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Yield Performances of Advanced Bread Wheat Mutant Lines

Damla BALABAN GÖÇMEN[1*] **Oğuz BİLGİN[1]** **Alpay BALKAN[1]** **İsmet BAŞER[1]** **Kamil ÖZCAN[2]**

[1] Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Field Crops, Türkiye

[2] Tekirdağ Namık Kemal University, Thrace Seed Valley Application and Research Center, Türkiye

[*] Corresponding author e-mail: dgocmen@nku.edu.tr

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ABSTRACT

The aim of this study is to identify the advanced mutant lines created by mutagen application to Sagittario, Flamura 85, NKÜ Lider, NKÜ Asiya and Tekirdağ varieties that are superior in terms of yield compared to their parents and commercial varieties. Thirty-five mutant lines developed by through gamma rays parent varieties and nine bread wheat commercial check varieties were used material. Forty-nine wheat genotypes were tested using a partially balanced lattice design. According to the variance analysis, there were statistically significant differences in grain yield among the parent varieties, mutant lines and commercial varieties. The NZFE 285 mutant line was the highest grain yield with 5961.9 kg ha^{-1}. The mutant lines of NZFE 285, NZFE 289, NZFE 249, NZFE 256, NZFE 242, NZFE 260, NZFE 284, NZFE 288, NZFE 287, NZFE 292, NZFE 239, NZFE 267, NZFE 245, NZFE 274, NZFE 269, NZFE 262 and NZFE 255 were the other highest grain yielding lines. The lowest grain yield was in NKÜ Asiya variety with 4804.6 kg ha^{-1}, followed by NZFE 271 with 4814.6 kg ha^{-1}, NZFE 277 with 5006.6 kg ha^{-1}. The three mutant lines from Sagittario variety, one mutant line from the NKÜ Lider variety, two mutant lines from Tekirdağ variety, and two of mutant lines from the NKÜ Asiya variety were the higher grain yield compared to parent variety means. The average grain yield of the nine commercial bread wheat varieties was 5693.8 kg ha^{-1}. The mutant lines NZFE 285, NZFE 289, NZFE 249, NZFE 256, NZFE 242, NZFE 260, NZFE 284 and NZFE 288 were higher grain yield than the average of commercial varieties and their parents.

Keywords: Bread wheat, mutant line, grain yield, control, standard variety

Introduction

Cereals have been one of the most widely produced and consumed agricultural commodities since humanity adopted a settled lifestyle and adopted traditional agriculture. Wheat is the largest contributor, accounting for approximately 30% of global grain production and 50% of global grain trade (Akter and Rafiqul Islam, 2017). It is the second-largest cultivated cereal crop after rice, with global wheat production of approximately 761 million tons annually The largest world producers of wheat are China (with an estimated output of 137.7 million tons), EU (134.2 million tons), India (104.0 million tons), Russia (92.0 million tons), and the USA (44.9 million tons), and Türkiye ranked 9th with a production of 22.3 million tons (FAOSTAT, 2023). It is estimated that developing countries will need to increase their wheat production by 77% to meet the nutritional demands of the growing population, and the world will need an additional 198 million tons of wheat by 2050 to meet future demands (Sharma et al., 2015). Among the various ways and methods of increasing production, the most realistic one is to increase productivity per unit area. Among the various ways and methods of increasing production, the most realistic one is the increase in yield per unit area that can be achieved through new variety breeding and improvements in agronomic practices. Breeding of wheat varieties that combine high grain yield and stability under drought stress conditions is crucial to boost yield gains to ensure food security and enhance climate resilience in wheat production systems.

For this purpose, the most commonly used breeding method for breeders to obtain new genotypes is cross breeding. Mutation breeding is one of the most popular breeding methods among breeders in many countries around the world. Mutagenesis has played a key role in generating new genetic stocks for the improvement of economic traits, including grain yield and quality, phenological traits, disease resistance, and heat and drought tolerance (Kumar et al., 2024, Wang et al., 2024). Today, a total of 3,401 mutant cultivars have been developed directly or indirectly through mutations in 233 plant species across 75 countries worldwide. The largest number of mutant cultivars has been registered in China (835), Japan (505), India (348), Russia (216), the Netherlands (176), and Germany (171), respectively. In our country, a total of 15 mutant varieties have been registered in different plant species (IAEA, 2022). Considering the advances in mutation breeding globally, unfortunately, there are no commercial wheat varieties developed through mutation in our country yet. Mutagenesis has significant potential in the development of novel wheat varieties to enhance genetic gains for key traits, which are vital for ensuring food security (OlaOlorun et al., 2021). Mutagenesis shows as an easy and effective mean of inducing genetic variation. Several researchers have used mutation breeding to improve grains yield of bread wheat (Balkan, 2018; Nazarenko, et al., 2018). Physical mutagens were the most commonly used method in developing mutant varieties, with a rate of 78% compared to chemical mutagens (11%). Of the mutant varieties obtained with physical mutagens, 69% were treated with gamma rays and 22% with X-rays (IAEA, 2022). Mutation breeding has some advantages compared to crossbreeding breeding; Homozygosity occurs at F_6 or F_7 in crossbreeding breeding, whereas M_2 or M_3 occurs in mutation breeding (Chakraborty and Paul, 2013). Mutational breeding is used to improve plant traits when conventional breeding has failed, when desired traits are recessive, or to improve one or two other traits in a commercial variety (Van Harten, 1998; Ahloowalia and Maluszynski, 2001). It is also possible that a new character will be discovered that is not present in the parent genotype. Given that mutation is a viable, sustainable, flexible, unregulated, non-hazardous, environmentally acceptable, highly effective and cost-effective plant breeding method (Kainthura and Srivastava, 2015), mutation techniques need to be used more effectively in wheat breeding programs in our country. As a result of the mutations induced by mutagens, plants can exhibit a wide range of variations in morphological and yield-related characteristics compared to normal plants. Scientists have demonstrated the role of induced mutations in increasing the genetic variability for agronomic traits in various crop plants (Chen et al., 2019)

The aim of the study is to determine candidate elite variety lines by examining the yield performances of advanced bread wheat mutant lines developed from populations generated by gamma irradiation to commercial bread wheat varieties with different characteristics.

Materials and Methods

Seeds of Sagittario, Flamura 85, NKÜ Lider, NKÜ Asiya and Tekirdağ bread wheat varieties were irradiated with gamma rays from ^{60}Co source at the Ankara Nuclear Research and Training Center of the Turkish Atomic Energy before sowing the 2017. No selection was made until 2021, and the single ears of plants that were superior in terms of agronomic characteristics in the same year, that is, the M_4 generation, were sown as single ear rows in 2022. In 2023, seeds taken from single spike rows were sown in separate plots, and 35 mutant lines with high agricultural value (agronomically) were identified from them. These 35 promising mutant lines, were included in the experiment, along with non-mutagen treated parents and nine bread wheat varieties commonly sown in the region. The study was carried out with 7x7 partially balanced lattice design with three replications. The study was conducted in Süleymanpaşa (Tekirdağ), Hayrabolu (Tekirdağ), Edirne and Silivri locations in 2024-2025 growing season. The 50 kg ha^{-1} of pure nitrogen and phosphorus (20.20.0 fertilizer) at sowing, 69 kg ha^{-1} of pure nitrogen at the tillering stage, 46 kg ha^{-1} of pure nitrogen at the beginning of stem formation, and 39 kg ha^{-1} of pure nitrogen before heading was applied. Herbicides were used to control weeds in the trial. The plots were harvested with a HEGE-160 plot combine harvester, and the obtained grain yield values were converted to yield per hectare.

The test of significance of the differences between the means for mutant lines, control varieties and commercial varieties was determined using the TARPOP-GEN statistical analysis program, using a partially balanced lattice design for variance analysis. Because the differences between the blocks were statistically insignificant, analyses were conducted using a randomized complete block design. Differences between the means were determined using Tukey's significance test.

Results and Discussion

The results of variance analysis performed on grain yield data obtained from experiments conducted in 4 different locations of Thrace region with 35 advanced mutant lines developed by gamma irradiation of five bread wheat varieties, their parent varieties and check varieties, showed that the differences between the means of genotypes and locations were statistically significant. The average grain yields and significance of the genotypes obtained at four different locations are presented in Table 1.

In the study, the average grain yields of bread wheat mutant lines and their parent varieties ranged from 6755.0 to 4855.7 kg ha^{-1} for Edirne location, ranged from 6210.0 to 4670.0 kg ha^{-1} for Hayrabolu location, ranged from 5892.5 to 3632.5 kg ha^{-1} for Silivri location and ranged from 7363.4 to 4553.3 kg ha^{-1} for Tekirdağ location. The general average grain yield of genotypes for the four locations ranged from 5962.7 to 4864.6 kg ha^{-1}.

The average grain yield in the parent variety Sagittario changed between 5152.7 and 6198.4 kg ha^{-1} for the locations and the general mean was 5693.0 kg ha^{-1}. While 8 mutant lines for the Edirne location, 7 mutant lines for the Hayrabolu location and 7 lines for the Tekirdağ location yielded above the average of the parent variety, it was observed that no mutant line showed such a feature in the Silivri location. The average grain yield across locations was 5693.0 kg ha^{-1}, exceeded by the yields of the NZFE 265, NZFE 260 and NZFE 284 mutant lines.

The four mutant lines was higher the grain yield mean than that of parent variety of Flamura 85 of 6155.0 kg ha^{-1} for Edirne location. The five mutant lines for Hayrabolu location, all mutant lines for Silivri location and Seven mutant lines for Tekirdağ location gave the more yield than the parent variety. All mutant lines yielded higher grain yields than the parent variety mean across locations. Of the two mutant lines obtained from the NKÜ Lider variety, 1 mutant line in each of the 4 locations and 1 mutant line on average yielded higher grain yields overall. Of the three mutant lines obtained from the NKÜ Ergene variety, two in the Edirne and Hayrabolu locations, and one in the Silivri location, yielded grain yields higher than the non-mutagen treated parent, while three mutant lines failed to meet the non-mutagen treated parent in the Tekirdağ location. The average grain yield of the Tekirdağ bread wheat variety in the Edirne location was 5236.7 kg ha^{-1}, the four mutant lines gave higher grain yield over the mean. Three mutant lines in the Hayrabolu location, three mutant lines in the Silivri location, and one mutant line in the Tekirdağ location were higher grain yield than the parent variety. The average across locations was 5218.1 kg ha^{-1} and all mutant lines yielded higher yields.

The out of 35 mutant lines NZFE 285, NZFE 289, NZFE 249, NZZFE 284, NZFE 269 and NZFE 275 gave higher grain yield than the average grain yield of nine commercial cultivars was 6028.3 kg ha^{-1} for Edirne location. The mutant lines NZFE 249, NZFE 256, NZFE 288, NZFE 287, NZFE 239, NZFE 245, NZFE 269, NZFE 274 and NZFE 247 gave higher grain yield for Hayrabolu location compare to the average grain yield of nine commercial bread wheat cultivars of 5387.3 kg ha^{-1}. The average grain yield of 8 commercial varieties (4997.2 kg ha^{-1}) was lower than that of NZFE 285, NZFE 289, NZFE 249, NZFE 242, NZFE 260, NZFE 284, NZFE 288, NZFE 287, NZFE 267, NZFE 274, NZFE 269, NZFE 273, NZFE 281 and NZFE 246 mutant lines grain yield means for Silivri location. Regarding grain yield for Tekirdağ location, NZFE 285, NZFE 289, NZFE 249, NZFE 256, NZFE 242, NZFE 260, NZFE 284, NZFE 292, NZFE 267, NZFE 245, NZFE 278, NZFE 255 and NZFE 286 mutant lines gave higher values compared to check means. Comparing the average grain yield of 5600.1 kg ha^{-1} of commercial varieties at four locations, it is understood that the mutant lines NZFE 285, NZFE 289, NZFE 249, NZFE 256, NZFE 242, NZFE 260 and NZFE 284 gave higher grain yield. The study showed that the average grain yields of the mutant lines obtained from 4 different locations ranged from 4877.1 to 5960.0 kg ha^{-1}, indicating promising yield potential. These yields are similar to those reported by other researchers (Aydoğan and Soylu, 2017; Öztürk and Korkut, 2018; Kahraman et al., 2021; Ersöz and Başçiftci, 2024).

Conclusions

The results obtained showed that gamma irradiation of five bread wheat varieties resulted in a wide variation, and genotypes with different characteristics were obtained successfully. While the yields of the mutant lines varied across locations, 16 of the mutant lines showed higher yields than their parent varieties. Of the 35 mutant lines obtained, 13 mutant lines (NZFE 285, NZFE 289, NZFE 249, NZFE 256, NZFE 242, NZFE 260, NZFE 284, NZFE 292, NZFE 267, NZFE 245, NZFE 278, NZFE 255 and NZFE 286) surpassed the commercial check and parent varieties, demonstrating that these are promising elite lines and can be variety candidates for both the region and the wheat production regions of our country. In conclusion, it is understood that the mutant lines have promising results and could be considered as potential variant candidates.

Author Contribution Statement

All authors contributed equally to the preparation of this paper.

Conflicting Interest Statement

All authors declare that they have no conflict of interest regarding this article.

Table 1. Mean grain yield per hectare and significance groups for advanced mutant lines and their parent varieties.

Genotypes	Edirne	Hayrabolu	Silivri	Süleymanpaşa	Mean
Sagittario	***5528.3 b-i***	***5152.7 abc***	***5892.5 a***	***6198.4 a-g***	***5693.0 a-f***
NZFE 256	5483.3 c-i	5583.4 abc	5042.5 a-g	7363.4 a	5868.1 ab
NZFE 260	6024.3 a-h	4669.0 c	5817.5 ab	6688.4 a-d	5799.8 a-d
NZFE 284	6533.3 a-d	4928.3 bc	5220.0 a-f	6418.3 a-e	5775.0 a-e
NZFE 267	5790.0 a-i	4817.1 c	5387.5 a-d	6616.7 a-d	5652.8 a-g
NZFE 245	5175.0 ghi	5575.0 abc	5065.0 a-g	6706.7 a-d	5630.4 a-g
NZFE 274	5756.7 a-i	5422.7 abc	5355.0 a-e	5926.7 b-g	5615.3 a-g
NZFE 262	5743.3 a-i	5170.0 abc	5115.0 a-g	5976.7 b-g	5501.3 a-h
NZFE 273	5150.0 hi	5200.0 abc	5600.0 abc	6021.7 b-g	5492.9 a-h
NZFE 278	5270.0 f-i	4988.3 bc	4982.5 a-g	6623.3 a-d	5466.0 a-h
NZFE 281	5833.3 a-i	4775.7 c	5220.0 a-f	5900.0 b-g	5432.3 a-i
NZFE 286	5413.3 e-i	4985.7 bc	4825.0 a-i	6450.0 a-e	5418.5 a-i
NZFE 251	5753.3 a-i	5416.7 abc	4660.0 a-i	5530.0 d-h	5340.0 b-j
NZFE 263	5653.0 b-i	5107.7 abc	4638.5 b-i	5860.0 b-g	5314.8 b-j
NZFE 246	5345.0 e-i	4695.00 c	5582.5 abc	5611.7 c-h	5308.6 b-j
NZFE 265	5515.0 b-i	4957.7 bc	4760.0 a-i	5825.0 b-g	5264.4 c-j
NZFE 247	4855.7 i	5626.7 abc	4713.0 a-i	5585.6 c-h	5195.2 f-j
NZFE 266	5385.0 e-i	4873.4 bc	4597.5 b-i	5876.7 b-g	5183.1 f-j
NZFE 241	5148.4 hi	4645.0 c	5045.0 a-g	5671.7 b-h	5127.5 g-j
Flamura 85	***6155.0 a-h***	***5180.3 abc***	***4645.0 b-i***	***5920.0 b-g***	***5475.1 a-h***
NZFE 285	6211.7 a-h	5366.7 abc	5547.5 abc	6725.0 abc	5962.7 a
NZFE 289	6535.0 abc	5155.0 abc	5300.0 a-e	6723.3 abc	5928.3 a
NZFE 249	6755.0 a	5568.4 abc	5122.5 a-g	6200.0 a-g	5911.5 a
NZFE 242	5771.7 a-i	5280.0 abc	5462.5 a-d	6791.7 ab	5826.5 abc
NZFE 288	5981.7 a-h	5480.8 abc	5517.5 abc	5986.7 b-g	5741.7 a-f
NZFE 287	5735.0 a-i	5701.8 abc	5182.5 a-f	6042.4 b-g	5665.4 a-g
NZFE 292	5985.0 a-h	5038.4 bc	4952.5 a-g	6683.4 a-d	5664.8 a-g
NZFE 275	6406.7 a-e	5148.3 abc	4700.0 a-i	5903.4 b-g	5539.6 a-h
NKÜ Lider	***5881.7 a-i***	***5191.3 abc***	***4562.5 c-i***	***5593.1 c-h***	***5307.1 b-j***
NZFE 279	5466.7 c-i	5689.0 abc	4790.0 a-i	5743.3 b-g	5422.3 a-i
NZFE 283	6311.7 a-f	5096.7 abc	4436.5 c-i	5061.7 gh	5226.6 e-j
NKÜ Ergene	***6226.7 a-h***	***4982.7 bc***	***4270.0 d-i***	***5426.7 e-h***	***5226.5 e-j***
NZFE 243	6113.4 a-h	5035.7 bc	4605.0 b-i	5126.7 fgh	5220.2 e-j
NZFE 277	5836.7 a-i	5201.7 abc	3690.0 hi	5278.4 e-h	5001.7 hij
NZFE 271	6044.3 a-h	4670.0 c	3632.5 i	5161.7 fgh	4877.1 ij
Tekirdağ	***5236.7 f-i***	***5168.4 abc***	***4262.5 d-i***	***6205.0 a-g***	***5218.1 e-j***
NZFE 239	5726.7 a-i	6210.0 a	4950.0 a-g	5737.1 b-g	5656.0 a-g
NZFE 269	6240.0 a-g	4940.2 bc	5183.0 a-f	6071.7 b-g	5687.0 a-g
NZFE 255	5253.3 f-i	5204.4 abc	4925.0 a-h	6341.7 a-e	5431.1 a-i
NZFE 264	5453.0 c-i	5609.0 abc	4145.0 e-i	5754.7 b-g	5240.4 d-j

Table 2. Mean grain yield per hectare and significance groups for advanced mutant lines and commercial check varieties.

Genotypes	Edirne	Hayrabolu	Silivri	Süleymanpaşa	Mean
NZFE 285	6211.7 a-h	5366.7 abc	5547.5 abc	6725.0 abc	5962.7 a
NZFE 289	6535.0 abc	5155.0 abc	5300.0 a-e	6723.3 abc	5928.3 a
NZFE 249	6755.0 a	5568.4 abc	5122.5 a-g	6200.0 a-g	5911.5 a
NZFE 256	5483.3 c-i	5583.4 abc	5042.5 a-g	7363.4 a	5868.1 ab
NZFE 242	5771.7 a-i	5280.0 abc	5462.5 a-d	6791.7 ab	5826.5 abc
NZFE 260	6024.3 a-h	4669.0 c	5817.5 ab	6688.4 a-d	5799.8 a-d
NZFE 284	6533.3 a-d	4928.3 bc	5220.0 a-f	6418.3 a-e	5775.0 a-e
NZFE 288	5981.7 a-h	5480.8 abc	5517.5 abc	5986.7 b-g	5741.7 a-f
NZFE 287	5735.0 a-i	5701.8 abc	5182.5 a-f	6042.4 b-g	5665.4 a-g
NZFE 292	5985.0 a-h	5038.4 bc	4952.5 a-g	6683.4 a-d	5664.8 a-g
NZFE 239	5726.7 a-i	6210.0 a	4950.0 a-g	5737.1 b-g	5656.0 a-g
NZFE 267	5790.0 a-i	4817.1 c	5387.5 a-d	6616.7 a-d	5652.8 a-g
NZFE 245	5175.0 ghi	5575.0 abc	5065.0 a-g	6706.7 a-d	5630.4 a-g
NZFE 274	5756.7 a-i	5422.7 abc	5355.0 a-e	5926.7 b-g	5615.3 a-g
NZFE 269	6240.0 a-g	4940.2 bc	5183.0 a-f	6071.7 b-g	5608.7 a-g
NZFE 275	6406.7 a-e	5148.3 abc	4700.0 a-i	5903.4 b-g	5539.6 a-h
NZFE 262	5743.3 a-i	5170.0 abc	5115.0 a-g	5976.7 b-g	5501.3 a-h
NZFE 273	5150.0 hi	5200.0 abc	5600.0 abc	6021.7 b-g	5492.9 a-h
NZFE 278	5270.0 f-i	4988.3 bc	4982.5 a-g	6623.3 a-d	5466.0 a-h
NZFE 281	5833.0 a-i	4775.7 c	5220.0 a-f	5900.0 b-g	5432.3 a-i
NZFE 255	5253.3 f-i	5204.4 abc	4925.0 a-h	6341.7 a-e	5431.1 a-i
NZFE 279	5466.7 c-i	5689.0 abc	4790.0 a-i	5743.3 b-g	5422.3 a-i
NZFE 286	5413.3 e-i	4985.7 bc	4825.0 a-i	6450.0 a-e	5418.5 a-i
NZFE 251	5753.3 a-i	5416.7 abc	4660.0 a-i	5530.0 d-h	5340.0 b-j
NZFE 263	5653.0 b-i	5107.7 abc	4638.5 b-i	5860.0 b-g	5314.8 b-j
NZFE 246	5345.0 e-i	4695.0 c	5582.5 abc	5611.7 c-h	5308.6 b-j
NZFE 265	5515.0 b-i	4957.7 bc	4760.0 a-i	5825.0 b-g	5264.4 c-j
NZFE 264	5453.0 c-i	5609.0 abc	4145.0 e-i	5754.7 b-g	5240.4 d-j
NZFE 283	6311.7 a-f	5096.7 abc	4436.5 c-i	5061.7 gh	5226.6 e-j
NZFE 243	6113.4 a-h	5035.7 bc	4605.0 b-i	5126.7 fgh	5220.2 e-j
NZFE 247	4855.7 i	5626.7 abc	4713.0 a-i	5585.6 c-h	5195.2 f-j
NZFE 266	5385.0 e-i	4873.4 bc	4597.5 b-i	5876.7 b-g	5183.1 f-j
NZFE 241	5148.4 hi	4645.0 c	5045.0 a-g	5671.7 b-h	5127.5 g-j
NZFE 277	5836.7 a-i	5201.7 abc	3690.0 hi	5278.4 e-h	5001.7 hij
NZFE 271	6044.3 a-h	4670.0 c	3632.5 i	5161.7 fgh	4877.1 ij
NKÜ Asiya	5626.7 b-i	4991.0 bc	4047.5 f-i	4553.3 h	4804.6 j
Rumeli	5450.0 d-i	5306.0 abc	4787.5 a-i	6349.3 a-e	5473.2 a-h
Maden	5940.0 a-i	5406.7 abc	5570.0 abc	6280.0 a-f	5799.2 a-d
LG Albufera	6239.7 a-g	5640.0 abc	3932.5 ghi	6081.7 b-g	5473.5 a-h
Oğalis	6143.3 a-h	5335.0 abc	5837.5 ab	6056.7 b-g	5843.1 ab
Axum	6573.3 ab	5348.3 abc	5092.5 a-g	5975.0 b-g	5747.3 a-f
Saban	6044.7 a-h	5040.0 bc	4957.5 a-g	6060.0 b-g	5525.5 a-h
Gelibolu	6180.0 a-h	5401.7 abc	5342.5 a-e	6196.7 a-g	5780.2 a-e
Glosa	6056.7 a-h	6006.7 ab	5407.5 a-d	6345.2 a-e	5954.0 a
Commercial Varieties Mean	**6028.3**	**5387.3**	**4997.2**	**5988.7**	**5600.1**

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