of Sids 1 for two traits (spikes/plant and grain yield) under non-stress and for 4 traits (plant height, spikes/plant, grains/spike and grain yield) under water stress and the M_2 of Sakha 93 for three traits (spikes/plant, 100-grain weight and grain yield) under non-stress conditions. Increases in grain yield of the M_2 generation following mutagenic treatments were accompanied by increases in number of spikes/plant, plant height and grains/spike in both cultivars and 100-grain weight in Sakha 93.On the contrary, significant reductions were exhibited in the M_2 generation due to mutagenic effects in 100-grain weight, especially in Sids 1 and plant height in both cultivars. It is worthy to note that the least reductions due to mutagenic effects were exhibited by spikes/plant and grain yield/plant, while the most frequent reductions were shown by 100-grain weight followed by grains/spike.

In general, increases in M_2 grain yield due to mutagenic treatments were more pronounced under water stress than under non-stress conditions, while the opposite was true for spikes/plant. It is noteworthy that the most responsive trait to increase by mutagens was number of spikes/plant followed by grain yield/plant. Moreover, under water stress Sids 1 cultivar showed more frequent significant increases (18 cases) than Sakha 93 (8 cases), while under non-stress conditions the opposite was true, where Sakha 93 exhibited (25 cases) more significant increases than Sids 1 (17 cases).

Several investigations also reported that gamma rays caused favorable effects on the M_2 generation traits of bread wheat. Singh and Kumar (1974) found that in wheat mean grain yield per plant of the M_2 was 22.27g, whereas, the parental mean was 12.32g. They also found an increase in 100-grain weight of wheat M_2 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 (1999) 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 internodes length of all short culm mutants was significantly reduced as compared to their parents. Al-Naggar *et al* (2004) reported that irradiation caused a grain yield increase of 14.6% in the M_2 generation of wheat under non-stress. They also stated that, irradiation caused favorable effects in increasing weight of 100-grains (by 11.1%) and in shortening of plant height by 5.7 and 20.6% in the M_2 generations *vs* parents under non-stress and stress conditions, respectively. Moreover some researchers reported favorable effects for EMS on wheat traits in the M_2 generation (Kalia *et al* 2000).

M_2 genotypic differences

Genotypic differences among M_2 bulks were found for all studied traits either under drought stress or non-stress conditions. The highest yielders under non-stress conditions were Sd-RAD-1(22.32g), Sk-EMS-2 (21.37g), Sk-EMS-4 (21.22g), Sk-RAD-3 (20.78g), Sk-EMS-3 (20.74g) and Sd-RAD-2 (20.67g). Under stress, Sd-EMS-2 (19.49g), Sd-RAD-3 (18.33g), Sd-EMS-1 (18.28g), Sk-EMS-2 (17.30g) and Sk-RAD-1 (16.25g) were the best yielders (Table 2). The least reduction in grain yield due to water stress (the most tolerant) was obtained by the M_2 bulk Sd-EMS-2 followed by Sd-RAD-3, Sd-EMS-1, Sk-RAD-1 and Sk-EMS-2. These genotypes are the same superior genotypes under water stress. Only one of them (Sk-EMS-2) was of superiority (*i.e.*, it was superior under stress and non-stress conditions). These genotypes (M_2 bulks) could be considered the most tolerant to water stress in this experiment.

The superiority of M_2 genotypes in grain yield/plant over parent cultivars was accompanied by superiority in one or more yield components. Superiority of Sd-EMS-2 under water stress in grain yield was accompanied by superiority in grains/spike (3.5%) and spikes/plant (24.8%). Superiority of Sd-RAD-3 (22.0%) and Sd-EMS-1 (21.7%) under drought conditions was accompanied by superiority in spikes/plant (29.1 and 29.9%, respectively). Many studies have also indicated that there is a genotypic variation in grain yield of wheat M_2 bulks derived *via* gamma irradiation under water stress and non-stress conditions (Khanna *et al* 1986, Sobieh and Ragab, 2000 and Al-Naggar *et al* 2004) and *via* EMS treatments (Kalia *et al* 2000).

Ranges of M_2 bulks

The highest limit and the range of M_2 bulks are presented in Table (3). In general, the highest ranges were exhibited by plant height and grain yield/plant, while the lowest estimates were for 100-grain weight. The highest increase in range due to studied mutagens over control (untreated cultivars) was shown by grain yield followed by plant height. In general, broadest range due to mutagenic treatments was higher under non-stress than under water stress conditions.

It could be concluded from the data of Table (3) that for most studied traits in M_2 generation under both stress and non-stress conditions especially for grain yield, spikes/plant and plant height, irradiation and EMS treatments cause increase in the magnitude of both range and its highest limit. This might be attributed to the creation of variation via irradiation or EMS treatments, which can help plant breeder in increasing the efficiency of selection for drought tolerance.

Coefficients of variation of M_2 bulks

The estimates of phenotypic (PCV) and genotypic (GCV) coefficients of variation are presented in Table (4). Highest estimates of PCV and GCV were exhibited by spikes/plant and grain yield traits, while the lowest ones were shown by grains/spike. Both PCV and GVC estimates were generally higher under water stress than non-stress conditions for grain yield, spikes/plant and plant height traits. M_2 bulks derived *via* irradiation or EMS treatments showed higher PCV and GCV estimates than non-irradiated (or non EMS treated) ones under both water stress and non-stress conditions for most studied traits.

Table 3. Ranges (R) and highest (H) limits of studied traits in M_2 generation of wheat bulks derived *via* gamma rays and EMS under drought stress (S) and non-stress (NS) conditions (Inshas, 2003/2004).

M_2 bulks and parents	Plant height (cm)				Spikes/ plant (No.)				Grains/spike (No.)				100-grain wt. (g)				Grain yield/plant (g)			
	NS		S		NS		S		NS		S		NS		S		NS		S	
	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H
Sids 1	30	110	20	80	5	12	3	8	12	69	15	68	2.1	6.0	1.5	5.8	12.2	28.3	7.5	19.9
Sd - RAD - 1	55	135	20	80	31	36	3	8	12	67	17	68	2.1	6.0	1.8	5.7	55.7	69.3	6.0	17.2
Sd - RAD - 2	39	124	51	111	19	24	12	17	17	69	8	65	2.1	6.1	1.8	5.8	47.6	61.0	36.6	48.3
Sd - RAD - 3	50	125	52	112	18	23	15	21	15	68	8	66	1.9	6.1	2.2	6.0	45.8	59.5	31.3	45.0
Sd - EMS - 1	50	125	53	115	19	24	15	21	20	70	15	68	2.3	6.2	2.1	5.8	63.7	77.7	26.1	40.5
Sd - EMS - 2	60	130	57	112	16	21	18	23	19	73	12	67	2.1	6.2	2.0	6.0	35.2	48.6	67.1	78.4
Sd - EMS - 3	42	112	57	117	11	16	11	16	14	69	14	68	2.0	6.0	1.3	5.4	18.9	32.3	32.3	43.1
Sd - EMS - 4	50	130	45	110	10	15	11	16	10	69	16	69	1.7	5.6	1.6	5.6	24.9	38.3	28.4	38.7
Sd - EMS - 5	55	130	50	110	19	24	15	20	16	69	15	68	2.4	6.2	1.5	5.6	55.3	68.8	27.2	39.5
Sakha 93	20	90	16	76	11	15	6	11	22	73	18	69	1.8	5.8	1.9	6.0	17.4	33.8	14.8	25.7
Sk - RAD - 1	30	100	32	97	12	17	26	29	18	71	18	68	3.2	6.8	2.3	6.2	28.1	42.3	56.6	68.9
Sk - RAD - 2	20	90	31	96	8	13	18	21	23	71	19	68	2.2	6.5	1.5	5.6	18.5	33.2	49.3	59.4
Sk - RAD - 3	30	100	45	100	17	23	21	23	24	72	20	68	4.2	6.8	2.1	6.0	19.8	36.9	31.2	42.4
Sk - EMS - 1	19	89	36	100	14	19	20	24	21	72	10	67	3.2	6.7	0.9	4.8	13.9	31.1	26.5	37.5
Sk - EMS - 2	20	100	37	102	10	15	28	32	17	74	11	68	1.3	5.2	1.6	5.5	16.2	32.0	46.4	58.4
Sk - EMS - 3	30	100	50	100	7	13	18	22	18	70	18	68	2.3	6.3	1.2	5.5	27.7	45.0	43.0	53.2
Sk - EMS - 4	15	95	35	100	10	16	21	25	14	69	14	66	1.9	5.8	1.8	6.0	14.6	31.1	35.0	45.8
Sk - EMS - 5	15	95	33	98	12	17	14	18	14	70	17	67	1.9	6.0	1.7	5.9	19.8	33.3	32.5	42.7

It could be concluded from these results that for most studied traits under water stress conditions; both irradiation and EMS treatments caused an increase in the magnitude of both PCV and GCV in the resulted M_2 bulks. This might be attributed to the induction of variations *via* irradiations or chemical mutagens, which can help in increasing the opportunity of selecting drought tolerant wheat variants. This conclusion was also reported by Al-Naggar *et al* (2004) on their work to induce genetic variation in wheat drought tolerance *via* irradiation.

Under water-stress conditions, the highest estimates of both PCV and GCV for grain yield were exhibited by the M_2 bulks Sd-EMS-2, Sk-RAD-2 and Sk-EMS-3. Under non-stress conditions, the two M_2 bulks Sd-RAD-1 and Sd-RAD-3 showed the highest estimates of both PCV and GCV for grain yield. Moreover, the highest coefficients of variations were also shown by the M_2 bulks Sd-EMS-1 and Sd-EMS-5 (for PCV) and Sd-EMS.2 and Sd-EMS-3 (for GCV) under non-stress.

It is worthy to mention that the superior M_2 bulks for GCV under both water stress and non-stress conditions were Sd- EMS-2 and Sd-EMS-3. while for PCV no one of the superior M_2 bulks under water-stress was superior under non-stress conditions superior M_2 bulks under water-stress was superior

Table 4. Estimates of phenotypic (PCV) and genotypic (GCV) coefficient of variations (%) of wheat M_2 bulks derived *via* gamma rays and EMS under stress and non-stress conditions in Inshas, 2003/2004 season.

M_2 bulks and parents	PCV					GCV				
	PH	SPP	GSP	100GW	GY	PH	SPP	GSP	100GW	GY
					Non-Stress					
Sids 1	6.3	24.0	5.6	10.1	13.9					
Sd - RAD - 1	11.8	70.7	4.8	12.2	57.8	10.1	72.3	9.8	6.7	58.7
Sd - RAD - 2	9.2	48.6	7.7	11.9	43.2	6.8	45.0	8.9	5.5	40.5
Sd - RAD -3	12.4	60.8	7.8	10.0	57.1	10.1	68.7	0.0	6.2	56.5
Sd - EMS - 1	13.3	62.6	6.6	12.1	70.8	7.0	45.5	5.2	5.7	41.3
Sd - EMS - 2	13.7	53.0	8.2	10.8	40.4	10.5	57.6	5.1	0.0	55.5
Sd - EMS - 3	10.8	35.1	5.7	10.9	26.0	11.4	59.1	3.3	5.1	69.6
Sd - EMS - 4	11.5	33.0	4.5	10.7	31.3	11.9	48.3	5.8	3.2	37.6
Sd - EMS - 5	13.9	66.1	6.5	14.6	64.3	8.8	29.7	1.3	0.8	21.9
Sakha 93	6.1	31.3	12.1	10.5	18.2					
Sk - RAD - 1	9.0	35.8	16.6	15.3	29.1	6.6	20.8	11.1	11.5	22.8
Sk - RAD - 2	6.9	28.3	9.6	11.2	23.7	2.7	0.0	0.0	5.3	15.4
Sk -RAD - 3	9.3	45.4	10.7	13.3	24.3	6.8	37.4	0.0	9.4	17.7
Sk - EMS - 1	7.5	39.9	8.0	16.1	15.7	3.5	27.0	0.0	12.7	0.0
Sk - EMS - 2	6.0	30.3	9.8	8.6	21.8	2.2	17.8	0.0	0.0	14.6
Sk - EMS - 3	10.4	21.0	8.1	10.9	27.4	8.1	0.0	0.0	5.6	21.8
Sk - EMS - 4	4.8	27.1	6.5	10.3	16.8	0.0	10.8	0.0	0.0	4.1
Sk - EMS - 5	5.3	37.6	7.0	8.8	26.2	0.0	23.2	0.0	0.0	18.5
					Stress					
Sids 1	6.6	16.2	8.0	8.6	14.5					
Sd - RAD - 1	5.9	11.9	5.9	9.9	9.9	0.0	0.0	0.0	3.9	0.0
Sd - RAD - 2	18.2	46.2	3.8	10.2	52.0	17.0	43.8	0.0	5.4	50.1
Sd - RAD - 3	18.3	49.5	3.8	12.5	47.0	17.2	47.8	0.0	8.0	45.5
Sd - EMS - 1	18.5	40.0	7.8	11.3	36.5	17.5	37.9	4.3	7.1	34.5
Sd - EMS - 2	17.8	50.7	5.9	12.1	72.2	16.6	49.0	0.0	8.4	71.3
Sd - EMS - 3	20.4	42.8	7.3	7.7	55.3	19.4	39.6	3.4	0.0	53.3
Sd - EMS - 4	14.8	45.7	9.0	8.9	54.8	13.6	43.1	6.4	2.2	52.7
Sd - EMS - 5	16.0	47.4	4.2	6.9	39.1	14.8	45.4	0.0	0.0	36.5
Sakha 93	5.6	23.9	8.5	11.2	22.9					
Sk - RAD - 1	10.1	78.1	6.3	13.7	35.9	8.4	73.9	0.0	7.9	28.9
Sk - RAD - 2	11.8	65.1	8.2	9.6	67.5	10.4	59.7	0.0	0.0	63.6
Sk -RAD - 3	17.7	93.9	9.0	10.8	48.5	16.7	89.0	1.3	0.0	42.4
Sk - EMS - 1	13.5	61.4	4.5	6.4	44.7	12.3	56.8	0.0	0.0	37.8
Sk - EMS - 2	13.9	78.1	3.8	7.8	52.9	12.7	75.0	0.0	0.0	49.0
Sk - EMS - 3	17.1	65.2	6.6	6.9	70.4	16.0	61.1	0.0	0.0	66.8
Sk - EMS - 4	12.2	76.2	6.8	10.4	55.8	10.8	72.9	0.0	0.0	50.3
Sk - EMS - 5	11.8	50.7	7.8	10.9	50.3	10.4	44.4	0.0	0.0	43.9

PH=Plant height (cm), SPP = Spikes/ plant, GPS = Grains/ spike, 100 GW = 100-grain/weight (g) t, GY= Grain yield/plant (g)

under non-stress conditions. Moreover, superior M_2 bulks for both PCV and GCV parameters under both water stress and non-stress conditions for grain yield/plant were also superior in both parameters for most of studied traits. For example, the M_2 bulk Sd-EMS-2 under water stress was superior in grain yield and 100-grain weight for PCV estimates and grain yield and 100-grain weight for GCV estimates.

Heritability and expected selection gain of M_2 bulks

Heritability in the broad-sense (h^2_b) and expected genetic advance from selection (GA) estimates of wheat M_2 bulks derived *via* irradiation and EMS treatments, under water-stress and non-stress conditions are presented in Table (5). The highest h^2_b estimates in M_2 generation were shown by grain yield/plant (average h^2_b = 64.58%) followed by spikes/plant (average h^2_b = 56.44%) under non-stress and spikes/plant (average h^2_b = 83.07%) followed by grain yield (average h^2_b = 80.02%) and plant height (average h^2_b= 78.58%) under water stress conditions. On the contrary, the lowest h^2_b in M_2 generation was shown by grains/spike trait under water stress (average h^2_b=16.57%) and non-stress (average h^2_b = 14.84%) conditions.

Under non-stress conditions, the M_2 bulks Sd-EMS-5, Sd-EMS-1, Sd-RAD-1 and Sd-RAD-3 showed the highest estimates of both h^2_b and GA% for grain yield/plant and one or more of its components, as well as for plant height. The expected genetic advance *via* one cycle of selection of the best 10% for these four M_2 bulks in the same order under non-stress is 11.08, 12.25, 9.95 and 9.77%, respectively for grain yield and 11.11, 10.40 , 12.09 and 10.14 %, respectively for number of spikes/plant (Table 5).

Under water stress conditions, the M_2 bulks Sd-EMS-2 and Sd-EMS-3 exhibited the highest h^2_b and GA% estimates for grain yield and one or more of yield components. Moreover, the M_2 bulks Sd-EMS-3 and Sk-RAD-2 were amongst those showing the highest GA% for grain yield under stress conditions; the GA for grain yield under water stress was 12.55, 11.76, 11.19 and 9.39% for Sd-EMS-2, Sk-EMS-3, Sk-RAD-2 and Sd-EMS-3, respectively (Table 5). The highest GA for spikes/plant under water stress was shown by Sk-RAD-3 (15.66%), Sk-EMS-2 (13.19%), Sk-RAD-1 (13.00%) and Sk-EMS-4 (12.82). It is worthy to note that practicing selection under water stress conditions in most M_2 bulks derived *via* irradiation or EMS treatments in the present study would expect to obtain a higher selection gain than under non-stress conditions in grain yield and number of spikes/plant traits. Summarizing the above mentioned results on M_2 bulks derived *via* irradiation and EMS treatments, it could be concluded that the best mutagenic treatments for inducing new genetic variation valid for the improvement of grain yield and its

Table 5. Estimates of heritability in broad sense (h_b^2 %) and expected genetic advance from selection (GA %) in wheat M_2 bulks derived *via* gamma rays and EMS treatments, evaluated under stress and non- stress conditions in Inshas,2003/ 2004 season.

	h_b^2 (%)					GA (%)				
M_2 bulks	PH	SPP	GSP	100GW	GY	PH	SPP	GSP	100GW	GY
					Non-Stress					
Sd - RAD - 1	73.9	94.4	0.0	26.2	95.8	1.8	12.1	0.0	1.1	10.0
Sd - RAD - 2	57.2	87.5	45.5	23.1	91.2	1.2	8.0	0.9	1.0	7.3
Sd - RAD - 3	71.6	89.6	43.6	0.0	94.6	1.8	10.1	0.9	0.0	9.8
Sd - EMS - 1	74.2	89.1	26.0	18.0	96.7	2.0	10.4	0.6	0.9	12.2
Sd - EMS - 2	75.8	83.3	50.3	8.6	86.8	2.1	8.5	1.0	0.6	6.6
Sd - EMS - 3	67.6	71.4	5.2	0.5	71.4	1.6	5.2	0.2	0.1	3.9
Sd - EMS - 4	71.3	60.9	0.0	0.0	80.0	1.7	4.5	0.0	0.0	4.9
Sd - EMS - 5	81.0	91.1	21.8	38.7	95.9	2.2	11.1	0.5	1.6	11.1
Sk - RAD - 1	54.3	33.5	45.0	56.7	61.4	1.2	3.7	2.0	2.0	4.0
Sk - RAD - 2	15.8	0.0	0.0	22.2	42.3	0.5	0.0	0.0	0.9	2.7
Sk -RAD - 3	53.6	67.8	0.0	49.5	53.2	1.2	6.6	0.0	1.6	3.1
Sk - EMS - 1	21.7	45.7	0.0	61.9	0.0	0.6	4.7	0.0	2.2	0.0
Sk - EMS - 2	13.4	34.6	0.0	0.0	45.0	0.4	3.1	0.0	0.0	2.6
Sk - EMS - 3	61.2	0.0	0.0	26.5	63.1	1.4	0.0	0.0	1.0	3.8
Sk - EMS - 4	0.0	15.9	0.0	0.0	6.0	0.0	1.9	0.0	0.0	0.7
Sk - EMS - 5	0.0	38.1	0.0	0.0	50.1	0.0	4.1	0.0	0.0	3.3
Average	49.5	56.4	14.8	20.7	64.6	1.2	5.9	0.4	0.8	5.4
					Stress					
Sd - RAD - 1	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0	0.7	0.0
Sd - RAD - 2	87.5	89.8	0.0	28.2	93.0	3.0	7.7	0.0	1.0	8.8
Sd - RAD - 3	88.0	93.5	0.0	41.3	93.6	3.0	8.4	0.0	1.4	8.0
Sd - EMS - 1	88.8	89.8	30.7	39.5	89.3	3.1	6.7	0.8	1.3	6.1
Sd - EMS - 2	87.8	93.4	0.0	47.4	97.6	2.9	8.6	0.0	1.5	12.5
Sd - EMS - 3	90.4	85.9	21.8	0.0	92.9	3.4	7.0	0.6	0.0	9.4
Sd - EMS - 4	84.4	88.7	50.6	6.0	92.6	2.4	7.6	1.1	0.4	9.3
Sd - EMS - 5	84.8	91.4	0.0	0.0	87.1	2.6	8.0	0.0	0.0	6.4
Sk - RAD - 1	68.0	89.4	0.0	33.1	64.6	1.5	13.0	0.0	1.4	5.1
Sk - RAD - 2	77.5	84.0	0.0	0.0	88.6	1.8	10.5	0.0	0.0	11.2
Sk -RAD - 3	89.2	89.8	2.0	0.0	76.4	2.9	15.7	0.2	0.0	7.5
Sk - EMS - 1	82.4	85.4	0.0	0.0	71.5	2.2	10.0	0.0	0.0	6.7
Sk - EMS - 2	84.2	92.0	0.0	0.0	85.6	2.2	13.2	0.0	0.0	8.6
Sk - EMS - 3	87.7	87.9	0.0	0.0	90.0	2.8	10.8	0.0	0.0	11.8
Sk - EMS - 4	78.8	91.3	0.0	0.0	81.3	1.9	12.8	0.0	0.0	8.9
Sk - EMS - 5	77.7	76.6	0.0	0.0	76.2	1.8	7.8	0.0	0.0	7.7
Average	78.6	83.1	6.6	13.2	80.0	2.4	9.2	0.2	0.5	8.0

PH=Plant height (cm), SPP = Spikes/ plant, GPS = Grains/ spike, 100 GW = 100-grain weight (g), GY= Grain yield/plant (g)

components *via* selection under water stress were different from those under non-stress conditions. The best ones under water stress were 0.2% EMS on Sids 1 cultivar followed by 25 Krad gamma radiations on Sakha 93 cultivar, 0.3% EMS on Sakha 93 and 0.3% EMS on Sids 1. The M_2 bulk Sd-EMS-2 was the most superior in 6 parameters (mean, range, PCV, GCV, h^2_b and GA) under water stress for grain yield and its components. Moreover, under water stress the M_2 bulks Sk-RAD-2 was superior in 4 parameters (range, PCV, GCV, and GA), Sk-EMS-3 in 3 parameters (PCV, GCV, and GA) and Sd-EMS-3 in 2 parameters (GCV, and GA).

Under non-stress, the best mutagenic treatment for the improvement of grain yield and its components in the M_2 generation was 15 Krad on Sids 1 (superiority in 6 parameters, *i.e.* mean, range, PCV, GCV, h^2_b and GA) followed by 0,1% EMS on Sids 1 and 0.5% EMS on Sids 1 (superiority in 4 parameters, i.e. range, PCV, h^2_b and GA) and 0.3% EMS on Sids 1 (superiority in 4 parameters, i.e. PCV,GCV, h^2_b and GA). Therefore, the best M_2 bulks derived *via* irradiation and EMS treatments for improving grain yield and its components under non-stress conditions were, Sd-RAD-1 followed by Sd-RAD-3, Sd-EMS-1 and Sd-EMS-5; all these M_2 bulks are derived from Sids 1 cultivar. In agreement with our results, gamma rays were found to increase heritability estimates of the mutated segregating generations for grain yield and its components in wheat (Kumar, 1977; Kar and Yadav, 1986; Khamankar, 1988; El-Rassas, 1991; Sobieh, 1999 and Al-Naggar *et al* 2004).

Experiment two (M_3 bulks)

Analysis of variance of M_3 bulks (not-presented) indicated that mean squares due to irrigation regimes and those due to M_3 bulks were significant or highly significant for all studied traits. Mean squares due to M_3 bulks derived *via* EMS *vs* M_3 bulks derived *via* gamma radiation were significant for all studied traits. This suggests that a significant difference exists due to effects of mutagenic sources, *i.e.* among EMS and irradiation treatments. Mean squares due to M_3 bulks X irrigation regimes interaction were highly significant for all studies traits, suggesting that performance of M_3 genotypes varies with water supply, confirming results of previous investigators (Fischer and Maurer 1978, Sharma and Bharagava 1996, Ragab and Sobieh 2000 and Al-Naggar *et al* 2004).

Water stress effect on M_3 bulks

Water stress caused significant reductions in all studied traits (Table 6) across all mutated and non-mutated M_3 bulks. Maximum reductions due to water stress in M_3 bulks was exhibited by grain yield trait (38.9%) followed by spikes/plant trait (32.7%) and plant height trait (17.5%), while minimum reductions were shown by grains/spike (2.7%). Reduction in

Table 6. Means of studied traits in wheat M_3 bulks *via* gamma rays and EMS from Sids and Sakha 93 cultivars under drought stress (S) and non-stress (NS) conditions (Inshas, 2004/2005 season).

M_3 bulks and parents	Plant height (cm)			Spikes/ plant			Grains/ spike			100-grain weight (g)			Grain yield/plant (g)		
	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)	NS	S	Red. (%)
Sids 1	89.9	68.6	23.8	6.4	6.2	2.8	61.7	59.0	4.5	4.9	4.9	0.6	19.0	14.9	21.2
Sd - RAD - 1	87.1	71.6	17.8	10.3	7.1	30.7	62.2	60.9	2.0	5.4	4.8	10.1	30.1	15.6	48.1
Sd - RAD - 2	91.0	71.1	21.9	9.2	6.0	34.4	63.6	61.9	2.7	5.3	4.8	10.1	25.0	13.6	45.8
Sd - RAD - 3	90.0	69.1	23.2	12.3	6.8	44.6	62.4	62.5	-0.3	5.3	4.5	14.3	28.9	14.9	48.6
Sd - EMS - 1	92.0	70.3	23.6	12.7	5.8	54.5	63.2	59.7	5.5	5.4	4.9	8.5	30.8	12.6	59.0
Sd - EMS - 2	87.2	66.4	23.8	10.6	5.6	47.3	63.9	58.3	8.7	4.9	4.9	-0.1	26.3	12.4	52.7
Sd - EMS - 3	93.3	71.1	23.8	10.7	7.4	31.2	62.7	60.7	3.1	5.5	5.1	6.6	29.0	16.7	42.3
Sd - EMS - 4	87.5	70.9	18.9	7.5	6.5	13.4	62.5	61.0	2.4	5.0	4.9	2.0	19.9	14.1	29.2
Sd - EMS - 5	87.3	70.5	19.3	7.3	6.2	14.2	61.4	61.4	0.1	5.2	4.9	6.5	20.2	14.1	29.9
Sakha 93	81.7	71.6	12.3	7.1	6.6	6.1	61.6	61.8	-0.2	4.8	4.8	1.2	19.0	15.2	20.1
Sk - RAD - 1	77.0	69.8	9.3	7.9	5.6	29.1	61.2	62.5	-2.2	4.7	4.7	0.1	21.4	12.6	41.0
Sk - RAD - 2	74.8	71.6	4.3	7.8	6.8	13.0	63.2	62.0	2.0	4.6	4.8	-4.3	19.1	16.7	12.4
Sk -RAD - 3	77.0	69.4	9.9	12.0	6.1	48.7	64.5	59.4	8.0	4.6	4.7	-2.5	19.7	12.2	38.4
Sk - EMS - 1	83.3	67.5	19.0	10.6	5.8	45.3	63.7	62.8	1.4	5.3	4.6	13.8	25.5	12.4	51.2
Sk - EMS - 2	78.5	68.5	12.7	11.4	5.9	48.7	61.8	61.0	1.3	5.0	4.7	5.4	24.0	12.7	47.1
Sk - EMS - 3	77.8	65.5	15.9	9.0	5.4	39.6	63.5	61.8	2.7	4.7	4.7	0.8	19.2	12.0	37.6
Sk - EMS - 4	80.5	66.1	17.8	9.8	5.8	40.8	62.8	60.3	3.9	4.7	4.8	-2.3	19.8	12.5	37.0
Sk - EMS - 5	80.2	65.7	18.0	8.8	5.2	41.5	62.8	60.9	3.1	4.8	4.7	2.9	18.7	11.6	38.3
Over all average	84.2	69.1	17.5	9.5	6.1	32.7	62.7	61.0	2.7	5.0	4.8	4.1	23.0	13.7	38.9
LSD 0.05:															
Irrigations (I)	2.1				1.4			0.0			0.1			1.1	
Genotypes (G)	1.8				0.7			0.1			0.1			1.0	
G x I	2.6				1.0			0.2			0.2			1.4	

grain yield due to water stress effect on M_3 bulks may be attributed mainly to reduction in number of spikes/plant. Reduction in grain yield due to water stress was higher in Sakha 93 M_2 bulks (41.9%) than in Sids 1 M_3 bulks (35.9%); a similar trend was exhibited in all studied traits, except in spikes/plant, where the opposite was true.

The greatest reduction in grain yield due to water stress (59%) was exhibited by the M_3 bulk Sd-EMS-1 followed by Sk-EMS-1.On the other hand, the lowest reduction because of water stress in grain yield was shown by the M_3 bulk Sk-RAD-2 (12.4%),suggesting high tolerance to drought for this M_3 bulk. It is worthy to mention that reduction in grain yield and spikes/plant due to water stress was greater in M_3 (Table 6) than in M_2 (Table 2) bulks. Such reductions in M_3 generation because of drought stress in bread wheat were also reported by other investigators Salam (1998).

Irradiation and EMS effects on M_3 generation

In the M_3 generation, mutagenic treatments caused a significant increase in grain yield/plant over the non-treated wheat parent cultivars Sids 1 or Sakha 93. Most of M_3 bulks showed significant increases over their parent cultivars under non-stress conditions. The highest significant increase in grain yield under non-stress occurred as a result of the treatment with 0.1% EMS on Sids-1 (62.0%) and Sakha 93 (34.3%). Other significant increases in grain yield under non-stress happened in M_3 resulted from the treatments 15 krad (58.2%), 25 krad (31.6%), 35 krad (51.9%), 0.2% EMS (38.1%) and 0.3% EMS (52.2%) on Sids 1 cultivar and 0.2% EMS (26.7%) and 15 krad (12.7%) on Sakha 93.

Under water stress increases in grain yield due to mutagenic agents occurred by 0.3% EMS on Sids 1 (11.3%) and 25 krad on Sakha 93 (10.2%).On the contrary, significant reductions in grain yield of M_3 bulks due to mutagens under water stress ranged from 5.9% for 0.5% EMS on Sids 1 to 23.7% for 0.5% EMS on Sakha 93.

Increases in M_3 grain yield following mutagen treatments were associated with increases in one or more yield components. The highest increases due to mutagens were exhibited in M_3 by number of spikes/plant, reaching up to 97.1% for 0.1% EMS on Sids 1 followed by 91.8% for 35 krad on Sids 1. Mutagens caused significant reductions in plant height of the M_3 in 8 cases under non-stress and 6 cases under water stress. Such significant reductions in plant height ranged from 3.2% for 0.2% EMS on Sids 1 to 8.4% for 25 krad on Sakha 93 under non-stress and from 4.1% for 0.2% EMS on Sids 1 to 8.6% for 0.1% EMS on Sakha 93 under water stress.

In general, increases in M_3 for grain yield and yield components because of mutagens happened in most cases under non-stress conditions. The most responsive trait in magnitude of increase by mutagens in the M_3 was number of spikes / plant followed by grain yield/plant. The best mutagenic treatments in increasing means of M_3 generation for grain yield and yield components were 0.3% EMS and 15 krad on Sids 1 under both stress and non-stress, 35 krad and 0.1 and 0.2 % EMS on Sids 1 and 35 Krad and 0.1% EMS on Sids 1 under non-stress and 25 krad on Sakha 93 under water stress conditions.

It is worthy to note that the three mutagen treatments on Sids 1 (15 krad, 35 krad and 0.1% EMS) showed significant increases in grain yield and its components for both M_2 and M_3 generations under non-stress conditions. However, under water stress conditions the highest significant increases in grain yield and its components due to mutagenic treatments were exhibited by different mutagens; i.e. by 35 krad 0.1 and 0.2% EMS on

Sids 1 and 35 Krad on Sakha 93 in M_2 and 15 krad and 0.3% EMS on Sids 1 and 25 krad on Sakha 93 in M_3 generation.

Salam (1998) reported that high grain yield/plant in wheat was found after 7.5 krad treatment in M_2 and M_3 mutagenic generations under drought conditions. This increase in grain yield and other traits might indicate an increase of drought tolerance and gives a promising initial material for breeding wheat cultivars for drought tolerance. Significant increases in grain yield and its components of wheat were also observed in the M_3 generation following irradiation by Singh and Kumar (1974) and EMS mutagen by Kalia *et al* (2000).

M_3 genotypic differences

Genotypic differences among M_3 bulks were found for all studied traits under drought stress and non-stress conditions. The highest yielders under non-stress conditions were Sd-EMS-1 (30.84g), Sd-RAD-1 (30.13g), Sd-EMS-3 (28.98g) and Sd-RAD-3 (28.93 g). Under water stress, the best M_3 yielders were Sd-EMS-3 (16.71g), Sk-RAD-2 (16.71g) and Sd-RAD-1 (15.65g); they could be considered the most drought tolerant in this study. The superiority of these M_3 genotypes in grain yield/plant over their parents was accompanied by superiority in one or more yield components. Under non-stress, the superiority in grain yield of M_3 bulks over the parent cultivar was due to superiority in spikes/plant (62.7%), and 100 grain weight (8.2%) for Sd-RAD-3; spikes/plant (91.8%) for Sd-RAD-3, spikes/plant (97.1%), and 100-grain weight (8.0%), for Sd-EMS-1; and, spikes/plant (66.4%) for Sd-EMS-3. Under water stress, superiority of M_3 bulks over parent cultivars in grain yield/plant was associated with superiority in spikes/plant (12.6%) and grains/spike (3.3%) for Sd-RAD-1 and spikes/plant (16.4%), 100-grain weight (4.3%) and grains/spike (3.0%) for Sd-EMS-3.

Ranges of M_3 bulks

Range and the highest limit of each M_3 bulk for studied traits are presented in Table (7). Grain yield/plant and plant height showed the widest ranges and the greatest magnitudes of the highest limits in M_3 bulks. On the contrary, 100-grain weight exhibited the narrowest ranges and smallest magnitude of the highest limits in the M_3 bulks. In general, broadening of M_3 ranges towards higher limits over the control (untreated parent cultivar) due to mutagenic treatments was higher under non-stress than under water stress, higher in Sids 1 than in Sakha 93 and higher *via* EMS than *via* irradiation.

Table 7. Ranges (R) and highest (H) limits of studied traits in M_3 generation of wheat bulks derived *via* gamma rays and EMS and evaluated under drought stress (S) and non-stress (NS) conditions (Inshas, 2004/2005).

M_3 bulks and parents	Plant height (cm)				Spikes/ Plant (No.)				Grains/Spike (No.)				100-grain wt. (g)				Grain yield/Plant (g)			
	NS		S		NS		S		NS		S		NS		S		NS		S	
	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H	R	H
Sids 1	32	109	12	78	7	12	3	8	16	70	20	69	1.9	6.2	1.6	5.9	13.8	29.1	7.9	20.3
Sd - RAD - 1	25	100	15	80	21	26	5	11	10	68	18	69	2.0	6.3	2.0	6.0	51.8	69.1	11.6	24.8
Sd - RAD - 2	25	105	20	80	14	19	2	7	10	69	18	69	2.3	6.2	1.5	5.6	25.6	43.2	4.3	15.5
Sd - RAD - 3	20	100	21	81	22	27	4	8	13	72	14	69	2.7	6.6	1.1	5.0	40.6	58.2	3.4	16.9
Sd - EMS - 1	35	105	15	80	22	28	3	8	14	72	18	68	2.3	6.7	1.8	5.9	53.7	71.0	6.8	17.5
Sd - EMS - 2	30	100	20	80	16	21	5	10	14	69	17	68	2.0	6.0	1.6	5.8	38.7	55.2	12.1	22.7
Sd - EMS - 3	20	105	25	85	15	20	10	16	16	70	18	69	2.2	6.5	1.5	5.8	42.7	59.2	26.7	40.3
Sd - EMS - 4	35	105	15	80	7	12	5	10	16	70	12	67	2.2	6.4	1.7	5.9	19.2	35.9	11.8	22.7
Sd - EMS - 5	37	109	18	78	6	12	3	7	14	69	15	69	2.0	6.6	1.6	5.8	18.6	35.9	5.4	15.6
Sakha 93	15	90	11	76	3	8	5	11	18	69	13	67	2.0	6.1	1.2	5.5	17.4	33.7	5.4	18.9
Sk - RAD - 1	20	90	20	80	5	11	3	7	16	68	17	69	1.9	5.9	1.9	6.0	63.2	79.3	7.4	17.6
Sk - RAD - 2	15	85	18	80	2	7	6	11	15	67	18	69	1.6	5.7	2.1	6.2	24.8	40.0	22.1	34.9
Sk - RAD - 3	18	88	10	75	4	8	8	13	14	70	13	67	2.1	6.1	1.5	5.7	22.9	40.0	16.3	26.8
Sk - EMS - 1	20	95	15	80	3	8	4	9	16	69	16	68	2.0	6.3	1.5	5.6	35.6	51.8	10.0	20.4
Sk - EMS - 2	17	87	10	75	5	10	7	12	18	69	14	67	2.6	6.4	1.6	5.8	48.3	64.9	15.1	25.4
Sk - EMS - 3	34	100	10	70	10	16	4	8	19	69	16	68	2.0	6.1	2.2	6.3	19.0	34.7	8.6	18.8
Sk - EMS - 4	25	95	15	75	5	10	4	8	15	69	19	68	2.3	6.1	2.0	6.2	12.1	29.2	7.9	19.2
Sk - EMS - 5	25	95	15	77	3	7	8	12	18	69	16	68	2.0	6.3	1.7	5.8	13.3	29.5	12.7	24.5

The broadest M_3 range for grain yield/plant under water stress was shown by Sd-EMS-3 (R = 26.7g) followed by Sk-RAD-2 (R = 22.1g), Sk-RAD-3 (R = 16.3g) and Sd-RAD-1 (R = 11.6g); they increased range magnitude over the parent cultivar by 2.56, 1.99, 1.20 and 0.55 fold, respectively. Under non-stress, the broadest M_3 range for grain yield/plant was exhibited by Sk-RAD-1 (R = 63.2g) followed by Sd-EMS-1 (R = 53.7g), Sd-RAD-1 (R = 51.8g) and Sk-EMS-2 (48.3g); with an increase in range over the parent cultivar by 2.63, 3.39, 3.55 and 1.78 fold, respectively. These M_3 bulks showed also the greatest higher limits of range for grain yield. It is worthno-thing that, the M_3 bulk Sd-RAD-1 was amongst the best ones for ranges and higher limits under both water stress and non-stress conditions

Under non-stress conditions, the M_3 bulk Sd-EMS-1 showed maximum number of traits (4) with broadest ranges and greatest higher limits (grain yield, 100-grain weight, spikes/plant, and plant height), followed by M_3 bulk Sd-RAD-3 (2 traits, i.e. spikes/plant and 100-grain weight) and the M_3 bulk Sd-RAd-1 (2 traits, i.e. grain yield and spikes/plant). Under water stress, the best M_3 bulks for ranges and higher limits were Sd-EMS-3 (for 3 traits, i.e. grain yield, spikes/ plant and plant height), Sd-RAD-1 (for 3 traits, i.e. grain yield, grains/spike and 100 grain weight). It's worthy to note that, Sd-EMS-1 and Sd-RAD-1 under non stress and Sk-RAD-2 under water stress were amongst the best bulks in ranges and higher limits for both M_2 and M_3 generations. Singh and Kumar (1974) reported a range of variability in M_3 generation due to gamma radiation in wheat for 1000-grain weight (24.56 – 49.60) and grain yield / plant (7.342 – 22.275). When they compared these values with parental means of each character, they mentioned that it is quite clear that a considerable variability has been generated by gamma rays for all characters.

Coefficients of variation of M_3 bulks

Estimates of phenotypic (PCV) and genotypic (GCV) coefficients of variation of M_3 bulks are presented in Table (8). In general, the highest estimates of PCV and GCV of M_3 bulks were shown by grain yield/plant and number of spikes/plant, while the lowest ones were exhibited by grains/spike. Estimates of PCV and GCV of M_3 bulks were generally higher under non-stress than under water stress, especially for spikes/plant and grain yield traits. M_3 bulks showed higher PCV and GCV estimates than non-treated (control) parent cultivars in most cases under both water stress and non-stress conditions, suggesting that used mutagens were generally efficient in the M_3 bulks for improving drought tolerance in wheat. This conclusion was in agreement with that reported by Al-Naggar *et al* (2004).

Under water stress, the M_3 bulk Sk-RAD-2 showed the highest PCV and GCV estimates for maximum number of studied traits (5). The M_3 bulk Sd-EMS-3 came in the 2nd rank. Moreover, in the 3rd and 4th places came the M_3 bulks Sk-RAR-3; and, SK-EMS-5 for PCV and Sd-RAD-1 and Sk-EMS-4 for GCV estimates. Under non-stress conditions, the best M_3 bulk was Sd-EMS-1 followed by Sd-RAD-1 and Sd-RAD-3 for both PCV and GCV estimates, Sk-EMS-2 for PCV and Sd-EMS-2 for GCV estimates.

In most cases, PCV was higher than the corresponding GCV value in M_3 generation. Thus, high genetic coefficient of variability in M_3 induced through gamma rays or EMS for studied traits provides the basis for genetic improvement in wheat. This result agrees with that of Singh and Kumar (1974) in wheat.

Heritability and expected selection gain of M_3 bulks

Heritability in the broad sense (h_b^2) and expected genetic advance from selection (GA) estimates for M_3 bulks are presented in Table (9). Estimates of h_b^2 in M_3 were on average higher under non-stress than under water stress for all studied traits. The highest h_b^2 estimates in M_3 bulks were shown by grain yield/plant (70.1%) followed by spikes/plant (64.7%) under

Table 8. Estimates of phenotypic (PCV) and genotypic (GCV) coefficient of variation (%) of wheat M_3 bulks derived *via* gamma rays and EMS under stress and non-stress conditions in Inshas, 2004/2005 season.

M_3 bulks and parent	PCV					GCV				
	PH	SPP	GSP	100GW	GY	PH	SPP	GSP	100GW	GY
					Non-Stress					
Sids 1	6.5	24.5	5.9	8.9	14.0					
Sd - RAD - 1	18.1	48.1	6.9	9.2	52.2	16.9	45.7	4.2	4.3	51.4
Sd - RAD - 2	7.1	35.7	6.5	11.7	29.0	3.5	31.5	3.8	8.3	27.0
Sd - RAD - 3	7.0	45.2	8.7	11.9	39.1	3.0	43.4	6.9	8.6	38.0
Sd - EMS - 1	9.8	40.9	8.4	12.7	51.7	7.7	39.0	6.5	9.8	51.0
Sd - EMS - 2	9.8	46.5	5.9	11.4	46.4	7.4	44.2	2.6	7.1	45.3
Sd - EMS - 3	6.2	37.7	7.3	10.5	41.2	1.1	34.8	5.0	6.8	40.2
Sd - EMS - 4	8.7	25.3	7.5	11.8	18.8	5.8	14.5	5.3	8.0	13.2
Sd - EMS - 5	9.5	24.2	7.5	11.8	20.8	6.9	11.6	5.2	8.3	16.1
Sakha 93	5.9	27.7	6.1	9.2	10.9					
Sk - RAD - 1	6.5	40.9	7.2	8.4	55.0	0.9	29.8	0.0	0.0	52.6
Sk - RAD - 2	5.4	37.4	5.8	7.6	24.4	0.0	24.4	0.0	0.0	16.4
Sk -RAD - 3	6.3	40.0	5.0	10.2	27.0	0.0	35.5	0.0	0.0	20.6
Sk - EMS - 1	7.4	43.2	5.8	11.9	40.2	4.5	37.9	0.0	7.4	37.8
Sk - EMS - 2	6.1	40.4	7.6	11.7	52.4	0.0	35.5	0.7	6.4	50.4
Sk - EMS - 3	11.0	33.5	8.0	11.1	32.7	9.0	22.8	3.1	3.9	27.3
Sk - EMS - 4	9.6	24.3	7.3	14.1	15.5	7.3	9.1	0.0	9.4	0.0
Sk - EMS - 5	7.2	41.6	6.5	9.5	12.7	3.7	33.3	0.0	0.0	0.0
					Stress					
Sids 1	6.5	15.8	7.3	8.2	13.7					
Sd - RAD - 1	6.3	17.6	7.4	10.0	15.7	0.0	10	1.8	5.8	7.2
Sd - RAD - 2	7.0	11.1	8.3	9.0	7.8	2.8	0.0	4.4	3.6	0.0
Sd - RAD - 3	6.7	12.8	6.8	6.6	5.7	1.2	0.0	0.0	0.0	0.0
Sd - EMS - 1	6.6	16.8	8.1	8.8	14.2	0.9	0.0	3.6	3.7	0.0
Sd - EMS - 2	20.0	18.5	8.4	8.9	18.2	18.8	2.4	3.8	3.9	4.8
Sd - EMS - 3	7.9	26.3	8.2	8.7	30.8	4.6	22.3	3.9	3.9	27.9
Sd - EMS - 4	4.4	15.9	9.2	11.9	16.6	0.0	1.0	3.1	4.6	6.0
Sd - EMS - 5	4.7	10.0	7.5	12.3	8.1	0.0	0.0	2.4	6.6	0.0
Sakha 93	5.8	20.0	6.9	6.6	20.7					
Sk - RAD - 1	7.4	12.9	9.0	10.5	10.3	4.6	0.0	6.0	6.7	0.0
Sk - RAD - 2	6.8	24.5	8.3	12.8	33.1	3.8	7.3	4.8	10.1	25.7
Sk -RAD - 3	6.0	24.5	5.8	7.6	24.7	1.4	0.0	0.0	0.0	0.0
Sk - EMS - 1	7.6	15.9	7.2	7.6	14.6	4.7	0.0	2.7	0.0	0.0
Sk - EMS - 2	4.8	24.4	5.4	7.4	23.0	0.0	0.0	0.0	0.0	0.0
Sk - EMS - 3	6.6	17.9	6.9	11.3	16.2	2.4	0.0	1.2	7.8	0.0
Sk - EMS - 4	6.4	19.9	6.6	10.6	16.0	1.9	0.0	0.0	7.2	0.0
Sk - EMS - 5	6.9	29.8	6.9	9.9	26.9	3.1	0.0	0.0	5.8	0.0

PH=Plant height (cm), SPP = Spikes/ plant, GPS = Grains/ spike, 100 GW = 100-grain weight (g), GY= Grain yield/plant (g)

Table 9. Estimates of broad-sense heritability (h_b^2%) and expected genetic advance from selection (GA %) in wheat M_3 bulks derived *via* gamma rays and EMS treatments evaluated under stress non-stress conditions (Inshas, 2004 / 2005 season)

	h_b^2 (%)					GA (%)				
M_2 bulks	PH	SPP	GSP	100GW	GY	PH	SPP	GSP	100GW	GY
					Non-Stress					
Sd - RAD - 1	87.0	90.3	37.6	21.7	97.2	3.0	8.0	0.7	0.8	9.1
Sd - RAD - 2	23.5	77.8	33.6	49.8	86.7	0.6	5.5	0.7	1.5	4.8
Sd - RAD - 3	18.8	92.3	61.9	51.6	94.5	0.5	7.6	1.2	1.5	6.7
Sd - EMS - 1	60.8	91.1	60.1	59.0	97.2	1.4	6.9	1.2	1.7	9.0
Sd - EMS - 2	56.2	90.2	20.0	38.6	95.3	1.3	7.8	0.5	1.2	8.0
Sd - EMS - 3	3.4	85.3	46.5	42.0	95.1	0.2	6.1	0.9	1.2	7.1
Sd - EMS - 4	44.7	33.0	49.1	46.0	49.6	1.0	2.6	0.9	1.4	2.3
Sd - EMS - 5	53.0	22.8	47.1	49.6	59.9	1.2	2.0	0.9	1.5	2.8
Sk - RAD - 1	1.8	53.1	0.0	0.0	91.4	0.2	5.2	0.0	0.0	9.3
Sk - RAD - 2	0.0	42.5	0.0	0.0	45.1	0.0	4.3	0.0	0.0	2.9
Sk -RAD - 3	0.0	78.7	0.0	0.0	58.0	0.0	6.2	0.0	0.0	3.6
Sk - EMS - 1	35.8	76.7	0.0	38.6	88.6	0.8	6.7	0.0	1.3	6.7
Sk - EMS - 2	0.0	77.1	0.7	29.4	92.5	0.0	6.2	0.1	1.1	8.9
Sk - EMS - 3	66.4	46.3	15.1	12.1	69.8	1.6	4.0	0.6	0.7	4.8
Sk - EMS - 4	58.3	13.9	0.0	45.0	0.0	1.3	1.6	0.0	1.7	0.0
Sk - EMS - 5	26.4	63.8	0.0	0.0	0.0	0.7	5.9	0.0	0.0	0.0
Average	33.5	64.7	23.2	30.2	70.1	0.9	5.4	0.5	1.0	5.4
					Stress					
Sd - RAD - 1	0.0	32.6	5.7	33.9	21.0	0.0	1.8	0.3	1.0	1.3
Sd - RAD - 2	15.5	0.0	28.2	15.8	0.0	0.5	0.0	0.8	0.6	0.0
Sd - RAD - 3	3.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Sd - EMS - 1	1.9	0.0	19.4	17.9	0.0	0.2	0.0	0.6	0.7	0.0
Sd - EMS - 2	88.1	1.7	20.2	19.2	7.0	3.3	0.4	0.7	0.7	0.8
Sd - EMS - 3	33.9	71.9	23	20.8	82.0	0.8	3.9	0.7	0.7	4.9
Sd - EMS - 4	0.0	0.4	15.6	25.3	13.1	0.0	0.2	0.5	0.8	1.1
Sd - EMS - 5	0.0	0.0	10.0	40.0	0.0	0.0	0.0	0.4	1.2	0.0
Sk - RAD - 1	39.1	0.0	44.1	41.4	0.0	0.8	0.0	1.1	1.2	0.0
Sk - RAD - 2	30.8	9.0	33.4	62.3	60.5	0.7	1.3	0.8	1.8	4.5
Sk -RAD - 3	5.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Sk - EMS - 1	38.3	0.0	13.8	0.0	0.0	0.8	0.0	0.5	0.0	0.0
Sk - EMS - 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sk - EMS - 3	13.0	0.0	2.8	48.1	0.0	0.4	0.0	0.2	1.4	0.0
Sk - EMS - 4	8.6	0.0	0.0	45.4	0.0	0.3	0.0	0.0	1.3	0.0
Sk - EMS - 5	20.6	0.0	0.0	33.8	0.0	0.5	0.0	0.0	1.0	0.0
Average	18.6	7.2	13.5	25.2	11.5	0.6	0.5	0.4	0.8	0.8

PH=Plant height (cm), SPP = Spikes/ plant, GPS = Grains/ spike, 100 GW = 100-grain weight (g), GY= Grain yield/plant (g)

non-stress and 100-grain weight (25.2%) followed by plant height (18.6%) under water stress. On the contrary, the lowest h_b^2 in M_3 bulks was shown by grains/spike (23.2%) under non-stress and spikes/plant (7.2%) under water stress.

The highest estimates of GA% were shown by spikes/plant and grain yield/plant under non-stress. However, under water stress, maximum number of M_3 bulks that showed GA estimates was exhibited by 100 grain weight. Although only five M_3 bulks showed GA estimates for grain yield under water stress, the magnitude of such GA estimates was relatively higher than that of other studied traits (Table 9).

Under water stress, the M_3 bulks Sd-RAD-1, Sd-EMS-3, Sd-EMS-4 and Sk-RAD-2 showed the highest estimates of both h_b^2 and GA% for maximum number of studied traits including grain yield. The expected genetic advance *via* one cycle of selection of the best 10% for these M_3 bulks in the same order under water stress was 1.3, 4.9, 1.1and 4.5%, respectively, for grain yield/plant (Table 9).

Under non-stress, the best M_3 bulks were Sd-RAD-1, Sd-RAD-3 and Sd-EMS-1 for both h_b^2 and GA, Sd-EMS-3 for h_b^2 and Sd-EMS-2, Sk,-EMS-2 and Sk-RAD-1 for GA. The predicted genetic gain from selection of the best 10% for grain yield/plant in the M_3 bulks Sd-RAD-1, Sd-RAD-3, Sd-EMS-1, Sd-EMS-2, Sk-RAD-1 and Sk-EMS-2 was 9.1, 6.7, 9.0, 8.0, 9.3 and 8.9%, respectively, under non-stress conditions.

Maximum gain from selection for grain yield under water stress conditions is expected to be 4.9 and 4.5% from the M_3 bulks Sd-EMS-3 and Sk-RAD-2, respectively. However, maximum GA% for grain yield under non-stress conditions is expected to be 9.3 and 9.1% from the M_3 bulks Sk-RAD-1 and Sd-RAD-1; both derived *via* irradiation. It is interesting to mention that, only the M_3 bulk Sd-RAD-1 showed genetic advance from selection under both non-stress (9.1%) and stress (1.3%) conditions.

Summarizing the above mentioned results on M_3 bulks, it could be concluded that the best ones for all studied genetic parameters of induced variability (mean, range, higher limit, PCV, GCV, h_b^2 and GA) were Sd-RAD-1, Sd-RAD-3, Sd-EMS-1 and Sd-EMS-2 under non-stress and Sd-RAD-1, Sd-EMS-3, Sd-EMS-4 and Sk-RAD-2 under water stress conditions. It is worthy to note that, Sd-RAD-1, was the only M_3 bulk which showed superiority for the improvement of grain yield and its components under both water stress and non-stress conditions, while other superior M_3 bulks under non-stress were different from those superior under water stress conditions for most studied parameters and most studied traits. It is interesting to mention that, only one M_3 bulk (Sk-RAD-2) amongst the 8 superior M_3 bulks was derived from Sakha 93, while 7 out of 8 superior M_3 bulks were derived from Sids 1 cultivar. This suggests that M_3 bulks derived from Sids 1 were more responsive to improvement and induction of useful variability *via* irradiation and EMS than those derived from Sakha 93 cultivar.

Summarizing the results of experiment one and two, for superiority in studied genetic parameters indicated that there were three common superior bulks in both M_2 and M_3 generations (Sd-RAD-1, Sd-RAD-3 and Sd-EMS-1) under non-stress, while under water stress there were two common superior bulks (Sd-EMS-3 and Sk-RAD-2) in both M_2 and M_3 generations. This inherited superiority for studied genetic parameters of induced variability from M_2 to M_3 generations of these induced bulks qualifies them for practicing efficient selection for the improvement of productivity under water stress and non-stress conditions and thus improving drought tolerance in wheat.

Since, the efficiency of selection would depend upon the magnitude of variability that is heritable and caused by genetic factors, the higher values, therefore, of heritability accompanied by high genetic advance for the characters studied should be quite valuable. It is obvious from the previous results of this study on M_2 and M_3 bulks, that superior bulks were characterized with high heritability accompanied by high values of genetic advance for grain yield/plant and one or more of yield components. Genetic improvements in these M_2 and M_3 bulks can therefore be achieved with care for these characters. Singh and Kumar (1974) also found high heritability and high genetic advance for grain hardness and 100 grain weight in 18 mutant lines (stabilized in M_3 generation) of bread wheat derived *via* different doses of gamma rays and reached to a similar conclusion. Results of Anand *et al* (1972) in a collection of 80 different strains of wheat from diverse sources were also similar for grains hardness.

Many investigators were able to induce genetic variation in the M_3 generation of wheat following irradiation (Singh and Kumar 1974, Kavanzhi *et al* 1986, Salam 1986, Savov 1989 and Salam 1998) and EMS treatments (Kalia *et al* 2000).

Experiment three (M_3 families selected under non-stress)

Analysis of variance of the 37 putative mutants (M_3 families selected under non-stress), 16 M_2 bulks and two parent cultivars (*i.e.* a total of 55 genotypes) evaluated in 2004/2005 season (data not presented) indicated that mean squares due to irrigation regimes and those due to genotypes were significant or highly significant for all studied traits, except for spikes/plant, suggesting that the irrigation regimes and genotypes had significant effects on most studied traits. Mean squares due to genotypes X irrigation regimes interaction were highly significant for all studied traits, suggesting that performance of the studied genotypes in this experiment varies with water supply, confirming the results of previous researchers (Fisher and Maurer

1978, Sharma and Bharagava 1996, Ragab and Sobieh, 2000 and Al-Naggar *et al 2004).*

Superiority of M_3 putative mutants selected under non-stress

Comparing mean grain yield/plant of the 37 putative mutants (M_3 families selected under non-stress conditions) with that of their corresponding parent cultivars and M_2 bulks showed different percentages of superiority or inferiority (Table 10). In general, superiority in grain yield of the M_3 families selected under non-stress was higher over the M_2 bulk than that over the parent cultivar. Moreover, number of induced mutants (M_3 families) in this experiment showed that significant superiority (increase) was higher under non-stress than under stress (27 *vs* 9 over parent cultivar and 27 *vs* 13 over M_2 bulk, respectively).

Table 10. Superiority (%) in grain yield (g)/plant (GY) of 37 putative mutants in M_3 selected under non-stress {M_3 NS families} over their parent cultivars (cv.) and M_2 bulks under water stress (S) and non-stress (NS) conditions (Inshas, 2004/2005 season).

Ser. No.	M_3 (NS) families	Superiority % in GY over				Ser. No.	M_3 (NS) families	Superiority % in GY over			
		Parent cv.		M_2 bulk				Parent cv.		M_2 bulk	
		NS	S	NS	S			NS	S	NS	S
1	Sd - RAD - 1 - 1	7.9*	0.0	10.9*	13.1*	20	Sd - EMS - 1 - 3	3.7	(-8.0)*	8.6*	(-9.6)*
2	Sd - RAD - 1- 2	37.4*	0.7	41.2*	13.9*	21	Sd - EMS - 2 - 1	(-6.3)	(-15.3)*	(-2.7)	2.7
3	Sd - RAD - 1 - 3	18.4*	7.3*	21.7*	21.4*	22	Sd - EMS - 2 - 2	(-5.8)	(-9.3)*	(-2.2)	9.9*
4	Sd - RAD - 1 - 4	11.1*	(-18.0)*	14.1*	(-7.2)*	23	Sd - EMS - 2 - 3	(-7.9)	(-15.3)*	(-4.4)	2.7
5	Sd - RAD - 1 - 5	10.5*	6.0*	13.6*	19.9*	24	Sd - EMS - 3 - 1	6.8*	(-6.7)*	1.1	(-4.4)
6	Sd - RAD - 1 - 6	7.9*	7.3*	10.9*	21.4*	25	Sd - EMS - 5 - 1	18.9*	(-9.3)*	16.7*	(-3.8)
7	Sd - RAD - 1 - 7	6.8*	13.3*	9.8*	28.2*	26	Sd - EMS - 5 - 2	(-0.5)	(-7.3)*	(-2.4)	(-1.7)
8	Sd - RAD - 1- 8	10.0*	(-4.0)	13.0*	8.6*	27	Sd - EMS - 5 - 3	2.6	(-7.3)*	0.7	(-1.7)
9	Sd - RAD - 2 - 1	24.7*	(-14.0)*	18.7*	(-16.8)*	28	Sd - EMS - 5 - 4	14.7*	(-8.7)*	12.6*	(-3.1)
10	Sd - RAD - 2 - 2	33.7*	0.0	27.2*	(-3.3)	29	Sd - EMS - 5 - 5	(-4.2)	(-4.7)	(-6.0)*	1.1
11	Sd - RAD - 2 - 3	15.8*	9.3*	10.2*	5.7*	30	Sd - EMS - 5 - 6	22.6*	(-4.7)	20.4*	1.1
12	Sd - RAD - 3 - 1	10.5*	(-16.7)*	12.4*	(-22.4)*	31	Sk - RAD - 1 - 1	3.2	1.4	(-10.2)*	24.7*
13	Sd - RAD - 3 - 2	8.4*	(-10.0)*	10.3*	(-16.2)*	32	Sk - RAD - 1 - 2	27.6*	9.0*	11.0*	34.1*
14	Sd - RAD - 3 - 3	15.3*	(-12.0)*	17.2*	(-18.1)*	33	Sk -RAD - 1 - 3	29.2*	10.4*	12.4*	35.8*
15	Sd - RAD - 3 - 4	25.8*	(-10.0)*	27.9*	(-16.2)*	34	Sk -RAD - 3 - 1	1.1	9.0*	(-7.0)	24.9*
16	Sd - RAD - 3 - 5	11.1*	(-10.0)*	13.0*	(-16.2)*	35	Sk -RAD - 3 - 2	11.9*	(-8.3)*	9.9*	5.0
17	Sd - RAD - 3 - 6	37.4*	(-14.7)*	39.7*	(-20.6)*	36	Sk - EMS - 2 - 1	5.9*	2.8	5.7*	1.2
18	Sd - EMS - 1 - 1	22.1*	(-6.7)*	27.9*	(-8.3)*	37	Sk - EMS - 2 - 2	19.5*	0.0	19.1*	(-1.5)
19	Sd - EMS - 1 - 2	(-1.1)	6.0*	3.6	4.1						

Under non-stress conditions, the significant superiority in this experiment ranged from 5.9% (Sk-EMS-2-1) to 37.4% (Sd-RAD-1-2 and Sd-RAD-3-6) over the corresponding parent cultivar and from 5.7% (Sk-EMS-2-1) to 41.2% (Sd-RAD-1-2) over the corresponding M_2 bulk (Table 10). The most superior M_3 families selected and evaluated under non-stress Sd-RAD-1-2, Sd-RAD-3-6, Sd-RAD-2-2, Sd-RAD-3-4, Sd-EMS-1-1, Sd-

RAD-5-6, Sk-RAD-1-2, Sk-RAD-1-3 and Sd-RAD-2-1 showed superiority in grain yield of 37.4, 37.4, 33.7, 25.8, 22.1, 22.6, 27.6, 29.2 and 24.7 over the parent cultivar and 41.2, 39.7, 27.2, 27.9, 27.9, 20.4, 11.0, 12.4 and 18.7% over the M_2 bulk, respectively.

Under water stress conditions of this experiment, the significant superiority in grain yield ranged from 6.0% (Sd-RAD-1-5 and Sd-EMS-1-2) to 13.3% (Sd-RAD-1-7) over the parent cultivar and from 5.7%(Sd-RAD-2-3) to 35.8% (Sk-RAD-1-3) over the M_2 bulk. The most superior M_3 families selected under non-stress and evaluated in this experiment under water stress conditions Sd-RAD-1-7, Sk-RAD-1-3, Sk-RAD-2, Sk-RAD-3-1, Sd-RAD-1-3, Sd-RAD-1-6 and Sd-RAD-2-3 exhibited superiority in grain yield of 13.3, 10.4, 9.0, 9.0, 7.3, 7.3 and 9.3% over the parent cultivar and 28.2, 35.8, 34.1, 24.9, 21.4, 21.4 and 5.7% over the M_2 bulk, respectively.

It is worthnoting that, the M_3 families selected under non-stress Sd-RAD-1-3, Sd-RAD-1-5, Sd-RAD-1-6, Sd-RAD-1-7, Sd-RAD-2-3, Sk-RAD-1-2 and Sk-RAD-1-3 showed significant superiority over both parent cultivar and M_2 bulk and under both water stress and non-stress conditions. These M_3 families along with Sk-RAD-3-1 which proved their genetic improvement in grain productivity could be recommended to wheat breeding programs for improving drought tolerance and grain yield potential. Moreover, the M_3 families selected from a non-stressed environment significantly surpassed their corresponding parent cultivar and M_2 bulk under non-stress conditions and they could also be recommended for improving wheat productivity but only under non-stress conditions.

Experiment four (M_3 families selected under stress)

Analysis of variance of the 64 putative mutants (M_3 families selected under water stress), 16 M_2 bulks and two parent cultivars (Sids 1 and Sakha 93) i.e. a total of 82 genotypes under water stress conditions only in 2004/2005 season (data not presented) indicated that mean squares due to genotypes were highly significant for all studied traits, suggesting the presence of significant differences among studied genotypes in their performance under drought conditions.

Superiority of M_3 putative mutants selected under water stress

Superiority or inferiority (%) in grain yield of the putative mutants (M_3 families) selected and evaluated under water stressed environment over the parent cultivars and M_2 bulks is presented in Table (11). Eight out of 23 families selected under stress from the M_2 bulks belonging to the parent cultivar Sids 1 showed significant increase (superiority) in grain yield/plant over their corresponding M_2 bulk, ranging from 8.9% (Sd-EMS-2-10) to 31.7% (Sd-EMS-2-5). However, none of M_3 families selected under stress from Sids 1 origin was superior in grain yield over their parent (Sids

Table 11. Superiority (%) in mean grain yield (g)/plant (GY) of 64 putative mutants in M_3 selected under water stress {M_3 S families} over their parent cultivars (cv.) and M_2 bulks under water stress (Inshas, 2004/2005)

Ser. No.	M_3 S families	superiority (%) in GY over		Ser. No.	M_3 S families	superiority (%) in GY over	
		Parent cv.	M_2 bulk			Parent cv.	M_2 bulk
1	Sd - RAD - 1 - 9	2.7	16.1*	33	Sk -RAD - 3 - 5	(-8.3)	5.6
2	Sd - RAD - 1 - 10	(-3.3)	9.4*	34	Sk -RAD - 3 - 6	(-9.7)*	4.0
3	Sd - RAD - 1 - 11	3.3	17.0*	35	Sk - EMS - 1 - 1	3.5	27.0*
4	Sd - RAD - 1 - 12	1.3	14.8*	36	Sk - EMS - 2 - 3	9.0*	15.4*
5	Sd - RAD - 1 - 13	1.3	14.8*	37	Sk - EMS - 2 - 4	13.2*	19.9*
6	Sd - RAD - 1 - 14	(-18.7)*	(-7.9)*	38	Sk - EMS - 2 - 5	7.6	14.0*
7	Sd - RAD - 2 - 4	(-11.3)*	(-14.2)*	39	Sk - EMS - 2 - 6	11.1*	17.6*
8	Sd - RAD - 2 - 5	(-19.3)*	(-21.9)*	40	Sk - EMS - 3 - 1	21.5*	24.1*
9	Sd - RAD - 2 - 6	3.3	0.0	41	Sk - EMS - 3 - 2	17.4*	19.9*
10	Sd - RAD - 2 - 7	(-4.0)	(-7.1)*	42	Sk - EMS - 3 - 3	(-1.1)	1.4
11	Sd - RAD - 3 - 7	(-2.0)	(-8.7)*	43	Sk - EMS - 3 - 4	(-6.3)	(-4.3)
12	Sd - RAD - 3 - 8	(-7.3)	(-13.7)*	44	Sk - EMS - 3 - 5	(-3.5)	(-1.4)
13	Sd - EMS - 2 - 4	(-13.3)*	5.7	45	Sk - EMS - 3 - 6	(-12.5)*	(-10.6)*
14	Sd - EMS - 2 - 5	8.0	31.7*	46	Sk - EMS - 3 - 7	9.0*	11.3*
15	Sd - EMS - 2 - 6	(-16.0)*	2.4	47	Sk - EMS - 3 - 8	(-2.8)	(-0.7)
16	Sd - EMS - 2 - 7	(-12.0)*	7.3*	48	Sk - EMS - 3 - 9	(-13.2)*	(-11.3)*
17	Sd - EMS - 2 - 8	(-14.7)*	4.1	49	Sk - EMS - 3 - 10	8.3	10.6*
18	Sd - EMS - 2 - 9	(-14.0)*	4.9	50	Sk - EMS - 4 - 1	(-11.1)*	2.4
19	Sd - EMS - 2 - 10	(-10.7)*	8.9*	51	Sk - EMS - 4 - 2	(-14.6)*	(-1.6)
20	Sd - EMS - 3 - 2	(-12.7)*	(-10.3)*	52	Sk - EMS - 4- 3	(-11.1)*	2.4
21	Sd - EMS - 5 - 7	(-8.1)	(-2.1)	53	Sk - EMS - 4 - 4	7.6	24.0*
22	Sd - EMS - 5 - 8	(-2.0)	4.3	54	Sk - EMS - 4 - 5	(-8.3)	5.6
23	Sd - EMS - 5 - 9	(-8.7)*	(-2.8)	55	Sk - EMS - 4 - 6	(-8.3)	5.6
24	Sk - RAD - 1 - 4	20.1*	47.9*	56	Sk - EMS - 4 - 7	(-2.8)	12.0*
25	Sk - RAD - 1 - 5	(-2.1)	20.5*	57	Sk - EMS - 4 - 8	43.8*	65.6*
26	Sk -RAD - 1 - 6	(-13.9)*	6.0	58	Sk - EMS - 4 – 9	2.1	17.6*
27	Sk - RAD - 1 - 7	(-10.4)*	10.3*	59	Sk - EMS - 5 - 1	(-2.1)	22.6*
28	Sk - RAD - 1 - 8	8.3	33.3*	60	Sk - EMS - 5 - 2	34.7*	68.7*
29	Sk -RAD - 1 - 9	(-1.1)	22.2*	61	Sk - EMS - 5- 3	26.4*	58.3*
30	Sk - RAD - 2 - 1	(-6.3)	8.0*	62	Sk - EMS - 5- 4	8.3	35.7*
31	Sk -RAD - 3 - 3	14.6*	32.0*	63	Sk - EMS - 5 - 5	(-2.8)	21.7*
32	Sk -RAD - 3 - 4	9.0*	25.6*	64	Sk - EMS - 5 – 6	23.6*	54.8*

1) under water stress. On the contrary, 11 out of 23 M_3 families selected under a stressed environment from M_2 bulks belonging to Sids 1 showed significant decreases in grain yield as compared to their parent cultivar under drought stress conditions.

For the 41 M_3 families selected under water stress from M_2 bulks belonging to the parent Sakha 93, there was 13 M_3's showing significant superiority in grain yield over the parent cultivar, ranging from 9% (Sk-RAD-3-4, Sk-EMS-2-3 and Sk-EMS-3-7) to 43.8% (Sk-EMS-4-8). Moreover, out of these 41 M_3 families, 26 M_3's showed superiority in grain yield over the corresponding M_2 bulk, ranging from 8.0% (Sk-RAD-2-1) to 68.7% (Sk-EMS-5-2).

The most superior M_3 families, that were selected and evaluated under water stress, in grain yield were Sk-EMS-4-8 (43.8 and 65.6%), Sk-EMS-5-2 (34.7 and 68.7%), Sk-EMS-5-3 (26.4 and 58.3%), Sk-EMS-5-6 (23.6 and 54.8%), Sk-EMS-3-1 (21.5 and 24.1%), Sk-RAD-1-4 (20.1 and 47.9%), Sk-EMS-3-2 (17.4 and 19.9%) and Sk-RAD-3-3 (14.6 and 32%) as compared to the parent cultivar (Sakha 93) and M_2 bulk, respectively. These M_3 families could be recommended to the wheat breeding programs for their use in improving drought tolerance.

In this experiment, selection in stressed environment succeeded to improve grain yield under water stress of the progeny of Sakha 93 in 31.7% of the M_3 families by up to 43.8% increase in grain yield. The selected M_3 families under water stress were superior over the corresponding M_2 bulks belonging to Sakha 93 cultivar in 63.4% of the families by up to 68.7% grain yield increase and over those belonging to Sids 1 cultivar in 34.8% of the families by up to 31.7% increase in grain yield.

On the contrary, out of 41 M_3 families selected under water stress from M_2 bulks derived via irradiation and EMS mutagens from Sakha 93 cultivar, 8 and 2 M_3 families showed significant decrease in grain yield (inferiority) as compared to the parent cultivar and the corresponding M_2 bulk, respectively, under water stress conditions.

Comparing the last two experiments, i.e. results of M_3 families selected under stressed environment (experiment four) with those of M_3 families selected under non-stressed one (experiment three), it is obvious that when selections were evaluated under water stress conditions the percentage of superior M_3 families over the M_2 bulk was higher for those selected under stressed environment (53.1%) than those selected under non-stress (35.1%) and the highest value of superiority was much higher for those selected under stress (68.7% for Sk-EMS-5-2) than for those selected under non-stress environment (35.8% for Sk-RAD-1-3). Moreover, superiority in grain yield of M_3 families over the parent cultivar, when evaluation was done under water-stress conditions, was much higher for those selected under water stress (43.8% for Sk-EMS-4-8) than those selected under non-stress conditions (13.3% for Sd-RAD-1-7). Thus, it could be concluded that practicing selection for increasing grain yield under drought conditions might be considered more efficient than practicing under optimal (non-stress) conditions. Higher actual selection gain could be realized under the drought target environment by practicing selection in drought rather than in non-drought environment.

Literature includes two contrasting strategies for identifying genotypes that will be high yielding under stress environments: (i) Genotypes may be evaluated under the conditions in which they will be ultimately produced, namely a certain type of stress environment, to minimize genotype X environment interaction. Ceccarelli (1989) has argued for this approach, but it may result in lower heritability, particularly across years. (ii) Genotypes may be evaluated under optimum conditions maximizing heritability; but perhaps encountering problems with genotype X environments. Braun *et al* (1992) has argued for this approach, citing results from 17 years of CIMMYT winter performance. Our results are in favour of the first strategy. The direct selection under water deficit stress environment would ensure the preservation of alleles for drought tolerance (Langer *et al* 1979) and direct selection under optimal environment would take advantage of the high heritability (Allen *et al* 1978, Blum 1988, Smith *et al* 1990 and Braun *et al* 1992). A third alternative, currently used at CIMMYT, which is simultaneous evaluation under optimum and stress conditions, with selection of those genotypes that perform well in both environments (Calhoun *et al* 1994). However, ultimate evaluation must be performed in the target environment prior to recommendation for a cultivar for commercial production.

Further selection and evaluation under drought stress conditions should be continued in the selected superior M_3 families derived from the present investigation in order to assure their superiority in drought tolerance and select the most stable and high yielding ones under drought stress conditions.

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استحداث طفرات قمح متحملة للجفاف بأشعه جاما و بالإيثايل ميثان سلفونيت

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أجريت هذه الدراسة بالمزرعة التجريبية لمركز البحوث النووية ، هيئة الطاقة الذرية،أنشاص خلال الموسم 2003/2002، 2004/2003، 2005/2004 في محاوله لاستحداث طفرات في صنفين تجاريين (سدس1 و سخا93) من قمح الخبز، لتكون متحملة الجفاف عن طريق مطفرأشعاعى (أشعه جاما) ومطفر كيماوى (الإيثايل ميثان سلفونيت EMS) . تم تقدير ثوابت التباين و كفاءة التوريث و التقدم الوراثى المتوقع بالانتخاب في عشائر الجيل الطفوري الثاني (M_2) و الثالث (M_3) التالية للمعاملات المطفره وكذلك تقييم تفوق الطفرات على آبائها تحت ظروف الاجهاد وعدم الإجهاد. لوحظ وجود فروق معنوية بين عشائر الـM_2 و بين عشائر الـ M_3 وكذلك بين الطفرات المستحدثة(عائلات الجيل الطفوري الثالث) المنتخبة سواء تحت ظروف الإجهاد أو عدم الإجهاد بالنسبة لكل الصفات المدروسة. نجحت مطفرات أشعه جاما و الـ EMS في استحداث تباينات جديدة معبر عنها بزيادة في المتوسط والمدى ومعامل الاختلاف المظهري (PCV) والوراثى (GCV) فى كثير من عشائر الـ M_2 و الـ M_3 تحت ظروف الإجهاد وعدم الإجهاد المائي. بمقارنه عشائر الجيل الطفوري الثاني بعشائر الجيل الطفوري الثالث من حيث التفوق في الثوابت المدروسة بما فيها كفاءة التوريث و التقدم الوراثى المتوقع بالانتخاب وجد أن هناك 3عشائر متفوقة مشتركه في الـM_2 و الـM_3 وهى Sd-RAD-3 Sd-EMS-1,RAD-1 تحت ظروف عدم الإجهاد وعشيرتين مشتركتين هما Sd-EMS-3, Sd-RAD-2 تحت ظروف الإجهاد. هذا التفوق وجد أنه من المتوقع أن يؤهل هذه العشائر لتحقيق تحسين وراثي في المحصول عن طريق الانتخاب تحت ظروف الإجهاد و عدم الإجهاد المائي . تم انتخاب عدد 101 طفرة مستحدثه من عشائر الجيل الطفري الثاني بناء على تفوقها في محصول الحبوب للنبات ، منهم 37 طفرة منتخبه تحت ظروف عدم

الإجهاد، 64 تحت ظروف الإجهاد المائي وحيث قيمت عائلاتها في الجيل الطفري الثالث. من هذه الـ 101 طفرة منتخبه ، أظهرت 22 منها تفوقا معنويا في محصول الحبوب على الأصناف الآباء تحت ظروف الجفاف. من هذه الـ22 طفرة متفوقة، 9 كانت ناتجة من الانتخاب تحت ظروف عدم الإجهاد (6 من أصل سدس او 3 من أصل سخا93) و 13 ناتجة من الانتخاب تحت ظروف الإجهاد المائي (كلها من أصل سخا93). أظهرت أحسن الطفرات المستحدثة المنتخبة تحت ظروف عدم الإجهاد والتي تم تقييمها تحت ظروف الإجهاد المائي وهى : Sd-RAD-1-7, Sk-RAD-1-3, Sd-RAD-2-3 بعض التفوق في محصول حبوب النبات عن الصنف الأب قدره 13.3، 10.4 ، 9.3 % على التوالي. في حين أن أحسن الطفرات المستحدثة المنتخبة تحت ظروف الإجهاد والتي تم تقييمها أيضا تحت ظروف الإجهاد المائي وهى:(Sk-EMS-4-8), (Sk-EMS-5-2), (Sk-EMS-3-1), (Sk-EMS-5-6), (Sk-EMS-5-3), أظهرت تفوقا عاليا في محصول حبوب النبات عن الأب المقابل قدره 34.8 ، 34.7 ، 26.4 ، 23.6 ، 21.5 ، 20.1 % على التوالي. هذه الطفرات المستحدثة المتفوقة يجب أن يجرى لها تقييم وانتخاب لمواسم أخرى للتأكد من تفوقها في تحمل الجفاف. أظهرت الدراسة أنه يمكن تحقيق تقدم حقيقي بالانتخاب أعلى تحت بيئة هدف مجهده مائيا وذلك بواسطة الانتخاب في بيئة انتخاب بها إجهاد مائى عن الانتخاب في بيئة جيدة (غير مجهده) .

المجله المصريه لتربية النبات ١١(٣): ١٣٥ ـ ١٦٥(٢٠٠٧)