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Induction of genetic variation and variability of Saudi Arabian cultivars of wheat

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Abstract *—This study was undertaken to explore the possibility of inducing micromutations in quantitative traits and meiotic anomalies of bread wheat (T. aestivum L.) after irradiated dry and soaked seeds with 0.0, 0.5, 5 and 10 Krad of gamma rays. Traits (number of spikes per plant, number of grains per spike, number of spikelets per spike, spike density, grain yield per plant, weight of grain yield per plant and weight of 1000-grain per plant) were analyzed quantitatively to assess the extent of the variation in M1 and M2 generations. At the same time, the number of economical traits (heading date, plant height, number of tillers per plant, average of spike length, total protein percent and wet and dry gluten percent) were also investigated.*

Results showed that all quantitative traits varied significantly in M1 and M2 at doses rather than seed condition. Specific action of dose 0.5 Krad showed significant increase for some traits for three lines in M1 and M2, and the magnitude and direction for number of spikes per plant, grain yield per plant and weight of grain per plant was significant for all three lines at treatments. There was a considerable increase in genotypic variance, heritability and genetic advance indicating the effectiveness of gamma doses in inducing polygenic mutation. The treatment with different doses caused a highly significant increase in abnormal cells, while pollen fertility percent decreased with increasing gamma ray doses. M1 and M2 irradiated generations showed presence of significant differences at doses rather than seed conditions. A 5 Krad dose showed a significant increase in some traits for dry and soaked seeds for three lines at <1 and M2 generations. There was also a considerable increase in genotypic variance, heritability and genetic advance for some traits. Radiation was shown to change the degree of association between traits.

***Keywords*— Genetics, Cultivars, Wheat, Gamma Rays.**

I. INTRODUCTION

Mutation breeding or variation breeding is a new paradigm of exposing plant components as additional source for creation of variability far from the conventional breeding procedures and can also be utilized to rectify one or a few undesirable traits exhibited in commercial varieties of plants (1). The mutation are rare in nature, their frequency can be enhanced through the use of certain mutagens such as ionizing radiation (2). Chromosomal aberrations such as lagging chromosomes, premature bivalence, disjunction, tripolar cells, bridges and micronuclei occur following irradiation (3). Most of the work on mutation and its application in crops deal with induction, identification, isolation and use of changes of phenotype involving major loci (1,4,5). Atak et al (2004) induced plastid mutations in soybean plant (Glycine max L. Merill) through 200 Gy gamma radiation dose and determined the mutations with RAPD. Induced mutations increased food production by at least 70% through unmasking of novel alleles that were harnessed to breed superior crop varieties (6).

On the other hand, the effectiveness of selection of breeding programs depends mainly on the amount of genetic variability among population of plants and crops. Induced genetic variation by irradiation in many characters of a given crop were reported by many investigators(7–11).

This study aimed to investigate on induction of polygenic variability and meiotic anomalies by gamma-rays, and determine the effects of gamma rays on the genetic variance of vegetative and chemical traits on three Saudi Arabian cultivars of bread wheat *Triticum aestivum L.*

II. MATERIALS AND METHODS

Three local cultivars of bread wheat of Saudi Arabia, L (5-130), L (17-41-90) and L (15-3-83) named L (1), L (2) and L (3) were used as genetic materials. Prior to irradiation, different seed lots from each line were soaked in water overnight and other were kept air dry. Dry and soaked seeds from each cultivar were irradiated with 0.0, 500, 5000 and 10,000 rad of gamma rays. Treated and untreated seeds were sown in pots filled with air-dried loam soil mixed with peat moss w/w 1:1 ratio. The experiment was planned in a completely randomized block design with four replications in a greenhouse in the College of Science in Riyadh,Saudi Arabia on November2018 to May 2019 to obtain M1 and M2 plants. Quantitative and cytological traits were studied.

The measurements for the induced variability were taken on a single plant basis for the following traits: heading date, plant height in cm, number of tillers, and average of spike length per plant cm, total protein percent, and dry and wet gluten percent. The statistical analyses were made for M1 and M2 irradiated generations according to Cohran and Cox (1957). The comparison test between treatments was made according to the least significant differences method (LSD). The broad sense heritability of characters was estimated according to the following formula: h^2 % = $\sigma^2 g$/ $\sigma^2 ph$ X 100, where $\sigma^2 g$ is the induced genetic variance, $\sigma^2 ph$ is the total phenotypic variance. The genetic advance (GA) was estimated according to the formula GA=K σph x $h^{2,}$ where σph is the phenotypic deviation, K is the constant (2.64 for 1% selection differential).

III. RESULTS AND DISCUSSION

Quantitative traits

The analyses of variance and mean squares for yields and yield components of lines, radiation doses, condition and the interaction between them in M1 and M2 irradiated generations are presented in (Table1). The mean squares of treatments in M1 and M2 generations were highly significant for all traits. On the other hand, differences between radiation doses were highly significant for number of spikes per plant, number of grains per plant and weight of grains yield per plant in M1 and M2 irradiated generations. Test of significance indicated no presence of significant differences between condition for all traits except spike density in M1 generation and number of spikes per plant and number of gains per plant were highly significant in M2 generation. The interaction between lines and doses were significant for all traits in M1 and M2 generations except number of grains per spike, number of spikelets per spike and weight of 1000-grain and spike density in M1 generation. The lines of condition and doses by condition were highly significant for number of spikes per plant and number of grains per plant in M2 generation. The mean squares of the interaction between lines, doses and seed conditions were not significant for all traits in M1 and M2 irradiated generations which indicates that there was no preference between the levels of radiation and the states of the seeds being soaked or dry. It appeared that the significance of treatments is mainly due to the significance of lines and radiation of doses rather than seed condition, since the mean squares of lines were highly significant for all studied traits except the number of spikelets per spike in M1 and M2 generations respectively. This indicates that the effect of either radiation doses or seeds condition varied from one trait to the other.The mean performances of the three cultivars for all doses of radiation for both dry and soaked seeds were calculated in M1 and M2 irradiated generations. (Table 2) The shift of treatment progenies mean from the control mean was not distinguishable in dry and soaked seed for any dose of gamma rays.

Table 1. Yield and yield components in M1 and M2 irradiated generations of three lines (ANOVA and mean squares).

Sources of variance S.V.	df	No. of spikes per plant	No. of grains per spike	No. of spikelets per spike	Spike gdensity	No. of grains per plant	Weight of grain yield per plant	Weight of 1000 grain per plant
Reps	3	0.81 0.88	27.05 296.10	9.40 22.79	0.67 2.34	2051.47 3382.59	5.32 9.89	33.49 53.97
Treats.	23	12.54 ** 13.34 **	2662.77 ** 213.69 **	371.02 ** 13.85 **	7.87 ** 6.98 **	7194.89 ** 24939.84 **	3.49 ** 9.35 **	34.4 * 92.59 **
Line	2	122.20 ** 71.01 **	29922.57 ** 1571.45 **	179.53 134.07 **	72.19 ** 64.28 **	35597.52 ** 106650.59 **	9.13 ** 16.93 **	280.12 ** 888.89 **
Dose	3	4.04 ** 15.95 **	58.24 78.55	2.94 4.67	1.44 2.03	8575.48 ** 45705.71 **	5.05 * 26.84 **	6.94 10.15
Cond.	1	0.07 12.91 **	19.00 2.87	4.08 0.83	5.62 ** 0.04	815.50 28593.61**	0.20 1.57	2.10 19.56
Line x dose	6	4.81 ** 5.72 **	95.53 67.63	5.05 3.13	1.99 * 2.73	10144.20 ** 16875.30 **	5.14 ** 8.01 **	6.13 19.47
Line x cond.	2	0.05 8.54 **	10.82 59.45	2.22 2.54	1.69 2.71	317.11 13728.14 **	0.15 5.56	17.64 21.39
Dose x cond.	3	0.36 10.77 **	96.23 154.70	3.28 1.22	1.11 0.19	142.49 11997.59 **	1.19 4.59	21.56 22.30
Line x dose x cond.	6	0.29 3.40	53.58 90.80	0.78 1.35	1.36 0.58	969.80 4983.91	1.99 4.35	11.60 12.56
Error	69	0.81 1.72	146.95 78.07	117.57 2.03	0.75 1.29	798.55 2701.20	1.24 2.39	17.57 15.24

*** , ** : significant at : 5 % and 1 % level of probability respectively (* : significant. - ** : highly significant.)**

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Table 2. Responses to different doses of radiation and condition on the means yield and yield components in M1 and M2 irradiated generations for three lines of wheat.

Treat ment / lines	Doses	M1 M2	No. of spikes / plant			No. of grains / spike			No. of spikelets / spike			Spike density			No. of grains / plant			Weight of grains / plant			Weight of 1000 grains / plant		
			L	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**
1 Dry	Control	1 2	1 1	1.48 3.85	5 9	30. 5 24	85.48 48.85	123 92	14. 5 11	20.34 18.75	24 25. 5	13. 81 16. 8	16.45 18.60	19.09 21.70	47 24	119.68 185.93	373 687	1.75 0.17	4.56 3.91	10.71 13.71	23. 0 5.2	36.38 20.29	44.4 20.08
	0.5 Krad	1 2	1 1	2.58 4.40	6 9	33 24	84.35 95.48	140 120.3	13. 3 12. 3	19.53 21.45 **	25 28	14. 47 15. 40	17.56 18.65	19.85 22.55	50 24	177.95 ** 256.70	429 529	1.65 0.47	5.66 5.18	14.93 15.07	19. 10 9.6	32.50 19.73	45.30 32.6
	5 Krad	1 2	1 1	1.53 6.35	3 10	19 33. 6	86.88 49.53	158 84.3	10 16. 2	20.35 19.68	25 24. 6	12. 50 16. 53	17.38 18.48	2088 21.35	57 50	112.95 309.45 **	349 584	1.48 0.25	4.00 6.38 *	9.88 13.29	24. 2 5	35.13 20.13	42.1 27.5
	10 Krad	1 2	1 1	1.78 4.70	6 10	21. 3 18	87.58 59.08	142 111.7	11. 7 9	20.73 21.10 *	25 27. 7	13. 92 15	16.94 19.15	23.07 23.72	64 18	140.68 254.00	479 569	1.78 0.25	4.84 4.98	9.10 12.42	18. 2 4.6	34.33 19.83	43.2 31.6
1 Soaked	Control	1 2	1 1	1.28 3.80	6 11	44. 6 30. 5	96.95 49.85	140 107.3	14 12	21.58 18.98	25 28. 8	13. 44 13. 19	17.51 19.08	20.83 22.35	45 41	114.80 192.15	388 522	0.74 0.40	4.06 4.01	11.76 12.32	1.4 8.5	34.38 21.03	40.6 28.9
	0.5 Krad	1 2	1 1	2.25 4.90	4 11	28. 5 30. 5	76.23 * 56.58	142 112	14. 3 13. 5	19.30 21.33	24 26. 5	13. 95 14. 29	17.42 19.33	19.07 25.61	57 56	157.48 * 257.45	298 607	2.21 0.71	5.11 6.10	8.24 16.69	24. 7 6.7	33.13 22.93	45.7 36.4
	5 Krad	1 2	1 1	1.83 4.90	5 17	13 16	86.48 66.43	135 107.3	12. 9 14	20.73 21.83 *	26 27	13. 33 11. 24	16.74 18.03	20 20.56	13 16	142.45 287.65	271 548	0.05 0.02	4.99 6.43 *	9.03 15.31	3.9 0.7	36.20 21.25	47.5 38.8
	10 Krad	1 2	1 1	1.95 6.25 **	5 11	35 30. 3	85.60 51.38	139 120	11 16. 3	19.80 20.35	25 26. 7	14. 67 16. 06	15.94 * 19.43	17.78 23.54	35 46	141.60 314.60 **	242 642	1.16 0.20	5.13 5.95	7.28 15.28	26. 9 4.1 0	35.70 18.18	40.7 32.4

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The number of spikes per plant showed positive direction for dry and soaked seeds for line (1) in M1 and M2 irradiated generations. On the other hand, the mean values were of positive and of negative direction in M1 and M2 generation for line (2) and (3) at seed conditions. Dose of 5 Krad caused significant increase in the number of spikes per plant at dry seed in M1 generation for line (2) and in M2 generation at dry and soaked seeds for line (3). The mean values in treated progenies for number of grains per spike were significantly lower in the control than at 0.5 Krad, while dose of 5 Krad caused significant increase for line (1) in M1 and M2 generations. The positive or negative direction of means for lines (2) and (3) were not significant. The means of spike density significantly decreased at soaked seeds in M1 generation with 10Krad for line (1) and with 5 and 10 Krad for line (3). In M2 generation, dose of 0.5 Krad seemed the same effect for line (3) at soaked seeds. The non-significance in the directions for number of grains per spike for lines (2) and (3) were similar to the findings of Jamil and Khan (2002) where they stated that 5, 10, 15 and 25 Krad doses of gamma radiation showed minor fluctuations in their effects. The significant decrease in spike density may be due to scattering of spikelets on the axle of spike. However, studies have suggested that uniformity in low dose radiation response in wheat is essentially at physiological level than at genetic level and the role of growth hormones could be crucial(12). Mutagenic treatment could not provide appreciable amount of genetic variation for number of spikelets per spike and spike density. It appears that these traits in spring wheat varieties could be improved through hybridization with divergent lines.

The mean performance for weight of grain per yield of plant was of positive or negative direction for three lines in M1 and M2 generations. Significant action of 5 Krad caused significant increase for lines (1) and (3) at dry and soaked seed win M2 generation. Also line (2) indicated significant increase with 5 Krad at dry seeds in M1 generation and with 0.5 Krad at soaked seeds in M2 generation. The results showed no significant increase or decrease by radiation dose for weight of 1000-grains for three lines at dry and soaked seeds except for the dose 5 Krad which caused significant increase for line (2) at soaked seeds in M2 generation. The same findings were also found by Singh et al (2010)and Jamil and Khan (2002)(12,13).

The number of spikes per plant was significantly and positively correlated to grain yield per plant and weight of grain yield per plant for three lines in M1 and M2 irradiated generations at dry and soaked seeds. This is consistent with the findings of Hanafy and Mohamed (2014)where they found that irradiation increased the grain yield through subsequent generations of wheat. These results were expected since each of these traits is dependent on each other(14).

Table 3 shows the genetic, phenotypic variance, heritability, genotypic and phenotypic variances. The highest genotypic coefficient of variation was 54.8% and the genetic advance was 8.71. Heritability was 96% for weight of grain yield per plant with 0.5 Krad at soaked seeds. At the same dose, genotypic variance increased by 89.46 and genetic advance was 23.37 for the number of grains per spike. This suggests a high degree of genetic variability at this dose. The weight of grains per plant with 5 Krad at soaked seeds showed the lowest genotypic variance and genetic advance. Heritability estimates were towards the higher side. It may be due to estimation from three lines and single generation. Fairly high estimates of heritability and genetic advance for plant height, number of tillers, and grains per spike suggested that selection for these traits could be practiced more effectively (15).

Table 3. Genotypic and phenotypic variance, heritability, phenotypic and genotypic coefficient of variation and genetic advance at dry and soaked seeds in M2.

Character	Treatment	Seed type	Induced genetic variance (σ^2 g)	Total phenotypic Variance (σ^2ph)	Heritability (h^2)	Genetic coefficient of variation (G.C.V)	Phenotypic coefficient of variation (P.C.V.)	Genetic advance (G.A.)
Number of spikes per plant	Control	Dry	5.33	5.94	0.89	34.72	36.65	5.75
		Soaked	1.11	1.33	0.83	20.51	22.52	2.53
	0.5 Krad	Dry	5.15	5.37	0.96	36.29	37.08	5.85
		Soaked	2.12	2.89	0.73	21.98	25.68	3.29
	5 Krad	Dry	5.78	6.8	0.85	27.64	29.97	5.85
		Soaked	2.26	3.37	0.67	23.10	28.22	3.24
	10 Krad	Dry	0.75	1.01	0.74	15.25	17.76	15.25
		Soaked	0.98	1.25	0.79	16.3	18.39	2.33

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Number of grains per spike	Control	Dry	4.16	18.59	0.22	4.52	9.54	2.55
		Soaked	8.11	12.79	0.63	6.22	7.81	5.99
	0.5 Krad	Dry	12.96	57.24	0.22	7.04	14.80	4.54
		Soaked	89.46	103.0	0.87	20.34	21.83	23.37
	5 Krad	Dry	13.08	14.94	0.87	7.92	8.48	8.95
		Soaked	89.80	141.1	0.64	17.93	22.47	19.97
	10 Krad	Dry	76.03	101.2	0.75	18.38	21.20	19.95
		Soaked	76.69	85.9	0.89	19.19	20.30	21.85
Number of spikelets per spike	Control	Dry	0.362	0.879	0.412	3.38	5.26	1.02
		Soaked	2.15	2.21	0.973	8.51	8.59	8.83
	0.5 Krad	Dry	4.95	5.83	0.849	11.88	12.80	5.40
		Soaked	6.18	6.57	0.941	13.55	13.90	6.36
	5 Krad	Dry	1.60	2.12	0.755	6.96	8.03	2.89
		Soaked	8.01	8.53	0.939	15.23	15.72	7.22
	10 Krad	Dry	4.83	5.13	0.94	12.33	12.75	5.64
		Soaked	7.55	8.50	0.989	14.57	13.40	8.76
Spike density	Control	Dry	0.035	0.698	0.05	1.051	4.72	0.110
		Soaked	1.004	1.76	0.57	5.71	7.55	1.99
	0.5 Krad	Dry	2.39	2.50	0.956	8.91	9.16	3.99
		Soaked	4.89	5.14	0.95	12.55	12.89	5.7
	5 Krad	Dry	1.55	1.72	0.90	7.29	7.67	3.11
		Soaked	1.35	1.68	0.80	6.84	7.63	2.75
	10 Krad	Dry	3.48	3.58	0.972	10.82	10.94	4.85
		Soaked	4.04	4.23	0.96	11.43	11.69	5.16
Weight of grains per plant	Control	Dry	5.21	6.41	0.812	39.28	43.58	5.43
		Soaked	1.04	1.35	0.77	23.12	26.30	3.36
	0.5 Krad	Dry	0.18	0.398	0.452	7.48	11.11	0.752
		Soaked	11.40	11.92	0.96	54.8	56.20	8.71
	5 Krad	Dry	1.53	1.98	0.77	16.18	18.49	2.87
		Soaked	0.196	0.358	0.55	6.2	8.39	0.86
	10 Krad	Dry	0.451	0.593	0.761	13.62	15.61	1.54
		Soaked	0.356	1.143	0.311	11.21	20.10	0.872
Weight of 1000 grains per plant	Control	Dry	28.02	35.73	0.78	26.70	30.13	12.35
		Soaked	22.69	24.76	0.912	25.04	26.20	11.93
	0.5 Krad	Dry	9.61	15.54	0.62	16.34	20.78	6.43
		Soaked	48.02	51.67	0.93	32.75	36.90	15.16
	5 Krad	Dry	5.08	5.93	0.86	11.23	12.14	5.52
		Soaked	27.8	29.85	0.93	23.75	24.61	13.42
	10 Krad	Dry	34.96	36.48	0.96	28.8	29.46	15.28
		Soaked	42.06	53.63	0.78	32.75	36.90	15.16

Cytological investigations

here were highly significant differences between treated and untreated plants at different meiotic stages, pollen viability and means of total percent of abnormal cells. This is due to the differences between lines and radiation doses. The significance in the interaction between lines and radiation doses may mean that there was a preference between the levels of radiation doses. The percentage of abnormal cells was found to increase with increase of radiation doses both at soaked seeds and dry seeds. There was also a significant decrease in pollen viability for dry seeds at line 3 at M1 and A1 stages. Abnormal cells also increased at 0.5 Krad for 3 lines of soaked seeds except A2. Pollen viability also significantly decreased for line 1 of soaked seeds. This suggests that pollen fertility decreased with increase gamma ray dose. (Table 4) Studies have shown that higher gamma ray doses decreased seed emerging rate, seedling height, spike length, spikelet number and seed set, and pollen fertility is higher in untreated plants(16,17). The production of gametes with duplication and deficiencies for a certain chromosome section and to pollen sterility occurred. The role of genetic factors affecting meiosis cannot be ruled out in this polyploidy. The orientation and the unbalanced type of changes in the chromosomes is the factor influencing sterility in plants (18). Doses of 5 and 15 Gy of radiation induce chromosomal aberrations in plants (3).

Table 4. Percentage of abnormal cells in different meiotic stages and pollen viability for three lines of wheat treated by gamma rays in M1 generation (mean squares).

Sources of variance	**df**	**Metaphase I**	**Anaphase I**	**Metaphase II**	**Anaphase II**	**Pollen viability**	$\bar{X}$ **of abnormal cells %**
Reps.	3	93.16	196.33	46.34	20.64	115.58	19.58
Treatments	23	491.18 **	1117.36 **	198.89 **	398.30 **	701.50 **	335.00 **
Lines	2	1042.78 **	5492.35 **	150.48 **	956.60 **	668.63 **	1277.60 **
Doses	3	1909.21 **	3279.10 *	738.93 **	760.25 **	1185.71 **	1381.30 **
Conditions	1	480.40 **	1.004	664.66 **	43.87	146.20	19.17
Lines x doses	6	254.42 **	471.65 **	111.92 **	224.29 *	910.13 **	57.12 *
Lines x condition	2	123.10	348.80 *	88.76 *	316.30 *	1455.40 **	174.58 **
Doses x condition	3	200.79 **	166.25	85.57 *	185.40	20.92	28.03
Lines x doses x condition	6	104.71 *	141.68	47.75	398.30 **	443.20 **	35.09
Error	69	45.86	82.97	28.26	88.81	120.67	19.19

*** , ** : significant at : 5 % and 1 % level of probability respectively**

The more common chromosomal aberrations in the treated plants in this study include lagging chromosomes of chromosomes bridge. This was similarly reported by Han et al in 2002, who reported that the frequency of lagging chromosomes and fragments of chromosomes increased significantly by enhanced radiation (19). Ring chromosomes also appeared to increase at M1 between treatments for three lines. This ring chromosomes in wheat maybe attributed to the large size of chromosomes, presumably large segment of chromosomes were involved in interchanges or the event of translocation. Similar observation was also observed by enhanced UV-B radiation on wheat roots with polykaryocytes and ring chromosomes (20).

Induced variability

Table 5 shows the variability for vegetative and chemical traits of lines, radiation doses, conditions and interactions between M1 and M2. The mean squares of treatment were significant in M1 and M2. This is probably due to the significance of lines for all traits in M2. Furthermore the lines x doses were significant for plant height, number of tillers per plant and spike length in M1. On the other hand, lines x condition was significant for protein and dry gluten percent in M1. Also, dry and wet gluten percent showed highly significant for doses x condition at M1. These results indicate that there was no preference between level of radiation and the states of the seeds, and that the effect of either radiation doses or seed condition varied from one trait to the other.

Table 5. Vegetative and chemical traits in M1 and M2 irradiated generations for three lines (ANOVA and mean squares).

Sources of variance	df	generation	Heading date	Plant height	No. of tillers per plant	Spike length	Protein %	Wet gluten %	Dry gluten %
Rep.	3	M1	41.15	67.94	6.51	3.06	0.49	1.83	1.88
		M2	22.47	32.90	14.87	2.53	12.09	3.92	1.83
Treatment	23	M1	35.01**	1068.51**	20.25 **	12.20 **	7.67 **	42.98 *	6.27 **
		M2	162.37 **	276.81**	30.64 **	2.86 **	22.63 **	4.83 **	4.57 **
Lines	2	M1	194.49 **	11581.31**	197.71**	125.43 **	80.93 **	448.69 **	56.10 **
		M2	1545.82 **	2852.50 **	215.17 **	19.95 **	239.51 **	28.22 **	43.26 **
Doses	3	M1	50.17 *	61.96	4.94	0.99	0.63	0.898	0.297
		M2	65.41*	76.81*	14.99	3.12 *	1.31	3.740	0.230
Condition	1	M1	2.54	6.61	1.63	0.01	0.21	0.0004	0.042
		M2	0.30	4.68	19.62	0.36	1.37	1.03	0.055
Line x doses	6	M1	27.02	139.67 **	6.35 **	3.41*	0.63	3.78	1.102
		M2	34.25	47.90	6.67	1.47	4.71*	2.69	0.85
Line x condition	2	M1	17.85	41.33	1.64	0.24	1.16 *	2.71	2.88 *
		M2	0.50	16.70	16.26	0.14	1.64	2.74	0.94
Dose x condition	3	M1	3.07	14.35	1.13	0.11	0.53	11.39 **	4.71**
		M2	5.77	24.96	22.08 **	0.41	0.47	0.475	1.39
Line x dose x condition	6	M1	9.38	42.81	1.53	0.93	0.81*	4.38*	0.803
		M2	37.08	5.09	11.83	0.96	0.55	3.22	1.13
Error	69	M1	15.84	28.51	1.99	1.14	0.29	1.73	0.664
		M2	18.46	25.55	7.91	0.96	1.81	1.98	0.897

*** , ** : significant at : 5 % and 1 % level of probability respectively**

The means of all traits obtained from the effect of radiation doses, condition and the interaction were significant in M1 and M2. The direct effect of radiation doses (0.5, 5, and 10 Krad) were observed to decrease of almost all traits in M1 and M2, while spike length showed a significant increase at 5 Krad in M2. There was also a significant decrease of total protein percent at 5 Krad in M1. (Table 6) On the contrary, gamma irradiation was reported to improve plant nutrition but not improve the nutritional quality of grains (Singh and Datta, 2010), and was also reported no significantly affect the protein content of the irradiated samples (Agundez-Arvisu et al, 2006). The means of all traits showed a continuous decrease in their magnitude as the doses increased in M1 and |M2 except the number of tillers per plant, dry gluten at 0.5 Krad in M1 and plant height in M2 for line 1 and spike length for line 3 in M2. The doe of 5 Krad caused significant increase of plant height and spike length in M2 for line 1, while in M2, plant height significantly increased. The dose of 0.5 and 5 Krad was found to be a good dose for most traits in lines 1 and 2 in M1 and M2. (Table 7) This finding is similar to the findings of Ahuja et al (2014) which showed similar results, however a higher dose created some abnormalities in plant types(21).

Table 6. Vegetative and chemical traits of wheat lines in M1 and M2 irradiated generations and at different radiation doses for three lines.

Characters / Treatment		generations	Heading date	Plant height	N0. of tillers per plant	Spike length	Protein %	Wet gluten %	Dry gluten %
Line 1		M1	92.06	99.34	2.37	12.12	21.73	30.16	10.33
		M2	85.80	79.73	6.03	10.83	25.28	31.84	11.98
Line 2		M1	87.23	61.92	5.52	8.57	18.56	23.10	7.78
		M2	71.85	61.58	10.25	9.49	21.03	29.97	9.65
Line 3		M1	90.49	74.66	7.28	8.83	20.38	28.84	9.66
		M2	79.15	74.80	10.73	10.88	26.13	30.99	10.92
LSD	0.05	M1	1.98	2.66	0.70	0.53	0.27	0.654	0.405
	0.01	M2	2.64	3.54	0.93	0.71	0.36	0.764	0.473
	0.05	M1	2.14	2.59	1.40	0.49	0.67	0.700	0.471
	0.01	M2	2.84	3.34	1.86	0.65	0.89	0.820	0.552
Control		M1	90.74	78.61	5.12	10.13	20.43	27.37	9.29
		M2	81.09	70.86	8.69	10.03	23.93	31.26	10.96
0.5 Krad		M1	88.72	79.23	5.67	9.82	20.21	27.14	9.40
		M2	78.15*	72.77	9.37	10.65	24.34	30.98	10.74
5 Krad		M1	88.70	80.26	4.76	9.73	20.03	27.62	9.17
		M2	77.25	73.19	9.86	10.77	24.36	31.27	10.89
10 Krad		M1	91.55	76.46	4.67	9.68	20.24	27.36	9.18
		M2	79.20	71.54	8.10	10.16	23.96	30.48	10.82
LSD	0.05	M1	2.29	3.07	0.81	0.62	0.31	0.755	0.470
	0.01	M2	3.04	4.08	1.08	0.82	0.41	0.883	0.547
	0.05	M1	2.47	2.91	1.62	0.56	0.77	0.517	0.544
	0.01	M2	3.28	3.87	2.15	0.75	1.03	0.603	0.636

*** , ** : significant at : 5 % and 1 % level of probability respectively (* : significant. - ** : highly significant.)**

Table 7. Means of wheat lines by radiation doses for vegetative and chemical traits in M1 and M2 irradiated generations

Characters	Treatment Krad	generations	Heading date	Plant height	No. of tillers per plant	Spike length	Protein %	Wet gluten %	Dry gluten %
Line 1	Control	M1	93.98	97.85	1.64	12.59	22.00	29.36	10.20
		M2	86.05	76.29	5.18	10.02	25.27	32.01	12.43
	0.5	M1	92.33	96.03	3.14	11.25	21.69	30.50	11.02
		M2	86.15	81.76	5.75	11.32	25.25	31.48	11.71
	5	M1	91.34	100.55	2.19	12.25	21.64	30.58	9.78
		M2	85.50	82.13	6.60	11.37	25.61	31.73	11.61
	10	M1	90.59	102.94	2.51	12.40	21.60	30.19	10.32
		M2	85.28	79.24	6.53	10.67	24.99	32.15	12.17
Line 2	Control	M1	87.41	60.20	5.25	8.34	18.54	23.38	7.95
		M2	73.80	62.29	10.58	9.70	19.71	30.22	9.76
	0.5	M1	85.53	63.28	5.73	8.76	18.43	22.17	7.57
		M2	70.35	60.58	10.93	9.18	21.23	29.61	9.46

	5	M1	85.90	65.95	6.18	8.89	18.25	23.93	7.97
		M2	71.70	60.06	10.80	9.89	21.93	30.37	9.91
	10	M1	90.06	58.26	4.91	8.31	129.04	22.98	7.66
		M2	71.55	63.20	8.67	9.19	21.24	29.66	9.48
Line 3	Control	M1	90.83	77.79	8.48	9.48	20.74	29.38	9.72
		M2	83.43	74.04	10.30	10.36	26.80	31.56	10.70
	0.5	M1	88.30	78.40	8.14	9.44	20.51	28.76	9.65
		M2	77.95	75.99	11.45	11.44	26.54	31.11	11.04
	5	M1	88.85	74.29	5.91	8.08	20.20	28.32	9.72
		M2	74.55	77.37	12.20	11.05	25.54	31.71	11.15
	10	M1	94.00	68.19	6.58	8.33	20.09	28.90	9.56
		M2	80.78	71.98	9.00	10.64	25.66	29.63	10.81
LSD	0.05	M1	3.97	5.32	1.41	1.07	0.54	1.31	0.812
	0.01	M2	5.27	7.57	1.87	1.41	0.71	1.53	0.949
	0.05	M1	4.283	5.04	2.804	0.975	1.341	1.40	0.943
	0.01	M2	5.687	6.69	3.723	1.295	1.782	1.64	1.104

The vegetative and chemical traits inM2 showed a recovery from radiation effect, although all traits were not significantly deviated from the control, except that the gluten percent significantly decreased at 0.5 Krad at dry and soaked seeds for line 1. Also, the heading date had a significant decrease with 0.5 and 5 Krad and wet gluten percent at 10 Krad for dry seeds line 3. There was also a large increase in spike length at 0.5 and 5 Krad for dry and soaked seeds for line 1. At the same conditions, protein percent significantly increased with 5 Krad for line 2. Dose of 10 Krad affected the dry seeds on the same trait. (Table 8).

Table 8. Means of wheat lines by conditions (line x condition) of dry and soaked seeds for vegetative and chemical traits in M1 and M2 irradiated generations

Characters	condition	generations	Heading date	Plant height	No. of tillers per plant	Spike length	Protein %	Wet gluten %	Dry gluten %
Line 1	Dry	M1	91.67	98.44	2.41	12.02	21.93	30.44	10.67
		M2	85.70	76.79	6.10	10.80	25.19	31.82	11.79
	Soaked	M1	92.44	100.24	2.33	12.23	21.53	29.88	9.99
		M2	85.80	82.66	5.96	10.85	25.37	31.86	12.16
Line 2	Dry	M1	87.09	62.24	5.48	8.64	18.67	23.15	7.75
		M2	71.80	61.92	10.28	9.62	21.12	30.41	9.81
	Soaked	M1	87.36	61.60	5.56	8.51	18.46	23.08	7.81
		M2	71.90	61.23	10.21	9.37	20.94	29.53	9.49
Line 3	Dry	M1	91.51	76.03	6.89	8.83	20.22	28.53	9.41
		M2	79.40	75.70	12.00	10.94	26.48	30.89	10.86
	Soaked	M1	89.48	73.29	7.66	8.83	20.55	29.15	9.91
		M2	78.90	73.90	9.45	10.81	25.78	31.10	10.97
LSD	0.05	M1	2.81	3.76	1.00	0.75	0.38	0.925	0.573
	0.01	M2	3.73	5.00	1.32	1.00	0.50	0.083	0.673
	0.05	M1	3.029	3.56	1.98	0.691	0.948	0.990	0.668
	0.01	M2	4.022	4.74	2.63	0.916	1.260	1.160	0.781

The ranges were always wider for all traits at all doses than the control. Our results indicate the possibility of using these plants at upper limits for future improvement. Therefore, it could be concluded that the medium dose of 5 Krad increase the performance of most vegetative traits. Similar results were observed with other studies on different versions of plants that agreed on the fact that a higher dose of gamma radiations may decrease the qualitative and quantitative characteristics of plant traits(12,22,23).

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