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Diversification of Crop Production by Means of Spreading Soybeans to the Northern Regions of the Republic of Kazakhstan

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Selection and ecological species evaluation at the Kazakh SRI of Agriculture and Crop Production and the Kostanai SRI of Agriculture is aimed at creating soybean varieties adapted to most agri-environmental conditions of each region of the country, in order to break away from the monoculture. The article shows the results of the selection work aimed at creating ultra-early, high-yield soybean varieties for Northern Kazakhstan. Selection stages are shown, from hybridization to top nurseries. The joint work of the Kazakh SRI of Agriculture and Crop Production and the Kostanai SRI of Agriculture has resulted in obtaining an early ripening maturing variety of soybeans "Ivushka (Willow)", ripening group 00, submitted for state strain test in 2015.

Key words: soybeans, variety, diversification, strain test, crossbreeding.

Agriculture is an important sector of the Kazakhstan economy. Development of agriculture promotes, above all, availability of huge land reserves with extensive areas of agricultural land, including tillage, grasslands and pastures. Crop production in Kazakhstan provides slightly less product than farming, but it employs most of the population of the rural areas. It is considered the leading sector of agriculture in the Republic, and provides bread for the population, and forage for stock raising. Kazakhstan produces a lot of high-quality commercial grain.

Despite the fairly powerful inflow of funds from the state into the development of domestic agriculture, the Kazakhstan agricultural sector is still experiencing system problems related to the backwardness of crops cultivation technologies, low yield capacity and high risks of farming, lack of proven scientific approaches and, in general, of management and organization of business processes. The head of the state N. Nazarbayev in his Address to the Nation has clearly outlined the challenges in the country's crop production, including diversification of crops, reduction of low-profit species and introduction of innovative technologies.

Soybean is one of the most important legumes of the world, and is promising for diversifying crop production in Kazakhstan. In the last decade, production of soybean in world

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agriculture has greatly increased. Among legumes, soybean stands apart in terms of all nutrients that are necessary for normal functioning of humans and animals, and therefore it is considered of utmost importance for solving the protein problem in the world practice. By their amino-acid composition, soybean proteins are similar to the meat proteins. Soybean oil (15-26 % of the weight of the seeds) is used in food and forage industry.

In Kazakhstan, commercial cultivation of soybean started in 1986, on the area less than 10 hectares. In 2015, soybean was cultivated in the Republic on the area about 115 thousand hectares.

Currently, serious work is ongoing in Kazakhstan for establishing the national gene pool. In this regard, since 2001, the Department of Fodder, Oil-seeds and Legumes, KazRDIC&A, has been performing research of collecting, studying, selecting, documenting [1] and storing the soybean gene pool. During this period, over 600 specie samples of soybean have been collected from such countries as Kazakhstan, Russia, the USA, Ukraine, Belarus, Serbia, France, Canada, Sweden, Bulgaria, Romania, Moldova, Poland, Hungary, Kyrgyzstan, and Uzbekistan.

On the base of the Kazakh SRI of Agriculture and Crop Production, about 25 varieties of soybean had been created, 10 of which have been approved for the use on the territory of the Republic of Kazakhstan, and the others are being tested at the State Commission for Studying Varieties. These are mainly the varieties of the southern ecotype with the vegetation period of 120 to 135 days.

Expanding the cultivated area used for this crop requires creating varieties adapted for various areas of the Republic of Kazakhstan. In particular, for the Northern and Eastern regions of the Republic, it is necessary to create ultra-early ripening varieties with grain production features, with the vegetation period of 80-95 days (ripeness groups 000 and 00), with high attachment of bottom beans, and resistance to cracking, and to fungal and bacterial diseases. Due to promoting this crop to the Northern regions, special attention should be paid to crossbreeding aimed at early ripening[2-4].

One of the factors that limit the promotion of this crop to the Northern areas is the action of low positive temperatures, since soybean is a plant of the tropical climate by its nature. Resistance of soybean to low temperatures depends on the species and the variety, development phase, and other factors. The plants are most demanding for heat during germination of seeds and seedling, flowering and pod formation[5]. The temperature of the environment considerably influences intensity and orientation of physiological and biochemical processes, plants growth and productivity[6, 7].

Numerous studies have established that the minimum temperature of conventional soybean varieties seeds germination is 8-10 °C, and the optimum is 20-22 °C. Young soybean plants tolerate quite well slight spring frost (-2.5°C), but greater temperature falls seriously affect germination. The lower the temperature of soil and air is, the longer the period between sowing and germination is[8]. At the same time, effective soybean production in case of sowing at the early stages requires cold-resistant varieties that are capable of germinating and growing quickly at low positive temperatures of soil, and of withstanding short freezing on soil at the initial stages of ontogenesis. As is well known, varieties of soybeans feature narrow geographic localization, as compared to cereal varieties, due to the photoperiodic reaction of this variety. As a rule, promotion by one degree of latitude requires a new set of varieties adapted to the local conditions[9].

Thus, northering of soybeans particularly requires studies related to searching and introducing into breeding the varieties that feature ability of seeds to germinate at low temperatures, which contributes to more effective use of spring moisture reserves by plants, as well as to the seedling vigor, earlier flowering and ripening[10].

The Kazakhstan crop breeders face the need to create ultra-early and early ripening varieties of this crop for promoting them to the Northern and Eastern regions of Kazakhstan. In this regard, soybean breeding was started at the East-Kazakhstan SRI of Agriculture (EKSRIAC) and the Kostanai SRI of Agriculture. Here soybean is subjected to environmental testing for adaptation to local conditions, as well as to complete crossbreeding with the aim of creating early ripening varieties of crops for these cultivation areas. Introduction of such measures will support domestic cattle and poultry breeding, and form the export potential of soybean and the products of

its processing.

Conditions, materials and methods

The experiments are aimed at identifying ecologically flexible soybean varieties featuring high productivity in the Northern regions of Kazakhstan. The objective of the research was grade testing-based identification of soybean varieties that are most stable in the Northern region of Kazakhstan that are suitable for mechanical harvesting, early ripening, resistant to low temperatures, feature high yield and high protein and fat content in seeds (Glycinemax L. Merrill.).

The study was conducted at the experimental fields of the Kostanai SRI of Agriculture. The experimental fields of the Kostanai SRI of Agriculture are located near the city of Kostanai, at the altitude of 167 meters above the sea level, 53°12'51" N, 63°37'28" E.

The research work with soybeans consisted of crossbreeding followed by selecting linear material with desired characteristics. Quality characteristics of seeds were studied at the crop quality laboratory of KazRDIC&A. The experiments for ecological testing of the varieties considered seed yield, protein content, plant height, vegetation period, resistance to pests and diseases, resistance to lodging, shattering, simultaneous ripening. The obtained material was subjected to laboratory and structural analysis.

For the research, ultra-early ripening varieties of soybeans were taken.

Sowing was performed in the second decade of May according to the method of B. A. Dospekhov, the reference were the ultra-early ripening varieties SibNIIK 315 and Bilyavka zoned for this area[11]. The agricultural technology was according to the recommendations of Karyagin Y.G. Phenological observations were performed according to the method of Fehr and Caviness. Structural analysis was performed according to the method of Korsakov N. I. [12].

Hybridization was performed according to the modified method of the All-Russian Research Institute of Oil Crops[13]. The biochemical studies were performed at an infrared analyzer.

The experiment was laid out on the herbicide farrow. It had been prepared by using the soil protection and moisture-saving technologies. Dust mulching was performed upon reaching physical ripeness of the soil by a rotating harrow that did not disturb the mulching layer. Secondary tillage for soybeans consisted of cultivation using a KPS-4 cultivator and soil packing. Sowing was performed at the optimal time, i.e., in the third decade of May, with the use of an SS-11 seeder, together with an MTZ tractor. The seeding amount was 0.7 million germinating grains per 1 ha. The seeds intended for laying all experiments had been processed with an inoculant fertilizer before sowing. Before its use, the inoculant fertilizer had been stored in a dry dark place. On the day of sowing, the inoculant fertilizer was diluted with clean water at the rate of 250-300 g of the inoculant fertilizer per 1 ha of the seeds. The seeds were wetted with the obtained liquid and thoroughly mixed. Inoculated seeds were sown immediately. All work associated with processing and sowing seeds was performed in locations without direct sunlight, since it kills bacteria. In the period between "complete germination" and "start of branching", the soybean seedlings were treated with the Aramo herbicide at the rate of 1.5 l/ha for removing miliary weeds.

During the soybeans vegetation period, the spaces between the plots were weeded, and the interstratific roads were mechanically processed several times. Harvesting was performed directly by continuous plot threshing with a "Sampo-2010" combine harvester, at seeds moisture of 15-16%, followed by cleaning and drying to 12-13%.

RESULTS AND DISCUSSION

The experimental field of the Kostanai SRI of Agriculture is located in the dry steppe zone. The soil is brown. The climate in the area of the Kostanai Agricultural Experimental Station (AES) is sharply continental: hot and dry summers and cold winters with little snow. The average annual amplitude of the air temperature is 75°C; in some years, it reached 88°C. In winter, the minimum temperature often drops down to minus 35-40°C, in a few cases - to minus 45-50°C. In summer, the absolute temperature is 41 to 43°C. The warm period with the mean daily *t* above 0°C lasts for 195-200 days, from April 7-12 to October 19-28. The duration of the frost-free period ranges between 108 and 130 days. The average annual *t* of the air is 0.3 to 2.3°C; in some years, it rises up to 4.5-5°C, or falls

to 0-1.2°C. The duration of the vegetation period increases from the North to the South; it is 166 to 174 days. The characteristic feature of the continental climate is the predominance of precipitation during the warm period (May to October), when precipitation amounts to 60-80% of the annual rate. The maximum precipitation is observed in the second half of the summer, most often in July. The moisture index (HTI) in the region varies between 0.9 in the North and 0.5 in the South. Weather conditions of vegetation in the years when field experiments were performed were characterized by the following indicators (Table 1).

The temperature profile during the vegetation season in the three years of the experiment was close to normal. The deviations from the average long-term weather indicators were detected by the amount of precipitation.

Precipitation in 2013-2014 was non-uniform. The first half of the vegetation period (May, June and up to July 20) was highly arid. E.g., in 2013, during the whole of June, the precipitation

Table 1. The average monthly air temperature and precipitation during the vegetation in years 2013 through 2015, The Kostanai SRI of Agriculture

Month	Temperature, °C			Precipitation, mm		
	Actual	Mean Annual	Deviation	Actual	Mean Annual	Deviation
2013						
May	13.6	13.7	-0.1	20.6	36.0	-15.4
June	20.2	20.0	+0.2	8.1	35.0	-26.9
July	20.4	20.9	-0.5	116.6	56.0	+60.6
August	18.8	18.9	-0.1	80.0	35.0	+45.0
2014						
May	17.1	13.7	3.4	13.5	36.0	-22.5
June	21.2	20.0	1.2	18.9	35.0	-16.1
July	16.7	20.9	-4.2	107.5	56.0	+51.5
August	21.1	18.9	+2.2	9.4	35.0	-25.6
September	9.7	12.5	-2.8	0.0	25.0	-25.0
2015						
May	15.1	13.0	+2.1	82.3	36.0	+46.3
June	22.2	18.3	+3.9	37.6	35.0	+2.6
July	20.2	20.2	0.0	47.9	56.0	-8.1
August	16.9	17.8	-0.9	23.0	35.0	-12.0
September	12.9	11.9	+1	37.9	25.0	+12.9

Table 2. Results of ultra-early soybean varieties hybridization

Crossing combination		Date of hybridization	The number of pollinated flowers, pcs.	The number of hybrid beans	
Female parent	Male parent			pcs.	%
Birlik KV	341	18.06	20	0	0.0
Birlik KV	323	19.06	16	6	37.5
Birlik KV	Rosinka	19.06	20	7	35.0
Birlik KV	470	19.06	20	10	50.0
Birlik KV	233	20.06	20	3	15.0
Birlik KV	236	20.06	20	3	15.0
Birlik KV	217	20.06	20	3	15.0
Birlik KV	195	20.06	20	10	50.0
Birlik KV	225	20.06	20	7	35.0
Birlik KV	242	20.06	19	7	36.8

was only 9.7 mm, while the mean annual norm was 35.0 mm. The second half of the vegetation season was humid – precipitation in July and August was twice higher than the mean value for many years. E.g., in 2014, during the whole of June, the precipitation was only 18.9 mm, while the mean annual norm was 35.0 mm. July precipitation exceeded the mean annual value by 50.9 mm. Ripening of the seeds occurred with sufficient soil moisturizing. Thus, by the amount of precipitation, the 2013-2014 vegetation period was favorable. This fact had a positive influence on the yield of soybean varieties and numbers. In the spring, before sowing, this fact contributed to germination of weeds and to their subsequent removal by general-purpose herbicides. In the second half of the growing period, precipitation was accompanied by low air temperature, which positively influenced the growth and development of soybean plants and the yield, though it made harvesting difficult due to non-uniform ripening. The sum of the effective temperatures, both by months and in general for the period of the vegetation, was above the normal mean annual value, which fact positively influenced development of soybeans due to good soil humidifying.

In 2015, in the Kostanai region, over three monthly norms of precipitation fell (Table 1), which hampered sowing, and the optimum sowing dates were postponed. Increased soil humidity, cold spells followed by warm spells with the daytime temperatures of 30 to 35°C, resulting soil crust - all these factors did not contribute to creating the optimum conditions for normal germination of soybean seeds. The weather conditions in June, July and August 2015 were characterized by the following indicators: June precipitation was 37.6 mm with the mean annual norm of 35 mm. In July, precipitation was 47.9 mm (85% of the average annual norm), i.e., the maximum July rainfall was not observed in the reporting year. In the first and the second decades of August, precipitation was only 12.7 mm, which was almost 2 times lower than the average norm. Therefore, the amount of precipitation per month was 1.5 times lower. Air temperature in June was 22.2°C, which was 2.2° above the long-time average annual norm, and the average air temperature in July was close to the long-time average annual norm of 20.2°C. The average temperature in August was 16.9°C, which was also close to the long-time average annual norm of 18.9°C, however, night wind chills down to minus 0-1°C were observed on 23.08 and 24.08, which contributed to slightly premature withering of soybean leaves. Precipitation in September (37.9 mm) was 1.5 times above the long-time average annual norm, and in the second decade, the precipitation amounted to 31.1 mm, which was 3.4 times above the long-time average annual norm (9.0 mm). The air temperature in September was

Table 3. Yield of the best soybean numbers at the KAI in 2013-2015

Number	Yield, hw/ha				Deviation from the reference, hw/ha	Growing period, days (average)
	2013	2014	2015	average		
			ripening group 000			
SibNIIK 315 (st)	18.2	19,5	21.0	19,5		85
445/2	23.9	21.7	20.0	21.8	+3.8	86
			ripening group 00			
Bilyavka (st)	21.1	18.0	18.0	19.0		97
K 589109	21.4	18.3	20.5	20.1	+1.1	94
422	22.0	23.5	26.5	24,0	+4.5	92
180/2	22.2	20.0	21.2	21.1	+2.1	94
177	23.6	20.5	23.2	22.4	+3.4	92
212	24.7	19.7	21.7	22.0	+3.0	94
186	23.6	21.7	21.5	22.3	+3.3	91
173	23.3	23.0	25.2	23.8	+4.8	93
126	23.3	20.1	22.0	21.8	+2.8	94
LSD 0.95	1.5	1.8	1.2			

identical to the long-time average annual norm, 12.9°C and 12.5°C, respectively; and no frost was observed.

The main method of obtaining new source material was intervarietal hybridization. The effectiveness of soybeans hybridization, as compared to other crops, was significantly lower; on the average, it was 15-20%. In respect of early maturing varieties, this indicator was even lower, 5 to 10%. Hybridization was performed at

Table 4. Economic and biological characteristics of the Ivushka variety compared to the reference

Indicators	Unit of measurement	This variety Ivushka				The best zoned variety SibNIIK 315			
		2013	2014	2015	mean	2013	2014	2015	mean
1. The yield of the variety seeds (at standard humidity of 14 %)	hw/ha	22.0	23.5	26.5	24.0	18.2	19.5	21.0	19.5
LSD 05	hw/ha	1.2	1.4	0.8		1.2	1.4	0.8	
2. Vegetation period (from sowing to ripeness)	days	102	105	107	104	98	95	98	97
including:	days	12	13	12	12	12	12	10	11
a) from sowing till complete germination									
b) from complete germination till full blossom	days	20	25	27	24	20	20	21	20
c) from full blossom till ripeness	days	70	67	68	68	66	63	67	66
d) from the beginning until the end of flowering	days	15	17	18	16	13	12	15	13
3. Vulnerability to diseases and damage by pests.	point								
a) anthracnose (veget. mass)	point	0.0	0.0	0.0	0.0	1.0	2.0	0.0	1.0
b) anthracnose (beans)	point	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.5
c) black stem (veget. mass)	point	0.0	0.0	1.0	0.3	1.0	2.0	1.0	1.3
d) black stem (beans)	point	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.3
e) bacterial blight (veget. mass)	point	0.0	0.5	0.5	0.5	2.0	2.0	2.0	2.0
f) bacterial blight (beans)	point	0.0	0.0	0.0	0.0	1.0	2.0	0.0	1.0
g) fusarial head blight	point	0.0	0.0	0.0	0.0	1.0	2.0	1.0	1.5
h) false mildew	point	0	0	0	0.0	0	0	0	0.0
i) septoria blight	point	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0
j) root rot	point	0.0	0.0	0.0	0.0	1.0	2.0	1.0	1.3
4. Vulnerability to disease in case of artificial infection:	point	Not performed				Not performed			
5. Intensity of nodules development (few, medium quantity, many)	point	many	many	many	many	many	many	many	many
6. Resistance to lodging by 5-point scale	point	5	5	5	5	5	5	5	5
7. Bruise of branches for soybeans		-	-	-	-	-	-	-	-
8. Resistivity to beans falling	point	5	5	5	5	5	5	5	5
9. Resistivity to beans dehiscence (seed cast)	point	5	5	5	5	4	4.5	4	4.3
10. Suitability for mechanized harvesting	point	4.5	4.5	5	4.6	4.5	4	4	4.3
11. Leaf shedding upon maturity		Simultaneous				Simultaneous			
12. Seed shell dehiscence	point	0	0	0	0	0	0	0	0
13. The content of crude protein from the absolutely dry substance (NX 6.25)	%	38.8	35.5	40.2	38.1	33.2	30.5	35.2	32.9
14. Content of fat from absolutely dry substance	%	23.5	21.2	22.3	22.3	23.5	22.7	21.8	22.6

KazRDIC&A.

In 2015, hybridization was performed on 10 combinations of crossbreeding, 195 flowers were caponized and pollinated. The fruit set rate ranged between 0 and 50 % for certain combinations (Table 2).

30 numbers of Kazakhstan-crossbred soybeans of two ripening groups - 000 and 00 - were studied in the nursery of competitive variety trial, with the vegetation period in the conditions of the Kostanai region, equal to 80-90 and 90-100 days, respectively. In the ripening group 00, number 422 was selected, which featured the average yield of 24.0 kg/ha, which was by 5.8 hw/ha higher than the yield of the SibNIIK 315 reference variety, and by 4.8 hw/ha higher than that of the Bilyavka variety. (Table 3).

Biochemical studies of the numbers in course of the competitive strain test identified the most protein-containing varieties - No. 422, No. 208, and No. 252 with protein content of 39.4 to 40.8 %. Fat content was in the range between 20.8 and 21.0%

Determination of adaptability of the studied soybean varieties to the local conditions showed that on the average over the 3 years of competitive trials at the Kostanai SRI of Agriculture, the crossbreeding number 422 formed the highest yield and showed good indicators for all the parameters. In 2015, this number was passed for the state variety strain test for zoning in the Kostanai, the Akmola and the Pavlodar regions under the "Ivushka" brand name (Table 4, Figure 2).

Morphological description

Seedlings are green, mesocotyls are green. In the flowering period, the stem is green without anthocyanin pigmentation, the main stem

a - flower cluster b – plant c – seeds

Fig. 1 . Morphological features of the Ivushka variety structure

is erect, and its thickness is average. Plant height is 60 to 70 cm. The height of lower beans attachment is 8 - 10 cm. The main stem has 10-12 internodes. The growth type is determinant. The bushes are compact, of medium branching. Pubescence is reddish-brown. The leaves are ternate, dark green, of medium size, ovate & pointed, and completely fall off after ripening. The foliage is strong. Medium sized flowers are collected into clusters 5-7 pieces each, the floral brush is shortened, the crown color is violet. The beans are slightly curved, with small points, light brown in color, with 2 or 3 seeds. The seeds are oval. The weight of 1,000 seeds is 175-185 g. The color of the seeds is yellow; the surface is smooth, glossy. The cicatrice is medium, oblong, light brown. The beans ripen at the same time without cracking; the grains do not clump.

Quality characteristics

Belongs to the early ripening group (ripening group 00), the vegetation period is 90-95 days. Grain yield at KAI in 2013-2015 was 24.0 hw/ha, the protein content in grains is 34.1 %, and oil content was 22.3 %. The variety does not lodge.

The variety is suitable for cultivating in the Kostanai, the Akmola, and the Pavlodar regions.

CONCLUSION

Soybeans with high content of protein and oil play an important role in the diversification

of crop production in the Northern region of Kazakhstan. Achieving this goal required creating new early ripening varieties of soybeans that are capable of ripening in the conditions of the short vegetation period in the North of the country. Restoring the complete soybean selection process in the Northern Kazakhstan allows creating high-yield, ultra-early ripening varieties of this crop for the particular region of cultivation. Breeding and ecological strain tests of soybeans were performed in cooperation of the Kazakh SRI of Agriculture and Crop Production, and the Kostanai SRI of Agriculture; crossbreeding was aimed at creating soybean varieties that are most adapted to the agri-ecological conditions of the Northern region. The result of the joint work had been the early ripening soybean variety Ivushka (ripening group 00) that was passed for state strain test in 2015.

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