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Determining Some Yield and Quality Characteristics of Mutants Induced from a Durum wheat (*Triticum durum* Desf.) Cultivar

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Abstract: Mutation breeding is one of the breeding methods used successfully in durum wheat for selecting lines with increased agronomic values. The aim of this study was to select mutant lines having a better agronomic potential than the mother variety Gediz-75 in the M_6 and M_7 generations. The mutants were derived from the variety Gediz-75 of durum wheat (*Triticum durum* Desf.). The seeds were either irradiated with gamma rays at Cobalt 60 (^{60}Co) or treated with ethyl-methane-sulfonate (EMS). Eighteen selected mutants and the mother variety Gediz-75 were examined in the M_6 and M_7 generations for yield and quality characteristics. The experiments were organized in a randomized complete block design with 3 replications. Gdem-2 and Gdem-12 showed yield stability across different environments, but the increases were not significant compared with Gediz-75. Therefore, more information on the new years and locations would greatly facilitate the evaluation of these lines. Gdem-4 had percentages of yellowberry kernels close to those of Gediz-75 in M_7. This high quality line is a promising parent candidate for quality breeding. The utilization of the high spike length of Gdem-2-1 by crossing to the mother variety or other varieties could give rise to new lines whose agronomic features could be superior to those of both parents.

Key Words: durum wheat, mutant, mutation breeding, yield, yellowberry kernel

Makarnalık (*Triticum durum* Desf.) Bir Buğday Çeşidinden Elde Edilen Mutantların Bazı Verim ve Kalite Özelliklerinin Belirlenmesi

Özet: Mutasyon ıslahı tarımsal değerleri artan hatların seçimi için makarnalık buğdayda başarılı bir şekilde kullanılan ıslah metotlarından birisi olmuştur. Bu çalışmanın amacı anaç çeşit "Gediz-75"den daha iyi bir tarımsal potansiyele sahip olan mutant hatları M_6 ve M_7 kuşaklarında elde etmektir. Mutantlar Gediz-75 makarnalık buğday (*Triticum durum* Desf.) çeşidinden üretilmiştir. Tohumlara hem Cobalt 60 (^{60}Co) kaynağında gama ışınları hem de ethyl-methane sulfonate (EMS) uygulanmıştır. Seçilen 18 mutant ve anaç çeşit Gediz-75 M_6 ve M_7 kuşaklarında verim ve kalite özellikleri bakımından denemeye alınmıştır. Denemeler üç tekerrürlü tesadüf blokları deneme desenine göre kurulmuştur. Gdem-2 ve Gdem-12 farklı çevrelerde verim stabilitesi göstermişlerdir, ancak verimdeki artışlar Gediz-75'e göre önemli değildir. Bu nedenle yeni yıllar ve lokasyonlarda elde edilecek bilgi bu hatların değerlendirilmesinde büyük kolaylık sağlayacaktır. Gdem-4, M_7 generasyonunda Gediz-75'e yakın dönmeli tane oranları vermiştir. Bu hat, yüksek kalitesi nedeniyle kalite ıslahı için ümitvar bir anaç adayıdır. Gdem-2-1'in yüksek başak uzunluğundan anaç çeşit veya diğer çeşitlerle melezlenerek yararlanılması anaç çeşitlere göre üstün agronomik özelliklere sahip yeni hatların elde edilmesini sağlayabilir.

Anahtar Sözcükler: makarnalık buğday, mutant, mutasyon ıslahı, verim, dönmeli tane

Introduction

Durum wheat production is restricted to marginal lands although this crop is of great economic importance in Turkey. Consequently, breeders were led to improve high yielding varieties that could compete with the bread wheat varieties in yielding ability. Mutation breeding has been used successfully in several crops for breeding agronomically important traits (Maluszynski et al., 1995). Bozzini et al. (1973) reported that it was possible to select mutant lines with increased agronomic value in durum wheat. Recently, 28 durum wheat varieties worldwide have been released by using mutagens (FAO/IAEA, 2003). In addition, induced durum wheat mutants have been intensively utilized in hybridization programs (Scarascia-Mugnozza et al., 1991).

Mutation breeding was developed to obtain diverse

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and valuable materials. If the desired genetic variability or a specific character is not available in a crop, then mutation breeding is a logical step (Knott, 1991). The range and frequency of desirable mutants induced may differ with mutagen and genotype (Konzak, 1987). The mutants induced in wheat have potential not only for hybridization programs but also for direct release.

Genetic variability produced in the M_2 and M_3 generations after mutagen applications allows the selection of mutant types with desirable changes. The performance of uniform M_{4-5} lines may be evaluated in replicated tests for the character under selection of important agronomic characters. The best mutants have been tested for release as varieties or for use as parents from generations M_6 to M_9. The aim of this study was to select mutant lines having a better agronomic potential than the mother variety Gediz-75 in the M_6 and M_7 generations.

Materials and Methods

This research was conducted in the 2000-2001 and 2001-2002 growing seasons at the Kazova Plain in Tokat, Turkey. The experimental soils were slightly alkaline (pH = 7.2-7.9), medium in calcium carbonate content (8.8-10.9%), poor in organic matter (1.48-1.81%) content and in P content (41.2-34.4 kg P_2O_5 ha^{-1}), and high in K content (796.0-376.0 kg K_2O ha^{-1}). Long-term average precipitation for this region was 387.2 mm per year. The amount of precipitation in the first year growing period was much lower (225.5 mm) than that in the second year (399.0 mm).

As plant materials, mutants derived from the Gediz-75 variety of durum wheat (*Triticum durum* Desf.) were used. Gediz-75 is an alternative type, of medium height, with strong straw, high yielding but with a low "semolina" flour yield. It was registered in 1986 and was adapted to the coastal regions of Turkey. Dry seeds, equilibrated at 11% water content, were irradiated at the Nuclear Research and Training Center, Ankara, Turkey, with 50 and 100 Gy (Gy = Gray (1 Gray = 10 krad)) gamma rays at a Cobalt 60 (^{60}Co) source as a physical mutagen (FAO/IAEA, 1977). Seeds without presoaking were also treated with 0.1%, 0.2%, 0.3%, and 0.4% doses of ethyl-methane-sulfonate (EMS) at 24 °C for 8 h and were washed for 6 h after treatment (Çiftçi et al., 1988).

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. The M_1 and M_2 generations were grown in Tokat-Kazova in 1996 and 1997. Selection of mutants was carried out in the M_2 and M_3 generations. M_2 plants showing a difference from the control and plants with desired phenotypes were harvested individually. Then M_3 progeny from selected M_2 plants according to the pedigree selection procedure were grown (Gaul et al., 1969). 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 generations (Bagnara et al., 1973). Population sizes of M_1 to M_3 are given in Table 1.

The mutants with good yielding properties as compared to the mother variety were transferred to the

Table 1. Population sizes in the M_1, M_2 and M_3 generations.

Doses	M_1 spikes (No.)	M_2 plants (No.)	Sampling M_2 plants (No.)	Growing lines in M_3 (No.)
Control	40	1102	100	20
EMS 0.1%	94	2595	100	25
EMS 0.2%	105	2879	100	25
EMS 0.3%	73	1975	100	25
EMS 0.4%	69	1859	100	25
Control	21	522	50	10
Gama 50 Gy	113	3013	100	25
Gama 100 Gy	50	1327	50	20

M_4 generation. Twenty-nine lines were examined along with Gediz-75. Description of the mutants and evaluation of their practical values were first tested for other important agronomic characteristics in the M_4 and M_5 generations (Fehr et al., 1987). The M_4 and M_5 generation tests were performed in the 1998-1999 and 1999-2000 growing seasons under Kazova Plain ecological conditions in Tokat. Selected mutant lines were evaluated for heading period, plant height, spike length, the number of kernels per spike, single spike yield, 1000 kernel weight and grain yield traits by comparison with Gediz-75. Eighteen desirable mutant lines from the M_5 generation were examined for release as varieties in the M_6 and M_7 trials. Thirteen of these (Gdem-1, Gdem-2, Gdem-4, Gdem-5, Gdem-7, Gdem-11, Gdem-12, Gdem-13, Gdem-14, Gdem-15, Gdem-16, Gdem-18, and Gdem-2/1) originated from the population treated with EMS, and the remaining mutant lines (Gdga-1, Gdga-2, Gdga-4, Gdga-10, and Gdga-11) were induced by gamma-irradiation. In addition, Gediz-75 was used as the mother variety.

The experiments were organized in a randomized complete block design with 3 replications. Each plot consisted of four 3.0 m long rows. Seeds were sown 20 cm apart in rows with a density of 400 plants per square meter. Sowing was performed by hand on November 7, 2000, in the first year of the trial and on November 2, 2001, in the second year. The total quantity of P fertilizer (60 kg P_20_5 ha^{-1}) was applied during sowing together with half of the N (totally 120 kg N ha^{-1}). The rest of the N was applied before the joint growth stage. Heading period was determined as a day between the emergence of plants date and the heading date of 75% of the plants in the plot. After removing a 0.5 m area from the beginning of each row, a 1.6 m^2 of plot was harvested. The observations and measurements were obtained from 10 spikes. Harvesting was performed by hand on July 8, 2001, in the first year of the trial and on July 12, 2002, in the second year.

Data were analyzed with ANOVA using MSTATC (Statistical Software Package). The comparison of the lines means was performed using the Duncan's test.

Results and Discussion

Yield components and grain yield

In many mutant lines, heading dates were significantly delayed in M_6 and M_7 (Table 2). Gdem-2-1 showed significantly late heading compared to the mother variety and other mutants in both generations. A similar result was reported by Shah et al. (1987). Earliness did not reach the level shown by the mother variety. Mutants transferred to the M_4 generation have also shown late heading periods. The reason for this could be performing selection especially for single plant grain yield. Frequency of early heading mutants appears to be lower than that of mutants with a late heading period (Larik et al., 1984). In addition, the genotype of the original variety greatly affects the occurrence of early heading mutants in wheat (Yamagata et al., 1989).

Five mutants in M_6 had a higher number of spikes per square meter compared to Gediz-75. Among these lines, Gdem-12 not only had the highest number of spikes, but also the highest yield (Table 2). The number of spikes per square meter of mutant lines in M_7 was lower than that of Gediz-75, except for Gdga-2. Gdga-2 in both generations had higher values and produced the highest yield in M_7. In addition, Gdem-2-1 had significantly lower numbers of spikes in both generations and its grain yields were low. The reasons for the differences in the numbers of spikes per square meter in different mutants are not fully understood. They may, however, be due to differences in the number of plants per square meter, tillering capacity and tolerance of genotypes to abiotic stress conditions. The mutant lines with a better tillering capacity could be more resistant to drought conditions and have a more efficient water use capacity. Therefore, yield reduction under adverse conditions may be minimized by selecting these lines (Scarascia-Mugnozza et al., 1991; Siddiqui et al., 1991).

Mutants with long or short spikes were observed in the M_6 generation, from which only Gdem-2-1 exhibited a spike length significantly higher than that of Gediz-75 (Table 2). In M_7, spike lengths of mutant lines were higher compared to the mother variety, except for Gdga-11. Moreover, increases in Gdem-11, Gdem-14 and Gdem-2-1 were significant in M_7. Gdem-2-1 in both generations gave the highest values, but its grain yields were low. Borojevic (1991) also determined that some mutant lines with long spikes had weaker agronomic traits and higher sterility. Gdem-11, having long spikes, maintained its high yield in the subsequent generations. A variety with long spikes may be preferred for additional yield stability. The positive correlation between spike

Table 2. Heading period, number of spikes per square meter and spike length values of mutant lines and Gediz-75 in the M_6 and M_7 generations.

Mutants and Gediz-75	Heading period		Number of spikes per square meter		Spike length (cm)	
	M_6	M_7	M_6	M_7	M_6	M_7
Gdem-1	181.3 bc	197.7 c-g	265.0 b-f	355.0 cde	6.9 b-g	7.5 bc
Gdem-2	178.0 e	196.0 f-j	280.0 a-e	401.7 bcd	6.5 c-g	7.9 bc
Gdem-4	181.3 bc	197.3 d-h	265.0 b-f	405.0 bcd	7.1 b-e	8.1 bc
Gdem-5	177.7 e	195.0 g-j	220.0 c-f	405.0 bcd	6.6 c-g	7.4 bc
Gdem-7	183.0 b	200.0 bcd	320.0 ab	403.3 bcd	7.0 b-f	8.2 bc
Gdem-11	182.7 b	197.7 c-g	215.0 def	405.0 bcd	7.5 bc	8.3 b
Gdem-12	178.7 de	196.7 e-ı	371.7 a	346.7 cde	7.6 bc	8.0 bc
Gdem-13	182.3 b	200.3 bc	310.0 a-d	321.7 cde	6.9 b-g	8.1 bc
Gdem-14	181.0 bcd	196.3 f-ı	241.7 b-f	303.3 e	7.8 b	8.4 b
Gdem-15	183.3 b	199.3 b-e	230.0 b-f	381.7 b-e	6.7 b-g	8.1 bc
Gdem-16	183.3 b	200.0 bcd	240.0 b-f	308.3 de	6.7 b-g	8.1 bc
Gdem-18	183.0 b	200.7 b	210.0 ef	375.0 b-e	7.1 b-f	8.0 bc
Gdem-2-1	193.7 a	205.7 a	178.3 f	331.7 cde	11.1 a	9.9 a
Gdga-1	182.7 b	198.3 b-f	238.3 b-f	381.7 b-e	7.3 bcd	8.3 bc
Gdga-2	177.7 e	194.7 hıj	300.0 a-e	530.0 a	6.0 fg	7.5 bc
Gdga-4	176.3 ef	195.3 g-j	276.7 b-e	411.7 bc	5.8 g	7.6 bc
Gdga-10	178.7 cde	195.3 g-j	210.0 ef	365.0 b-e	6.0 efg	7.5 bc
Gdga-11	176.7 ef	194.3 ıj	315.0 abc	413.3 bc	6.3 d-g	6.2 d
Gediz-75	174.7 f	193.3 j	290.0 a-e	456.7 ab	6.8 b-g	7.3 c
Mean	180.8	197.6	261.9	384.3	7.0	7.9
Blocks	NS	*	NS	*	*	**
Lines	**	**	**	**	**	**
Error						
CV %	0.6	0.6	14.0	9.7	6.2	4.9

*,** indicate significance at 0.05 and 001 respectively, NS indicates not significant
Different letters in the same column indicate a significant difference

length and yield (Korkut et al., 1993) promotes the selection of long spiked lines in breeding studies.

Significant differences ($P < 0.01$) among the lines for test weight were observed in both generations. Only Gdem-12 in M_6 exhibited a test weight higher than that of Gediz-75, but the difference was not statistically significant, whereas a clear reduction was determined in Gdem-2-1 (Table 3). In M_7, all mutant lines had lower test weights compared to the mother variety. The test weight in the M_6 generation was slightly higher than that of the M_7 generation. The reason for increasing test weights could be the lower numbers of kernels per spike in M_6 (Finney et al., 1987). Test weights under more favorable conditions in M_7 decreased with kernel deformation due to shriveling together with increases in the number of kernels per spike. In M_6, the genotypes had not only the highest test weight, but also high percentages of vitreous kernel. However, grain yield decreased while the quality characteristics of genotypes increased. Gdem-12 had not only high test weights but also high grain yields. A high test weight is an important quality character in durum wheat, being directly related to high “semolina” flour yield (Crowley et al., 1991). A positive correlation between test weights and grain yield

Table 3. Test weight, grain yield and yellowberry kernel percentage values of mutant lines and Gediz-75 in the M_6 and M_7 generations.

Mutants and	Test weight (kg)		Grain yield (kg ha^{-1})		Yellowberry kernel percentages (%)	
Gediz-75	M_6	M_7	M_6	M_7	M_6	M_7
Gdem-1	82.7 a-d	79.8 ab	1915 c-h	4314 b	7.7 a	23.8 de
Gdem-2	81.3 bcd	81.8 a	2787 ab	7057 a	4.9 bc	44.7 b
Gdem-4	80.7 cd	81.0 a	2285 a-d	6375 a	6.5 ab	18.8 e
Gdem-5	83.2 a-d	82.8 a	1909 c-h	6432 a	4.6 bc	46.8 b
Gdem-7	82.5 a-d	81.7 a	1843 c-h	6508 a	5.6 bc	35.8 c
Gdem-11	84.2 ab	81.9 a	2052 c-g	7519 a	4.2 c	51.6 b
Gdem-12	85.3 a	82.6 a	2884 a	7262 a	4.0 c	48.2 b
Gdem-13	81.5 bcd	79.6 ab	1637 d-h	6242 a	4.8 bc	46.0 b
Gdem-14	84.2 ab	81.0 a	2555 abc	6359 a	5.4 bc	49.8 b
Gdem-15	81.5 bcd	81.3 a	1654 d-h	6278 a	4.4 c	46.8 b
Gdem-16	81.5 bcd	80.7 ab	1465 fgh	6235 a	5.5 bc	27.8 cde
Gdem-18	81.2 bcd	79.6 ab	1836 c-h	6173 a	5.7 bc	29.2 cd
Gdem-2-1	73.7 e	77.6 b	1395 gh	3000 b	4.6 bc	7.2 f
Gdga-1	83.8 abc	82.3 a	2164 b-f	7501 a	2.2 d	33.6 c
Gdga-2	80.1 d	80.3 ab	1681 d-h	7575 a	4.9 bc	34.0 c
Gdga-4	82.8 a-d	80.4 ab	1483 e-h	6656 a	5.5 bc	30.8 cd
Gdga-10	82.4 a-d	81.5 a	1186 h	6727 a	5.0 bc	66.8 a
Gdga-11	82.7 a-d	82.4 a	2211 a-e	6522 a	4.8 bc	62.4 a
Gediz-75	84.4 ab	82.7 a	2511 abc	6702 a	4.4 c	20.0 e
Mean	82.1	81.1	1971	6391	5.0	38.1
Blocks	NS	NS	NS	NS	NS	NS
Lines	**	**	**	**	**	**
Error						
CV %	1.5	1.5	14.4	11.1	16.1	9.9

** indicates significance at 001, NS indicates not significant
Different letters in the same column indicate a significant difference

has been determined (Kırtok et al., 1988). Therefore, Gdem-12, with acceptable test weight and high grain yield, must be evaluated in the breeding programs.

Mutants generally had grain yields lower than that of Gediz-75 in the first year, and 7 mutants showed a marked reduction. In addition, Gdem-2, Gdem-12 and Gdem-14 had higher grain yields, but the differences were not statistically significant in M_6 (Table 3). These lines with an increased yield performance presented one or more improved characteristics. Other mutants could have been negatively affected by adverse conditions. In addition, mutants mostly exhibited heading periods significantly higher than that of Gediz-75 in M_6. Heading period also shows a clear response to environmental conditions. Therefore, Gdem-13, Gdem-15, Gdem-16 and Gdem-2-1 had lower grain yields. Since early types produce a longer heading-maturity period, the accumulation of dry matter in grain increased and consequently grain yield increased as well (Klatt et al., 1973). In M_7, 6 out of 18 tested mutants exhibited grain yields higher than that of Gediz-75, but the increases were not significant. There were more mutant lines with higher yields when compared with M_6. However, mutant lines provided similar grain yields to Gediz-75, except for Gdem-1 and Gdem-2-1. Gdga-2 in the second year had the highest grain yield due to the high number of spikes per square meter. Gdem-2 and Gdem-12 in the subsequent generations showed a similar yield performance. Yield stability is also important in wheat areas characterized by annual fluctuations in temperature and precipitation. Grain yields obtained in M_6 (1971 kg ha^{-1}) did not show any similarity to those observed in the M_7 (6391 kg ha^{-1}) generation. The average grain yield in M_6 was lower than that in M_7. Responses of the mutants depended on the environmental conditions, which varied during the generations. In the first year of the trial, the low number of spikes per square meter negatively affected the grain yield although an increase in 1000-kernel weight was observed. The increase in grain yield in the M_7 generation depended on yield-attributing characters: number of spikes per square meter, number of kernels per spike and single spike yield.

Yellowberry kernel percentage

Yellowberry kernel percentages of mutants in both generations were generally higher than those of the mother variety (Table 3). However, Gdem-11, Gdem-12 and Gdga-1 had lower values compared to Gediz-75, and only the yellowberry kernel percentage (2.2%) of Gdga-1 was significantly decreased. Similarly, Gdem-4 and Gdem-2-1 in M_7 gave low values in comparison with Gediz-75. Yellowberry kernels affect milling quality and there was a negative relationship between the percentages of yellowberry and the protein content (Porceddu et al., 1973). Gdem-2-1 had not only a low percentage of yellowberry kernel, but also low test weights and grain yield. Bagnara et al. (1973) reported that mutant lines with a higher protein content tended to have lower yields with shorter culms, later heading times, lower test weights and lower percentages of yellowberry kernels. Gdem-4 had percentages of yellowberry kernels similar to those of Gediz-75 in M_7. This line with its high quality seems an ideal type for selection. The average percentage of yellowberry kernel in M_7 (38.1%) was considerably higher than that in M_6 (5.0%). Heavy annual precipitation in M_7 resulted in a higher accumulation of dry matter. Therefore, the percentages of yellowberry kernels increased. Ryan et al. (1997) determined that the responses for quality characters of genotypes clearly varied with growing conditions.

Promising mutants

Based on the results of this study, some mutant lines had better agronomic features than did others. Descriptions of these lines are given below:

Gdem-2 had heading periods close to those of the mother variety and showed yield stability across different environments.

Gdem-12 exhibited heading dates similar to those of Gediz-75 and had a low percentage of yellowberry kernel. In addition, this line maintained its yield performance and had high test weight values in both years.

Gdem-14, in both generations, had high spike lengths and its yield performance was similar to that of the mother variety. Its high test weight affected grain yield in M_6.

Gdem-2-1 with long spikes had a long heading period but was not resistant to drought conditions. This line had good quality with low yellowberry kernel percentages.

Gdga-2 exhibited a heading period similar to that of the mother variety and had a higher number of spikes per square meter in both generations.

Conclusion

Gdem-2 and Gdem-12 showed yield stability across different environments, but the increases were not significant compared with Gediz-75. Therefore, more information on the new years and locations would greatly facilitate the evaluation of these lines. Gdem-4 had percentages of yellowberry kernels close to those of Gediz-75 in M_7. This line with high quality seems an ideal type for selection. The utilization of the high spike length of Gdem-2-1 by crossing to the mother variety or other varieties could give rise to new lines whose agronomic features could be superior to those of both parents. Mutant lines having yield stability and high values of both yield and quality characters could be used for durum wheat improvement.

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