Advances in Biological Research 3 (5-6): 215-221, 2009
ISSN 1992-0067

Induced Mutations in Bread Wheat (*Triticum aestivum* L.) CV. 'Kharchia 65' for Reduced Plant Height and Improve Grain Quality Traits

[1]N.K. Singh and [2]H.S. Balyan

[1]Department of Biotechnology in Applied Mechanics,
Motilal Nehru National, Institute of Technology, Allahabad, 211 004, India
[2]Department of Genetics Plant Breeding, Ch. Charan Singh University, Meerut, 250 004, India

Abstract: Through mutagenesis with gamma rays, mutants characterized by reduced plant height, square head, awnless ear, amber seed colour, bold seeds and storage capacities were induced in bread wheat (*Triticum aestivum* L) cv. Kharchia 65. The were isolated in M_2 generation; derived from 10, 20, 30 and 40 kR of gamma rays treated M_1 population. In the M_3 generation, some, progenies with morphological mutants were recovered. The pattern of segregation was found to be controlled by monogenic recessive control of mutant phenotypes and showed a good fit for 3 normal:1 mutant and 1 normal:2 segregating:1 mutant between and within the progenies respectively. Out of the thirteen reduced plant height homozygous mutant progenies, only three progenies namely 398, 446-7 and 621 showed superiority over control population for several traits. For instance, these progenies had significantly higher mean values for number of tillers per plant and number of spikelets per spike (progeny no. 398), biological yield, number of tillers per plant and number of spikelets per spike (progeny no. 446-7) and harvest index (progeny no. 621) compared to the control cv. Kharchia 65. Therefore, it is these three mutant progenies may prove useful for yield improvement in wheat breeding programme. The amber seed colour, bold and plumb seed producing M_3 mutant progenies namely 351, 446-1, 498 and 632 stored in plastic box for seven years but they not showed significantly high storage capacity against to cereal weevil compared to the control cv. Kharchia 65.

Kew words: Mutation · wheat · Kharchia 65 · Plant height · Grain quality

INTRODUCTION

The use of physical mutagens, like X-rays, gamma rays and neutrons and chemical mutagens for inducing variation, is well established. Induced mutations have been used to the Joint afford of FAO/IAEA Division of the Nuclear Techniques in Agriculture, more than 1800 cultivars obtained either as direct mutants or derived from their crosses have been released worldwide in 50 countries [1]. These induced mutation help to develop of many agronomical important traits such as shorter growing period, suitable for rotation, increased tolerance or resistance to abiotic and biotic stresses use in major crops such as wheat, rice, barley, cotton, peanuts and beans [1, 2].

Wheat is one of the most important food crop of the world. In India it is the second major food crop next to rice. The bread wheat (*Triticum aestivum* L.) account 86% and durum wheat only 12% of total area under wheat cultivation in India [3]. Mutation breeding is relatively a quicker method for improvement of crops [4]. Hundreds of useful mutants have been induced for various plant characters in variety of crops including wheat through treatment with physical and chemical mutagens [5-9]. In this experiment, the effect of gamma rays to induced different types of morphological mutants 10]. The reduced plant height, square head, awnless ear, amber seed colour, bold seeds in M_3 generation were recovered and these morphological mutants were storage at normal conditions in years year (1998 to 2006) for the study storage ability.

MATERIALS AND METHODS

An old tall cultivar of bread wheat (*Triticum aestivum* L.) cv. 'Kharchia 65' was used in this study. The seed material was initially procured from Directed of

Corresponding Author: N.K. Singh, Department of Biotechnology in Applied Mechanics, Motilal Nehru National, Institute of Technology, Allahabad 211 004, India

Wheat Research, Karnal India. Subsequently, it was multiplied before use in the work. Cultivar Kharchia 65 was evolve by backcross method using Kharchia Local as recurrent parent and EG953 as donor parent. The cv. Kharchia 65 is salt tolerant; it can grow and set seeds up to pH 9.4 [11-13]. However this cultivar have red colour seed and lodging susceptibility.

Dormant uniform sized seeds (300) with a moisture content of 5.6% were treated with acute doses of 10, 20, 30 and 40 kR of gamma rays at the rate of 5.6 r/second from gamma cell at Genetic Division, IARI New Delhi, India. The irradiated seeds of each dose were sown under RBD design with three replications at experimental field of Department of Genetics and Plant Breeding Ch. Charan Singh University Meerut U.P India in November 1995. The lethal dose 50 (LD_{50}) was calculated following regression of the germination data per cent lethality over control on gamma rays doses. The data were recorded in M_1 M_2 and M_3 generations (Singh and Balyan 2000). The morphological mutants were identified at the time of anthesis and maturity of plant. The use of X^2 for study of segregation mutation in M_2 and M_3 generation. In M_3 generation; three economic important traits amber seed colour, bold and plumb seeds were also be recovered in reduced height mutant population. For the study of cereal bevels resistant these seed character mutants were stored in 50x50x20 cm plastic box in three replication from July 1998 to September 2006. Data were recorded damaged and undamaged seed by Grain Weevil (*Sitophilus granaries)* in month of September in each year.

RESULTS AND DISCUSSION

The germination in M_1 populations was less than over the control population and it was varied from 96.98% in population derived from 10 kR gamma rays treatment to 10.95% in population derived due to 40 kR gamma rays treatment. The data showed that in comparison with the control population the germination in the mutagen treated population was lower. The increase in the dose of gamma rays, the reduced the germination per cent was observed. The similar results were also be obtained on various crop plant species including wheat [11, 14-17]. The lethality dose on gamma rays that LD_{50} was 31.39 was calculated (Table 1). In M_2 generation morphological mutants with reduced plant height, awnless ear, square head, amber seed colour and bold seed were identified and recorded. The total mutation frequency was 6.79%. The mutation frequency was minimum (1.65%) in M_2 population obtained due to 10 kR of gamma rays treatment while it was maximum (50.0 %) in M_2 population obtained due to 40 kR gamma-rays treatment. The various types of morphological mutants were identified. The reduced plant height mutations were recovered in all four M_2 population derived due to different doses of gamma rays (Fig. 1). The frequency of these mutations ranged from 1.65% (10 kR) to 50% (40 kR). (Table 1). The awnless mutant plant were recovered in only 30 kR gamma rays dose and these frequency was 0.57% (Fig. 2). The awnless ear mutant plant also exhibited reduced plant height. The square head mutant bearing square head ears were recovered in of M_2 population derived from 30 kR gamma rays dose (Fig. 3) and these frequency was 1.14%. The semi sterile mutant plants bearing spikes with reduced grain setting (Fig. 4) by 30 kR gamma rays dose in M_2 population the frequency was 0.57% observed. The this result showing an increase in the mutation frequency with an increase in the dose of mutagen are in agreement with the results of several earlier workers also on various crop plants including wheat [18-28]. The relative frequency of reduce plant height mutations were manifold greater than the frequencies of all other morphological mutation. The agreement with the present results, [29] also reported that the reduced plant height or semi dwarf mutation s are induced more frequently than other vital mutation in duram wheat, bread wheat and in diploid cereals such as barley and rice. The squire head ear mutations recovered, similar result were also be reported by several workers

Table 1: Germination per cent in M_1 generation, frequency of mutation in M_2 generation and frequency of morphological M_2 generation

	Germination % in Control and tread population in M_1 generation			Frequency of mutation in M_2 generation		Frequency of morphological mutation			
Treatment	No. of seedling (out of 300 seeds)	Germination % over control	Percent lethality over control	No. of M_1 plant to progeny row	Frequency of mutations	Reduced plant height	Squire head	Awnless	Semi sterile
Control	265	-	-	13	0.00	-	-	-	-
10 kR	257	96.98	3.02	242	1.65	1.65	-	-	-
20 kR	225	84.91	15.09	208	3.85	3.85	-	-	-
30 kR	201	75.85	24.15	175	21.26	18.98	1.14	0.57	0.57
40 kR	28	10.56	89.44	8	50.00	50.00	-	-	-

Table 2: Segregation for various types of mutations within M_1 plant to progeny row in M_2 generation

S.No	M_1 plant to progeny row number	Number of normal plants	Number of mutant plant	Chi-squire value	Probability value (3:1)	Dose of mutagens (kR)	Type of mutations
1	10	10	2	0.44	0.70-0.50	10	Plant height
2	206	9	2	0.27	0.70-0.50	10	"
3	225	13	3	0.33	0.70-0.50	10	"
4	237	11	4	0.02	0.90-0.80	10	"
5	263	8	5	1.26	0.30-0.20	20	"
6	269	13	4	0.02	0.90-0.80	20	"
7	283	10	3	0.03	0.90-0.80	20	"
8	304	6	3	0.04	0.90-0.80	20	"
9	309	9	3	0.00	1.00	20	"
10	337	6	4	1.20	0.30-0.20	20	"
11	345	8	2	0.13	0.80-0.70	20	"
12	346	10	2	0.44	0.70-0.50	20	"
13	351	9	5	0.86	0.50-0.30	30	Awnless
14	355	8	3	0.03	0.90-0.80	30	Plant height
15	356	9	2	0.27	0.70-0.50	30	"
16	360	8	1	0.93	0.50-0.30	30	"
17	387	11	1	1.78	0.20-0.10	30	"
18	398	6	3	0.33	0.70-0.50	30	"
19	409	9	3	0.00	1.00	30	"
20	410	12	2	0.86	0.50-0.30	30	"
21	446	11	1	1.78	0.20-0.10	30	Square head
22	471	9	4	0.25	0.70-0.50	30	Plant height
23	478	6	2	0.00	1.00	30	"
24	498	4	2	0.22	0.70-0.50	30	"
25	502	6	3	0.33	0.70-0.50	30	"
26	503	11	4	0.02	0.90-0.80	30	"
27	513	7	2	0.04	0.90-0.80	30	"
28	516	11	2	0.64	0.50-0.30	30	"
29	525	7	2	0.04	0.90-0.80	30	Square head
30	555	5	2	0.05	0.90-0.80	30	Plant height
31	556	6	1	0.43	0.50-0.30	30	"
32	574	11	1	1.78	0.20-0.10	30	"
33	593	12	3	0.20	0.70-0.50	30	"
34	594	9	2	0.27	0.70-0.50	30	"
35	595	3	1	1.48	0.30-0.20	30	"
36	600	7	1	0.67	0.50-0.30	30	"
37	609	5	1	0.22	0.70-0.50	30	"
38	616	8	2	0.13	0.80-0.70	30	"
39	621	9	2	0.27	0.70-0.50	30	Semi-sterile
40	628	3	2	0.60	0.50-0.30	40	Plant height
41	631	9	1	1.20	0.30-0.20	40	"
42	632	2	2	1.33	0.30-0.20	40	"
43	633	10	2	0.44	0.70-0.50	40	"
Pooled	-	363	102	2.33	0.20-0.10	-	-

[21, 30-32]. In this study only four type of morphological mutations were obtained, due to polyploidy nature of bread wheat the viable morphological mutations may occur only at loci in which phenotype buffering caused by duplication dose not exist [33, 34] suggested that number of such loci are few in bread wheat and hence in the spectrum of mutation remains narrow. Segregation pattern of different types of morphological mutation was deliberate. A total of 43 M_1 plant to progeny rows in M_2 generation exhibited a good fit for 3 (normal): 1 (mutant) segregation. No heterogeneity was detected between various segregating progenies and the pooled analysis of data also exhibited a good fit for 3 (normal): 1 (mutant) segregation. This suggested monogenic recessive control of the mutant characters (Table 2).

Seeds from all the M_2 segregating progenies for different mutant types were raised in plant to progeny rows in M_3 generation. The data on mean performance of

Table 3: Progeny rows segregation for various type of mutants

			Number of M_3 Progenies				
S.No	Progeny row number	Types of mutant	Normal	Segregating	Mutant	Chi- squire value (1:2:1)	Probability value
1	263	Plant height	4	7	2	0.384	0.90-0.80
2	351	Plant height	4	6	1	2.00	0.50-0.30
3	398	Plant height	2	6	2	0.650	0.90-0.80
4	446-1	Plant height,					
Squire head	3	6	1	1.450	0.50-0.30		
5	446-7	Plant height	1	2	1	0.000	1.00-0.99
6	498	Plant height	2	2	1	1.00	0.70-0.50
7	525	Plant height					
Squire head	3	4	1	1.000	0.70-0.50		
8	555	Plant height	2	3	1	0.142	0.95-0.90
9	593	Plant height	5	7	2	1.285	0.70-0.50
10	595	Plant height	4	7	1	1.833	0.50-0.30
11	609	Plant height	2	3	1	0.333	0.90-0.80
12	621	Plant height,					
semi sterile	3	5	2	0.200	0.95-0.90		
13	632	Plant height	1	2	1	0.000	1.00-0.99

Table 4: Segregation within M_3 progeny rows for various types of mutants

S.No.	Progeny row number	Types of mutant	Number of normal plant	Number of mutant plant	Chi- squire value (3:1)	Probability value
1	263	Plant height	19	5	0.222	0.70-0.50
2	351	Plant height	8	4	0.444	0.70-0.50
3	398	Plant height	17	5	0.060	0.90-0.80
4	446-1	Plant height, Squire head	17	5	0.332	0.70-0.50
5	446-7	Plant height	19	5	0.002	0.70-0.50
6	498	Plant height	25	7	0.166	0.70-0.50
7	525	Plant height Squire head	18	5	0.130	0.80-0.70
8	555	Plant height	38	10	0.444	0.70-0.50
9	593	Plant height	64	21	0.003	0.98-0.95
10	595	Plant height	36	12	0.000	0.1-0.99
11	609	Plant height	4	2	0.222	0.70-0.50
12	621	Plant height, semi sterile	26	8	0.039	0.98-0.80
13	632	Plant height	15	5	0.000	1.00-0.99

Table 5: Mean value for eight characters in a reduced plant height mutant M_3 progenies and control population

S.No	Mutant Progeny number	Secondary characters	Plant height (cm)	Biological yield/plant (gm)	Number of tillers/ plant	Number of spikletts/spike	Grain Yield/ plant (gm)	1000 grain weight (gm)	Harvest index
1	263	Plump seeds	75.25*	15.00	9.25*	27.50	4.35*	23.00*	28.00*
2	351	Awnless ear and plump seeds	94.46*	17.93	8.86*	35.30*	2.16*	20.96*	13.64*
3	398	-	84.00*	44.44*	18.11*	47.33*	5.37*	15.95*	12.31*
4	446-1	Squarehead, Amber and plump seeds	83.00*	14.75*	7.12*	40.12*	2.39*	22.44*	19.50*
5	446-7	-	89.00*	37.05*	16.14*	52.00*	9.60*	21.21*	25.91*
6	498	Plump seeds	78.00*	37.50*	16.50*	38.25*	2.67*	21.25*	11.05*
7	525	Square head	73.00*	20.50*	9.66*	47.00*	0.82*	21.91*	3.84*
8	555	-	64.00*	13.66*	7.10*	36.16*	0.92*	16.95*	6.97*
9	593	-	101.19*	27.14*	10.71*	44.57*	5.44*	18.57*	20.64*
10	595	-	81.00*	14.61*	6.66*	44.66*	2.27*	13.94*	12.77*
11	609	-	74.50*	32.50*	10.50*	43.50*	6.80*	25.25*	26.70*
12	621	Semi sterile spike	63.33*	15.66*	4.33*	40.00*	1.93*	25.16	16.32*
13	632	Plumb and bold seeds	89.11*	18.22*	8.88*	38.00*	3.58*	21.66	18.55*
14	Control cv. 'Kharchiya 65'		110.02	32.92	12.00	46.19	7.44	23.65	24.14

* Means significantly different from control cultivar cv. Kharchia 65 at 5% level of significance

Fig. 1

Fig. 2

Fig. 3

Fig. 4

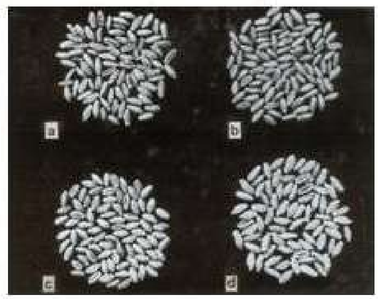

Fig. 5

Fig. 1: Representative plants of cv. Kharchia 65 (a) and reduced height mutants derived due to 10 kR (b), 20 kR (c) 30 kR (d) and 40 kR (e) gamma- rays treatments.

Fig. 2: Representative plants of cv. Kharchia 65 (a) and awnless mutant derived due to 30 kR gamma- ray treatment (b)

Fig. 3: Representative plants of cv. Kharchia 65 (a) and square head mutant derived due to 30 kR gamma rays treatment (b)

Fig. 4: Representative plants of cv. Kharchia 65 (a) and semi-sterile mutant derived due to 30 kR gamma rays treatment (b).

Fig. 5: Representative (a) shriveled red grain of cv. Kharchia 65, (b) Plump grains of mutant progeny number 263 (c), amber grains of mutant progeny number 351 and (d) bold grains of mutant progeny number 632.

the different characters of homozygous mutant progenies were also recovered. The total of 13 different mutant plant progeny rows in M_3 generation exhibited a good fit for 1 (normal): 2 (segregating): 1 (mutant) and 3 (normal): 1 (mutant) segregation for between progeny row and within progeny row respectively. This conformed recessive control of mutant traits (Table 3 and 4).

Mean Performance of Some Quantitative Traits: The mean performance of reduced plant height mutants was significantly less compared to the mean plant height (110cm) of the control. Biological yield and number of spiklets per spike in only two progenies, namely 398 and 446-7, number of tillers per plant only three progenies namely 398, 446-7 and 498 and harvest index of one homozygous progeny 263 showed higher mean value compare to control plants. The remaining progenies showed little against the control population of cv. Kharchia 65 (Table 5)

Qualitative Traits: Data on some economic important qualitative traits including grain colour and grain structure were focused. The grain colour of the control cv. 'Kharchia 65' was red with shriveled seeds. However, mutant progenies, namely 351 and 446-1 had amber seed colour and plump grain size, the progenies 263 and 498 had only plump seed and progeny, 632 had plump and bold seeds (Singh and Kulshrestha 1996) Fig. 5.

Out of thirteen of homozygous mutants progenies, only one progeny namely 446-7 showed superiority over control population for seven traits. After the harvested M_3 plants seed those have amber colour and bold and plumb seeds stored bethought any treated by pesticide in 50x50x20 cm plastic box. Each year in month of September data were recorded. After the statistical analysis dose not found significant different between mutant and control. This indicated that above mentioned mutant not affect the storage ability of bread wheat by gamma rays irradiations.

REFERENCES

1. Ahloowalia, B.S. and M. Maluszynski, 2001. Induced mutations - A new paradigm in plant. Euphytica, 118 (2): 167-173.
2. Maluszynski, M. and K.J. Kasha (Eds.), 2002. Mutations, *In vitro* and Molecular Techniques for Environmentally Sustainable Crop Improvement. Kluwer Academic Publishers, Dordrecht/Boston/London. ISBN 1-4020-0602-0.
3. Singh, R.B. and V.P. Kulshrestha, 1996. Wheat in 50 years of crop science research in India Proda, R.S. and Chandha, K.Z. By Dr. R.D.Sharma, Director, Directorate of publication and information on Agriculture, ICAR, Krishi Anusandhan Bhawan Pusa, New Delhi, pp: 219-249.
4. Ilirjana, S., Y. Ariana and D. Andon, 2007. Induced Mutations for Improving Production on Bread and Durum Wheat. Sixth International Conference of The Balkan Physical Union. AIP. Smithsonian/NASA ADS Physics Abstract Service. Conference Proceedings, 899: 747-747.
5. Ram Din, M.M. Khan, M. Qasim, S. Jehan and M.M. Iqbal Khan, 2003. Induced mutation studies in three wheat (*Triticume aestivum L.*) varieties for some morphological and agronomical characters, Asian J. Plant Sci., 2(17-24): 1179-1182.
6. Khan, M., M. Ram Din, M. Qasim, S. Jehan and M.M. Iqbal, 2003. Induced mutability studies for yield and yield related characters in three wheat (*Triticume aestivum* L) varieties, Asian J. Plant Sci., 2(17): 1183-1187.
7. Curtis, J.T., S.O. Louise Pozniak, C. Iwona Birk, P.J. Donoughue, Ménard, Hucl and B.K. Singh, 2004. Physiological and Molecular Characterization of Mutation-Derived Imidazolinone Resistance in Spring Wheat. Crop Sci., 44: 1434-1443.
8. Njau, P.N., M.G. Kinyua, P.K. Kimurto, H.K. Okwaro and M. Maluszynski, 2005. Drought tolerant wheat varieties developed through mutation breeding technique. Journal of Agriculture, Sci. Technol., 7(1): 18-29.
9. Morten, L., C. Feng, X. Xianchun, W. Manilal, J.P. Roberto, R. Trethowan and Z. He, 2006. Puroindoline grain hardness alleles in CIMMYT bread wheat germplams. J. Cereal Sci., 44(1): 86-92.
10. Jamil, M. and U.Q. Khan, 2002. Study of Genetic Variation in Yield Components of Wheat Cultivar Bukhtwar-92 as Induced by Gamma Radiation. Asian J. Plant Sci., 1(5): 579-580.
11. Singh, B.D., 1993. Plant breeding Principles and Methods. Kalyani Publishers, Ludhiana, pp: 227-257.
12. Ali, Y., Z. Aslam, G. Sarwar and F. Hussain, 2005. Genotypic and environmental interaction in advanced lines of wheat under salt-affected soils environment of Punjab. Intl. J. Enviorn. Sci. Technol., 2: 223-228.
13. Rana, M., A. Richard, James and André Läuchli, 2006. Approaches to increasing the salt tolerance of wheat and other cereals. Journal of experimental Botany. J. Experimental Botany, 57(5): 1025-1043.
14. Chang, W.T. and S.S. Hsies, 1957. Mutations in rice induced by X-rays J. Agric., 7: 7-14.
15. Choudhary, J.B. and T. Nirmala, 1976. Effect of gamma-rays on seedling height and chromosome aberration in Triticale. Acta. Bot. India, 4: 126-130.
16. Sharma, R.P., 1979. Mutation breeding in barley in India: Achievements, prospects and problem. In Proc. Symp. The Role of Induced Mutation in Crop Improvement, Hydrabad, pp: 134-147.
17. Wiersinski, N., 1984. Mutation research in triticale. Comparative studies on the susceptibility of wheat, rye and triticale to mutagens. ***Archiv, Zuchtunge,*** 14: 181-192.
18. Gaul, H., 1960. Tritical analysis of the method for determining the mutation frequency after seed treatment with mutagens. Genet Agr., 12: 297-318.
19. Gaul, H., 1964. Mutations in *Plant breeding*. Rad. Bot., 4: 155-232.
20. Swaminathan, M.S., 1961a. Effect of diplontic selection on the frequency and spectrum of mutations induced in polyploids following seed irradiation. In Proc. Int. Symp. " The effects of Ionizing Radiations on Seeds" IAEA, Vienna. pp: 279-288.
21. Bhatia, C. and M.S. Swaminathan, 1963. Frequency and spectrum of mutations induced radiations in some varieties of bread wheat. Euphytica, 12: 97-112.
22. Gaustafsson, A., 1963. Productive mutations induced in barley by ionizing radiations and chemical mutation. Hereditas, 50: 15-39.
23. Gupta, P.K. and Yashvir, 1975. Induced mutations in foxtail millet (*Setaria italica* Beauv.). I. Chlorophyll mutations induced by gamma rays, EMS and dES. Theor. Appl. Genet., 45: 242-249.
24. Grzesik, H., 1980 a. Influence of various mutagens on the variation of certain traits in several forms of winter triticales. Hod Rasil Akli. J. Nasic., 24: 121-168.
25. Grzesik, H., 1980 b. Influence of various mutagens on the variation of certain traits in several forms of winter triticales. Hod Rasil Akli. J. Nasic., 24: 593-600.

26. Gulyyan, A.A., A.G. Saakyan and S.P. Simerdzhyan, 1982. Mutability of hexaploid triticale after treatment of the grain with gamma- rays and chemical mutagens. B Viol.Zhurnal Armenii, 35: 160-165.
27. Reddy, C.S. and J.D. Smith, 1983. Viable mutations in grain sorghum induced by gamma-rays. Chemical mutagens and their combinations with cysteine. Genet. Agr., 37: 7-22.
28. Reddy, V.R.K., 1985. Chromosome constitution and induced mutations in triticale (X *Triticosecale* Wittmack). Ph. D Thesis, Merut University, Meerut. pp: 2-00.
29. Konzak, C.F., 1981b. Induced mutations for genetic analysis and crop improvement of wheat. n induced mutation- A tool for plant research". IAEA. Vieanna, pp: 469-488.
30. Sham Rao, H.K. and P.M.V. Rao, 1964. EMS indiced compactum type mutation in *Triticum aestivum* sp. vulgare. Crop Sci., 4: 435-436.
31. Molotkov, D.I., 1980. Mutagenic effect in winter wheat after treatment with N- nitrose-N-methylurea. sp. nauch.tr.Belarus. S. Khakad, 65: 28-34.
32. Molotkov, D.I., 1982. Chemical mutagenesis and yield in winter wheat plant sp nauch tr. Belarus.S. Khakad, 65: 28-34.
33. Stadler, L.J., 1932. On the genetic nature of induced mutations in plants. In Proc. 6th Intern. Congr Genet Ithaca, USA, 1: 274-294.
34. MacKey, J., 1954a. Mutation breeding in poliploid cereals. Acta Agric. Scand, 4: 549-557.