Research Article
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Ekin
Journal of Crop Breeding and Genetics
7(2):68-73, 2021
Ekin International biannual peer-reviewed journal

Determination of Variability for Grain Yield and Quality Traits in Gamma-Ray Irradiated Bread Wheat Populations

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Citation:
Korkut ZK., Başer I., Bilgin O., Balkan A., Deviren B., 2021. Determination of Variability for Grain Yield and Quality Traits in Gamma-Ray Irradiated Bread Wheat Populations. Ekin J. 7(2):68-73.

Received: 11.02.2021 ***Accepted: 29.03.2021*** ***Published Online: 29.07.2021*** ***Printed: 30.07.2021***

ABSTRACT

The study was carried out in the experimental area of the Field Crops Department, Faculty of Agriculture, Namik Kemal University in the growing season of 2011-12. In the study, grain yield and its components and some quality traits such as 1000 grain weight, wet gluten content, gluten index, sedimentation value and protein content were investigated. The results exhibited significant differences among the tested genotypes, for all studied characters except spike length, indicating genetic variation among them. The genetic variation was higher for grain yield and its components when compared with quality characteristics. These differences show that the effects of increasing gamma irradiation are not systematically negative for plant height, while positive for all other characters in comparison with controls. In general, it is understood that the highest percent changes are achieved in 200 and 250 Gy of gamma radiation doses for yield components, while are in 300-350 Gy for the quality characteristics. The values of phenotypic coefficient of variation PCV were slightly higher than their corresponding values of GCV for all traits. Moderate estimates of genotypic coefficient of variation GCV were obtained by grain yield (12.50%), gluten content (11.20%) and grain weight per spike (10.20%), respectively. Low estimates of GCV (less than 10) were recorded for the other characters investigated. The h^2 values ranged from 37.3%, for sedimentation value, and 86.6%, for plant height, while the values of GA% ranged between 0.09 and 593.0.5% at 10% selection intensity for grain weight per spike and grain yield, respectively. The high values of heritability coupled with high values of genetic advance (%) were recorded by plant height, indicates the importance of the additive gene effects, so, selection would be effective in early generations for the trait. The high values of heritability coupled with moderate values of genetic advance (%) for harvest index and gluten index indicate selection would be a delay in later generations.

***Keywords*:** Bread wheat, gamma rays, yield, quality, mutated population

Introduction

The main purpose of using mutagens has been to induce genetic variation especially in homozygous genotypes of self-pollinated crops which is the first step in a breeding program (Galal et al. 1975). Genetic variation in major crops has been successfully unlocked, shuffled, recombined, and sometimes created, by plant breeders over the last century to achieve yield increase. The success of induced variation will mainly depend on the precision in selection techniques (Mac Key 1984 and Konzak 1987). The expected response to selection can be measured by determining the parameters like mean, coefficient of variation, standard deviation, heritability and genetic advance (Ibrahim and Sharaan 1974; Scossiroli 1977; Shabana et al. 1994 and Amer et al. 2001).

Changes in morphological, physiological and quality characters after mutation application are common, and therefore it has been demonstrated that induced mutation can increase yield as well as other agronomic characters such as stiffness of straw, time of maturity, adaptability, shattering resistance, disease resistance, protein content, baking quality, malting quality and numerous other characters (Ibrahim and Sharaan 1974; Borojevic 1990; Brunner 1991). Several achievements in crop improvement through mutation breeding have resulted in two major outcomes: improved varieties that are directly used for commercial cultivation and new genetic stocks with improved characters or with better combining ability of traits (Roychowdhury and Tah 2013). More than 3,200 mutant varieties have been directly or indirectly derived through mutation induction, nearly 80% of these crop varieties are seed propagated, almost half of which (48%) are cereals (Jankowicz-Cieslak et al. 2017) including 274 bread wheat varieties (International Atomic Energy Agency, IAEA, 2018) and are being grown in different countries of the world. Considering the improvements in mutation breeding in the world, unfortunately, there is no mutant wheat variety in our country yet. This inferiority is that the mutation breeding work in our country is very limited. The primary aim of this study is to contribute to the accumulation of knowledge on mutation breeding. Knowledge of the high value of heritability and predicted genetic advance clarifies that the selection among genotypes would be effective for yield and yield components (Shabana et al. 1994, Tammam et al. 2000, Kashif and Khaliq 2004 and Baloch et al. 2013). High heritability in the broad sense associated with high genetic advance reveals a strong contribution of additive genetic variance for the expression of the traits and the selection based on these traits could play a vital role in improving grain yield (Laghari et al. 2010). Therefore, the present work was planned to estimate genetic variation, heritability (h^2) and genetic advance (% mean). The results may be helpful to plan appropriate selection strategies for improving the grain yield of wheat crop in Turkey.

Materials and Methods

Plant material

Three bread wheat (*Triticum aestivum* L.) advanced lines, BSB (Bezostaja 1 x Saraybosna; tall, mid-late, awnless, superior in flour quality for bread making, but inferior in lodging resistance and yield capacity), FA (Flamura 80 x Atilla 12;mid-tall, mid-early, awned and inferior in flour quality for bread making, disease resistance and superior in lodging and yield capacity), PK (Pehlivan x Kate A-1; tall, mid-late, awnless and inferior in flour quality for bread making, lodging and disease resistance) were used as the experimental material.

Gamma irradiation

The moisture contents of seeds of wheat genotypes (*Triticum aestivum* L.) used in the study were around 12.0%. Gamma treatment was applied in 0 (Control), 100, 150, 200, 250, 300 and 350 Gy obtained from ^{60}Cobalt, Ob-Servo Sanguis Co-60 Research Irradiator with isotope model, while the dose rate was 2.190 kGy h^{-1} in before the 2010-11 growing season sowing at the Turkish Atomic Energy Authority, Sarayköy Nuclear Research and Training Center, Ankara, Turkey. Right after irradiation, the experiment was set up using a total of 30 M_0 combination seeds together with the un-irradiated (control) in the experimental field of the Field Crops Department of the Faculty of Agriculture of Namik Kemal University during the growing season of 2010-11. The experiment was carried out in a randomized complete block design (RCBD) with 3 replicates. Plots were sown on Nov.15, 2010, by hand at the rate of 350 seeds per m^2 and were 2 m in length x 1.0 m wide, with 6 rows 0.2 m apart. The crop was kept free of weeds by hand hoeing when necessary. The seeds obtained from the harvested plants in M_1 generation were planted in M_2generation as 20 cm row distance in 5 meters of 6-row parcels with 4 replicates and as 400 seeds in each row. Morphological and yield characters were recorded on 15 random and guarded plants to study the effect of irradiation doses on the studied genotypes on plant height, spike length, the number of spikelets per spike, number of grains per spike, grain weight per spike and harvest index. Grain yield and some grain quality characters such as thousand grain weight, test weight, gluten content, gluten index, sedimentation value and protein content were investigated in each seed of M_2 generation.

Statistical analyses

Genetic parameters

The genotypic and phenotypic variances and their corresponding coefficients of variations were estimated, using the pertinent mean square expectations, according to the method, suggested by Johnson et al. (1955). Broad sense heritability (h^2), genetic advance as % of mean was calculated following Hanson et al. (1956) and Allard (1999).

Mean squares were used to estimate

$\boldsymbol{\sigma}^2_g$ = (MSS-MSE)/r

$\boldsymbol{\sigma}^2_{ph} = \boldsymbol{\sigma}^2_e + \boldsymbol{\sigma}^2_g$, where broad-sense heritability (h^2_{bs}) was estimated as follows:

$h^2 = (\boldsymbol{\sigma}^2_g / \boldsymbol{\sigma}^2_{ph})$ x 100 and the phenotypic and genotypic coefficients of variation were computed as follows:

PCV $= 100\ x\ \sqrt{\sigma^2_{ph}}/\bar{X}$ **GCV** $= 100\ x\ \sqrt{\sigma^2_g}/\bar{X}$

Expected genetic advance: Expected genetic advance from direct selection for all studied traits was calculated according to Singh and Chaudhary (1999) as follows:

GA% at **10% (selection intensity)**$=100\,x\,k\,x\,h^2\,x\,\sigma_{ph}/\bar{X}$,

Where $\bar{X}$: general mean and k is selection differential (k= 1.76 for 10% selection).

T-test was performed to compare the mean values obtained from treatments with different gamma irradiation with the untreated (control) means for each character studied.

Results and Discussion

Mean performance

The mean values of yield and quality characters for the three tested genotypes, evaluated in M_2 generation, are given in Table 1.

The grain yield means of M_2 populations of bread wheat genotypes varied between 367-589 gm^{-2}. Gamma irradiation caused significant increases for all three genotypes of bread wheat. The highest grain yield increases were obtained from 300 and 350 for BSB, FA and BK. There was an increase in thousand kernel weight in all doses except 100 gray. While the gluten ratio value was not significant affected by the application of gamma irradiation for the BSB mutated population, the other two mutated population resulted in significant increases in doses after 200 gray doses. The gluten index showed a significant decrease for the BK mutated population, but there was an increase for the BSB mutated population. However, there was no significant increase in the FA population for the traits. In terms of sedimentation value, the BSB mutated population showed an increase in only 350 gray applications, while BK increased in all doses. Protein ratio was increased statistically by application of mutagen in populations of all three varieties.

The results exhibited significant differences among the tested genotypes, for all studied characters except spike length, indicating genetic variation among them. But it can be said that this genetic variation is higher for grain yield and its components when compared with quality characteristics. These differences show that the effects of increasing gamma irradiation are not systematically negative for plant height, while positive for all other characters in comparison with controls. In general, it is understood that the highest percent changes (data was not shown) are achieved in 200 and 250 Gy of gamma radiation doses for yield components, while are in 300-350 Gy for the quality characteristics. Chen et al. (1997) observed wide differences between different irradiation doses. Similarly, a high contribution of genotypes to the total variance of seed yield was reported by (Dhillon et al. 1999, Gebeyehu and Assefa 2003 and Albokari et al. 2015).

Genotypic and phenotypic variances and their corresponding coefficient of variations, broad-sense heritability (h^2), and genetic advance (GA) expressed as a per cent of mean for the studied traits, evaluated in M_2 generation, are presented in Table 2.

Shivsubramanium and Madhavmenon (1973) are suggested for classified PCV and GCV as a per cent of mean as low (<10%), moderate (10-20%) and high (>20%). According to this classification, the GCV and PCV values obtained in our study are moderate and low. Moderate estimates of genotypic coefficient of variation GCV were obtained by grain yield (12.50%), gluten content (11.20%) and grain weight pers pike (10.20%) in M_2 generation, respectively. Low estimates of GCV (less than 10) were recorded for the other characters investigated.

On the other hand, the values of phenotypic coefficient of variation PCV were slightly higher than their corresponding values of GCV for all traits which reflect the somewhat environmental influence on the expression of characters in M_2 generation. These results indicated that the selection would be effective to improve these traits among the tested genotypes.

It is important to emphasize that, the heritability values (h^2) would not be practically valuable in the selection depends on phenotypic appearance without considering genetic advance (GA). (Johnson et al. 1955). Confirmed that heritability estimates, in conjunction with genetic advance would give the more reliable index of selection value.

In the present study, the h^2 values ranged from 37.3%, for sedimentation value, and 86.6%, for plant height, while the values of GA% ranged between 0.09 and 593.05 % at 10% selection intensity for grain weight per spike and grain yield, respectively. According to Singh (2001), the heritability of a trait is considered as high when the value is 80% or moderate when it ranged from 40-80% and when it is less than 40%, it is low. Deshmukh et al. (1986) classified genetic advance as per cent of mean as low (<10%), moderate (10-20%) and high (>20%).

The high values of heritability ($h^2 \geq 80\%$) coupled with high values of genetic advance (%), both at 10% selection intensity ($GA \geq 20\%$), were recorded by plant height. Such previous results indicated the importance of the additive gene effects, so, selection would be effective in early generations for the trait. The high values of heritability ($h^2 \geq 80\%$) coupled with moderate values of genetic advance (%), both at 10% selection intensity ($GA \geq 10\%$) for harvest index and gluten index indicate selection would be a delay in later generations.

Table 1. Mean performance of wheat genotypes for some yield and quality characters during M_2 generation in 2011/12 season.

Genotypes	Gamma Doses	Plant Height (cm)	Spike Length (cm)	Number of Spikelets Per Spike (no)	Number of Grains Pers Pike (no)	Grain Weight Per Spike (g)	Harvest Index (%)	Thousand Grain Weight (g)	Grain Yield (gm^{-2})	Wet Gluten Content (%)	Gluten Index	Sedimentation Value (ml)	Protein Content (%)
BSB	Cont	121.5	10.2	20.2	46.2	1.820	37.8	38.8	367	30.0	89.0	50.0	12.70
	100	119.9*	10.0	21.0*	44.4*	1.857	38.5	39.8	397*	31.0	90.3	47.7*	13.07**
	150	118.5**	9.9	20.9	47.8*	2.187*	39.3*	40.0*	390*	29.7	91.0*	49.3	12.77
	200	115.6**	10.3	22.4**	48.7*	2.567**	40.2**	40.4**	445**	30.7	91.7*	50.0	12.87
	250	112.8**	10.5	21.6*	47.8*	2.440**	41.7**	41.0*	451**	31.7	91.0*	48.0	13.00*
	300	107.9**	10.4	21.4*	46.4	2.410**	42.1**	41.5**	459**	32.0	90.7	49.7	12.97*
	350	106.0**	10.2	21.2*	42.7**	2.377**	41.6**	41.7**	492**	29.0	92.0*	52.0	12.83
BK	Cont	116.7	9.7	19.2	45.2	2.053	34.9	38.9	378	24.7	95.0	46.0	11.90
	100	116.2	9.7	20.1*	50.4**	2.173*	37.1*	39.5	412**	26.0	92.7*	46.3	12.00
	150	112.3**	9.9	20.7**	48.3**	2.253**	37.8**	39.7*	425**	24.0	95.7	49.0*	12.03*
	200	109.9**	9.8	21.0**	52.4**	2.217**	39.1**	40.1**	443**	28.0**	91.0**	49.0*	12.40**
	250	104.6**	10.1	21.9**	53.7**	2.283*	39.4**	40.9*	455**	30.7**	90.7**	51.3**	12.87**
	300	102.8**	10.0	22.0**	52.2**	2.467**	41.0**	41.0**	469**	30.0**	90.7**	47.7	12.93**
	350	100.0**	9.6	20.6**	48.0**	2.660**	39.3**	39.7	434**	31.0**	91.7**	51.0**	13.00**
FA	Cont	105.9	7.9	19.1	38.1	1.757	39.4	37.2	457	22.3	85.0	47.3	11.87
	100	105.2	8.1	19.4*	40.4**	2.050**	41.5**	37.9	507**	21.7	85.0	45.0**	11.67*
	150	102.6**	7.9	19.9**	42.1**	2.073**	41.8**	38.8*	511**	24.0	86.0	46.3	12.00
	200	101.1**	8.2	20.3**	47.7**	2.107**	42.2**	39.6**	537**	24.7**	86.0	50.7**	12.53**
	250	97.7**	7.8	21.3**	47.5**	2.230**	42.6**	40.4**	574**	24.7**	85.0	48.0	12.63**
	300	97.0**	8.9**	20.8**	47.5**	2.410**	43.2**	41.7**	560**	27.7**	88.3**	49.0	12.80**
	350	90.2**	8.6**	20.8**	48.9**	2.560**	43.7**	42.6**	589**	28.7**	85.3	49.7**	12.77**

*=Significant at 0.05% level, **=Significant at 0.01% level

Table 2. Range, mean, phenotypic and genotypic coefficient of variation, heritability and expected genetic advance for agronomic characters in M_2 bread wheat mutated populations.

Agronomic Characters	Range	Grand Mean	Coefficient of Variation (%)		h^2 (%)	GA Mean (10%)
			PCV	GCV		
Plant height (cm)	85.0-125.4	107.8	8.19	7.62	0.866	118.80
Spike length (cm)	7.2-11.2	9.4	10.51	9.49	0.817	1.40
Number of spikelets per spike (no)	18.2-23.7	20.7	5.62	3.54	0.398	0.95
Number of grains per spike (no)	35.5-57.5	47.0	10.39	6.91	0.442	18.56
Grain weight per spike (g)	1.500-3.040	2.236	12.81	10.20	0.637	0.09
Thousand grain weight (g)	36.8-43.4	40.1	3.68	3.08	0.701	2.69
Harvest index	34.57-44.42	40.20	5.85	5.43	0.863	8.39
Grain yield (gm^2)	329.0-625.0	464.4	15.61	12.50	0.641	593.05
Gluten content (%)	19.0-33.0	27.7	12.93	11.20	0.751	6.95
Gluten index	84.0-96.0	89.7	3.78	3.51	0.862	7.45
Sedimentation value (ml)	45.0-55.0	48.7	5.04	3.08	0.373	3.95
Protein content (%)	11.00-13.40	12.55	4.00	3.34	0.697	0.31

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