Results of Utilization of Chernobyl Radio Mutant in Breeding Programmes of *Triticum aestivum* L.

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Abstract

A large spectrum of mutations was observed as a result of winter wheat *T.aestivum* L. irradiation for two consecutive vegetative seasons (during 1986-87) in the fields close to the ruined reactor of the Chernobyl Nuclear Power Station. Mutants taken from the different generations (L147/91, BC 47 square head, dwarf 20104/89) were used for development of the varieties Lybid, Yasochka and Tsarivna to utilize traits from the mutants such as hardiness, drought tolerance, disease and lodging resistance and bread quality. These varieties were included in the State Variety Register of Ukraine, while another one, Lisova Pisnya is included in the list of perspective varieties.

Introduction

The genetic changes in winter wheat that occurred due to the ionizing radiation, which appeared as a result of Chernobyl Nuclear Power Plant accident, were investigated during 1988-2007 at the research station in Bila Tserkva. Irradiation received by plants was chronic. External gamma-irradiation, internal irradiation, irradiation by beta and alpha particles from incorporated radionuclide formed a cumulative incorporated doze. [1] 239 accessions of common wheat, which during two years in plantations in 1986 and in self-sowing 1987, grown near the Chernobyl Reactor were picked up by academician D.M. Grodzinsky, and professors P.K. Shkvarnikov and V.F. Batygin, who kindly provided them to our station for further investigation and analysis. The objective was to assess their possible utilization in breeding by selecting among them the mutants with attractive agronomic important traits to be subsequently introduced in breeding programmes. Another goal was to identify the remote consequences of the irradiation, which may later be used to forecast genetic changes for numerous populations remaining in the zone polluted by the radionuclide. [2]

Results and Discussion

The four varieties of common wheat, Bilotserkivska 47, Poliska 70, Myronivska 808 and Kyianka were planted at the fields of Chernobyl area before the accident. Even in M_2, a large spectrum of mutations was discovered. Because of genetic instability, the mutant diversity increased each year and, to date, the collection includes up to 2,000 mutants. [3] Plants with different kinds of abnormalities in structure appeared among mutants of different generations. We called them chimerical plants and they had no value for breeding. Moreover, the direct selection from mutants of all studied varieties did not yield positive results due to the high instability of all characteristics in many generations. This was particularly true for the segregation in plant height and morphology observed as well as for yield and gluten quality.

At the same time, several selected lines of mutants that showed some advantageous agronomic characteristics, were applied to the breeding programmes. The first one was Mutant 20168/89, where even in M_3 segregation was observed in the progeny of seeds collected from one ear: 54% of plants had square head ear with awns, a stem height 90-105cm and were resistant to brown rust, whereas 46% of plants closely resembled Myronivska 808 - lyutestsens sub-variety, with a stem height of 116cm and were highly susceptible to lodging and brown rust.

In M_4, a heterozygous ear mutant of Lyutestsens 147 (L147) was selected. The segregated population from this mutant (M_5) exhibited 89% awnless plants with a normal ear density, 10% of plants appeared to be square head form and 1% of plants were small chimeras with a height of 25cm. A separate segregation by height was also observed simultaneously, with variation between 75 and 110cm. Genetic instability of Mutant 20168/89 was also observed in later generations. (**Fig. 1**)

Figure 1 Splitting of genetically unstable mutant – 20168/89 in later generations (M6-M12): 1 – Lyutestsens with normal ear density L147/91, which became the female parent in the creation of Lybid and Yasochka; 2 – compactoid semi-awned with twisted ear stem; 3 – "transparent" ear without ear stem, with spikelets attached to each other; 4 – ear with deformed awns and sterile upper part; 5 – awnless squared head; 6 – well developed awned squared head with noticeable changes in the middle of the ear.

In M_6, the segregation of L147 continued by ear morphology and plant height. In this population the constant mutant L147/91 was selected, awnless and with high resistance to brown rust, septoria and *Fusarium* spp., because of which the plants have green leaves during all stages of ripening. This mutant has high gluten content in seeds up to 41-48%, coupled with low quality of this gluten.

Further, mutant L147/91 with normal awnless ear was selected as a female component for crossing with the strong common wheat variety Novoukrainka Bilotserkivska. This was aimed at decreasing height and increasing thickness of the stem of cv. Novoukrainka Bilotserkivska while simultaneously improving its resistance to a number of diseases.

An F_2 population of 2,000 plants from those progenitors was studied and 105 among them were collected and sown. In the F_3 population from those plants, 23 families were selected for control nursery. Such lines were highly productive, winter-resistant (especially in winter conditions

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with snow) as well as lodging-resistant, and they had high gluten content of good quality. Therefore, in this crossing the low gluten quality derived from mutant L147 was inherited as a recessive trait and the level of gluten content as heterozygous.

Line № 728/98, which was selected for further investigation in control nursery, was registered in Ukraine in 2006 as variety Lybid` and recommended for cultivation in all zones of Ukraine. This variety is awnless, with an intermediate date of ripeness, high winter resistance (it successfully passed the 90-days of ice crust winter condition in 2003), drought tolerant, has resistance to brown rust, powdery mildew and septoria. It is a semi-dwarf, highly productive variety and belongs to the strong wheats. A maximum productivity of 9.6 t. per hectare was achieved by Bila Tserkva State Variety Testing Station (SVTS) of Kiev State Center for Plant Variety Expertise (CPVE) during the very dry 2007 season, which superseded the standard variety Podolianka by 0.9 t. per hectare.

Mutant L147/91 was also successfully used as female parent with variety Napivkarlyk 3 crossing, resulting in the creation of variety Yasochka. Unlike regular crossings with stable varieties, splitting by awn trait was recorded immediately in F_1: crossing of two awnless parental forms generated 1% of awned offspring. A wide variety of recombinants was also observed in further generations. There were 56 hybrid lines studied in F3 with 14 selected for the control nursery. A wide variability was obtained, both morphologically and for traits useful in breeding.

Thus, the variation in the control nursery for winter resistance ranged from three to four (on a five-point scale); brown rust resistance ranged from 2% to 65%, yield from 5.4 to 7.4 t. per hectare, stem height from 90 to 100cm, gluten content from filler with Gluten Deformation Index (GDI) of 113 to strong wheat with 15% of protein and GDI of 78. The difference in ripening season reached 10 days. The most productive line from this crossing, 199/02, was included after the state variety testing in the State Plant Variety Register for 2006 as Yasochka variety. Yasochka is awned, of mid-size height and mid-term ripening. It has a high drought tolerance, above average winter resistance and big kernels, having inherited resistance to brown rust, septoria, *Fusarium* spp. and lodging from mutant L147/91. Gluten quantity was also inherited from the mutant L147/91 with no connection to gluten quality. As a result, the variety was classified among strong wheats by gluten. A maximal yield of 8.5 t per hectare was achieved in 2004 in Vinnytsa CPVE and 8.4 t per hectare in Dnipropetrivsk CPVE. Yasochka is recommended for cultivation in the Steep-forest region.

Figure 2 Mutants of Bilotserkivska 47 common winter wheat. 4 – parental variety Bilotserkivska 47, 20035 – mutant of Bilotserkivska 47 – female form in crossing leaded to development of varieties Tsarivna, Lisova Pisnya and Romantica.

In the collection of Chernobyl mutants the most numerous and least stable are a group of mutants of Bila Tserkva 47 – BC 47 squared head (BC 47 sqr). In M_3 they differ from the original variety by thicker upper half of the ear, meaning they possess a squared head ear. In 1989, there were 40 families of such mutants, with 25% of them awned and of even height. Others got split by height from 85 to 105cm, different morphological traits of the ear stem and leaves. In different generations different systemic mutations were noted. They possessed traits of other species: *T.spelta* (L), *T.compactum* (Host) and *T.vavilovi* (Tum. i Jakubz). [4] All of them, like the original genotypes, belong to hexaploid wheat. Some mutations had no noticeable morphological differences but had different quantitative traits such as productivity, bread quality, winter resistance, disease resistance etc., of practical application for breeding. For their identification, analysis of useful traits was conducted along with the study of morphological changes, whreby mutant BC 47 sqr. # 774/89 (**Fig. 2**) was selected.

Unlike many other mutants in this group (**Fig. 3**), BC47 had no significant deviations from normal ear structure with an exception of hardly noticeable square head and doubled spikelets on some parts of the ear. In addition, during nine years of testing (1991–1999), BC 47 sqr. has proven to be winter-resistant and of high bread quality. After multiple selections by pedigree method, BC 47 sqr. became more stable and was introduced for crossing with a steppe ecotype variety, Odesska 162, to improve winter resistance of the latter. After multiple selections from the progeny, three selected lines became new varieties: Tsarivna (included in the State Registry in 2008), and Lisova Pisnya and Romantica (included in 2009). Romantica variety is presently under state testing. All three varieties were found to be winter-resistant when tested in freezers, classified as belonging to the strong wheat group, and having high productivity. Maximal productivity of Tsarivna variety is 8.8 t. per hectare, while 9.0 t. per hectare was achieved with Lisova Pisnya in the Variety Study Centre in Kiev region in 2006.

Figure 3 Splitting of genetically unstable mutant of Bilotserkivsra 47 in M9: 9.- spikelets after threshing; 11.- T. spelta; 10,12- Spelta-Compactum; 14- spikelets are on a single side of ear stem.

Varieties obtained from crossing with radio mutants are characterized by high drought tolerance. In dry 2007 in Steppe region (Kirovograd Testing and Breeding Station), Tsarivna yielded 8.3 t per hectare and Lybid yielded 8.5 t. per hectare, which is higher than the standard variety Podolyanka by 0.9 and 1.1 t. per hectare, respectively. In the marshy woodlands zone at Borodianska Testing and Breeding Station, Lisova Pisnya delivered 6.2 t per hectare, outperforming Podolyanka by 2.8 t per hectare.

Another mutant, dwarf 20104/89, was found to be a prospective parent for future selection. In M3, it was heterozygous by many traits, the progeny obtained from one ear having a height ranging from 48 to 76cm, with compactum-type short ear. In the upper part of the ear many

spikelets had sterile flowers. In M_4 and M_5, the splitting continued with square headed, awned and awnless forms, tall and dwarf plants, early and late ripened plants. In M_6 a dwarf plant (60cm tall), with a strong stem and good ear density, but with low productivity was selected, and was introduced for breeding with the good bread-making quality variety Novoukrainka Bilotserkivska, which was susceptible to lodging. Transgression by productivity was obtained as a result. In the control nursery 24 numbers out of 63 surpassed the productivity of the original variety. The most productive lines achieved 7.7-7.8 t per hectare. They were resistant to lodging and to brown rust belonging to strong wheats. The best line, named Vidrada, was taken for the state testing. From dwarf mutant 20104/89 it inherited strong stem and quality of the strong wheat.

Thus, disease resistance (L 147/91), lodging resistance (20104/89), drought tolerance and winter resistance traits (BC 47 sqr.), plus gluten content and gluten quality (20104/89 and BC47 sqr.) were utilized for breeding. The use of stable (after multiple selections) lines of Chernobyl mutants as parental genotypes in crosses enhanced the genetic pool of winter wheat and helped to develop highly productive varieties with good bread-baking qualities and increased adaptive potential for hostile environments.

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