# Improvement of Wheat Productivity Through Mutation Techniques

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## Abstract

The harsh climatic conditions of Mongolia and specific characteristic /late warming soil in the spring and early cold in the autumn/ of the high altitude agricultural zone /late warming soil in the spring and early cold in the autumn/ cause the need for short-maturity varieties. Breeding works are also in the process of selecting new varieties. Breeding of new varieties is moving in this direction as well. In recent years, physical and chemical mutagens have been widely used in the breeding of new wheat varieties and lines with good characters. Early maturity variety of wheat (*Triticum aestivum* L.) developed by induced mutation. New wheat mutant varieties have a high yield capacity and early maturity comparing most of local varieties, selected from hybridization. The mutants had been matured from two to ten days earlier than other varieties.

## Introduction

The wheat is dominant crop and cultivated in about 80% of arable land in Mongolia including over 70% in the Central crop production zone, over 20% in the Western zone and 5-8% in the Eastern zone.

Due to the negative impact of climate change the drought frequency increased, carrying capacity of pasture land declined and plant species composition reduced by 2-4 times and yield declined 4-6 times, soil erosion and degradation increased by 7-25 times, soil humus content declined by 37-52% and annually 0.5-1.5 t/ha organic matter decomposed, yield potential of existing crop varieties reduced and pest and disease distribution, frequency and damage increased.

Also, the Western and Khangai mountain cultivation areas located above at the 1500-1900 m above sea level and daily average temperature ranges between 13-18°C in the warmest season of June and July, also the crop duration ranges between 75-110 days. These harsh conditions of the Western and Khangai mountain area allow growing cereals with very short duration.

Existing commercial wheat varieties have not good grain quality, drought tolerance, and disease and pests resistance and cannot sustain stable yield under climate change. Therefore, more new varieties with high stable yield potential and quality are needed in these mountain areas.

The induced-mutation considered useful efficient tool for the improvement specific plant traits like yield, stress tolerance, disease resistance, quality and increase breeding efficiency. Thus, development of early maturity, drought and heat tolerant wheat varieties with potential stable yield under changing climate condition through application of mutation techniques has needed for stable food production in Mongolia.

## Materials and Methods

### Mutation induction in wheat

The studies carried out at the Institute of Plant and Agricultural Sciences during 2013-2017. We evaluated 10334 mutant lines $M_1$-$M_3$ generation in the initial materials field, including 3131 mutant lines originated chemical mutagen treatment. Table 1.

**Table 1.** Mutants in the initial materials field

| Year | Generation /lines | | | Total |
|---|---|---|---|---|
| | $M_1$ | $M_2$ | $M_3$ | |
| 2013 | 394 | 720 | 302 | 1416 |
| 2014 | 1025 | 750 | 477 | 2252 |
| 2015 | 460 | 1170 | 660 | 2290 |
| 2016 | 180 | 786 | 1440 | 2406 |
| 2017 | - | 840 | 1130 | 1970 |
| Total | 2059 | 4266 | 4009 | 10334 |

### The yield trail of mutant varieties

In the yield trail the 12 registered wheat varieties selected for the test. Three of them mutant and nine are conventional varieties originated from domestic and Russian breeding. Origin of mutant Darkhan-141 variety is gamma ray 18000 rad, but origin of Darkhan-172 mutant variety has derived from chemical mutagen Sodium azide. The varieties grown in the black fallow, with three replications and a plot size was 50 $m^2$. The crop sown at a rate of 3.5 million seeds per hectare. The soil of the experimental site is Darkhan Uul province (49°28'N, 105°54'E), with pH 6.22, percentage of organic matter 1.35, available N-$NO_3$ 3.5 mg/kg, $P_2O_5$ 3.9 mg/$kg^{-1}$ and $K_2O$ 17.6 mg/ $kg^{-1}$. The plots harvested with a Wintersteiger harvester. Yield data adjusted to 14% moisture content and the following grain quality parameters were determined. Grain from each plot was dried and a composite 500 g sub-sample taken for quality (duplicate / triplicate) analysis. Protein (percent of dry matter) was calculated by multiplying the corresponding total

nitrogen (by Kjeldahl) content by factor 5.7 (ICC 105/2) using a Kjeldahl auto analyzer. The wet gluten quantity extracted from whole meal flour in an automated gluten washer (Single head gluten tester MJ-IIA).

## Results and discussion

### Experiment on initial materials of wheat mutation breeding

In 2013-2017, the 10334 mutant progenies studied and evaluated by agro-morphological traits and stress tolerance. About 1808 advanced mutant lines selected and used for wheat hybridization breeding material in the wheat breeding program. Table 2.

**Table 2.** Average yield and yield components of mutants in the $M_3$ generation

| | Plant height, cm | Plant number per $m^2$ | Productable stem per $m^2$ | Seed number per spike | Seed weight per spike | Yield, t/ha |
|---|---|---|---|---|---|---|
| Parents | 77.6 | 166 | 428 | 35.7 | 1.3 | 4.38 |
| Mutant lines | 72.3 | 182 | 440 | 36.7 | 1.4 | 4.43 |
| Variance, ± | -5.3 | +16 | +12 | +1.0 | +0.1 | +0.15 |

### Study of mutants in the yield trails

Maturity: Early and late maturing mutants have frequently induced through mutagenesis and identified easily. Early maturity in cereal crops is one of the useful characteristics for cultivation in cool temperate regions, offering the opportunity to flower frost-free conditions, harvest prior to frost and in drought –prone regions, the ability to produce a viable crop prior to drought conditions.

The heading time and maturity of wheat controlled by the plant's ability to sense via temperature and day length. The growth duration of wheat varieties in the yield trail fluctuated from 78-91 days. The Khalkh gol-1 variety matured very early 78 days, but Darkhan-144 late matured within 91 days.

The mutant variety Darkhan-196 matured in 2-12 days earlier than other varieties. Mutant variety Darkhan-172 matured in 2-10 days earlier than other varieties. Also, these varieties matured in 1-3 days earlier than control Darkhan-131 variety which are suitable in the mountain agricultural area. The mutant variety Darkhan-141 has growth duration of 84 days which is in 1-7 earlier than Darkhan -34, Altaiskaya -100, Altaiskaya -50, Arvin, and Darkhan -144 varieties. Table 3.

**Yield and yield components:** Stable and high yield potential in specific environmental conditions is the most important objective of Mongolian plant breeding program. Yield is complex trait and influenced by breeding objectives such as plant architecture, maturity, nitrogen utilization efficiency and resistance to biotic and abiotic stresses.

The grain yield of wheat varieties in the yield trail varied from 1.94 to 2.08 t/ha which are higher than the average yield of control varieties of 1.67 to 1.88 t/ha. The highest grain yield (2.08 t/ha) has the variety Arvin, however lowest was the Khalkh gol-1 variety (1.67 t/ha). The mutant variety Darkhan-141 has grain yield of 1.94 t/ha, which is 0.02 t/ha higher than mean yield of varieties. The mutant variety Darkhan-172 and Darkhan-196 have same grain yield (2.02 t/ha), which are higher (0.10 t/ha) than mean of varieties. These three mutants included in high yielding varieties. Table 3.

The thousand kernel weight of wheat varieties fluctuated from 30.5 g to 38.0 g. The highest was the Darkhan-172 mutant of 38.0 g, but lowest was Khalkh gol-1 variety-30.5 g. Thousand kernel weight of mutant variety Darkhan-196 was 31.7 g and Darkhan-141 was 34.6 g.

**Table 3.** Growth duration and yield of wheat varieties

| No | Variety name | Maturity, days | Seed number per spike | 1000 kernel weight, g | Yield, t/ha |
|---|---|---|---|---|---|
| 1. | Khalkh gol-1 | 78 | 30 | 30.5 | 1.67 d |
| 2. | Darkhan-196 mutant | 79 | 29 | 31.7 | 2.02 ab |
| 3. | Karagandinskaya-22 | 81 | 31 | 36.4 | 1.79 d |
| 4. | Darkhan -172 mutant | 81 | 30 | 38.0 | 2.02 ab |
| 5. | Orkhon | 84 | 30 | 33.2 | 1.88 c |
| 6. | Darkhan -34 | 85 | 32 | 35.1 | 2.04 ab |
| 7. | Darkhan -141 mutant | 84 | 29 | 34.6 | 1.94 b |
| 8. | Altaiskaya -99 | 83 | 31 | 34.7 | 1.86 c |
| 9. | Altaiskaya -100 | 86 | 30 | 34.1 | 1.99 b |
| 10. | Altaiskaya -50 | 86 | 26 | 36.2 | 1.72 d |
| 11. | Darkhan -166 | 86 | 33 | 36.0 | 2.08 a |
| 12. | Darkhan -144 | 91 | 33 | 36.9 | 2.03 ab |
| | Mean | 84 | 30 | 34.8 | 1.92 |

**Grain quality of wheat varieties:** Quality parameters of new mutant varieties meet requirements of the national standard for food wheat MNS 0097:2010. The protein content of varieties varied 11.9-13.7%. The Altaiskaya-100 variety grain contained lowest protein 11.9%, however the Darkhan-196 mutant variety contains highest 13.7%. The medium maturity mutant variety Darkhan-141 has good grain quality comparing to other varieties. Protein content of Darkhan-141 mutant variety was 13.0%, it is 0.2-1.1% higher than other varieties, wet gluten (31%) 2.2- 5.7% higher and flour yield (73.0%) 1.7-6.4% higher than other varieties. Bread making quality score of mutant varieties Darkhan-172 and Darkhan-141 were highest (4.3-4.4).

**Table 4.** Comparing of grain quality of mutants and local varieties

| No | Variety name | Protein, | Gluten, | Flour yield, | Bread making score |
|---|---|---|---|---|---|
| 1. | Khalkh gol-1 | 13.0 | 29.4 | 68.5 | 4.1 |
| 2. | Darkhan-196 mutant | 13.7 | 29.5 | 68.7 | 3.8 |
| 3. | Karagandinskaya-22 | 12.3 | 28.3 | 69.3 | 3.9 |
| 4. | Darkhan -172 mutant | 12.5 | 28.5 | 68.0 | 4.4 |
| 5. | Orkhon | 12.3 | 28.2 | 66.8 | 4.1 |
| 6. | Darkhan -34 | 12.8 | 28.1 | 69.4 | 4.0 |
| 7. | Darkhan -141 mutant | 13.0 | 31.8 | 73.0 | 4.3 |
| 8. | Altaiskaya -99 | 12.5 | 29.6 | 71.3 | 3.8 |
| 9. | Altaiskaya -100 | 11.9 | 27.1 | 70.9 | 3.5 |
| 10. | Altaiskaya -50 | 12.2 | 26.1 | 67.0 | 3.7 |
| 11. | Arvin | 12.3 | 29.2 | 66.6 | 4.3 |
| 12. | Darkhan -144 | 13.1 | 32.2 | 68.6 | 4.3 |

**Fertilizer use effeciency of mutant varieties**

We have studied organic and mineral fertilizers influences for mutant variety's yield and grain quality. Analysis of soil samples from planting depth (0-20 cm) indicated low level of available nitrogen and phosphorus, medium in potassium, indicating that the nutrient may be a limiting factor for wheat production in the area. The upper 20 cm (arable layer) contains low (0.86%) organic matter (C), increasing to 1.22% in the subsoil (soil layer 20-40 cm). During the growth stage of wheat the soil nutrients in different treatments had different trend over time. We observed that the application of fertilizers influenced positively to the soil fertility. The use of fertilizers at sowing time, are

effective on improvement of seed germination and seedling growth of wheat mutant varieties, especially for Darkhan 141. Field germination of selected varieties increased from 6.3 % to 14.3% under fertilization.

These results showed that interactive effect of varieties and fertilizers had significant effect ($P<0.05$). The highest increased grain yield was recorded in NPK treatment. Application of N-P-K at the rate of 30-20-20 kg/ha to Darkhan 141 had maximum increased (1.22 t/ha or 83.6% compare to control) grain yield. The lowest grain yield (on an average 1.23 t/ha) was recorded in Darkhan 34 standart variety. Darkhan-172 mutant had 43.3% additional yield under the complex mineral fertilizer application. Table 5.

**Table 5.** Effect of fertilizers on yield of wheat mutant varieties, 2014-2016

| Treatments | Darkhan-34 | | Darkhan 141 | | Darkhan 172 | |
|---|---|---|---|---|---|---|
| | t/ha | Additional yield, % | t/ha | Additional yield, % | t/ha | Additional yield, % |
| Control | 1.15 | - | 1.46 | - | 2.03 | - |
| N | 1.05 | - | 1.64 | 12.3 | 2.30 | 13.3 |
| NP | 1.27 | 10.4 | 2.16 | 47.9 | 2.90 | 42.8 |
| NPK | - | - | 2.68 | 83.6 | 2.91 | 43.3 |
| Gumat | 1.44 | 25.2 | 1.62 | 11.0 | 1.98 | - |
| Mean | 1.23 | 17.8 | 1.91 | 38.7 | 2.42 | 33.1 |

The fertilization effected positively on grain protein content and increased 0.4-2.79 %. The highest percentage of grain protein (16.3%) and gluten content (36.9) were obtained from combined nitrogen and phosphorus (NP) fertilizer. Table 6.

**Table 6.** Effect of fertilizers on grain quality of mutant varieties, 2014-2016

| Treatments | Darkhan 34 | | Darkhan141 | | Darkhan 172 | |
|---|---|---|---|---|---|---|
| | Protein, % | Gluten, % | Protein, % | Gluten, % | Protein, % | Gluten, % |
| Control | 12.5 | 29.2 | 11.9 | 29.5 | 13.0 | 29.6 |
| N | 14.1 | 30.9 | 12.6 | 30.8 | 13.2 | 34.0 |
| NP | 16.3 | 36.9 | 13.0 | 34.4 | 12.9 | 30.1 |
| NPK | - | - | 14.2 | 31.4 | 13.5 | 32.8 |
| Gumat | 11.9 | 23.8 | 11.5 | 24.6 | - | - |

## Conclusion

The experiment results showed developing new varieties with high yield early maturity and good grain quality through mutation induction. Mutant varieties has very high fertilizer use efficiency.

The new mutant variety Darkhan-172 is registered as promising new early wheat variety for growing in the western and mountain areas in Mongolia.


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