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IMPROVEMENT OF GRAIN YIELD AND YIELD ASSOCIATED TRAITS IN WHEAT GENOTYPES THROUGH MUTATION BREEDING

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ABSTRACT

The experiment was conducted at Nuclear Institute of Agriculture (NIA), Tando Jam during rabi season 2012-13 to evaluate the performance of newly developed mutant populations (M_3 generation) originated from two commercial wheat varieties namely Khirman and NIA-Saarang by treating them with different doses of gamma rays *i.e.*, 150, 200, 250, and 300 Gy. The mutant populations were evaluated along with both mother varieties (non-irradiated) under field conditions. The objectives of the study were to determine the effect of different doses of gamma rays on various yield associated traits and to select superior mutant plants with desired traits from mutant populations. The mean squares obtained from analysis of variance for treatments were significant for the traits spike length, grains spike^{-1}, grain yield plant^{-1} at $P < 0.05$, however, spikelets spike^{-1} and 1000 grain weight were non-significant.The mean squares for genotypes were significantly different for spikelets spike^{-1}, grains spike^{-1}, spike length and 1000 grain weight ($P \leq 0.01$) while grains spike^{-1}were significantly different at $P \leq 0.05$. The mean squares for genotype x treatment (GxT) interaction were non-significant for spike length, spikelets spike^{-1}, grains spike^{-1}, grain yield plant^{-1}. It was observed by taking overall mean that NIA-Saarang produced 13.0 g grain yield plant^{-1} followed by Khirman (control) which produced 11.9 g grains yield plant^{-1}.

Key-words: Wheat, Pakistan, Mutation, Yield, Physical Mutagens.

INTRODUCTION

Bread wheat being the staple food grain plays a important role in meeting the diversified food requirements of both the urban and rural population of the country. Wheat (*Triticum aestivum* L.) is the main cereal crop in Pakistan and covers an area around 9.13 million hectares with the annual production near 23.31 million tones. Wheat crop demands an urgent need to enhance its production in Pakistan either by increasing the area under cultivation or by enhancing the productivity per unit area through the adoption of improved production technology. Wheat crop is grown in large irrigated and rain-fed areas of the country. Pakistan is basically an agricultural country, where 70% of the population depends directly and 16 % indirectly on agriculture.

Mutations have been used successfully in several crops for breeding to improve important traits. Induced mutations in wheat have been obtained for morphological and quantitative characters by treatment with different mutagens (Maluszynski, *et al.,* 1995). The main purpose of using mutagens has been to induce genetic variation, which is the first step in a breeding programme. Since wheat is a polyploid plant, duplication of genes allows a greater number of primary induced changes to be preserved and transmitted to the next generation. Grain yield, a complex polygenic trait is highly affected due to environmental stresses (Sial *et al.,* 2010). Improvement of various complex traits can be possible through different breeding approaches. Induced mutations have significant impact along with conventional breeding approaches in cereals. Mutagenesis has become an established tool in plant breeding to supplement existing germplasm and to improve several specific morphological traits. A large number of varieties of different plants and crop species possesses improved traits have been developed and released to farmers throughout the world; demonstrating the economic value of the technology (Maluszynski *et al.,* 1995).

The present studies were, therefore, undertaken to investigate the morphological and physiological performance of newly evolved stable mutant lines with comparison to local check varieties. The information generated will hopefully be helpful for the breeders while making selection of the high yielding stable mutant lines with improved traits for future breeding. The objectives of the present study were:

1. To determine the effects of gamma rays on various yield associated traits.
2. To observe the variation in mutated population
3. To evaluate the value of induced mutations in wheat improvement

MATERIALS AND METHODS

The experiment was conducted at Nuclear Institute of Agriculture (NIA), Tando Jam during Rabi season 2012-13, to evaluate the effect of gamma rays on M_3 generation of wheat genotypes, the research studies were conducted on M_3 generation under field conditions. The mutated population of two wheat genotypes *viz*., Khirman and NIA-8/7 (NIA-Saarang) originated from four different doses of gamma rays (150, 200, 250, and 300 Gy) were evaluated along with parental lines (non-irradiated) as control. The seeds were irradiated with different doses of gamma rays from Nuclear Institute of Medicine and Radiotherapy (NIMRA) Jamshoro.

The experiment was laid out in RCBD factorial design with three replications arranged in a plot size of 9 m^2 (row length 4m, number of lines 4, row to row distance 30 cm) Each genotype was sown in four rows, 4m long. Data recorded on spike length, spikelete $spike^{-1}$, grains $spike^{-1}$, 1000 grain weight and grain yield $plant^{-1}$. All the required cultural operations were adopted uniformly in all the plots throughout the growing period as and when required.

Treatments: Four (Irradiation with different doses of gamma rays)
T1= 150 Gy T2= 200 Gy T3= 250 Gy T4= 300 Gy

Genotypes: 04
i. Parents: V_1= Khirman V_2= NIA-Saarang
ii. Mutants MR-KHR MR-SARG

Statistical analysis

Data recorded from plants were statistically analyzed using analysis of variance (ANOVA) according to Gomez and Gomez (1984) and the means were compared through Duncan's Multiple Range test (DMRT) by STATISTIX-10.0 version computer package.

RESULTS

The present studies were carried out to evaluate the performance of newly developed mutant populations (M_3 generation) originated from two commercial wheat varieties namely Khirman and NIA-Saarang.

The analysis of variance (ANOVA) was carried out to investigate the differences among mutants and non-irradiated parental varieties for various yield and yield associated traits are presented in Table 1. The overall mean performance of wheat genotypes are represented in Table 2-6. The results indicated that the mean square (MS) obtained from ANOVA for genotypes were significantly ($P \leq 0.05$) different with each other for all the measured traits. The mean square for treatment was significantly different with each other for all the traits except spikelets $spike^{-1}$, spike length and 1000-grain weight.

Table 1. Mean squares (MS) from pooled ANOVA for different morphological traits of wheat genotype.

Source of variation	D.F	Mean Squares (M.S)				
		Spike length (cm)	Spikelet $spike^{-1}$	Grain $Spike^{-1}$	1000 grain weight (g)	Grain yield-$plant^{-1}$ (g)
Replications	2	0.00396	0.1575	326.101	1.4433	11.4355
Treatment	3	0.85477*	2.2608	189.512*	4.4694	6.9515*
Genotype	3	3.24116**	24.9514**	187.177*	33.7368**	11.6187**
Treatment x Genotype	9	0.21186	1.4640	70.165	7.5391	3.6485
Error	30	0.22229	0.8542	61.815	5.7136	2.4458
Total	47					

Spike length:

Khirman mutant showed lead in spike length as it acquired (12.1cm) length as compared to its parent Khirman and other genotypes. NIA-Saarang mutant and Khirman control showed non-significant difference among each other. Both these varieties were non-significantly different from each other but significantly different from Khirman mutant line and NIA-Saarang control variety. It was recorded that NIA-Saarang control show minimum spike length(10.8) but was significantly different from all other parent mutant genotypes. The result obtained from over all treatment wise mean showed that T_1 and T_4 were non significantly different with each other but significantly different from T_2 and T_3. Same is the case of T_2 and T_3; both treatments were non significantly different from each-others and significantly different from T_1 and T_4 (Table 2).

Table 2. Effect of different doses of gamma irradiations on Spike length (cm) of wheat genotypes.

Genotypes	Mutated population (M_3 generation)				Overall genotypic mean
	T1 (150 Gy)	T2 (200 Gy)	T3 (250 Gy)	T4 (300 Gy)	
Khirman (Mutant)	11.7	12.1	12.7	11.9	12.1a
NIA-Saarang (Mutant)	10.9	11.9	11.7	11.2	11.4b
Khirman (Control)	11.2	11.7	11.2	11.4	11.4b
NIA-Saarang (Control)	10.8	10.9	11.1	10.5	10.8c
Overall treatment mean	11.1a	11.6b	11.6b	11.2a	

Spikelets spike^{-1}:

The Khirman mutant could produce significantly the highest number of spikelets per spike (24) which were significantly highest than its parent (control) variety and other mutants and varieties. NIA-Saarang mutant showed an increase in number of spikelets spike^{-1} followed by Khirman mutant. However, parent varieties of both the mutant lines were non-significantly different with each other. More number of spikelets spike-^{1} (22.4) were acquired by T_3 (250 Gy) whereas T_4 showed decrease in this trait. T_1 and T_2 were non significantly different with each other and were at par to T_3.

Table 3. Effect of different doses of gamma irradiations on spikelets spike^{-1} of wheat genotypes.

Genotypes	Mutated population (M_3 generation)				Overall genotypic mean
	T1 (150 Gy)	T2(200 Gy)	T3(250 Gy)	T4(300 Gy)	
Khirman (Mutant)	24.8	23.9	24.7	22.6	24.0a
NIA-Saarang (Mutant)	22.1	22.2	22.6	21.3	22.1b
Khirman (Control)	20.5	21.4	20.1	21.1	20.8c
NIA-Saarang (Control)	20.9	21.0	22.2	20.5	21.1c
Overall treatment mean	22.0ab	22.1ab	22.4a	21.4b	

Grains spike^{-1}

Khirman-mutant ranked first regarding the parameter grains per spike (69.5) which was significantly different from all other genotypes including its parental variety and other mutant line and parent variety. NIA-Saarang control followed by the Khirman control could also produced highest number of grains spike^{-1} (63.6 and 64.6 respectively). NIA-Saarangmutant produced less grains spike^{1} and was significantly different from all other genotypes. Overall treatment wise mean showed that T_3 followed by T_2 produced significantly the highest grains spike^{1} (69.9 and 64.6 respectively). Whereas, non-significant difference was observed in T_1 and T_2 (61.3 and 61.8 respectively) for this trait (Table 4).

Table 4. Effect of different doses of gamma irradiations onGrains per spike of wheat genotypes.

Genotypes	Mutated population (M_3 generation)				Overall genotypic mean
	T1 (150 Gy)	T2 (200 Gy)	T3 (250 Gy)	T4 (300 Gy)	
Khirman (Mutant)	62.3	69.9	76.4	69.4	69.5a
NIA-Saarang (Mutant)	61.1	61.6	62.1	55.1	59.9b
Khirman (Control)	60.6	66.1	63.1	64.6	63.6ab
NIA-Saarang (Control)	61.1	60.9	78.2	58.2	64.6ab
Overall treatment mean	61.3b	64.6ab	69.9a	61.8b	

1000 grain weight

The significantly highest (47.0g) 1000-grain weight was recorded by Khirman control followed by mutant of Khirman (46.7g). NIA-Saarang mutant, Khirman control and NIA-Saarang control were significantly different from each other having (43.4g), (47g) and (42.8g) thousand grain weight respectively. Khirman mutant showed (46.7g)

1000 grain weight which showed significant difference from NIA-Saarang mutant and Khirman control and NIA-Saarang control. The result obtained from overall treatment wise mean at different gamma irradiation doses showed non-significant difference between the treatments (Table 5).

Table 5. Effect of different doses of gamma irradiations on1000 grain weight of wheat genotypes.

Genotypes	Mutated population (M_2 generation)				Overall genotypic mean
	T1 (150 Gy)	T2(200 Gy)	T3(250 Gy)	T4(300 Gy)	
Khirman (Mutant)	49.1	44.7	46.6	46.4	46.7ab
NIA-Saarang (Mutant)	42.3	42.3	43.5	45.5	43.4c
Khirman (Control)	46.1	46.2	48.0	47.6	47.0a
NIA-Saarang (Control)	44.3	45.5	46.6	42.8	44.8bc
Overall treatment mean	45.5a	44.7a	46.1a	45.5a	

Grain yield plant^{-1}

The parameter grain yield per plant indicated that Khirman mutant produced the highest grain yeild^1/plant (12.9g) followed by its mother variety Khirman (control) as it produced (11.9g) grain yeild^1/plant and NIA-Saarang (control). Both were non significantly different to each other but significant different from NIA-Saarang mutant. Taking overall mean of different radiation doses, it was observed that significant highest yield (12.9 g) was produced by T3 as compared to other treatments. There were no any significant difference among 3 treatments (T1, T2 and T4) (Table 6).

Table 6. Effect of different doses of gamma irradiations on grain yield plant^{-1} of wheat genotypes.

Genotypes	Mutated population (M_3 generation)				Overall genotypic mean
	T1 (150 Gy)	T2(200 Gy)	T3(250 Gy)	T4(300 Gy)	
Khirman (Mutant)	12.3	12.5	14.2	12.8	12.9a
NIA-Saarang (Mutant)	11.2	10.8	10.5	9.6	10.5b
Khirman (Control)	11.2	12.2	12.1	12.2	11.9a
NIA-Saarang (Control)	11.3	10.3	15.0	10.9	11.8ab
Overall treatment mean	11.5b	11.4b	12.9a	11.4b	

DISCUSSION

Spike length

Spike length of Khirman mutant showed significant increase as compared to its parent Khirman and other genotypes. NIA-Saarang mutant and Khirman control showed non-significant difference among each other. Both these varieties were non significantly different from each other but significantly different from Khirman mutant line and NIA-Saarang control variety. It was recorded that NIA-Saarang control show minimum spike length (10.8) but was significantly different from all other parent mutant genotypes. The result obtained from over all treatment wise mean showed that T_1 and T_4 were non-significantly different with each other but significantly different from T_2 and T_3. Same is the case of T_2 and T_3; both treatment were non significantly different from each and significantly different from T_1 and T_4. Similar results were recorded by several other researchers in wheat and other cereals (Ahloowalia and Maluszynski, 2001; Naju *et al.*, 2005; Jamil and Khan, 2002; Ram Din *et al.*, 2003; Khan *et al.*, 2003; Ilirjana *et al.*, 2007).

Spikelets spike^{-1}

Spikelets spike-^{1} showed significant increase at T_3 whereas decrease at T_4. T_1 and T_2 were non significantly different with each other and were at par to T3.The Khirman mutant could produce significantly the highest number of spikelets spike^{-1} (24) which were significantly highest than its parent (control) variety and other mutants and varieties. NIA-Saarang mutant showed an increase in number of spikelet spike^{-1} followed by Khirman mutant. However, parent variety of both the mutant lines were non-significantly different with each other. The previous workers like Abbate *et al* (1997) and Singh *et al* (2005) obtained the similar result as increasing the radiation dose and decreased in spikelets spike-^{1}.

Grains spike^{-1}

Higher gamma rays dose (T_3) followed by T_2 showed significant increase in grains spike^{-1} as compared to other doses. Whereas, non-significant difference was observed in T_1 and T_2 (61.3 and 61.8 respectively) for this trait. (Farag and EL-Khawaga 2013) reported that, wheat grains irradiated with low dose (10Gy) of Gamma radiation surpassed the other two irradiation doses (20 and 30 Gy) and the control in each of plant height(cm), spike length (cm), Flag leaf area(cm^2)at heading ,number of spikes m^2, number of spikelets spike^{-1}, number of grains spikelet^{-1}, grain weight spike^{-1}(g) , grain weight spikelet^{-1} (mg), 1000- grains weight(g), grain , straw and biological yields. Khirman-mutant ranked first regarding the parameter grains per spike (69.5) which was significantly different from all other genotypes including its parental variety and other mutant line and parent variety. NIA-Saarang control followed by the Khirman control could also produced highest number of grains spike^{-1} (63.6 and 64.6 respectively). NIA-Saarangmutant produced less grains spike^{-1} and was significantly different from all other genotypes. Overall treatment wise mean showed that Spano *et al* (2005) and Sak *et al* (2005) demonstrate in their result the higher number of grains with the higher dose of radiations. This might may be the rearrangement of the genes on the same or other chromosomes.

1000-Grain weight

The results from analysis of variance summarized and tabulated (Table 1) showed that the genotypes were highly significant for this trait indicating the existence of high variance among the entries i.e., the mutant lines performed differently with each other and also with the mother varieties. The significantly highest (47.0g) 1000-grain weight was recorded by Khirman control followed by mutant of Khirman (46.7g). NIA-Saarang mutant, Khirman control and NIA-Saarang control were significantly different from each other having (43.4g), (47g) and (42.8g) thousand grain weight respectively. Khirman mutant showed (46.7g) 1000 grain weight which showed significant difference from NIA-Saarang mutant and Khirman control and NIA-Saarang control. The result obtained from overall treatment wise mean at different gamma irradiation doses showed non-significant difference between the treatments. Singh and Balyan (2009) reported some promising mutants produced higher 1000-grain weight, number of tillers plant^{-1}, spikelets spike^{-1} in M_3 generation as compared to control. The use of the ionizing radiation technology may be considered as a revolution in agronomic research, especially in the plant protection, plant breeding and crop production. Several workers reported that, gamma irradiation at low doses, have positive and stimulatory effects on the plants growth, development and yields. Farag and EL-Khawaga (2013) also reported that, gamma irradiation at low doses of 10 Gy, was effective to increase grain weight plant^{-1} of 3 wheat cultivars.

Grain yield plant^{-1}

Similarly, significantly higher yield was recorded at higher gamma rays (T_3 as compared to other treatments. There was no significant difference among 3 treatments (T_1, T_2 and $T_{4.}$ The increase in grain yield at higher doses (T_3) by wheat mutants are I agreement with the findings of other researchers (Arain *et al.*, 2001; Jamil and Khan 2002; Singh and Balyan 2009). Gamma rays in particular are important physical mutagen which is well known with their effects on the plant growth and development by inducing morphological, cytological and physiological changes in cells and tissues (Larik *et al.*, 2009). The parameter grain yield plant^{-1} indicated that Khirman mutant produced the highest grain yield^{-1} followed by its mother variety Khirman (control) as it produced (11.9g) grain yieldplant^{-1} and NIA-Saarang (control). Both were non significantly different to each other but significant different from NIA-Saarang mutant. It indicated that the population has wider variation for this trait.

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