MODIFICATIONS OF GENE EXPRESSION OF SOME QUALITY TRAITS IN BREAD WHEAT USING GAMMA IRRADIATION

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Wheat is the most widely grown crop in over 120 countries worldwide (FAO, 2002). *Triticum aestivum* (including the common bread wheat) is the most commercially relevant species of genus *Triticum* widely grown all over the world. In addition to its high-energy content, wheat is also a good source of protein and contains considerably more protein on average than other cereals. The proteins of wheat are complex, they can be divided into two broad categories based on their biological function to the biologically active enzymes; albumins and globulins and the biologically inactive storage protein; gliadins and glutenins (Lookhart and Bean, 2000). The gliadins and glutenins are referred to collectively as the gluten proteins, and are mainly located within the mealy endosperm of the grain.

The gluten proteins play a key role in the formation of dough for bread making, and it was considered as important target to several investigations for the close correlation between the strength and quantity of gluten protein with the wheat bread making quality (Moczulski and Salmanowicz, 2003). Gamma ray has been used in a number of previous investigations as a good inducer for many useful mutations. Good results were obtained on the level of yield parameters such as number of tillers/ plant, number of spikes/plant, grain yield per plant and weight of one hundred grains (Abdel-Hady and Ali, 2006; Irfaq and Nawab, 2001). On the other hand, many investigations studied the effect of radiation on wheat quality improvement to extend shelf life of whole-wheat flour (Marathe *et al.*, 2002) and to increase the activity of wheat grain endogenous amylases (Gralik and Warchalewski, 2006). In addition, there are a number of studies to elucidate the effect of gamma irradiation treatments on gluten protein (Koksel *et al*., 1998) and gluten fractions (Nayeem *et al*., 1999).

The objectives of the present study were to:

1- Investigate the effects of gamma radiations on some yield-related-traits associated with to the quality of wheat grains in four Egyptian wheat cultivars.

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2- Study the effect of different doses of gamma irradiation on some quality traits of wheat grains in these cultivars.

3- Study possible modification in gene expression of irradiated plants through SDS-protein fractions.

MATERIALS AND METHODS

1. Plant materials

Dry grains of four bread wheat cultivars; Sakha-92, Sakha-61, Sids-1 and Giza-168 were irradiated with three doses of gamma rays (100, 150 and 200 Gy in addition to 0 Gy as control). Irradiation treatments were achieved by a ^{60}Co gamma unit which delivered 5.6 KGy per hour.

2. Methods

2.1. Field experiment

Irradiated and non-irradiated grains of the four cultivars were sown to obtain M_1 plants, and then M_2 and M_3 generations. Data on plant height (cm), number of tillers/plant, number of spikes/plant, length of main spike (cm), grain yield per plant (g), and weight of 100 grain (g) traits were taken on M_2 generation. The outstanding to the plant at number of tillers and number of spikes per plant followed by high in grain yield per plant were selected from each treatment to examine the sedimentation value as an indicator of gluten strength, the ratio of both gluten fractions; gliadin and glutenin and for SDS- electrophoresis (SDS-PAGE). The data of M_1, M_2 and M_3 generation were statistically analyzed for split plot design according to Gomez and Gomez (1984). The Duncan's test was used to estimate the differences between means (Waller and Duncan, 1969).

2.2. Quality experiments

Regarding gluten quality and determination of the SDS-sedimentation test (MST) values, the method of Dick and Quick (1983) was applied by using 1.0 g of ground wheat for the sample. The concentration and percentage of gliadin and glutenin for irradiated and non-irradiated samples were determined according to the method of Suchy *et al.* (2007).

2.3. SDS-electrophoresis

Gliadin and glutenin protein fractions were extracted according to the method of Ariyama and Khan (1990). Protein fractions were performed on vertical slabs gel electrophoresis apparatus according to the method of Laemmli (1970) modified by Studier (1973). Gels were photographed using a digital camera and scanned with Bio-Rad video densitometer model 620, at a wave length of 577. Software data analysis for Bio-Rad Model 620 USA densitometer and computer were used as according to the manufacturer's instructions.

RESULTS AND DISCUSSION

1. Effect of gamma irradiation on yield-related traits in M_2 generation at harvest

Twenty plants from each cultivar under each treatment were selected randomly to measure the means of the six aforementioned yield-related traits (Data not shown). It was noted that the effect of γ-irradiation on the four wheat cultivars generally showed significant differences for the yield-related traits which agreed with Irfaq and Nawab (2001) and Khan *et al*. (2003). The cultivars showed different trends under the three doses for the number of tillers/plant and number of spikes/plant. Irradiated plants of Sakha-92 cultivar showed slight decrease for number of tillers/plant and number of spikes/plant at both 100 and 200 Gy doses, while it exhibited significant decrease at 150 Gy dose.

According to the importance of the yield-related traits as economic traits and in addition to their associations with the quality traits of both proteins and the grains of wheat (Huang *et al*., 2006), the outstanding plants in the number of tillers followed by increasing grain yield per plant were selected from each cultivar in each dose to assess the effect of the used gamma doses on the quality traits; sedimentation value and concentration of gluten fractions (gliadin and glutenin). In addition, to study the differences at the level of gene expression using SDS- gluten electrophoresis and compare the results with their respective controls. The values of the six studied yield–related traits for the superior selected plants (Data not shown) indicated that the irradiated plants of cultivar Sids-1 at 100, 150 and 200 Gy doses had the highest values for number of spikes/plant and number of tillers/plant and grain yield at 200, 100 and 150 Gy doses, respectively, compared with the other selected plants. Although Sids-1 under 200 Gy dose scored the same values of both number of tillers and spikes per plant compared with control, one outstanding individual plant was taken from this treatment which scored 71 tillers and spikes per plant as a good model for wheat quality studies.

2. *Effect of gamma radiation on the quality of gluten and ratio of its fractions*

The concentration and percentage of each gluten fractions; gliadin and glutenin and the SDS-sedimentation test (MST) values determined for the selected plants (parents) and M_2 plants for each treatment indicated differences in the determined values between the cultivars and among the irradiated sample and it's control as shown in Table (1). The results illustrated that; the variety Sakha-92 showed the highest sedimentation value compared with other cultivars, and this was associated with the high gluten concentration. The irradiated lower samples for both Sakha 92 and Giza-168 cultivars at the three used doses recorded lower sedimentation value comparing with control. On the other hand, the sedimentation value was increased for the irradiated sample compared with control for both Sids-1 and Sakha-61 cultivars. It is noteworthy that the increasing in sedimentation value was associated with the increase of the glutenin concentration comparing with control in addition to the decrease in the gliadin concentration comparing with control. For Giza-168 cultivar, although the increase in the total protein in all irradiated sample comparing with control was observed, it showed a decrease in the sedimentation value in all three used doses. This could be due to the gluten strength affected by the ratio of both gliadin and glutenin that increasing of glutenin ratio led to increasing in the sedimentation value which means a more gluten strength. The increasing in glutein strength is not related only to the increasing in the total protein, but the difference in the ratio between the two fractions of gluten determined the gluten strength and the quality of end product until with the same concentration of the total protein. Our results agreed with those of Wieser *et al.* (2003) who found that both the amount of glutenin subunits (positively) and the ratio of gliadins to glutenin subunits (negatively) had a strong influence on the maximum resistance and extension area of gluten and on the bread volume.

3. Gliadin and glutenin protein electrophoresis

The results of SDS-PAGE analysis of wheat protein fractions of sample understudy are illustrated in Figs (1 & 2) and Tables (2 & 3).

The results of electrophoretic analysis of gliadins showed a total of 21 bands ranging from 2.45 to 71.28 KDa which not necessarily present in all tested samples. The number of total bands varied between the four studied cultivars whereas the lowest number of 14 bands appeared in cultivar Sakha-92, and the highest number of 20 bands appeared in cultivar Sakha-61. The region of omega-gliadin had a wider range for the number of bands (eight bands) than all other regions of gliadins, these results agreed with those reported by Rashed *et al.* (2007). Among such gliadin protein bands, eight bands were commonly detected in all irradiated and non-irradiated wheat samples with different molecular weights (monomorphic bands). Three common bands at motilities of 0.21, 0.23 and 0.39 with molecular weights 71.28, 67.29 and 30.70 KDa, respectively, were found in omega zone, five at mobility 0.73, 0.78, 0.85, and 0.95 with molecular weights 6.56, 5.19, 4.32, 3.66 and 2.45 KDa, respectively, were found in alpha zone. In addition, two bands were present in the control samples for the four wheat cultivars while they disappeared in some irradiated samples such as Sids-1 and Giza-168 cultivars, one of these bands in omega zone at mobility 0.37 with molecular weight of 34.50 KDa and the other in gamma zone at mobility of 0.41 with molecular weight of 28.17 KDa. The other bands were distributed between irradiated and non-irradiated samples (polymorphic bands). The band at mobility of 0.46 with molecular weight of 21.19 KDa identified Sakha-92, Sakha-61 and Sids-1 cultivars while it was absent from cultivar Giza-168 although it was detected in its three irradiated samples. The band at mobility of 0.25 with molecular weight of 58.15 KDa identified one sample only which was irradiated by 100Gy dose in the cultivar Sakha-61 while this band disappeared from all another samples. The band at mobility of 0.26 with molecular weight of 54.17 KDa identified the sample of cultivar Sids-1 and the three irradiated samples for both Sakha-61 and Giza-168 cultivars and the irradiated sample at 100 Gy dose for cultivar Sakha-92. The band at mobility of 0.32 with molecular weight of 40.01 KDa identified only cultivar Sakha-61 control sample while it disappeared in the other cultivars, it was noted that it also appeared with the irradiated sample at 100 Gy dose for the four studied cultivars.

The band at mobility of 0.54 with molecular weight of 15.43 KDa was present in cultivars; Sakha-61 and Sids-1 control samples although it disappeared from some of their irradiated samples, while it was absent in both Sakha-92 and Giza-168 cultivar's samples and all their irradiated samples at all used doses. The bands at mobility of 0.43 and 0.59 with molecular weights of 22.48 and 11.31 KDa, respectively, were present among both Sakha-92 and Sakha-61 cultivars and all their irradiated samples at the three used doses while neither was present in the control samples for Sids-1 and Giza-168 cultivars nor their irradiated samples. The band at mobility of 0.66 with molecular weight of 9.43 KDa was present in the three cultivars; Sakha-61, Sids-1 and Giza-168, although it was absent in Sakha-92 cultivar, it was detected in the irradiated sample at 100 Gy dose for Sakha-92 cultivar. The band at mobility of 0.69 with molecular weight of 7.79 KDa was exhibited only in the control sample for Sakha-61 cultivar and both its irradiated samples; 100 and 150 Gy doses.

For the glutenin analysis, 25 polypeptide bands were observedwith molecular weights ranging from 11.59 to 113.09 KDa which were not necessarily present in all varieties. Among such glutenin protein's bands, eleven bands were commonly detected in all studied samples with different molecular weights (monomorphic bands) while, another fourteen bands were distributed between the irradiated and non irradiated studied samples (polymorphic bands). The bands with molecular weight of 113.09 and 97.46 KDa were identified only in the irradiated sample at 100 Gy dose for cultivar Sakha-61. The band with molecular weight of 59.93 KDa was present in four cultivars in addition to all irradiated samples for cultivars; Sids-1 and Giza-168, while it was absent in the irradiated samples for cultivar Sakha-61 in all doses and the irradiated sample for cultivar Sakha-92 at 100 Gy dose. The bands with molecular weights of 87.98, 71.19 and 20.37 KDa were present only in the irradiated samples for Sids-1 cultivar at the three used doses. The band with molecular weight 65.40 KDa was present in irradiated samples of cultivar Sids-1 and the irradiated sample at 100 Gy dose for cultivar Giza-168. The band with molecular weight of 51.00 KDa was exhibited only in the irradiated samples for cultivar Giza-168 in the three used doses. The band with molecular weight of 43.87 KDa was present in the control sample of cultivar Sakha-92 and the irradiated samples for cultivar Sakha-61 while it was absent from the other three cultivars. The band with molecular weight of 27.77 KDa was present in Sakha-92 and Sakha-61 cultivars and their irradiated samples and all irradiated samples of cultivar Sids-1. The band with molecular weight 25.40 KDa was absent in the four studied cultivars while it was detected at a number of the irradiated samples of these cultivars.

4. The relationships between gliadin & glutenin bands and wheat quality

The relationship between the gliadin & glutenin bands for irradiated and non-irradiated samples with sedimentation values was investigated. At the level of SDS-electrophoresis pattern of gliadin, it was not possible to relate between the observed bands and the increase or decrease in sedimentation values. On the other hand, SDS- electrophoresis pattern of glutenin exhibited a number of bands that may be associated with low and high quality. Three bands number; 3, 7 and 20 with molecular weights; 87.98, 71.19 and 20.37 KDa, respectively, could be detected only in the three irradiated samples of Sids-1 cultivar, these samples scored increasing in the sedimentation values comparing with the control. This indicated that these three bands could be associated with the increase of gluten strength. It was worthy to mention that band 7 with molecular weight of 71.19 KDa was identified by Payne *et al*. (1979) who named it as subunit 2 but he could not correlate between this subunit and bread-making quality. Band number 10 with molecular weight of 51.00 KDa characterized the three irradiated samples of Giza-168 cultivar (with low sedimentation value) this may be considered as marker for the gluten low quality. This band was also identified by Payne *et al*. (1979), who named it subunit 3 and they found that most of investigated plants which contained this band had low sedimentation values; they suggested that there is inverse correlation between subunit 3 and quality. At M_3 generation, two plants from cultivar Sakha-92 at 100 Gy dose and one from cultivar Sk-61 at 200 Gy dose could be selected for superiority in grain yield per plant and sedimentation values, respectively, comparing with the control. Two superior plants at 100 and 150 Gy doses each, and three plants from 200 Gy dose were selected from M_3 generation plants of cultivar Sids-1 due to their superiority in the six yield-related traits and sedimentation values comparing with the control. These selected plants in M_3 generation of the three previous cultivars could be planted for next generations to assess the stability of the mutant genotypes.

SUMMARY

Four Egyptian bread wheat cultivars (*Triticum aestivum* L.); Sakha-92, Sakha-61, Sids-1 and Giza-168 were exposed to different gamma radiation doses; 0, 100, 150 and 200 Gy, from a ^{60}Co gamma ray source. The effect of gamma rays on a number of yield-related traits and sedimentation values were studied on M_1, M_2 and M_3 generations. The effect of gamma rays at 150 Gy on Sids-1 cultivar gave significant increase and surpassed the control in all yield-related traits in M_2. The increase or decrease in sedimentation values were more related to the variation

in glutenin concentration. The difference in the gliadin to glutenin ratio was more than the variation in gliadin concentration. Giza-168 cultivar -under the three doses- recorded low mean values for all traits comparing with the control. Three SDS-bands with molecular weights of 87.98, 71.19 and 20.37 KDa could be used as indication related to the increase of gluten strength in the three irradiated samples of Sids-1 cultivar which scored marked increase in sedimentation values comparing with control. On the contrary, band with molecular weight; 51.00 KDa identified only the three irradiated samples of Giza-168 cultivar (with low sedimentation value), this may be considered as marker for low quality gluten. Three M_3 generation plants in Sids-1 cultivar from different irradiation doses showed outstanding performance for both the six yield-related traits and sedimentation values comparing with the M_3 control plant.

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Table (1): The effect of γ-irradiation on the sedimentation value (MST) and the concentration of gliadin and glutenin proteins in the four wheat cultivars (P) and their M_2.

Genotypes	treatment	Total concentration	Gliadin concentration	Glutenin concentration	Gliadin%	Glutenine%	MST-test value
Sakha92 (P)		0.518	0.419	0.099	80.97	19.03	61.7
Sakha61 (P)		0.532	0.399	0.131	75.10	24.9	61.2
Sids1 (P)		0.581	0.449	0.131	77.15	22.84	72.5
Giza168 (P)		0.551	0.461	0.089	82.90	17.09	59.1
Sakha92	Control	0.517	0.402	0.114	77.86	22.14	79.7
	100 Gy	0.523	0.421	0.102	80.56	19.44	60.3
	150 Gy	0.517	0.422	0.095	81.65	18.35	59.0
	200 Gy	0.515	0.431	0.084	83.80	16.20	55.4
Sakha61	Control	0.485	0.378	0.103	78.76	21.07	50.0
	100 Gy	0.515	0.383	0.133	74.27	25.73	64.0
	150 Gy	0.564	0.406	0.158	71.92	28.08	72.7
	200 Gy	0.564	0.441	0.122	78.29	21.71	58.0
Sids1	Control	0.596	0.489	0.108	81.94	18.06	60.0
	100 Gy	0.563	0.436	0.127	77.49	22.50	70.3
	150 Gy	0.632	0.452	0.177	71.52	28.25	80.3
	200 Gy	0.634	0.451	0.183	70.44	29.56	79.3
Giza168	Control	0.490	0.384	0.106	78.41	21.59	60.3
	100 Gy	0.570	0.474	0.095	83.25	16.75	51.3
	150 Gy	0.594	0.526	0.068	86.33	13.67	43.3
	200 Gy	0.550	0.459	0.090	83.63	16.37	45.3

Table (2): SDS-PAGE pattern of alcohol soluble protein (gliadin) from Sakha-92, Sakha-61, Sids-1 and Giza-168 cultivars under γ-irradiation.

BN		MW	RF	Wheat samples/treatments															
				Sk92 control	Sk92 100 Gy	Sk92 150 Gy	Sk92 200 Gy	Sk61 Control	Sk61 100 Gy	Sk61 150 Gy	Sk61 200 Gy	Sids1 control	Sids1 100 Gy	Sids1 150 Gy	Sids1 200 Gy	Giza168 Control	Giza168 100 Gy	Giza168 150 Gy	Giza168 200 Gy
ωzone	1	71.28	0.21	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++
	2	67.29	0.22	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++
	3	58.15	0.25	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-
	4	54.17	0.26		+	-	-	-	++	++	++	++	-	-	-	-	++	++	++
	5	47.08	0.29	-	+++	-	-	+++	++	-	+	++	-	+++	+++	++	++	++	++
	6	40.01	0.32	-	++	-	-	++	++	-	-	-	++	-	-	-	+	-	-
	7	34.5	0.37	+++	+++	++	++	+++	+++	+++	+++	+++	+++	++	++	+++	-	-	-
	8	30.7	0.39	+++	+++	++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
γzone	11	28.17	0.41	+++	+	+++	+++	+++	+++	+++	+++	+++	-	+++	+++	+++	+++	+++	+++
	10	22.48	0.43	+	++	+	+	+	+	+	+	-	-	-	-	-	-	-	-
	11	21.19	0.47	++	-	++	++	++	++	++	++	++	+	++	-	-	+++	+++	+
	12	15.43	0.54	-	-	-	-	+	+	+	-	++	-	+	+	-	+++	+++	-
	13	11.31	0.59	+++	+++	+++	+++	+++	+++	+++	+++	-	-	+	+	-	-	-	-
Bzone	14	10.61	0.63	+++	+++	+++	+++	+++	+++	+++	+++	-	-	++	++	++	++	++	++
	15	9.43	0.66	-	+	-	-	+	+	+	-	++	++	++	++	++	++	++	++
	16	7.79	0.69	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-
αzone	17	6.56	0.73	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
	18	5.19	0.79	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
	19	4.32	0.84	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
	20	3.66	0.89	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
	21	2.45	0.95	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Total of band				14	17	14	14	19	20	18	16	15	12	16	15	13	16	15	14

Bands were indicated by dye marker intensities; (+): very weak, (++): weak, (+++): intensive, (++++): very intensive
RF=Relative front, MW=Molecular weight, BN=band number

Table (3): SDS-PAGE pattern of acetic acid soluble proteins (glutenin) from Sakha-92 , Sakha-61 ,Sids-1 and Giza-168 cultivars under γ-irradiation.

BN	MW	RF	Sk92 control	Sk92 100 Gy	Sk92 150 Gy	Sk92 200 Gy	Sk61 control	Sk61 100 Gy	Sk61 150 Gy	Sk61 200 Gy	Sids1 control	Sids1 100 Gy	Sids1 150 Gy	Sids1 200 Gy	Giza168 Control	Giza168 100 Gy	Giza168 150 Gy	Giza168 200 Gy
1	113.09	0.23	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-
2	97.46	0.28	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-
3	87.98	0.30	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-
4	78.89	0.34	-	-	-	-	-	-	-	-	+ +	+++	+++	+++	++	+++	+	++
5	75.87	0.36	+++	++	+++	++	+++	+++	+++	+++	++	+++	+++	+++	++	+++	++	++
6	73.78	0.37	++++	++++	++++	+++	++++	++++	++++	++++	+++	++++	++++	++++	++++	++++	++++	++++
7	71.19	0.39	-	-	-	-	-	-	-	-	-	+++	+++	+++	-	-	-	-
8	65.40	0.42	-	-	-	-	-	-	-	-	+	++	++	++	-	++	-	-
9	59.93	0.44	++	-	+	+	+	-	-	-	+	+++	+++	+++	++	++	++	+++
10	51.00	0.48	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	+++	+++
11	48.07	0.51	++++	++++	++++	++++	++++	++++	++++	++++	+	++++	++++	++++	++	+	++	++
12	46.07	0.52	-	++	++++	++++	+++	+++	+++	+++	+	++++	++++	++++	++	++	++	++
13	43.87	0.62	++	-	-	-	-	+++	+++	+++	-	-	-	-	-	-	-	-
14	32.83	0.68	++	++	+	+	+	++	+++	+++	++	++	++	++	++	++	++	++
15	27.77	0.69	++	++	+	++	+	++	+++	+++	-	++	++	++	-	-	-	-
16	25.39	0.72			++	++	-	++	++	++	-	-	-	-	-	++	-	++
17	24.43	0.75	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
18	23.27	0.76	++	-	++	++	++	++	++	++	-	-	-	-	-	-	-	-
19	21.9	0.77	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
20	20.37	0.79	-	-	-	-	-	-	-	-	-	+++	+++	+++	-	-	-	-
21	17.73	0.84	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
22	15.06	0.89	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
23	14.79	0.92	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++
24	12.68	0.97	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
25	11.52	0.98	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Total of band			15	13	16	16	15	18	16	16	15	19	20	20	14	17	15	16

Bands were indicated by dye marker intensities; (+): very weak, (++): weak, (+++): intensive, (++++): very intensive
RF=Relative front, MW=Molecular weight, BN=band number

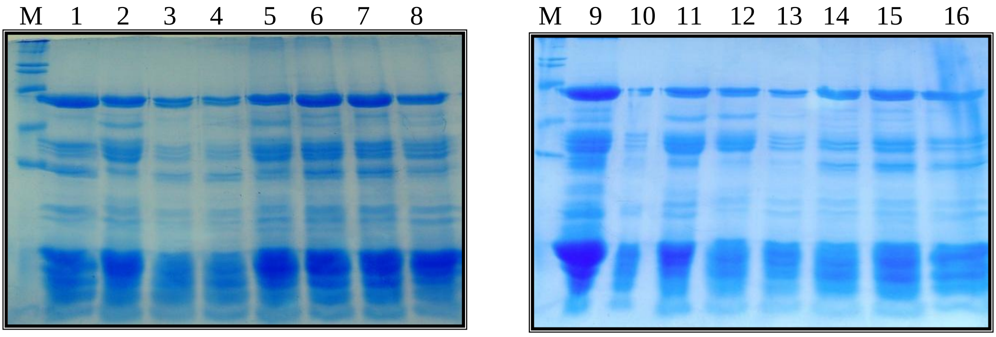

Fig. (1): SDS-PAGE pattern of gliadin proteins in M_2 of the four wheat cultivars under different γ-irradiation doses.
(M= marker as KDa), 1; Sk92 (0 Gy), 2; Sk92 (100 Gy), 3; Sk92 (150 Gy), 4; Sk92 (200 Gy), 5; Sk61 (0 Gy), 6, Sk61 (100 Gy), 7; Sk61 (150 Gy), 8; Sk61 (200 Gy), 9; Sids1 (0 Gy), 10; Sids1 (100 Gy), 11; Sids1 (150 Gy), 12; Sids1 (200 Gy), 13; G168 (0 Gy), 14; G168 (100 Gy), 15; G168 (150 Gy), 16; G168 (200 Gy)

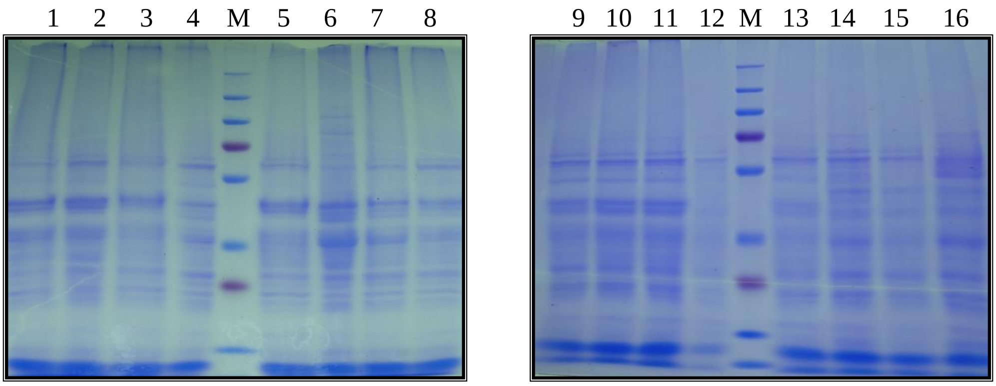

Fig. (2): SDS-PAGE pattern of glutenin proteins in M_2 of the four wheat cultivars under different γ-irradiation doses.
(M= marker as KDa), 1; Sk92 (0 Gy), 2; Sk92 (100 Gy), 3; Sk92 (150 Gy), 4; Sk92 (200 Gy), 5; Sk61 (0 Gy), 6, Sk61 (100 Gy), 7; Sk61 (150 Gy), 8; Sk61 (200 Gy), 9; Sids1 (0 Gy), 10; Sids1 (100 Gy), 11; Sids1 (150 Gy), 12; Sids1 (200 Gy), 13; G168 (0 Gy), 14; G168 (100 Gy), 15; G168 (150 Gy), 16; G168 (200 Gy)