Bulgarian Journal of Agricultural Science, 16 (No 1) 2010, 9-16
Agricultural Academy

MORPHOLOGICAL AND BIOLOGICAL PECULIARITIES OF MUTANT LINES OF NAKED OATS, CV. MINA

N. ANTONOVA and G. RACHOVSKA
Institute of Plant Genetic Resources "K. Malkov", BG – 4122 Sadovo, Bulgaria

Abstract

ANTONOVA, N. and G. RACHOVSKA, 2010. Morphological and Biological Peculiarities of Mutant Lines of Naked Oats, cv. Mina. *Bulg. J. Agric. Sci.*, 16: 9-16

A study was carried out on 25 parameters of mutant lines of spring naked oats cv. Mina, obtained by seed treatment. The mutant lines M 15/2, M 20/23, Mx 5/18 and Mx 20/56, obtained after gamma irradiation (in doses of 150 and 200 Gy) as well as treatment with natrium azide 0.10 mM and 10 mM, excelled the standard Mina in terms of grain yield, length, width and area of the flag and second leaves. They were characterized with shorter stem and early ripening. The used mutagenic factors and doses gave a reason to predict higher grain yields, when the area of the flag leaf was about 38 cm^2 and second leaf – 55 – 62 cm^2.

Key words: experimental mutagenesis, *Avena*, naked oats, breeding

Introduction

Experimental mutagenesis is popular among breeders and geneticists (Gramatikova et al., 2002; Maluszynski et al., 2001). Its inclusion in traditional breeding schemes leads to the increase of germplasm variability and use (Burrows et al., 2001). Up to the 90s of the past century, experimental mutagenesis accounted for the development of 80 wheat, 74 barley and 13 oat varieties (Mahan, 1989) and over 1800 varieties from direct mutant lines or their crosses (Ahloowalia and Maluszynski, 2001).

The interest in naked oats is great but its productive potential for grain yield is lower compared to hulled oats. The limited germplasm imposes the application of both conventional breeding and the methods of experimental mutagenesis. They contribute significantly to the enrichment of the existing genetic variability (Gramatikova and Mihov, 2005; Rachovska and Yanev, 1997; Valkova, 1997). Using gamma irradiation, Kibite (2002) obtained oat plants with variable phenotypic transformations such as reduced stalk, short peduncle of the panicle, extreme earliness, very long vegetation period and very wide leaves as well as variegated leaves.

The objective of the study was to use natrium azide and gamma irradiation to expand the genetic variability of the species *A. sativa* ssp. *nudisativa* with mutant lines, carriers of valuable agronomical traits.

Material and Methods

The research was carried out at the Institute of Plant Genetic Resources "K. Malkov" in 1998 – 2005. Seeds of spring naked oats cv. Mina (used as a standard for naked oats in Bulgaria) were treated with gamma rays Co^{60} in 4 doses – 50, 100, 150 and 200 Gy as well as 4 concentrations of natrium azide – 0.1

mM, 0.3 mM, 1 mM and 10 mÌ . The method was described in detail in other publications of our own (Rachovska and Antonova, 1995, 1996).

The selection of mutant generations and lines was performed according to the classical scheme of mutational breeding (Rukmanski, 2005). The productivity of mutant lines was evaluated in competitive trials in 3 and 4 replications on a production area of 10 m^2. Sowing took place in early spring, the earliest possible. Primary cultivar Mina was used as a standard. The indexes were calculated during the phases and scales as per the requirements of the international descriptors of COMECON (1984) and IBPGR (1985), namely:

1. Pubescence of penultimate leaf blade margins (score); 2. Duration of vegetative period (germination to heading – days, number); 3. Flag leaf attitude (score); 4. Pubescence of the last node (score); 5. Pubescence density of the last node (score); 6. Leaf to stem angle of attachment (score); 7. Second leaf pubescence (score); 8. Second leaf length (cm); 9. Second leaf width (cm); 10. Blade area of the second leaf (cm^2); 11. Flag leaf length (cm); 12. Flag leaf width (cm); 13. Blade area of the flag leaf (cm^2); 14. Flag leaf habit (score); 15. Panicle, attitude of branches (score); 16. Panicle, arrangement of branches (score); 17. Panicle, arrangement of spikelets (score); 18. Glumes, pubescence (score); 19. First grain, pubescence of lower glume (score); 20. First grain, pubescence density (score); 21. First grain, basal pubescence (score); 22. Basal pubescence length (score); 23. Stem height (cm); 24. Panicle color (score); 25. Grain yield (kg/da). Data were processed with SPSS software.

Results and Discussion

After the screening of about 4000 generations, 49 consolidated lines made it to the competitive testing. Morphological differences, expressed as a score, were found in the flag leaf (attitude and habit) and panicle (attitude, arrangement and color of branches). Those differences qualified as insignificant, being within the error range. Therefore, nine (9) indexes with quantitative expressions were discussed (Table 1).

All three values (length, width and leaf blade area) of the leaf indexes were below the standard in only 5 lines, treated with gamma rays at a dose of 50 Gy M

Table 1
Length, width and leaf area of the second and flag leaves, height, vegetative period and grain yield of mutant lines of cv. Mina

Mutant lines	Second leaf			Flag leaf			Height, cm	Vegetative period, days	Grain yield, kg/da %
	Length, cm	Width, cm	Leaf area, cm²	Length, cm	Width, cm	Leaf area, cm²			
1	2	3	4	5	6	7	8	9	10
1. Mina -St.	34.4	1.7	38.3	22.8	1.7	25.4	110	69.2	177.6
2. M 5/3/12	34.6	1.9	45.3	20.8	1.7	23.2	111	70	173.4
3. M 5/5	27.4	1.5	26.9	16.6	1.3	17.4	108	68.6	192.4
4. M 5/16	28.8	1.5	28.3	18.8	1.4	17.2	113	68.6	187.2
5. M 5/21	32.8	1.6	34.4	19.8	1.5	19.4	112	69.2	195.8
6. M 5/24	36.2	1.9	45	22	1.9	27.4	113	70	183.8
7. M 5/31	37	1.9	46	23.2	1.8	27.3	108	69.2	181.4
8. M 5/36	36.8	1.9	45.8	23.4	1.9	29.1	105	68.8	169.8
9. M 5/38	41.4	2.1	56.9	27.6	2	36.1	103	69.4	174.2

(continued)

Table 1 (continued)

1	2	3	4	5	6	7	8	9	10
10. M 5/50	37.2	2	48.7	24.6	1.9	30.6	110	66.8	172.8
11. M 10/21	36.6	1.7	40.7	23.2	1.6	24.3	103	69.4	175
12. M 10/26	37.8	2	49.5	23.8	2	31.2	112	69.6	188.4
13. M 10/27/2	38	2.2	54.7	24	2.2	34.6	105	69.2	175.2
14. M 10/37	38.4	2.2	55.3	23.6	1.9	29.4	109	68.4	172.8
15. M 10/46	40.2	2.1	55.3	24.8	2	32.5	108	68.6	176.4
16. M 10/48	40.2	1.9	50	23.8	1.9	29.6	110	68.2	183.4
17. M 15/2	39.8	2	52.1	24.4	2	32	110	68.4	208.6
18. M 15/14/2	39.8	2.3	59.9	26.8	2.4	42.1	107	69.6	166.6
19. M 15/21	42.6	1.9	53	26.2	1.9	32.6	104	68	154.8
20. M 15/25	37	2	48.5	25.2	1.9	31.4	108	69.4	191.6
21. M 15/44	40.2	2.1	55.3	25.2	2.1	34.7	103	69.2	189.2
22. M 15/7/1	39.2	1.9	48.8	26	1.8	30.6	103	68.2	181.8
23. M 20/23	43.8	2.1	60.2	27	2.1	37.1	100	67.6	207.6
24. M 20/26	40.8	1.9	50.8	25.2	1.9	31.4	98	67.8	158.4
25. M 20/48	41.4	1.8	48.8	26	1.8	30.6	106	69.6	180.6
26. Mx 5/3	37.4	2.3	56.3	24.2	2.1	33.3	107	68.2	164.8
27. Mx 5/13	39.2	2.2	56.5	24	2.1	33	102	69	187.2
28. Mx 5/18	40.2	2	52.7	24.6	1.9	30.6	103	69.4	206.4
29. Mx 5/31	40.8	2.2	58.8	28	2.1	38.5	107	68.6	188.4
30. Mx 5/47	38.8	1.9	48.3	23.4	1.7	26	100	66.8	158.8
31. Mx 5/48	36.8	2.1	50.6	23.6	1.9	29.4	99	69.2	165.6
32. Mx 10/15	38	2	49.8	22.8	2	29.9	108	69.6	184.2
33. Mx 10/33	38.2	2.1	52.5	24	2	31.4	115	68.6	168.4
34. Mx 10/38	37	2.1	50.9	22.8	2	29.9	107	69.2	176.8
35. Mx 10/42	38.8	2.1	53.4	25.4	1.9	31.6	109	70	165.4
36. Mx 10/43	41	2.2	59.1	26.4	2.1	36.3	105	70	164
37. Mx 15/20/7	38.6	2.3	58.1	25.2	2.1	34.7	110	68.4	156.2
38. Mx 20/3	36.8	2.3	55.4	22	2	28.8	110	70	190.4
39. Mx 20/55	38.4	2.3	57.8	23	2.2	33.1	110	69.4	183.2
40. Mx 20/56	36.8	2.2	53	21.8	2.1	30	108	69	192.4
41. Mx 20/4	39.4	2	51.6	24.4	1.9	30.4	114	67.2	165
42. Mx 20/22/7	40.2	2.2	57.9	24.6	2	32.2	102	69	169
43. Mx 20/24/4	39.2	1.8	46.2	23.4	1.7	26	91	68	166.6
44. Mx 20/31	39.4	1.9	49	24.8	1.9	30.9	111	69.6	173.4
45. Mx 20/37	38.6	2.1	53.1	26.6	2	34.8	110	69.8	178
46. Ms 2	37.2	1.8	43.8	23.6	1.7	26.2	97	68.8	134.8
47. Ms 3	38.6	2.1	53.1	24.8	1.9	30.9	94	69.4	144.2

(continued)

Table 1 (continued)

1	2	3	4	5	6	7	8	9	10
48. Ms 4	43.8	2	57.4	29.4	2.1	40.4	98	69.6	166.4
49. Ms 8	39	2.1	53.6	24.2	1	31.7	91	69.4	145
50. Ms14	37.8	1.7	42.1	24.8	1.7	27.4	98	69.4	136.8
Average ± s ×	38±0.4	2±0.03	50.4±1.0	24±0.3	1.9±0.0	31±0.7	106±0.81	68.9±0.11	175±2.31
Variance	9	0.04	53.6	4.9	0.06	24.6	32.8	0.64	267
VC%	7.9	10	14.50%	9.2	12.7	16.2	5.4	1.16	9.3
R	16.4	0.8	33.3	12.8	1.4	24.9	24	3.2	73.8
Min	27.4	1.5	26.9	16.6	1	17.2	91	66.8	137.8
Max	43.8	2.3	60.2	29.4	2.4	42.1	115	70	208.6

5/5, M 5/16, M 5/21, M 5/3/12 and M 5/24. The remaining 44 lines were characterized with a larger leaf area. Similar data on increased leaf area of mutant lines were also reported by Krashna-Murthy and Vasodevan (1984).

The period of grain filling and maturing in the conditions of Bulgaria often coincides with the typical for the season warm winds, called “dry winds”. That is why early varieties are given a definite priority. The vegetative period of the approved mutant lines is shorter than the standard, with minor deviations.

The main disadvantage of oats – lodging – is closely related to height. Therefore, the objective in mutant line breeding was a healthy and resistant stem. Except for 7 lines, the height of the remaining ones was equal to or lower than the standard. Eight (8) mutant lines had shorter stem (over 10 cm). Line Mx 20/24/4, treated with natrium azide dose of 10 mM, was characterized with a considerably shorter stem (up to 19 cm).

The maximum grain yield (116 - 117%) was obtained from the lines Mx 5/18, M 15/2 and M 20/23, treated with natrium azide in a concentration of 0.1 mM and gamma irradiation at doses of 150 and 200 Gy, respectively. Ten (10) mutant lines exceeded the yield of the standard cultivar Mina with 5 – 10 %.

The genetic similarity of the lines, developed by us, was presented by means of cluster analysis (Figure

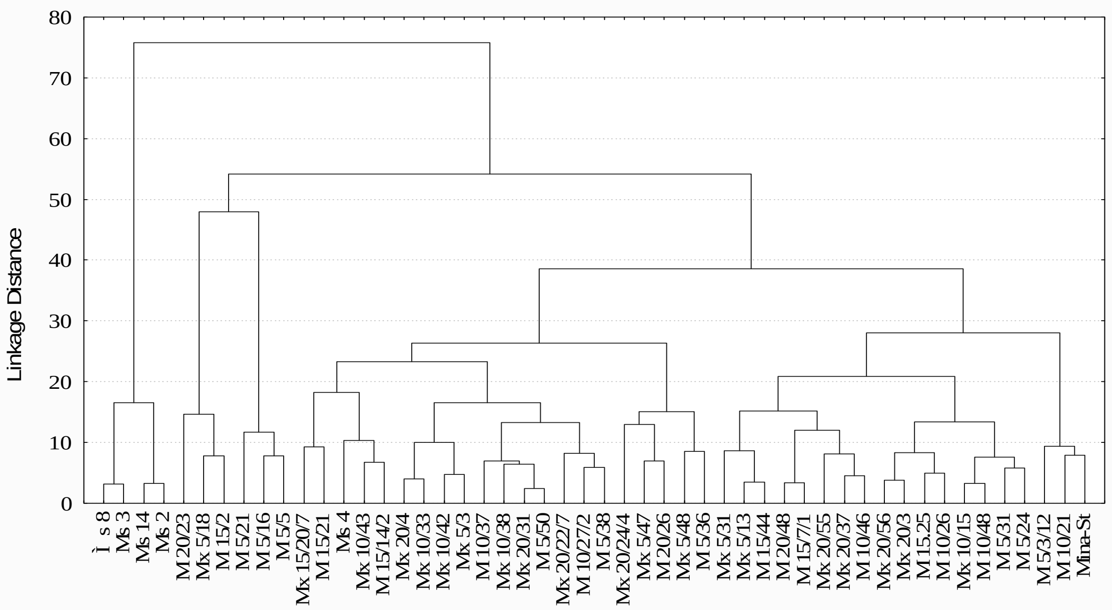

Fig. 1. A dendrogram of similarity of mutant lines of cv. Mina

Table 2
Average values of groups of similarities and their deviation from the total average of the indexes, included in the dendrogram (Fig. 1)

Groups of similarities	Indexes								
	Length II leaf, cm	Width II leaf, cm	Leaf area II leaf, cm²	Length flag leaf, cm	Width flag leaf, cm	Leaf flag leaf, cm²	Height, cm	Vegetative period, days	Grain yield kg/da
I group (3)	35.2	1.8	41.4	22.3	1.7	24.3	108	69.5	175.3
± D	-3	-0.2	-9	-1.8	-0.2	-6.2	2.3	0.6	0.3
II group (8)	37.5	2	49.6	23.1	1.9	29.4	109.7	69.4	186.9
± D	-0.7	0	-0.8	11	0	-1.1	4	0.5	11.9
III group (8)	39.7	2.1	54.3	25.4	2	33.5	106.1	69	183.6
± D	1.5	0.1	3.9	1.3	0.1	3	0.4	0.1	8.1
IV group (6)	39	1.9	49.8	24.4	1.8	29.7	99.3	68.3	165.6
± D	0.8	-0.1	-0.6	0.3	-0.1	-0.8	16.4	-0.6	-9.4
V group (6)	36.7	2	49.1	22.7	1.9	29.1	107.3	68.7	173.3
± D	-1.5	0	-1.3	-1.4	0	-1.4	1.6	-0.2	-1.7
VI group (4)	38.4	2.1	53.4	24.5	2	31.7	111.2	68.5	165.9
± D	0.2	0.1	3	0.4	0.1	1.2	5.5	-0.4	-9.1
VII group (5)	41.2	2.1	57.5	26.8	2.1	37.2	106.4	69.1	169.8
± D	3	0.1	7.1	2.7	0.2	6.7	0.7	0.2	-5.2
VIII group (6)	35.5	1.8	42.4	21.9	1.7	25.6	107.6	68.6	199.7
± D	-2.7	-0.2	-0.8	-2.2	-0.2	-4.9	1.9	-0.3	24.7
IX group (4)	38.1	1.9	48.1	24.3	1.6	29.5	95	69.2	140.2
± D	-0.1	-0.1	-2.3	0.2	-0.3	-1.5	10.7	0.3	-34.8

1). Three (3) basic groups (a, b and c) stood out at the highest hierarchical level. The Euclidean distance that expressed the differences between the mutant lines, was 78.

The first basic group (a) was most numerous (Table 2). It encompassed 40 mutant lines, including the standard variety Mina. Regardless of forming a large number of small groups of similarity – a total of 7 (Group I to VII) (Table 2), the genetic differences between them were the least expressed – up to level 40. A positive but insignificant expression for all indexes was observed only in group III. The average grain yield of the lines in the group was close to the standard Mina (103%).

The second basic group (b) almost reached level 50 and was identical to Group VIII. Those were six lines, characterized with a considerable superiority in terms of grain yield. Four of the lines were obtained by treatment with the lowest concentration of natrium azide (0.1 mM) and the lowest dose of gamma irradiation (50 Gy). The lines M 15/2 and M 20/23/ were induced by gamma irradiation in higher doses - 150 and 200 Gy. The mutant lines that belonged to that group were lower and earlier, compared to the standard Mina. The wide genetic origin of the lines in the group classified them as the most perspective.

Group three (c) encompassed the mutant lines (4 of them), which formed Group IX. They were characterized with being very different from the other two basic groups (reaching level 78). They were largely inferior to the average standard in terms of grain yield but had the shortest stem – 91-97 cm.

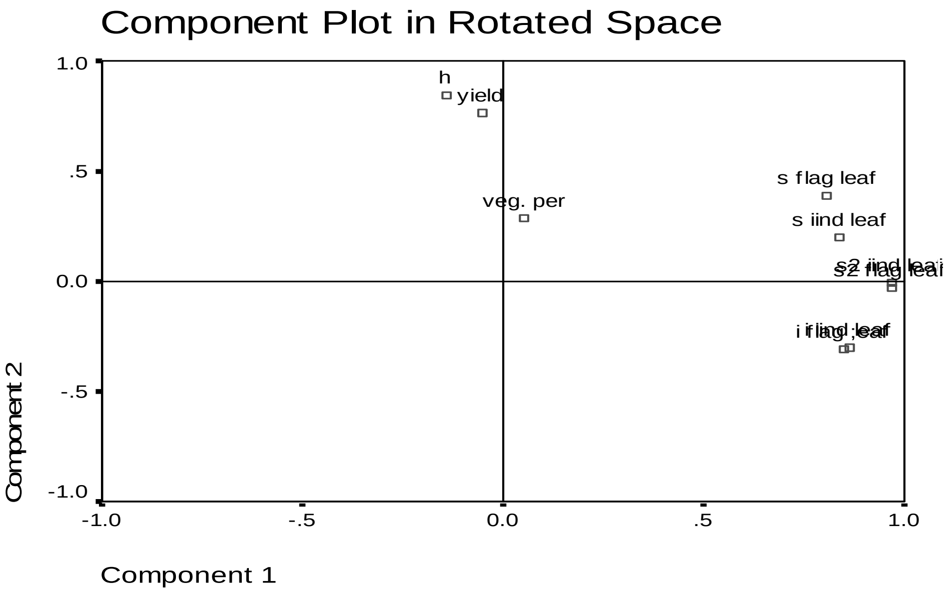

Fig. 2. Correlations between the studied indexes and main parameters

Table 3
Results of the Principal components analysis

Indexes	Component 1	Component 2
Second leaf length	0.86	-0.30
Second leaf width	0.84	0.20
Second leaf area	0.97	0.00
Flag leaf length	0.85	-0.31
Flag leaf width	0.81	0.39
Flag leaf area	0.97	-0.03
Height	-0.14	0.85
Yield	-0.05	0.76
Vegetative period	0.05	0.28
Latent roots (Eigen values)	4.75	1.74
% of total variance explained	52.74	19.36
Cumulative variation, %	52.74	72.10

The relative effect of heterogeneous indexes on variation was evaluated by PC analysis. Two components were identified, based on the screen test (Table 3). The correlations between the variables of the studied indexes and principal components were expressed graphically (Figure 2). Variability was clearly expressed by the high positive correlations of length, width and area of the second and flag leaves with the first principal component. It accounted for 52.7% of the total variation of studied lines. The second principal component was defined by the high positive correlation of height and yield – 0.85 and 0.76, respectively (Figure 2). These characteristics were important not only for the identification of the relationship between the genotypes, but most of all for the direction of selection. Their variability covered about 19% of the total variability in the second principal component. The two principal components accounted for 72% of the

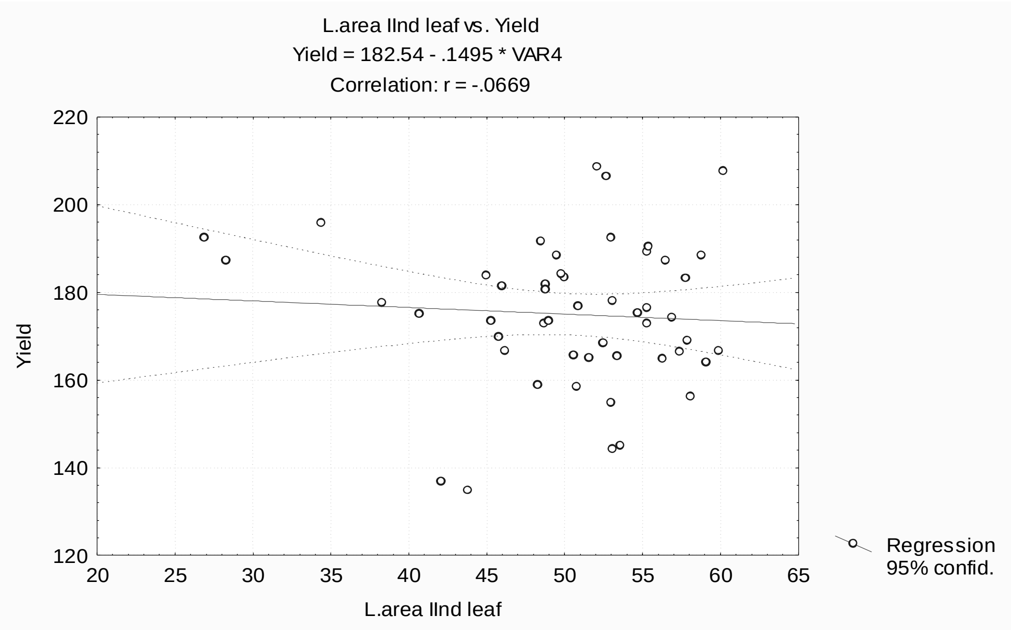

Fig. 3. Regression trend of 2nd leaf area (cm^2) and yield

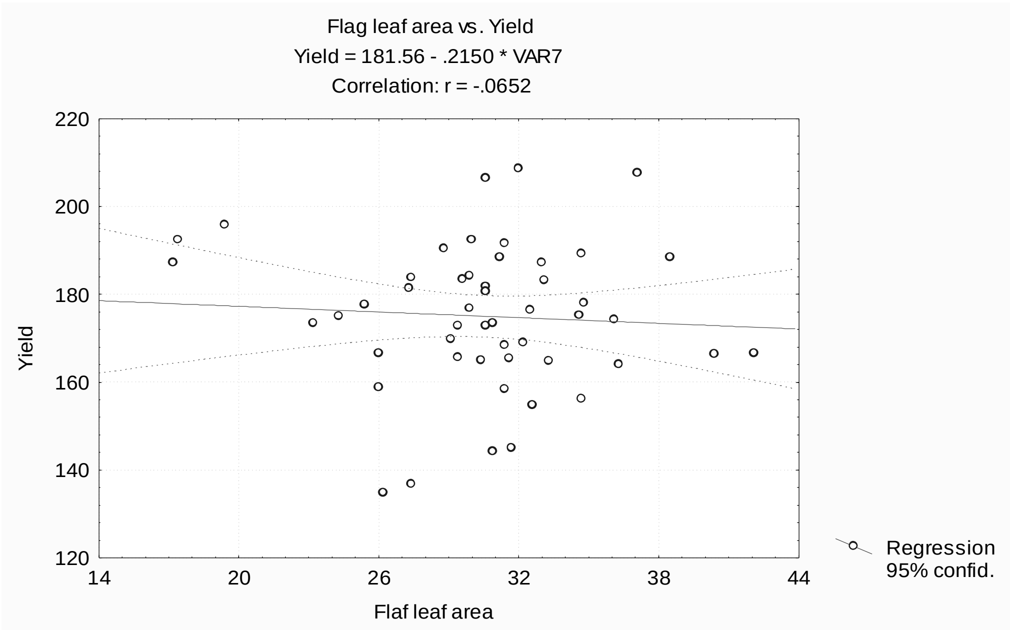

Fig. 4. Regression trend of flag leaf area (cm^2) and yield

total variation of the indexes of the studied mutant lines.

The regression equation for the varying indexes is linear and looks as follows:

$y = 237.62 + x_1 (-3.39) + x_2 (-157.79) + x_3 5.24 + x_4 (-6.48) + x_5 13.8 + x_6 1.67 + x_7 1.14 + x_8 1.13$

where: y is the yield; x_1, x_2 and x_3 are the length, width and leaf area of the second leaf; x_4, x_5 and x_6 – length, width and leaf area of the flag leaf; x_7 – height and x_8 – duration of vegetative period. Leaf area is of importance for grain yield.

The regression trend of the second and flag leaf areas in some of the lines with higher grain yield showed that it was close to the area of the second leaf 52 – 62 cm^2 and for the flag leaf – about 38 cm^2 (Figures 3 and 4).

Conclusions

Mutant lines M 15/2, M 20/23, Mx 5/18 and Mx 20/56Â, superior to the standard Mina with regard to grain yield, length, width and area of the flag and second leaves, were obtained after gamma irradiation in doses of 150 and 200 Gy as well as treatment with natrium azide 0.10 mM and 10 mM. They were characterized with even shorter stem and vegetative period.

The indexes with the highest variability, namely the parameters of the flag and second leaves, grain yield and stem height were defined with high rate of accurateness and proved important for crop breeding.

The used mutagenic factors and doses will give an opportunity to predict higher grain yield when the area of the second leaf is 55 – 62 cm^2 and the flag leaf – about 38 cm^2.

Acknowledgements

The present study was carried out with the financial support of the Science Fund of the Ministry of Education and Science.

References

Ahloowalia, B. S. and M. Maluszynski, 2001. Induced mutations – A new paradigm in plant breeding. *Euphytica*. **118**: 167-173.

Bar, A., 1986. In list of varieties. *Mutation Breeding Newsletter*. **28**: 19.

Burrows, V. D., C. F. Konzak, G. McDiamid and J. Dey, 2001. A naked oat mutant with very short rachillas. *Canadian Journal Plant Science*, **82**: 83-84.

Gramatikova, M., G. Rachovska, Y. Burgazova and G. Rachovski, 2002. Increase of genetic variability in barley and wheat by gamma irradiation and natrium azide treatment. *Scientific papers ÀÓ*. XLVII (1): 119-124.

International Classifier of COMECON for the Genus Avena L., 1984. Vavilov Institute of Plant Production, Leningrad.

Kibite, S., 2002. Discovery of Variegated Leaf Mutants in Oats (*Avena sativa* L.). *Oat news letter*, **48**: 36-37.

Krashna-Murthy, C. S. and C. Vasodevan, 1984. Induced polygenic variation following single and combination treatment with azide, EMS and gamma rays in oats. *Crop Improvement*. **11**: 1.

Mahan, F., 1989. Results of treatment of vegetative winter rye plants with natrium azide. *Mutational breeding of cereals*. Coordination Center of COMECON. Piestany: pp. 86-90 (Ru).

Maluszynski, M., I. Szarejiko and J. Maluszynska, 2001. Induced Mutations in Wheat. The world Wheat book: A History of Wheat Breeding. Lavoisier. Zondres-Paris-New Jork: pp. 939-977.

Oat Descriptors, 1985. IBPGR Secretariat. Rome.

Rachovska, G. and N. Antonova, 1995. Effect of natrium azide and gamma rays on hexaploid oats in the first and second mutant generations. Coll. of papers from Jubilee scientific conference. **IV** (1): 375-379 (Bg).

Rachovska, G. and N. Antonova, 1996. Effect of natrium azide in spring oats of the first mutant generation. Scientific papers. Institute of Barley, Karnobat. **7**: 189-192 (Bg).

Rachovska, G., 1999. Diversification of genetic variability of common winter wheat by treating with natrium azide and gamma irradiation. Thesis summary. Sofia (Bg).

Sou, A. R. F., 1995. Utilizing the potential of induced mutagenesis and somaclonal variation for increasing the genetic variability of rice (*Oryza sativa* L.). Thesis summary. Specialized Scientific Council on plant breeding and plant biotechnology at the Agricultural Academy – Ñî ô èÿ. (Bg).

Valkova, N., 1997. Mutagenic efficiency of gamma rays in irradiation of seeds of interspecies hybrids. *Coll. Problems of plant science and practice in Bulgaria*. Agricultural University of Plovdiv: pp. 495- 498 (Bg).

Yanev, Sh., 1989. Induced mutagenesis of durum wheat – research directions and results. *Mutational breeding of cereals*. Coordination Center of COMECON. Piestany: pp. 13-19.

Yanev, Sh., 1997. New varieties of durum wheat, created by experimental mutagenesis. *Coll. Problems of plant science and practice in Bulgaria*. Agricultural University of Plovdiv: pp: 491- 494 (Bg).

Received January, 22, 2009; accepted for printing December, 22, 2009.