



Monitoring Quality and Yield Capacity of Soybean Varieties during the Creation of Various Ecotypes in Kazakhstan

Svetlana Vladimirovna Didorenko^{1*)}, Aigul Izteleuovna Abugaliyeva¹⁾, Raushan Saylaunva Yerzhebeyeva¹⁾, Vladimir Gennadievich Plotnikov²⁾ and Andrey Viktorovich Ageyenko¹⁾

¹⁾ Kazakh Research Institute of Agriculture and Plant Growing, 1 Erlepesov str., Almalybak village, Karasai district, Almaty region, 040909, Republic of Kazakhstan

²⁾ Karaganda State University, 28 Universitetskaya str., Karaganda, 100028, Republic of Kazakhstan

ARTICLE INFO

Keywords:

Germplasm
 Seed quality
 Soybean
 Various ecotypes
 Yield capacity

Article History:

Received: August 31, 2020

Accepted: August 12, 2021

*) Corresponding author:

E-mail: didorenko.s.v@bk.ru

ABSTRACT

In 2020, on the territory of the Republic of Kazakhstan, soybeans were cultivated on an area of about 127.7 thousand hectares. To expand the acreage of this crop, it is necessary to create new varieties with a high genetic potential for productivity and quality and adaptive to the various soil and climatic zones of the Republic. The work aims to monitor the quality indicators and productivity of new highly productive varieties of soybeans with a high content of protein and oil in seeds. In Kazakhstan, 18 varieties of soybeans have been bred and approved for production at latitudes from 53 to 42°N. The varieties belong to maturity groups 00, 0, I, II, III. There is a tendency to an increase in the collection of oil and protein in the varieties of the new generation. In the varieties created in the 70s-80s, the collection of protein per hectare was 1,078.0-1,238.3 kg and oil at 577.5-734.5 kg. In the new generation varieties, the collection of protein per hectare is in the range of 944.7-1,705.3 kg, and oil at 415.9-974.6 kg. The yield capacity of different varieties falls in the range of 20.9 to 43.9 kg/ha, depending on the maturity group.

INTRODUCTION

The uniqueness of the quality composition of soybeans is the high content of protein and oil. Soybean seeds contain 24 to 57% protein, 6 to 27% fat, 20 to 32% carbohydrates, fat and protein together account for 50 - 60% of the seed mass (USDA, 2018). The amino acid composition of soybean protein practically corresponds to the protein of animal origin. It has little and less less methionine, cysteine, and lysine compared to animal protein; thus it can be attributed to the most valuable proteins of plant origin.

Looking at the current use of soybeans in the world, approximately 85% of the world's soybeans are processed into soy products or soy oil. About 98% of processed soybeans are further processed into animal feed, partly into soy flour and proteins. Concerning the oil, 95% soybean oil is consumed as edible oil, and the rest is used for the production of industrial products such as fatty acids, soaps, and

biodiesel (Olkhovatov, Ponomarenko, & Kovalenko, 2015; Qi & Lee, 2014). There are many soy products on the market, such as soy milk, soy cheese (tofu), fermented soy curd (tempeh), puddings, soy substitutes for meat, poultry, and fish. Soy is used to make cocoa, coffee, and chocolate. The global production of soybeans will grow annually, and in 2019 the sown area of soybeans amounted to 125.6 million ha (World Agriculture Production, 2020).

Currently, three countries (the United States, Brazil, and Argentina) account for more than 80% of world soybean production (SoyStats, 2018). The Committee on Statistics of the Republic of Kazakhstan (2021) states the sown area of soybeans in Kazakhstan over the past 10 years has grown by more than 2.5 times from 53.6 thousand ha in 2009 to 139.5 thousand ha in 2019 and the crop yield during this period increased from 18.0 centners/ha up to 20.7 centners/ha. Currently, 48 soybean varieties are registered in the State Register of

ISSN: 0126-0537 Accredited First Grade by Ministry of Research, Technology and Higher Education of The Republic of Indonesia, Decree No: 30/E/KPT/2018

Cite this as: Didorenko, S. V., Abugaliyeva, A. I., Yerzhebeyeva, R. S., Plotnikov, V. G., & Ageyenko, A. V. (2021). Monitoring quality and yield capacity of soybean varieties during the creation of various ecotypes in Kazakhstan. *AGRIVITA Journal of Agricultural Science*, 43(3), 558–568. <https://doi.org/10.17503/agrivita.v43i3.2799>

Svetlana Vladimirovna Didorenko *et al.*: *Yield and Quality of Soybean on Ecotypes*

Breeding Achievements and approved for use in the Republic of Kazakhstan, Eighteen of these varieties are Kazakh breeding varieties created at the Kazakh Research Institute of Agriculture and Plant Growing (KazNIIZiR) (Ministry of Agriculture of the Republic of Kazakhstan, 2021).

The main factor in increasing the level and stability of soybean production in the country is the use of new productive varieties with improved biochemical characteristics (Yusova, Asanov, & Omelyanyuk, 2017). The quality of raw materials of crops is a basic requirement that is relevant for all areas of their use. In soybeans, this is primarily the quality of the seeds: the content and composition of protein and oil, and anti-nutritional substances (Vishnyakova, Seferova, & Samsonova, 2017).

The global soybean breeding was originally aimed to increase the oil content in seeds, but in recent decades, breeding work around the world has turned towards To increase the protein content (Zelentsov & Moshnenko, 2016). Breeding soybeans for quality is no less difficult than breeding for yield capacity, taking into account on the influence of the environment and the relationship with other traits and properties of the genotype, with resistance to pathogens and other factors (Bellaloui *et al.*, 2015; Song *et al.*, 2016).

Very often, breeders want to find sources in the gene pool for breeding a variety with a high protein and oil contents at the same time, using their total indicator. Over the past 30-40 years, protein and oil contents on the existing varieties have increased from 49.7 to 66.3% (mainly due to a decrease in the proportion of the seed coat) and has practically reached the limits for this culture (Petibskaya, 2012). However, the accumulation of protein and oil in soybean seeds usually shows a strong negative bond that cannot be broken. It was found that the negative correlation between traits could vary from $r = -0.25$ to $r = -0.93$ (Yusova, Asanov, & Omelyanyuk, 2018) and had a high heritability coefficient of 0.89-0.93 (Stobaugh, Florez—Palacios, Chen, & Orazaly, 2017).

Overall plant productivity is often negatively correlated with protein content, although this relationship is weaker than between protein and oil content. It has been shown, however, that no insurmountable metabolic barriers exist between these traits. The amount of protein in seeds can be increased by backcrossing. Thus, to increase by 4.7%, it took eight cycles of recurrent selection

(Wilcox, 1998). It was also reported to increase the proportion of protein by 5.6-6.9% without a decrease in oil content and productivity with one-sided intra-variety selection. The content of protein and oil in seeds is subjected to high modification variability, and the effect of the environment on oil content is much less significant than on protein (Bellaloui *et al.*, 2011; Novikova *et al.*, 2018).

In Kazakhstan, KazNIIZiR Limited Liability Partnership organized a study of the genetic diversity of soybean varieties of various maturity groups in terms of productivity and quality (Abugalieva & Didorenko, 2016; Novikova *et al.*, 2018), the composition of fatty acids (Lee, Spankulova, Orazbayeva, Didorenko, & Atabayeva, 2016a; 2016b), and the content of anti-nutrients (Bulatova *et al.*, 2019). The work aims to monitor the quality indicators and yield of new highly productive varieties of soybeans were adaptive to various ecological and geographical zones of Kazakhstan, with a high content of protein and oil in seeds.

MATERIALS AND METHODS

The research was conducted from 2012 to 2019 at the field stations of KazNIIZiR Limited Liability Partnership, which are located in the Almaty region of the Republic of Kazakhstan.

Materials

The material for the study was 1,650 soybean samples of 7 maturity groups (000, 00, 0, I, II, III, IV). The sample is represented by the gene pool from the collection of the All-Russian Institute of Plant Genetic Resources originating from 26 countries, and the numbers of preliminary, control and competitive variety trials of breeding in Kazakhstan and varieties created on the premises of KazNIIZiR Limited Liability Partnership. The numbers of Kazakh selection are the linear material of the individual selection of hybrid populations obtained by crossing the varieties of the gene pool that were distinguished by economically valuable traits. The study included 84 to 331 samples annually. Each sample was studied for one to six years. The longest observations that lasted 12 years (2008 to 2019) were performed on the Zhansaya variety, which was the standard in the field and biochemical evaluation of samples.

Weather and Climatic Characteristics of the Research Area

The studies were carried out at the field stations of KazNIIZiR Limited Liability Partnership which are

located in the Almaty region, at an altitude of 740 m above sea level, 43°15'N., 76°54'E. The zone is characterized by continental climatic conditions. The most optimal weather conditions for the formation of high yield of soybeans were in 2013, 2016, 2018, and 2019 (Table 1). The worst conditions were recorded in 2012, 2014, 2015, and 2017.

Methods

Sowing was carried out according to the method of Dospekhov (2012), with four-row plots, a row spacing of 30 cm, in the area of area of 20 m². The seeding rate for early-maturing varieties is 650 thousand, for mid-maturing (550 thousand), and for late-maturing (450 thousand) germinating seeds per ha. The sample placement was randomized in triplicate. Agricultural technologies were used in experiments according to the methodological recommendations for the southeast of Kazakhstan. Phenological observations were carried out on the main phases of plant development, i.e. sowing, shoots (VE), the appearance of a trigeminal leaf (V1), flowering (R2), bean formation (R4), filling of beans (R6), maturing (R8) (Licht, 2017). Field assessment was performed following the All-Russian Institute of Plant Genetic Resources methodological guidelines (Vishnyakova *et al.*, 2018). Gravity vegetation irrigation

was carried out three times: in the third 10 days of June, the second 10 days of July, and the first 10 days of August with an irrigation rate of 1,200 m³/ha.

The protein content was determined according to Kjeldahl (GOST 10846-91. "Grain and products of its processing. Method for determination of protein") while, the fat content (oil content) was determined according to GOST 10857-64 "Oilseeds; the method for determination of oil content" in the Soxhlet apparatus. Sampling for the determination of protein and fat was carried out following GOST 10852-86 (Oilseeds. Acceptance rules and sampling methods). From a volume of 5 kg, 300 g samples was taken from three field replicates. The average content of protein and oil was calculated for breeding centers for each year.

The statistical processing was carried out by the method of cluster analysis based on the similarity measure for the minimum product between the Euclidean distances and the correlation coefficient $D(1-R)^2$ (Savin, Abugaliev, & Abugalieva, 1998). Cluster analysis was carried out according to Martynov using the measure of the minimum of the product between the Euclidean distances and the correlation coefficient for a complex of features (yield capacity, length of the growing season, protein content and fat content).

Table 1. Dynamics of average monthly temperatures and atmospheric precipitation from April to September. Data from the meteorological station of KazNIIZIR Limited Liability Partnership, Almaty region.

Month	Long-term average value 2001-2019	Year							
		2012	2013	2014	2015	2016	2017	2018	2019
Temperature (°C)									
April	12.2	16.1	12.3	10.1	18.8	13.5	11.2	12.4	12.4
May	17.2	18.6	16.9	18.6	22.6	16.7	19.0	16.3	16.9
June	21.8	21.0	21.3	23.0	27.3	23.0	22.3	22.3	22.3
July	23.8	25.9	24.9	25.9	23.7	23.7	27.0	25.2	26.9
August	22.4	24.7	23.6	24.1	15.6	22.9	22.6	24.5	24.9
September	18.2	16.0	19.9	18.0	18.8	21.2	23.3	17.3	18.5
Precipitation (mm)									
April	109.0	45.2	164.0	106.7	41.2	166.6	222.7	81.6	183.0
May	101.9	68.9	80.7	58.8	92.6	216.2	115.9	124.9	39.3
June	62.1	130.3	82.0	35.3	6.1	136.8	54.5	28.7	72.7
July	52.4	8.6	42.4	8.6	43.2	111.3	9.9	32.3	25.7
August	30.6	0.0	85.2	0.0	24.6	0.4	0.4	43.5	67.7
September	24.8	0.6	7.2	10.8	41.2	36.4	29.8	18.9	54.1
Total for the growing season	380.8	253.6	461.5	220.2	248.9	667.7	433.2	329.9	442.5

Svetlana Vladimirovna Didorenko *et al.*: *Yield and Quality of Soybean on Ecotypes*

The estimation of Pearson's linear correlation coefficients was carried out in the software environment R (R version 3.6.1 (2019-07-05) "Action of the Toes") with open source code as part of the GNU (GNU's Not UNIX) project. The language and environment are available under the GNU General Public License, distributed as source codes, as well as compiled applications for several operating systems: FreeBSD, Solaris. The matrices of linear Pearson correlation coefficients (using `cor` command) were calculated from the built-in {stats} package, the graphs for them (`corrplot`) were built using the package.

RESULTS AND DISCUSSION

Soybean breeding in Kazakhstan started at KazNIIZiR Limited Liability Partnership in 1961 and continues to the present day. Over the years, about 30 varieties have been created, of which 18 are approved for use in different ecological and geographical zones of Kazakhstan, such as Almaty, Kyzylorda, Zhambyl, Turkestan, East Kazakhstan, Akmola, Pavlodar and Kostanay regions. The first stage of breeding work in 1971-1990 was aimed to create adaptive and improved productivity of new soybean varieties. The results of the work were the created late-maturing varieties of soybeans (Kazakhstanskaya 200, Gibrinaya 670, Kazakhstanskaya 2309, Evrika 357). These varieties had a potential yield capacity of 2.5-3 t/ha and were adapted to the conditions of the south and southeast of Kazakhstan during the growing season.

With the gradual expansion of the cultivated areas, it became necessary to grow soybeans in the east of Kazakhstan. In this regard, for the next 15 years, selection development was aimed at to create early maturing soybean varieties. Early maturing soybean varieties, such as Misula, Almaty, Zhalspaksay with a vegetation period of 105-110 days were created and recommended for cultivation in the East Kazakhstan region.

Faced with the problem of photoperiodism at the next stage of 2006-2017, breeding work was launched in the East Kazakhstan and North Kazakhstan regions with the involvement of specialists from the East Kazakhstan Research Institute of Agriculture and the Kostanay Research Institute of Agriculture. Well-coordinated joint work, early-maturing varieties were bred and subsequently approved for use, such as the ultra-early-maturing Ivushka in Pavlodar, Akmola, and Kostanay regions;

the early-maturing Birlik KV in the East Kazakhstan region; and the mid and late maturing Zhansaya and Lastochka in the Almaty region.

At the present stage, since 2010, breeding has been used to create varieties not only with a classic set of characteristics but also with improved physical and chemical parameters and organoleptic properties of seeds, thus expanding the scope of their application in production. Breeding for quality takes into account not only the differentiation of the complex chemical composition of soybeans but also the improvement of technological, physical, and organoleptic qualities to increase marketability in a broad sense and suitability for dynamic loads during harvesting.

Productivity is inversely correlated with certain qualitative indicators (Zelentsov & Moshnenko, 2016). In the United States, the main sowing country in the world, when studying the influence of several factors on the biochemical parameters of soybean seeds, it was proved that the environment was the most important source of variability in protein and oil content (Bellaloui *et al.*, 2015). The quality of soybean numbers was monitored in all breeding centers. The average protein content in soybean seeds in the years of research in all breeding centers was in the range of 35.5-41.0%, and the maximum values were observed in the demonstration breeding center, equal to 42.9-46.9% (Table 2).

Over the years, sharp fluctuations in protein content have not been observed, however, in 2014, there was a noticeable decrease in the average protein content for all studied breeding centers (Fig. 1). This year is characterized by the lowest precipitation index for all the years of research, 220.2 mm. A decrease in the rate of precipitation was noted in all growing months, especially in July, August, and September, which gave a total of 19.4 mm. Besides, the temperature background in July and August was significantly higher than the average long-term indicators by 2.1 to 1.7°C.

The yield capacity data for the demonstration breeding center and the standard variety Zhansaya in 2014 turned out to be the lowest in comparison with long-term values (Fig. 2). The results of our studies do not support the data found in published literature that stating the protein content increases with dry weather and elevated temperatures (Petibskaya, 2012). It has been repeatedly shown that in different regions of the world the influence of climate on the protein content in seeds is much

Svetlana Vladimirovna Didorenko *et al.*: Yield and Quality of Soybean on Ecotypes

more pronounced than on the oil content (Ermolina, Antonov, & Korotkova, 2011; Novikova *et al.*, 2018). Our research has also revealed a small variability of the oil content trait over the years of research. The average oil content in soybean seeds for all breeding centers is in the range of 20.2 to 22.6% (Table 3).

According to some reports, there is evidence that humidity is of great importance for the synthesis

of oil. If the protein content rises under drought conditions, then with an increase in humidity at favorable temperatures (above 18-19°C), oil synthesis increases (Dornbos & Mullen, 1992). However, in our studies, the maximum values of the oil content are observed in dry years, such as 2012 (23.0-23.5%) and 2014 (24.5-25.1%) in all breeding centers.

Table 2. Protein content in soybean seeds for all breeding centers (2012-2019)

Plant breeding center	Value	Protein content in soybean seeds (%)							
		2012	2013	2014	2015	2016	2017	2018	2019
Demonstration breeding center	Maximum	43.3	46.9	44.2	42.9	46.8	44.8	45.2	42.9
	Minimum	37.7	37.5	31.4	37.5	36.7	36.1	36.4	34.6
	Average	40.2	40.8	36.7	39.4	39.6	38.8	38.9	38.0
Preliminary variety testing	Maximum	42.6	41.9	39.1	43.1	43.9	42.6	45.1	43.3
	Minimum	36.6	36.4	32.2	35.2	35.3	37.8	37.5	33.1
	Average	40.1	39.4	35.8	39.2	39.2	40.4	40.8	39.2
Control variety testing	Maximum	42.6	43.7	39.1	41.6	41.5	41.5	42.1	44.2
	Minimum	37.7	37.2	32.3	34.9	36.6	36.9	36.7	37.3
	Average	40.1	39.9	35.5	38.7	39.0	39.5	39.4	41.0
Competitive variety testing	Maximum	42.0	44.5	41.0	42.6	40.9	41.8	41.7	40.9
	Minimum	36.7	37.6	32.4	36.8	35.8	36.5	36.2	35.9
	Average	39.7	40.4	36.6	38.7	38.7	39.4	39.1	38.4
Zhansaya (standard)		37.9	39.5	38.0	38.3	40.5	38.0	40.1	39.6

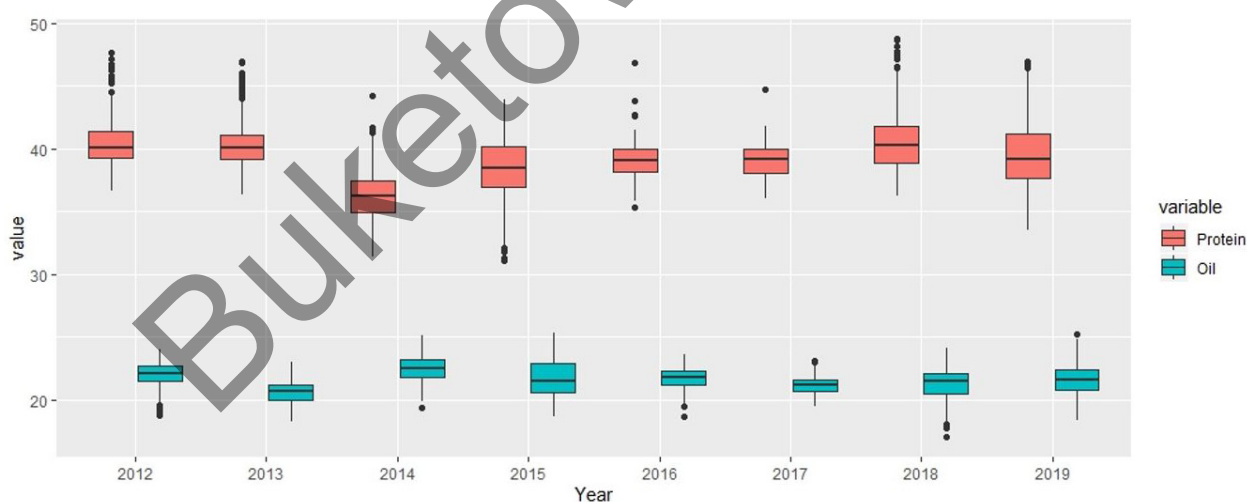


Fig. 1. Protein and oil content in soybean seeds in an 8-year retrospective

Svetlana Vladimirovna Didorenko et al.: Yield and Quality of Soybean on Ecotypes

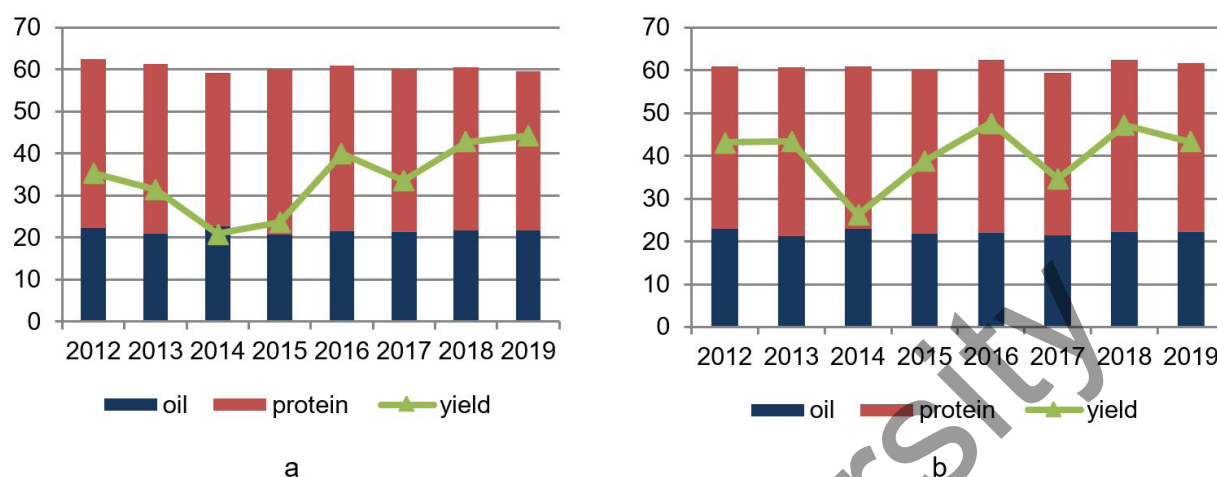


Fig. 2. Yield capacity, protein, and oil content (2012-2019): (a) the demonstration breeding center, (b) the Zhansaya soybean

Table 3. Oil content in soybean seeds for all breeding centers (2012-2019)

Plant breeding center	Value	Oil content in soybean seeds (%)							
		2012	2013	2014	2015	2016	2017	2018	2019
Demonstration breeding center	Maximum	23.5	22.9	25.1	21.9	23.3	23.0	23.7	23.4
	Minimum	20.4	18.3	19.3	19.1	18.7	20.4	20.4	20.5
	Average	21.8	21.1	22.6	20.8	21.5	21.4	21.9	21.8
Preliminary variety testing	Maximum	23.4	21.5	25.0	22.6	23.4	22.1	23.2	22.8
	Minimum	20.9	18.9	19.8	18.6	20.0	19.7	18.6	19.2
	Average	22.0	20.2	22.2	20.7	21.8	21.2	21.5	21.3
Control variety testing	Maximum	23.9	22.2	24.6	22.9	23.5	21.8	22.3	22.6
	Minimum	19.2	18.4	20.0	19.8	19.5	19.4	19.7	19.0
	Average	22.1	20.4	22.6	21.1	21.6	20.9	21.1	21.1
Competitive variety testing	Maximum	23.3	22.2	24.9	23.0	23.6	23.1	22.3	23.6
	Minimum	20.4	18.7	20.2	18.9	20.4	20.1	20.0	19.7
	Average	22.0	20.7	22.5	20.7	22.0	21.2	21.2	21.5
Zhansaya (standard)		23.0	21.2	23.0	21.9	22.0	21.5	22.3	22.2

The correlation analysis data show an average positive relationship between the amount of atmospheric precipitation throughout the growing season for protein content ($r = 0.67$), while precipitation in August has an average negative relationship for oil content ($r = -0.65$). The precipitation recorded in July has a medium-positive correlation with yield capacity ($r = 0.41$). Higher temperatures in May, June, July, and September reduce the protein content in soybean seeds ($r = 0.34-0.46$). An increase in the temperature background in April, May, and July leads to an increase in the oil content ($r = 0.33-0.50$), and in September, on the contrary,

to its decrease ($r = -0.30$) (Table 4).

The analysis of soybean samples by maturity groups confirms numerous data on a decrease in protein content with an increase in the growing season. Thus, in the earliest maturity group (000) with a vegetation period of 78-89 days, the protein content averaged at 42.7%, while it amounted to 38.1% in the very late maturity (III) group with a vegetation period of 125-158 days. There was no significant variation in oil content by maturity groups (Fig. 3).

The length of the growing season has a positive correlation with the crop yield. In the studied

samples, the average yield by maturity groups was: 000 — 14.1 centners/ha, 00 — 16.7 centners/ha, 0 — 26.5 centners/ha, I — 29.7 centners/ha, II — 34, 8 centners/ha, III — 35.3 centners/ha (Fig. 4).

Considering the stages of soybean breeding in Kazakhstan and the qualitative characteristics of the created varieties, there is a tendency to increase the collection of oil and protein in the new generation varieties. New varieties are characterized not only by a higher yield potential compared to old varieties but also by an increase in the protein content in seeds for each maturity group. In the varieties created at the first stage of selection, the collection of protein per ha was 1,078.0-1,238.3 kg, and the oil collection amounted to 577.5-734.5 kg. In the varieties created in the period 2006-2010, the collection of protein per ha is 1,092.0-1,333.9 kg, and the collection of oil is 535.1-763.8 kg. In the new generation varieties, the collection of protein

per ha is in the range of 944.7 to 1,705.3 kg, and the collection of oil is 415.9 to 974.6 kg.

For each maturity group, varieties with the largest collection of protein and oil per ha are distinguished. Thus, in the mid-maturing group (I) for the Vostochnaya Krasavitsa soybean variety, the average rate of protein collection is 1,705.3 kg/ha, and oil collection equals 838.4 kg/ha. In the middle-late group (II), the Zhansaya soybean variety stands out, where the protein collection rate is 1,707.7 kg/ha, oil collection rate is 974.6 kg/ha, and in the late-maturing group III, the Lastochka variety stands out with the protein collection rate of 1,635.8 kg/ha and oil collection rate of 894.6 kg/ha (Table 5).

To visualize the similarities and differences in yield, protein content, fat, and their collection per ha of created and approved for production soybean varieties, cluster analysis was carried out and a dendrogram was built (Fig. 5).

Table 4. The genotypic correlation coefficient

What is it??	April	May	June	July	August	September	Total for the growing season
Precipitation (mm)							
Protein	0.45	0.44	0.48	0.50	0.33	0.40	0.67
Oil	-0.26	-0.23	0.16	0.03	-0.65	-0.28	-0.31
Temperature (°C)							
Protein	-0.24	-0.46	-0.35	-0.34	-0.03	-0.34	
Oil	0.33	0.33	0.18	0.50	0.03	-0.30	

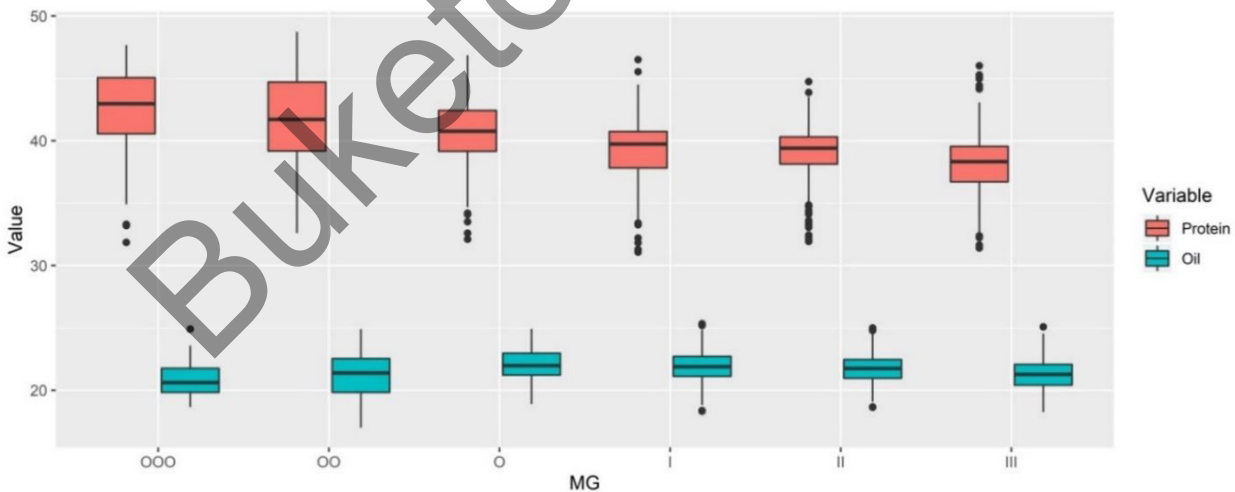


Fig. 3. The protein and oil content by soybean maturity groups

Svetlana Vladimirovna Didorenko et al.: Yield and Quality of Soybean on Ecotypes

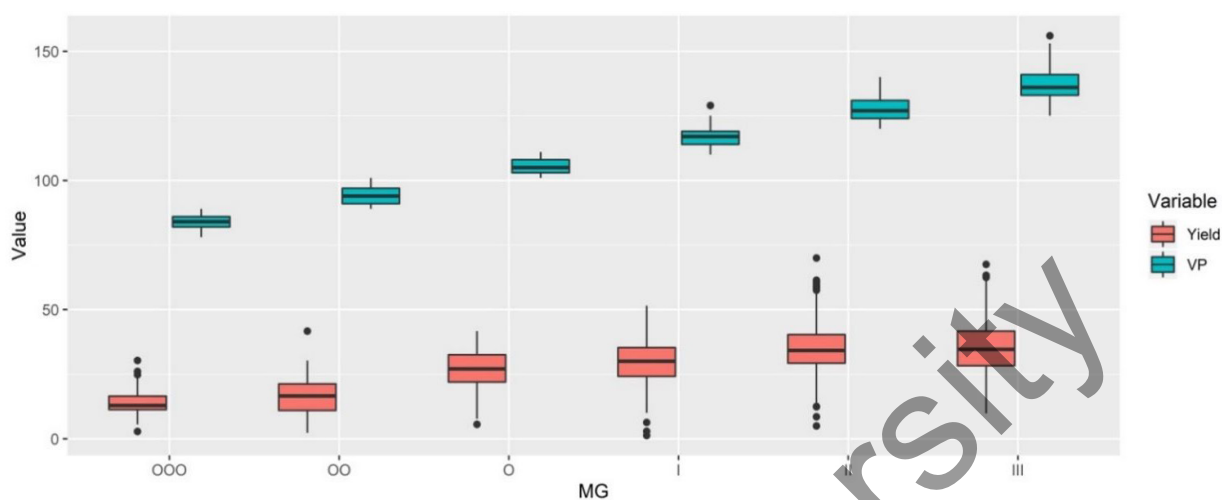


Fig. 4. Productivity and growing season depending on the groups of soybean maturity

Table 5. Characteristics of soybean varieties approved for use in Kazakhstan

Variety	Year of zoning	Vegetative period (days)	Yield capacity (centners/ha)	Protein	Yield of protein per ha (kg)	Oil (%)	Yield of oil per ha (kg)
Ivushka	2018	96.0	20.9	45.2	944.7	19.9	415.9
Birlik KV	2017	108.8	25.4	41.8	1061.7	21.6	548.6
I							
Misula	1997	117.7	31.3	40.2	1,258.3	21.7	679.2
Zhalpaksai	2003	121.6	32.5	38.1	1,238.3	22.6	734.5
Almaty	2006	117.3	33.6	39.7	1,333.9	21.5	722.4
Perizat	2013	124.6	36.6	38.8	1,420.1	21.5	786.9
Pamyat YuGK	2018	121.4	38.9	38.5	1,497.7	21.5	836.4
Vostochnaya krasavitsa	2019	120.5	40.7	41.9	1,705.3	20.6	838.4
II							
Vita	2008	131.6	35.2	37.8	1,330.6	21.7	763.8
Zhansaya	2012	125.8	43.9	38.9	1,707.7	22.2	974.6
Danaya	2016	129.6	36.0	39.0	1,404.0	21.2	763.2
Sabira	2016	133.2	37.1	37.3	1,383.8	21.6	801.4
III							
Kazakhstanskaya 2309	1992	139.7	27.5	39.2	1,078.0	21.0	577.5
Evrika	1998	136.7	29.6	39.2	1,160.3	21.1	624.6
Radost	2010	143.3	27.3	40.0	1,092.0	19.6	535.1
Lastochka	2011	135.9	42.6	38.4	1,635.8	21.0	894.6
Accu	2017	143.3	38.2	37.5	1,432.5	22.7	867.1
Ayzere	2020	141.6	40.1	36.8	1,475.7	21.7	870.2

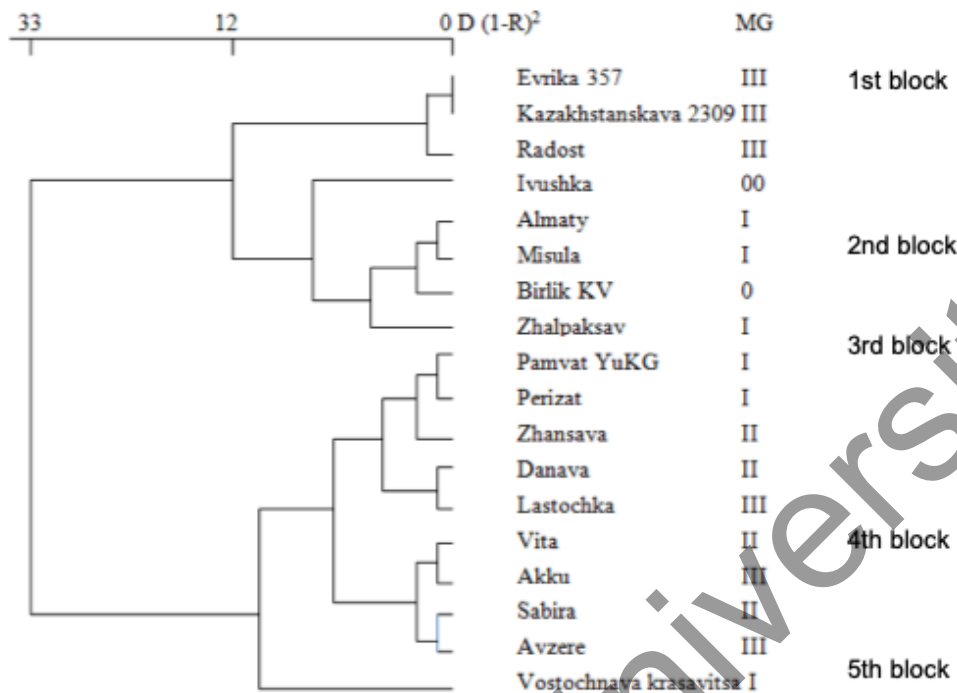


Fig. 5. Dendrogram of the similarities and differences of soybean varieties of different maturity groups (00-III) in terms of yield capacity, protein content, fat content and their collection per ha based on the results of cluster analysis for the minimum product D (1-R)

As a result of cluster analysis, the varieties were combined into five blocks. The first block includes late-maturing soybean varieties Evrika 357, Kazakhstanskaya 2309, and Radost, having a low yield and average protein levels, as a result, they have a low rate of protein harvest per ha. These varieties are gradually giving way in production crops to more productive varieties of the same maturity group of the fourth block Akku and Avzere, which are approved for use in the south of Kazakhstan.

The second block consists of early maturing varieties. All of them were created for the conditions of East Kazakhstan. However, being sensitive to the photoperiod, the varieties Misula and Almaty did not pass zoning there. A new early maturing variety of the second block Birlik KV, with signs of high yield, high protein content, photoneutrality, drought resistance, is expanding production areas in East Kazakhstan. The varieties of the third block are most suitable for the conditions of the Almaty region. The most popular varieties in production (Zhansaya and Lastochka) occupied an area of about 45 thousand ha in 2020. The Vostochnaya Krasavitsa soybean

variety, the variety of the fifth block, approved for use in the East Kazakhstan region, was not included in the third block, apparently due to the lack of long-term indicators.

Separately, it should be noted the Ivushka ultra-early-maturing soybean variety was assigned to the first block due to the low rate of protein collection per ha. This is the only Kazakh soybean variety allowed for production in the north of Kazakhstan (in Kostanay, Pavlodar, and Akmola regions), and it has the highest protein content in seeds, 42.5%.

CONCLUSION

In the new generation varieties, the collection of protein per hectare is in the range of 944.7-1,705.3 kg, oil – 415.9-974.6 kg. In the maturity group MG I, the soybean variety Vostochnaya Krasavitsa has an indicator of protein collection – 1,705.3 kg/ha, oil – 838.4 kg/ha. In the maturity group MG II, the Zhansaya variety stands out with a protein collection rate of 1,707.7 kg/ha, oil – 974.6 kg/ha. In the maturity group MG III, the Lastochka variety stands out with a protein collection rate of

Svetlana Vladimirovna Didorenko *et al.*: *Yield and Quality of Soybean on Ecotypes*

1,635.8 kg/ha, oil – 894.6 kg/ha. The yield capacity of different varieties falls in the range of 20.9 to 43.9 kg/ha, depending on the maturity group.

ACKNOWLEDGEMENT

This research was funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP08955940).

REFERENCES

- Abugalieva, A. I., & Didorenko, S. V. (2016). Geneticheskoe raznoobrazie sortov soi razlichnykh grupp spelosti po priznakam produktivnosti i kachestva [Genetic diversity of soybean varieties of different maturity groups in terms of productivity and quality]. *Vavilovskii zhurnal genetiki i seleksii*, 20(3), 303-310. <https://doi.org/10.18699/VJ16.168>
- Bellaloui, N., Bruns, H. A., Abbas, H. K., Mengistu, A., Fisher, D. K., & Reddy, K. N. (2015). Agricultural practices altered soybean seed protein, oil, fatty acids, sugars, and minerals in the Midsouth USA. *Frontiers in Plant Science*, 6, 31. <https://doi.org/10.3389/fpls.2015.00031>
- Bellaloui, N., Reddy, K. N., Bruns, A., Gillen, A. M., Mengistu, A., Zobiole, L. H. S., ... Kremer, R. J. (2011). Soybean seed composition and quality: interactions of environment, genotype, and management practices. In: J. Maxwell (Ed.), *Soybeans: cultivation, uses and nutrition* (pp. 1-42). Nova Science Publishers. Retrieved from https://www.researchgate.net/publication/280113044_Soybean_Seed_Composition_and_Quality_Interactions_of_Environment_Genotype_and_Management_Practices
- Bulatova, K., Mazkirat, Sh., Didorenko, S., Babissekova, D., Kudaibergenov, M., Alchinbayeva, P., ... Shavrukov, Y. (2019). Trypsin inhibitor assessment with biochemical and molecular markers in a soybean germplasm collection and hybrid populations for seed quality improvement. *Agronomy*, 9, 76. <https://doi.org/10.3390/agronomy9020076>
- Committee on Statistics of the Republic of Kazakhstan. (2021). Statistics of agriculture, forestry, hunting and fisheries. Retrieved from <https://stat.gov.kz/official/industry/14/statistic/6>
- Dornbos, D. L., & Mullen, R. E. (1992). Soybean seed protein and oil contents and fatty acid composition adjustments by drought and temperature. *Journal of the American Oil Chemists' Society*, 69, 228-231. <https://doi.org/10.1007/BF02635891>
- Dospikhov, B. A. (2012). *Metodika polevogo opyta (s osnovami statisticheskoi obrabotki rezul'tatov issledovaniy) [Field experiment technique (with the basics of statistical processing of research results)]*. Moscow: Kniga po Trebovaniyu, 352 p. Retrieved from <https://static.my-shop.ru/product/pdf/119/1184632.pdf>
- Ermolina, O. V., Antonov, S. I., & Korotkova, O. V. (2011). Izmnenie kachestva semyan soi v protsesse seleksii na Donu [Changes in the quality of soybean seeds in the process of breeding in the Don region]. *Zernovoe khoz-vo Rossii*, 6, 20-28. Retrieved from <https://elibrary.ru/item.asp?id=17248385>
- Lee, T. E., Spankulova, Z. B., Orazbayeva, U. M., Didorenko, S., & Atabayeva, S. (2016a). Amino acid profiles and sucrose content in developing soybean seeds. *Journal of Biotechnology*, 231, S41-S42. <https://doi.org/10.1016/j.jbiotec.2016.05.162>
- Lee, T. E., Spankulova, Z. B., Orazbayeva, U. M., Didorenko, S., & Atabayeva, S. (2016b). Polyunsaturated fatty acids content in soybean oil. *Advance Journal Of Food Science And Technology*, 4, 1–6. <https://doi.org/10.19026%2fajfst.12.3305>
- Licht, M. A. (2017). *Soybean growth and development – soybean staging*. Soybean Extension Agronomist Department of Agronomy. Iowa State University, 28 p. Retrieved from <https://store.extension.iastate.edu/product/14827>
- Ministry of Agriculture of the Republic of Kazakhstan. (2021). Gosudarstvennyi reestr selektsionnykh dostizhenii, rekomenduemykh k ispolzovaniyu v Respublike Kazakhstan [State register of selective breeding results recommended for use in the Republic of Kazakhstan]. Nur-Sultan, 125 p. Retrieved from https://adilet.zan.kz/rus/docs/V090005759_
- Novikova, L. Yu., Seferova, I. V., Nekrasov, A. Yu., Perchuk, I. N., Shelenga, T. V., Samsonova, M. G., & Vishnyakova, M. A. (2018). Vliyanie pogodno-klimaticheskikh uslovii na sodержanie belka i masla v semenakh soi na Severnom Kavkaze [Influence of weather and climatic conditions on the content of protein and oil in soybean seeds in the North Caucasus]. *Vavilovskii zhurnal genetiki i seleksii*, 22(6), 708-715. <https://doi.org/10.18699/VJ18.414>
- Olkhovatov, E. A., Ponomarenko, L. V., & Kovalenko, M. P. (2015). Ispolzovanie soi v pishchevykh i meditsinskikh [The use of soybeans for food and medical purposes]. *Molodoi uchenyi*, 15(95), 231-235. Retrieved from <https://moluch.ru/archive/95/21494/>

Svetlana Vladimirovna Didorenko et al.: Yield and Quality of Soybean on Ecotypes

- Petibskaya, V. S. (2012). *Soya: Khimicheskii sostav i ispolzovanie [Soy: chemical composition and uses]*. Krasnodar: All-Russian Scientific Research Institute of Oilseeds named after V.S. Pustovoyt. Retrieved from <http://elib.timacad.ru/dl/full/4008.pdf/download/4008.pdf>
- Qi, D. H., & Lee, C. F. (2014). Influence of soybean biodiesel content on basic properties of biodiesel-diesel blends. *Journal of the Taiwan Institute of Chemical Engineers*, 45(2), 504–507. <https://doi.org/10.1016/j.jtice.2013.06.021>
- Savin, V. N., Abugaliev, I. A., & Abugalieva, A. I. (1998). Optimizatsiya analiticheskikh issledovaniy v rasteniyevodstve [Optimization of analytical research in crop production]. *Doklady RASKhN*, 2, 13-15.
- Song, W., Yang, R., Wu, T., Wu, C., Sun, S., Zhang, S., ... Han, T. (2016). Analyzing the effects of climate factors on soybean protein, oil contents, and composition by extensive and high-density sampling in China. *Journal of Agricultural and Food Chemistry*, 64(20), 4121-4130. <https://doi.org/10.1021/acs.jafc.6b00008>
- SoyStats. (2018). A reference guide to important soybean facts and figures. American Soybean Association. Retrieved from <https://ndsoygrowers.com/wp-content/uploads/2018/09/2018ASA-SoyStats.pdf>
- Stobaugh, B., Florez—Palacios, L., Chen, P., & Orazaly, M. (2017). Agronomic evaluation of high-protein and high-oil soybean genotypes for specialty markets. *Journal of Crop Improvement*, 31(2), 247-260. <https://doi.org/10.1080/15427528.2017.1287807>
- USDA. (2018). *Agricultural research service*. United States Department of Agriculture. Retrieved from <https://www.ars-grin.gov/npgs/index.html>
- Vishnyakova, M. A., Seferova, I. V., & Samsonova, M. G. (2017). Trebovaniya k iskhodnomu materialu dlya selektsii soi v kontekste sovremennykh biotekhnologii [Requirements for the starting material for soybean breeding in the context of modern biotechnology]. *Selskokhozyaistvennaya biologiya*, 52(5), 905-916. <https://doi.org/10.15389/agrobiologiya.2017.5.905rus>
- Vishnyakova, M. A., Seferova, I. V., Buravtseva T. V., Burlyaeva, M. O., Semenova, E. V., Filipenko, G. I., ... Drugova, E. V. (2018). *Kollektsiya mirovykh geneticheskikh resursov zernovykh bobovykh VIR: popolnenie, sokhranenie i izuchenie (metodicheskie ukazaniya) [VIR global collection of grain legume crop genetic resources: replenishment, conservation and studying (methodological guidelines)]*. St. Petersburg: VIR, 143 p. Retrieved from http://www.vir.nw.ru/wp-content/uploads/2019/05/collection_zbvir.pdf
- Wilcox, J. R. (1998). Increasing seed protein in soybean with eight cycles of recurrent selection. *Crop Science*, 38(6), 1536-1540. <https://doi.org/10.2135/cropsci1998.0011183X00380060021x>
- World Agriculture Production. (2020, February). Circular Series. USDA, Foreign Agricultural Service. Retrieved from <https://apps.fas.usda.gov/psdonline/circulars/production.pdf>
- Yusova, O. A., Asanov, A. M., & Omelyanyuk, L. V. (2017). Urozhainost i kachestvo zerna sortov soi selektsii Sibirskogo NIISKh v usloviyakh yuzhnoi lesostepi Zapadnoi Sibiri [Productivity and grain quality of soybean varieties of the Siberian Research Institute of Agriculture under the conditions of the southern forest-steppe of Western Siberia]. *Maslichnye kultury. Nauchno-tekhnicheskii byulleten Vserossiiskogo nauchno-issledovatel'skogo instituta maslichnykh kultur*, 4(172), 18–24. Retrieved from <https://vniimk.ru/upload/3.+++%D0%AE%D1%81%D0%BE%D0%B2%D0%B0%20-%20%D1%81%D1%82%D0%B0%D1%82%D1%8C%D1%8F.pdf>
- Yusova, O. A., Asanov, A. M., & Omelyanyuk, L. V. (2018). Kharakteristika perspektivnykh istochnikov soi s povyshennym kachestvom semyan i urozhainost'yu v usloviyakh yuzhnoi lesostepi Zapadnoi Sibiri [Characteristics of promising sources of soybeans with increased seed quality and yield in the southern forest-steppe of Western Siberia]. *Maslichnye kultury. Nauchno-tekhnicheskii byulleten Vserossiiskogo nauchno-issledovatel'skogo instituta maslichnykh kultur*, 3(175), 40–45. <https://doi.org/10.25230/2412-608Kh-2018-3-175-40-45>
- Zelentsov, S. V., & Moshnenko, E. V. (2016). Perspektivy selektsii vysokobelkovykh sortov soi: modelirovanie mekhanizmov uvelicheniya belka v semenakh (soobshchenie 1) [Prospects for breeding high-protein soybean varieties: modeling the mechanisms of increasing protein in seeds (report 1)]. *Maslichnye kultury. Nauchno-tekhnicheskii byulleten Vserossiiskogo nauchno-issledovatel'skogo instituta maslichnykh kultur*, 2(166), 34-41. Retrieved from <https://vniimk.ru/upload/34-41%20%D0%97%D0%B5%D0%B%D0%B5%D0%BD%D1%86%D0%BE%D0%B2,%20%D0%9C%D0%BE%D1%88%D0%BD%D0%B5%D0%BD%D0%BA%D0%BE.pdf>