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Selection Studies on Mutant Bread Wheat (*Triticum aestivum* L.) Populations in Turkey

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The effect of gamma irradiation on five common wheat cultivars which are all the spring cultivars, namely Gonen, Cumhuriyet, Ziyabey, Izmir and Basribey were studied. Various doses of gamma irradiation, i.e. (0-150-300 Gy) were applied to dry seed. The mutated populations were grown at two locations (Bornova and Alasehir) in the 2003–2004 and 2004–2005 growing season. A total of 100 single plants were selected from each mutant and control population in 2003–2004 growing season. Twenty-five percent selection pressure was applied. The progeny rows of the selected mutant plants were grown at two locations in 2004–2005 growing season. A second stage selection was applied in each progeny population and selected mutant lines were advanced to the micro yield testing. Genetic advance at each stage of selection was estimated for single plant yield, and expected progeny means for plot yield was estimated. In certain mutant populations, heritability and phenotypic standard deviation values, genetic gains were higher than control population. The progeny means of the certain mutant populations were higher when compared with control populations as well.

Keywords: wheat, gamma ray, genetic gain, selection

Introduction

Common wheat (*Triticum aestivum* L.) production is of great economic importance in Turkey and widely cultivated in many parts of central and coastal of Turkey. According to the FAO (2008), Turkey has totally 8.6 million hectares sowing area and 20.5 million tones production of the wheat. Wheat production has approximately composed of 90% of common wheat and 10% of durum wheat (*T. durum* desf.) in Turkey (Cetin and Turan 1999).

Breeders try to improve high yielding cultivars that could complete with the bread wheat cultivars in yielding ability (Sakin et al. 2005). Among the different breeding methods used, mutagenesis has been used as an important tool to supplement existing variability and to create additional variability for qualitatively, as well as, quantitatively inherited traits in different plants (Muthusamy et al. 2005). Mutagenesis is considered as an alternative method to increase genetic variability in plant breeding (Camargo et al. 2000). Muta-

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genesis is often used to correct defects in a cultivar, which has a set of good agronomic characteristics (Sigurbjörnsson 1977). The use of nuclear techniques in plant breeding has been mostly directed for inducing mutations. Since the discovery of X-rays about one hundred years ago, the use of ionizing radiation, such as X-rays, gamma rays and neutrons for inducing variation, has become an established technology. Induced mutations have been used in the improvement of major crops such as wheat (*Triticum* spp.), rice *(Oryza sativa),* barley *(Hordeum vulgare),* cotton *(Gossypium hirsutum),* chickpea *(Cicer arietinum)* which are seed propagated (Ahloowalia and Maluszynski 2001).

Since its establishment, the Joint FAO/IAEA Division of the Nuclear Techniques in Food and Agriculture, Vienna, has sponsored extensive research and development activities in their member states on mutation induction to enhance the genetic diversity in the germplasm of food and industrial crops. These efforts have resulted in the official release to farmers of over 2700 new crop cultivars in approximately 170 species (Lagoda 2008).

In many mutagenic studies, gamma ray and X-rays have been used to induce mutations. The key factor in the irradiation of plant material is the dose, which is the amount of radiation energy absorbed by the material (Ahloowalia and Maluszynski 2001). The purpose of the study was to investigate the effects of a second stage selection on the common wheat cultivars constructed by induced mutations in terms of yield and estimate the genetic gains in the M_2 and the M_3 generations.

Material and Methods

Five common wheat cultivars (Gonen, Cumhuriyet, Ziyabey, Izmir, and Basribey) in Table 1 were chosen for irradiation using gamma rays. Dry seeds, equilibrated at 11% moisture content, were irradiated at the Nuclear Research and Training Center Saraykoy-Ankara Turkey, with 0, 150, 300 Gy (Gy = gray (1 Gray = 10 krad)) gamma rays at Cobalt 60 (Co^{60}) source as a physical mutagen (FAO/IAEA1997).

Table 1. Five common wheat cultivars used in the study

Gonen	8156-RESELECTION/MARA//BLUEBIRD[2964];
Cumhuriyet	SONORA-64*2//TEZANOS-PINTOS-PRECOZ/YAQUI-54/3/ANDES-64-A/4/2* FROCOR// YAQUI /KENTANA[667][114][144][2406];
Ziyabey	ND/VG-9144//KALYANSONA/BLUEBIRD/3/YACO/4/VEERY-5[2400];
Izmir	UNKNOW-SEL. FROM-ISWYN[1281];
Basribey	JUPATECO-73/(SIB)BLUEJAY//URES-81[1610][2850];

Irradiated seeds and control seeds were sown on an average with a density of 400 plants per square meter. Sowing was performed by hand on November 25, 2002 at Alasehir, and on November 20 at Bornova. Harvesting was completed using the bulk method by hand in first week of July at two locations in 2003. The testing procedure was introduced by Yildirim et al. (1987).

M_1 plants grown after mutagenic treatments were propagated based on the spike progeny method. The M_2 seeds obtained from each spike were sown to rows. Selection of mu-

tants was carried out in the M_1 and the M_2 generations. M_2 plants showing a difference from the control were considered to be macro mutant types and the plants with desirable phenotypes were harvested individually in 2003–2004 growing season. Then M_3 progeny from selected M_2 plants, were selected according to micro mutation procedure which is a method of selecting single plants randomly, were grown in the 2004–2005 growing season (Gaul 1964; 1965). The mutants were identified by visual screening for long spike and maturity and were confirmed by measuring for single spike yield and single plant grain yield in the M_2 and M_3 (Bagnara et al. 1973; Sakin et al. 2005). Histograms of grain yield per plant were used to select plants with the highest 25% grain yield in each population. The selected plants were advanced to the next generation. Mutant types selected in the M_2 generation were grown in a randomized complete block design with two replications in the M_3 generation. Each plot consisted of 20 seeds planted in 1 m long row with 20 cm between rows and 5 cm between plants within a row. The following traits were measured; Plant height (measured from surface of soil to top of the spike (excluding awns)), spike length (measured from beginning of the spike to end of the spike (excluding awns)), grain yield per plant (10 plants harvested from each plot were threshed and weighed and divided by 10), kernel number per spike (determined by carefully counting the seeds on the primary tiller), tiller number per plant (plants was rooted by hand from soil then root of each plants cleaned by water and counted plants that each plant has a fertile spike), thousand kernel weight (estimated as the average of four 100-kernel samples multiplied with 10).

Statistical analysis

The data obtained for measured traits from two years growing at Bornova and Alasehir were analyzed and combined over years and locations in order to get a better heritability estimate by applying variance components method (Allard 1999). Single plant yields of the selections done in the original populations were analyzed statistically assuming normal distribution and mean standard deviation and the coefficient of variation (C.V.) values were calculated (Steel and Torrie 1980) while the effects of radiation doses and their cultivar response were compared by Duncan's new multiple range test. The data were analyzed with ANOVA using Tarist (Acikgöz and Akkaş 1994). Selection differential is determined by the selection intensity applied to the population and the phenotypic variation present on the population. Genetic advance is the rate of change on a population under selection and difference between parental and progeny values. The genetic gains were estimated by following formula; Genetic gain = $H \times Sf \times I$, where; H = heritability in broad sense, Sf = phenotypic standard deviation, i = selection intensity (1.40, 1.755 and 2.064 for 20, 10 percent and 5 percent selection, respectively) (Falconer and Mackay 1996).

Results and Discussion

Selection in the base populations

The results of selection applied in the base populations grown at Bornova and Alasehir in 2003–2004 growing season are shown (Tables 2 and 3).

Table 2. The estimates of genetic gains and the expected progeny population means as to grain yield per plant based on the selection applied at Bornova in 2003–2004 growing season

Population	Doses	Mean (g) (n = 100)	Standard deviation	Mean of selected group (n = 25)	Selection differential (g)	Genetic advance (g)	Expected plant yield (g)
Gonen	0	3.14±0.16	1.66	5.68	2.54	–0.11	3.03
Gonen	150	3.16±0.66	1.61	5.48	2.32	0.04	3.20
Gonen	300	2.66±0.14	1.48	4.52	1.86	0.41	3.07
Cumhuriyet	0	3.92±0.15	1.57	4.83	0.91	0.02	3.94
Cumhuriyet	150	3.36±0.17	1.71	6.14	2.78	–0.13	3.23
Cumhuriyet	300	3.25±0.16	1.62	5.47	2.22	0.01	3.26
Ziyabey	0	3.37±0.14	1.44	5.75	2.38	–0.22	3.15
Ziyabey	150	3.58±0.17	1.75	6.13	2.55	–0.02	3.56
Ziyabey	300	3.71±0.17	1.76	6.15	2.44	0.01	3.72
Izmir	0	2.26±0.08	0.89	3.53	1.27	0.05	2.31
Izmir	150	3.23±0.19	1.95	6.13	**2.90**	–0.01	3.22
Izmir	300	2.30±0.08	0.86	3.49	1.19	0.01	2.31
Basribey	0	2.95±0.12	1.27	4.78	1.83	0.02	2.97
Basribey	150	3.81±0.15	1.54	6.02	2.21	–0.11	3.70
Basribey	300	2.19±0.13	1.32	4.06	1.87	0.10	2.29

Table 3. The estimates of genetic gains and the expected progeny population means as to grain yield per plant based on the selection applied at Alasehir in 2003–2004 growing season

Population	Doses	Mean (g) (n = 100)	Standard Deviation	Mean of selected group (n = 25)	Selection differential (g)	Genetic advance (g)	Expected plant yield (g)
Gonen	0	3.11±0.16	1.63	5.15	2.04	0.33	3.44
Gonen	150	3.26±0.15	1.58	5.48	2.22	0.04	3.30
Gonen	300	2.93±0.15	1.50	5.10	2.17	0.06	2.99
Cumhuriyet	0	3.81±0.16	1.65	4.88	1.07	0.02	3.83
Cumhuriyet	150	3.42±0.16	1.61	6.20	2.78	–0.14	3.28
Cumhuriyet	300	4.02±0.17	1.77	5.46	1.44	0.01	4.03
Ziyabey	0	3.39±0.14	1.43	5.34	1.95	0.05	3.44
Ziyabey	150	3.75±0.17	1.78	6.18	2.43	0.01	3.76
Ziyabey	300	3.81±0.17	1.79	6.34	2.53	0.02	3.83
Izmir	0	2.32±0.09	0.97	3.67	1.35	0.01	2.33
Izmir	150	3.31±0.19	1.98	6.11	**2.80**	–0.07	3.24
Izmir	300	2.43±0.12	1.27	4.11	1.68	0.04	2.47
Basribey	0	2.94±0.12	1.29	4.81	1.87	0.01	2.95
Basribey	150	3.18±0.13	1.37	5.33	2.15	–0.05	3.13
Basribey	300	1.81±0.12	1.21	3.30	1.49	–0.07	1.74

Izmir had the biggest selection differential value at 150 Gy dose in both locations (2.90 and 2.80 g). The expected progeny means were in agreement with the actual mean of selected groups at both locations. Mostly, in all mutant wheat populations. the 150 Gy dose

applications have showed higher means for grain yield per plant trait compared to control populations.

The source of variation created by the method has been beneficial for breeding quantitative traits. In addition, it has been recorded in wheat that negative micro mutation can decrease the means of quantitative traits (Borojevic and Borojevic 1972; Kusaksız 1996; Budak and Yildirim 2001; Irfaq and Nawab 2001; Jamil and Khan 2002). Besides, harmful micro mutations that cause lower means of quantitative traits may be overcome during the selection process. Having some agreements between the expected single plant yields and the actual means of the selected groups at this location could be accepted as an indicator of positive selection.

Selection in the progeny populations

The mutant populations had higher plot yield means than the control populations (Table 4). For instance, Ziyabey at 150 Gy dose at Bornova and Alasehir locations (219.1 g and 220.8 g) had high means as compared to control populations, respectively (199.3 g and 190.9 g). It could be concluded that mutant populations (by a majority 150 Gy dose) had high plot yield as compared the control cultivars. The higher expected plot yields obtained for mutant populations were promising. Therefore, a second stage selection was applied to the mutant population in order to select mutant lines with high yield and good agronomical traits. Twenty percent of the top yielding progeny rows in each mutant and control population were selected and genetic gain and expected plot yield were estimated. The results of the second stage selections are given in Table 4. The estimates of genetic gain for the mutant progeny populations were higher than those of the control populations. Ziyabey at 150 Gy dose in Bornova location and Izmir at 300 Gy in Alasehir location had higher genetic gains compared with the control population in both locations, respectively (72.32 g and 74.48 g) (Table 4).

The high genetic gain estimates obtained as a result of the second stage selection for plot yield in the mutant populations indicated positive effects of selection on means. Some researchers indicated that genetic gain obtained by selection compared each generation of the mutant population or line with the best lines selected from control population (Gaul and Hesemann 1966).

Agronomical characteristics of selected mutant lines

The highest top yielding mutant genotypes from each population were selected advanced to the micro yield testing in the breeding program (Table 5). Those mutant genotypes had better agronomic traits when compared to the control cultivars. The findings indicated that selection done using micro mutant populations has had higher yield than the control population. In this research, these populations are used usually from 150 Gy doses which increased the frequency of positive changes (Gaul 1965; Gustaffson et al. 1968). Increasing the dose has enhanced the variability and the frequency of the negative effects (Cagirgan and Yildirim 1989).

Table 4. The means, range, coefficient of variation, phenotypic standard deviations, genetic gain, expected plot yield of the plot/yields for progeny populations grown at Alasehir locations in 2004–2005 growing season (n = 25 for each population)

Population	Dose	Mean (g)		Range		C.V (%)		Phenotypic Sd. Deviation		Heritability		Genetic Gain (g)		Expected Plot Yield (g)	
		B	A	B	A	B	A	B	A	B	A	B	A	B	A
Gonen	0	200.6	197.5	148.7 357.5	148.7 290.7	21.8	19.1	51.47	40.04	0.10	0.08	7.21	4.48	207.81	201.98
	150	198.9	199.0	149.7 289.6	151.6 291.3	18.3	18.3	35.31	35.31	0.84	0.84	41.52	41.52	240.42	240.52
	300	177.6	185.8	124.2 300.3	136.9 301.3	25.6	20.6	43.27	38.25	0.50	0.99	30.29	53.01	207.89	238.81
Cumhuriyet	0	176.6	177.4	138.0 252.2	135.0 246.4	15.3	14.9	27.51	27.05	0.65	0.47	25.03	17.80	201.63	195.20
	150	216.6	218.4	178.6 296.0	179.2 297.5	13.4	13.0	28.42	30.52	0.90	0.71	35.81	30.84	252.41	248.74
	300	197.8	197.7	147.6 330.8	145.3 332.5	22.9	22.7	46.26	46.10	0.42	0.43	27.20	27.75	225.00	225.45
Ziyabey	0	199.3	190.9	157.9 346.9	151.2 269.3	17.8	12.7	42.98	26.43	0.88	0.25	52.95	9.25	252.25	200.15
	150	219.1	220.8	256.6 350.2	155.0 361.2	24.1	21.9	**52.18**	**48.14**	**0.99**	**0.97**	**72.32**	**65.37**	**291.42**	**286.17**
	300	221.7	229.4	169.9 331.9	159.8 335.4	20.9	19.6	**48.14**	**43.39**	**0.98**	**0.98**	**66.05**	**59.53**	**287.75**	**288.93**
Izmir	0	129.2	132.6	101.2 198.7	97.6 230.4	19.3	22.9	23.58	30.47	0.72	0.48	23.77	20.48	152.97	153.08
	150	220.6	217.5	164.9 298.3	155.0 340.9	19.6	22.2	43.76	49.54	0.99	0.98	60.65	67.97	281.25	285.47
	300	126.7	149.6	93.2 182.2	94.7 250.4	19.1	35.1	24.42	53.74	0.99	0.99	33.85	74.48	160.55	224.08
Basribey	0	172.8	174.5	135.0 213.0	135.0 221.0	14.8	14.2	26.33	24.53	0.99	0.18	36.49	6.18	209.29	180.68
	150	213.0	190.4	178.6 284.4	110.9 261.3	11.3	16.0	24.04	32.31	0.90	0.42	30.29	19.00	243.29	209.40
	300	149.9	116.5	99.4 240.1	64.8 260.3	27.7	49.9	39.72	59.60	0.10	0.57	5.56	47.56	155.46	164.06

B: Bornova; A: Alasehir

Table 5. Means of five traits of mutant and control lines selected at Bornova and Alasehir locations in 2004–2005 growing season

Population	Doses	Location	Plant yield per plant (g)	Kernel number in spike (number)	1000-kernel weight (g)	Plant height (cm)	Spike height (cm)
Gonen	0	Bornova	5.57	47.56	36.34	62.48	7.68
Gonen	150	Bornova	5.52	48.12	37.70	64.00	8.29
Gonen	300	Bornova	4.93	44.34	36.04	62.82	6.99
Gonen	0	Alasehir	5.48	48.72	36.34	65.90	8.30
Gonen	150	Alasehir	5.52	48.12	37.70	63.94	8.29
Gonen	300	Alasehir	5.16	44.94	36.04	60.12	7.00
Cumhuriyet	0	Bornova	4.85	45.46	50.88	80.74	10.58
Cumhuriyet	150	Bornova	**6.01**	43.30	46.74	71.20	10.44
Cumhuriyet	300	Bornova	5.48	47.76	51.30	74.56	11.08
Cumhuriyet	0	Alasehir	4.90	45.46	50.76	80.38	10.56
Cumhuriyet	150	Alasehir	**6.06**	48.62	50.08	71.46	10.48
Cumhuriyet	300	Alasehir	5.47	48.24	51.12	74.48	10.96
Ziyabey	0	Bornova	5.53	46.92	37.32	68.06	8.63
Ziyabey	150	Bornova	**6.11**	47.70	37.92	71.12	8.97
Ziyabey	300	Bornova	**6.16**	42.54	37.88	63.64	8.35
Ziyabey	0	Alasehir	5.39	47.28	37.32	69.94	8.62
Ziyabey	150	Alasehir	**6.19**	47.76	37.92	71.02	8.92
Ziyabey	300	Alasehir	**6.36**	42.30	37.92	63.54	8.53
Izmir	0	Bornova	3.58	42.78	33.88	64.78	7.06
Izmir	150	Bornova	**6.12**	51.48	35.24	64.88	9.66
Izmir	300	Bornova	3.50	44.76	33.58	57.50	7.05
Izmir	0	Alasehir	3.68	42.78	33.80	66.50	7.08
Izmir	150	Alasehir	**6.04**	50.76	35.22	66.06	9.64
Izmir	300	Alasehir	4.15	45.72	33.68	59.56	7.28
Basribey	0	Bornova	4.80	41.16	37.28	66.82	10.34
Basribey	150	Bornova	**5.91**	43.18	38.24	61.88	10.36
Basribey	300	Bornova	4.16	53.34	38.38	59.73	8.52
Basribey	0	Alasehir	4.82	39.66	37.90	62.40	10.54
Basribey	150	Alasehir	5.28	42.68	36.96	60.92	10.44
Basribey	300	Alasehir	3.23	52.76	37.40	59.30	8.86

The results obtained from this study imply the increase means in the progeny population were higher compared to control. The similar results have been reported by Allard (1999); Gustafsson et al. (1968); Yildirim (1982); Kusaksiz (1996); Yildirim et al. (2005); Kusaksiz and Dere (2008). It noted that some control populations also had positive expected genetic gain. Some experts say that even in pure lines after selection, genetic variation can be detected (Gustafsson et al. 1968; Cagirgan and Yildirim 1989). As a matter of course, mutations followed by selection or environmental effects can give unexpected results.

Conclusions

Selection applied for high individual plant yield in the base population and selection applied for high plot yield in the progeny population resulted in mutant lines with improved agronomical and quality characteristics. Therefore, it may be concluded that mutation breeding in common wheat will be successful if suitable techniques in constructing the base population and applying selection in the base and offspring populations are used. The favorable gamma rays dose in the study was found to be 150 Gy for the reason that of its stimulatory effect on the characters.

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