CHAPTER «AGRICULTURAL SCIENCES»

BREEDING OF DROUGHT-RESISTANT SOYBEAN VARIETIES UNDER CLIMATE CHANGE

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Abstract. Thus, the primary task of breeding is to create varieties that combine high yield with drought resistance. It is important to have a sufficiently high level of adaptability of the variety to the conditions of the growing region, where the variety remains the main reserve for resource conservation and intensification of agricultural production in Ukraine. Generally accepted methods are used, namely scientific, special, laboratory, mathematical and statistical. In conditions of insufficient moisture, the use of early maturing and very early maturing varieties is relevant. Indicators of soybean yield in all oblasts of Ukraine are provided. According to the results of the analysis of 17-year meteorological observations, it was found that the climatic characteristics of Poltava oblast became more arid. The dynamics of indicators of the soybean gross yield in Poltava oblast (2002–2018) is analyzed against the background of the amount of precipitation during the growing season (4–8 months). In the research laboratory of Breeding, Seed Production and Varietal Soybean Agrotechnics of Poltava State Agrarian University, it was created Almaz, Antratsyt, Adamos, Aleksandryt, Akvamaryn, Avantiuryn soybean varieties, which were listed the State Register of Plant Varieties Suitable for Spreading in Ukraine. Indicators of agricultural suitability of these varieties and their advantages are presented. Varieties of Poltava breeding are distinguished by drought resistance, resistance to diseases and pests, non-lodging, when the seeds mature, the

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beans do not crack. These varieties are guaranteed predecessors for winter crops in the Steppe and Forest-Steppe of Ukraine.

1. Introduction

Since the 13th century, soybean has been a traditional crop in East and South Asia, where it was not only a legume, but also an effective substitute for dairy and meat products. Despite this, it began to acquire great worldwide popularity only in the second half of the 20th century. Thus, over the past 50 years, the world production of soybean has been constantly growing. First of all, this was facilitated by the creation of new, more productive varieties and the improvement of production and processing technology. The decrease in losses during the soybean harvesting also took place for the increase in the indicators of the average world yield. Another reason was the development of infrastructure, which led to the revitalization of world trade, and this enabled manufacturers to sell finished products to new markets. The United States, Brazil, Argentina are the invariable leaders, which in 2016/17 harvested a record 286 million tons of soybean, which is 82% of world production. Also, the leading manufacturers include China, India, and Paraguay.

Soybean is a highly profitable crop. Significant growth of sown areas and gross soybean yield testifies to its extremely important role in the agricultural complex. Steady trends towards an increase in the volume of soybean and its production, constant demand for crops from agricultural producers, changing climatic conditions in the direction of warming, significant success of breeding in creating early varieties help to increase its relevance and guaranteed production of this crop in different climatic zones of Ukraine. The interest of domestic farmers in growing soybean is explained by the good opportunities for its marketing to the EU countries, Egypt, and Turkey.

The main areas of soybean crops in Ukraine (2008–2015) are concentrated in the "soybean belt" (Kyiv, Khmelnytskyi, Vinnytsia, Poltava, Cherkasy, Kirovohrad, Zhytomyr, Sumy, Kherson oblasts). In recent years, soybean yield in Ukraine has ranged from 1.7 to 2.4 t/ha (2012–2020). Record soybean yields reach 5–8 t/ha. In 2018, 4.46 million tons of soybeans were harvested in Ukraine, which is 14.4% more than in 2017. The largest soybean areas in 2018 were recorded in Poltava, Khmelnytskyi, Kyiv and

Sumy oblasts. Thus, Khmelnytskyi oblast harvested 511.7 thousand tons, Poltava – 409.4 thousand tons, Zhytomyr – 372.6 thousand tons, Kherson – 361.9 thousand tons, Kyiv – 348.5 thousand tons.

The average soybean yield in 2018 was as follows: Kherson (3.3 t/ha), Zaporizhzhia (3.2 t/ha), Ivano-Frankivsk (3.2 t/ha), Ternopil (3.03 t/ha), Khmelnytskyi oblasts (2.99 t/ha).

The variety remains the main reserve of resource conservation and intensification of agro-industrial production in Ukraine [1; 2]. The efficiency of growing a crop increases significantly if it is included in the State Register of Plant Varieties Suitable for Spreading in Ukraine of high-yielding drought-resistant soybean varieties, adapted against a complex of unfavorable factors.

Thus, the primary task of breeding is to create varieties that combine high yields with relatively high resistance to adverse soil and climatic conditions and have a sufficiently high level of adaptability of the variety to the conditions of the growing region.

The negative effect of unfavorable abiotic environmental factors can be leveled out as a result of expanding the diversity of varieties and increasing their adaptive potential. *The purpose of creating high-yielding varieties* is to achieve the optimal ratio of the main elements of the crop structure, the maximum weakening of the factors that negatively affect their formation [3].

2. The value of the variety and its adaptability

It is known that the main components of seed productivity are the number of productive nodes, the number of beans in the node, beans and seeds of the plant, which are associated with plant height, branching, foliage, stem thickness, size of beans and leaves, length of internodes and inflorescence tassel, percentage of abortion of beans and seeds, etc. Recently, there have been some changes in the modern breeding process: the created Ukrainian soybean varieties have a unique appearance [4]. At the optimum standing density, they are erect, weakly branched, have a thickened stem, characteristic trifoliate leaves, large seeds, high attachment of the beans of the lower tier, high quality of seeds.

Adaptive potential is characterized by the ability of plants to survive and reproduce the functioning of genetic systems of ontogenetic and phylogenetic adaptations. Designing adaptive biosystems under conditions

of ecological stability is a guaranteed basis for a significant increase in productivity and environmental sustainability [5]. The best varieties in terms of adaptive and productive potential for the Forest-Steppe of Ukraine among medium-ripe varieties are Artemida and Ahat.

The contribution of plant breeding to climate protection and adaptability to climate change is quite significant [6]. Soybean varieties with a deep root system (over 1.5 m), cold-resistant ones for a fairly early sowing period, are created, which makes it possible to form a seed yield before summer droughts.

The researchers argue that modern breeding methods and approaches to creating high-yielding varieties should be revised in the context of climate change. However, to determine the genetic basis for increasing yield and improving its stress resistance against climatic factors, separate studies are needed.

Thus, most foreign new varieties with high yields suffer enough from climate change in the conditions of our country.

Numerous literature data suggest that the high yield of soybean seeds may be due to different combinations of elements of the crop structure [7]. It is known that, despite the presence of close relationships between yield and its individual elements, the use of the latter as a breeding criterion in the design of plants is ineffective. The development of mathematically sound models of modern soybean varieties helps to optimize the parameters of selected genotypes [8].

The "number of nodes" marker has greater stability than "productivity" or "plant height". Low variability is also characteristic of "1000 seed weight"; however, this feature is practically unrelated to yield and cannot be used in productivity breeding. The number of seeds per plant is most closely related to productivity ($r = 0.6–0.9$), so it is possible to use this trait for individual breeding. There is a close covariance of productivity and number of seeds of the plant, which indicates a high dependence of the trait on the environment. This connection is more ecological than genetic one.

Scientists-breeders established the presence of many significant relationships between yield and its individual elements, but their use as breeding criteria in the process of creating a variety is ineffective. For certain soil and climatic conditions of cultivation it is necessary to take into account real ecological and economic factors. The modeling of a variety

in the breeding process aims to scientifically substantiate the set of traits that a variety should have. One of the main directions of creating a model of a variety is the use of statistical substantiation of the size of individual morphological features of the plant [9].

Assessment of the adaptive potential and reliability of genetic protection of the crop is of particular importance. It is necessary to develop the parameters of the model of key indicators for varieties of a particular ecotype.

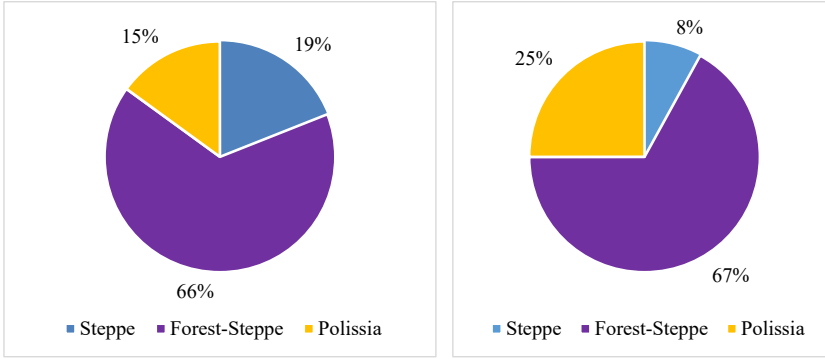
Determining correlations makes it possible to establish ways to increase the productivity of the variety, its plasticity and stability. It is shown that in early-maturing soybean varieties, among all components, the greatest contribution to productivity is provided by the indicator of the number of nodes of the main stem. The "number of nodes – yield" correlation coefficient is 0.45–0.55, including the influence of the growing season – 0.46. Even in regions where soybean has been bred for decades, there is a possibility of further increasing the potential and yield of soybean. Thus, there was an attempt to create a reasonable model of precocious variety at the Institute of Arable Farming of the National Academy of Agrarian Sciences. Under modern conditions, the breeding process can be accelerated at the first stage, namely: on the basis of markers. It is advisable to create such varieties that will form a consistently high yield due to sufficient adaptation to soil and climatic conditions of the region. Modern approaches to the creation of high-yielding varieties need constant improvement and adjustment, especially in the context of global warming and new requirements for them.

3. The main results of soybean breeding for drought resistance under climate change

The publications of a number of foreign and Ukrainian authors cover the issues of the influence of natural and climatic conditions and the latest varieties on the yield of soybean culture and economic efficiency of its cultivation [10].

In Ukraine, soybean crops until 2014 were concentrated in the Forest-Steppe zone (66%), in the Steppe – 19%, in Polissia – 15% (Figure 1a). During the period from 2016 to 2020, there was an increase in sown areas in Polissia and a decrease by half in the Steppe (Figure 1b).

In the Forest-Steppe there is an increase in crop yield. Rapid growth of gross yield was observed in Khmelnytskyi, Chernivtsi, Vinnytsia, Sumy,



a. b.

Figure 1. The structure of soybean acreage in Ukraine: a – in 2009–2014, b – in 2015–2020

Zhytomyr oblasts. Reduction of sown areas under soybeans in the oblasts of Ukraine, compared to 2017, was observed in Luhansk by 59.1%, in Dnipropetrovsk – by 47.7%, in Mykolaiv – by 43.2%, in Kharkiv – by 36.5%, in Odesa – by 29%, in Kirovohrad – by 27.3%.

The main reason for this phenomenon is the amendment to the Law of Ukraine No. 2245-VIII of 21 December 2017, according to which, from 1 September 2018 to 31 December 2021, the budget VAT refund for soybean exports will be abolished. This had a severe effect on the reduction of sown areas, and most importantly – on the share reduction of the varieties of traditional breeding. As a result, the demand for varieties of national breeding decreased, which negatively affected the efficiency of the national seed system. Soybean production in Ukraine is quite unstable (Figure 2a). Its yield for the period of 1992–2020 ranged from 1.7–2.4 t/ha. Among national breeding institutions, only 4 of them have a high rating (2017–2018): «Soievyy Vik» Breeding and Seed Company, National Scientific Center Institute of Arable Farming of the NAAS, Plant Breeding and Genetics Institute – the National Centre for Seed Breeding and Cultivar Studying of the National Academy of Agrarian Sciences, and Poltava State Agrarian Academy of the Ministry of Education and Science of Ukraine.

In 2020, the following harvests were obtained in the oblasts of Ukraine (Figure 3). Their variation was influenced by weather conditions [11; 12].

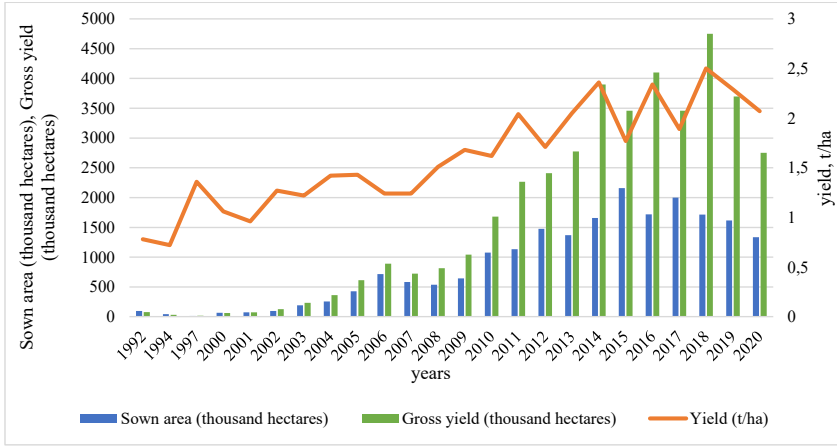


Figure 2. Dynamics of soybean production in Ukraine, 1992–2020

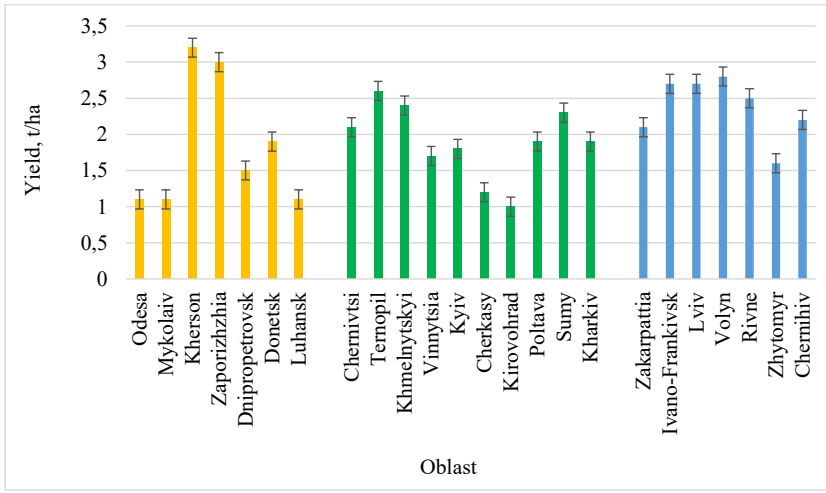


Figure 3. Soybean yield indicators by oblasts in the climatic zones of Ukraine, 2020

Over the past 17 years, the climate of Poltava oblast has become drier. This requires breeders to create varieties that are better adapted to arid growing conditions, have important economic characteristics and properties and form a high yield.

Figure 4 shows the dynamics of soybean production in Poltava oblast (2000-2018) and the amount of precipitation during the growing season (April-August).

The equation of the linear trend of the gross soybean yield and the value of the reliability of the approximation is as follows – y = 25,857x – 51738 with R^2 = 0,8213; precipitation, respectively y = –1,6348x + 3569,3 with R^2=0,0121. During the years with a dry growing season there is a decrease in gross yield. The dynamics of soybean yield in Poltava oblast (2002–2018) and the hydrothermal coefficient of Selianinov (hereinafter reffered to as HTC) for the growing season (April-August) are presented in Figure 5.

The equation of the linear trend of the HTC and the value of the reliability of the approximation is as follows – y = -0,0078x + 1,2118 with R^2 = 0,0279; and yield, respectively y = 0,0539x + 1,162 with R^2 = 0,4485.

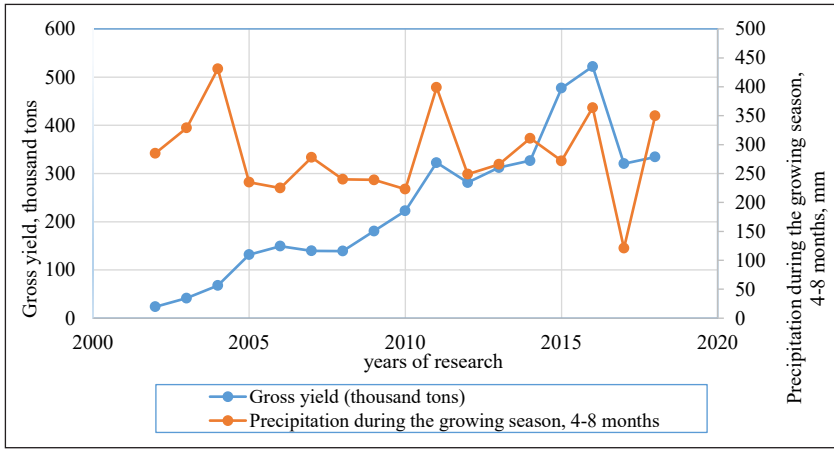


Figure 4. Dynamics of soybean seed production indicators in Poltava oblast and precipitation for the growing season (April-August), 2002–2018 (according to the State Statistics Service and Poltava Meteorological Center)

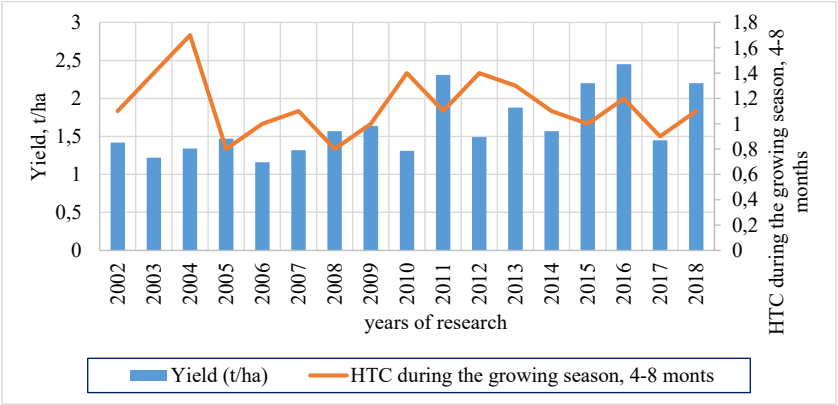


Figure 5. Dynamics of soybean yield indicators in Poltava oblast and the HTC for the growing season (April-August), 2002–2018

There is an increase in yield against the background of the HTC declining.

In extreme weather conditions (excessive rainfall during ripening or their absence, drought, epiphytosis of diseases), the decisive role belongs to adapted modern varieties.

As a result of many years of soybean breeding work at Krasnohrad Research Station of the Institute of Grain Management of UAAS (1991–2000) and the Research Field of Poltava State Agrarian Academy (2001–2018), the authors of the article created a number of high-yielding, precocious and environmentally adaptable soybean varieties. Breeding work was carried out in very contrasting soil and climatic conditions. Source and hybrid material, soybean varieties were carefully studied on dark gray podzolic (pH 5.3–5.5) soils and chernozems (pH 6.2–7.0) in arid conditions of the Steppe and Forest-Steppe of Ukraine.

In Poltava oblast in recent years there have been frequent droughts during the growing season (Figure 6). Thus, in 2017, the minimum amount of precipitation during the growing season (April-August) for the entire period of research (121.1 mm with a long-term average of 268 mm) was noted.

In Figure 6 it can be seen that of the 16 analyzed in 10 years, the amount of precipitation during the growing season was lower than the

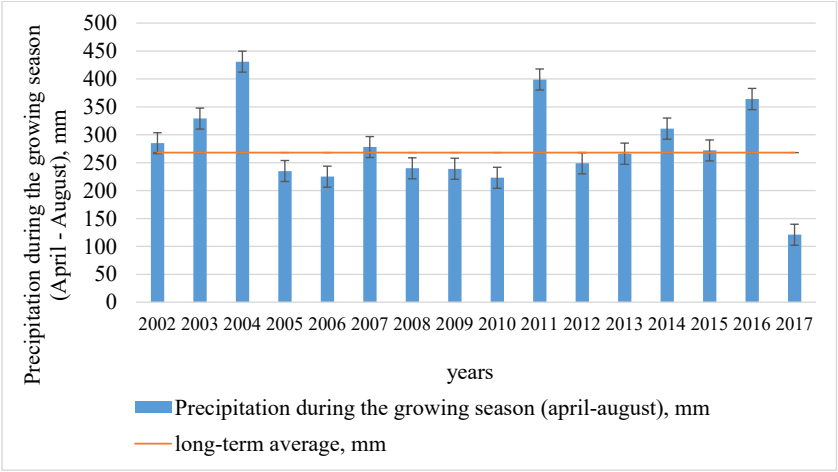


Figure 6. Dynamics of precipitation during the growing season (April-August) against the background of the long-term average in Poltava oblast, 2002–2017

long-term average. The improvement of soybean varieties is currently taking place against the background of climate change and requires an objective assessment of new varieties, which is carried out during the State Qualification Examination. Since 1995, Ukraine has become a member of the UPOV (International Union for the Protection of New Varieties of Plants) and officially provided breeders with legal protection for varieties that are subject to intellectual property: the Law of Ukraine *On Protection of Plant Varieties* and the Resolution of the Cabinet of Ministers *On the Register of Plant Varieties of Ukraine*. Since 1991, soybean varieties have been regularly registered in the State Register of Plant Varieties.

In conditions of insufficient moisture during the growing season, it is important to use very early and early maturing varieties. Poltava State Agrarian University is the only institution of higher education that conducts breeding work with a unique crop – soybean. The breeders of the laboratory of breeding, seed production and varietal agricultural technology of soybean created a number of varieties with high adaptability and stability, which had high indicators of economic suitability (Table 1).

Table 1

Soybean varieties which are included in the State Register of Plant Varieties Suitable for Spreading in Ukraine, 1998–2015

Variety	Growing area*	Duration of the growing season, days	Yield, t/ha	Seed content, %	
				protein	fat
Ametyst	SF	100-105	2.7-2.8	38-40	19-22
Ahat	SF	135-150	2.7-3.2	39-41	22-23
Artemida	S	120-125	2.2-2.7	38-39	19-20
Almaz	F	100-105	2.6-3.0	37-39	24-26
Vinni	SF	112-127	2.4-2.8	38-39	19-20
Vezha	S	104-120	2.4-2.7	39-40	19-20
Antratsyt	S	95-105	3.0-4.0	37-39	24-26
Aleksandryt	SFP	95-100	2.7-3.3	37-39	19-22
Adamos	FP	95-100	3.2-3.5	38-40	22-25
Avantiuryn	F	98-100	3.0-3.2	38-39	21-22
Akvamaryn	FP	98-100	3.0-3.2	42-43	21-22

Notes: *climatic zone: S – Steppe, F – Forest-Steppe, P – Polissia

Thus, during the period of 2001–2010, Almaz and Antratsyt varieties were created. During 2008–2013 – Aleksandryt and Adamos varieties, and during 2010–2015 – Avantiuryn and Akvamaryn varieties.

The soybean varieties created by us, which are registered in Ukraine and recommended for distribution, have a vegetation period of 85–120 days): – early maturing: Ametyst, Almaz, Antratsyt, Aleksandryt, Adamos, Avantiuryn, Akvamaryn; – medium early maturing: Ahat, Artemida, Vinni, Vezha.

Early maturing varieties are of the highest value: Almaz, Antratsyt, Adamos, Aleksandryt, Akvamaryn, Avantiuryn. According to the state variety testing, Ametyst, Antratsyt, Adamos varieties are recommended for the Steppe; for the Forest-Steppe – Ametyst, Almaz, Avantiuryn, Akvamaryn.

We provide morpho-biological characteristics of the soybean varieties created by us.

Ametyst soybean variety. The height of the plant is 60–70 cm; the height of the attachment of the lower bean is 12–14 cm. The weight of 1000 seeds is 160–200 g. The duration of the vegetation period is 100–105 days. It is a

variety of grain type of use, early maturing. In the conditions of the Steppe and Forest-Steppe of Ukraine, seed yield is 2.0–2.78 t/ha. The protein content in the grain is 37.6–39.6%, the fat content is 19.0–22.0%.

It has high drought resistance. The variety is resistant to bacterial and viral diseases, suitable for mechanized harvesting. In production and research crops of Poltava M.I. Vavilov State Agricultural Experimental Station and Ustymivka Experimental Station for Plant Production of the NAAS, Ametyst variety provided a yield of 2.7 t/ha.

Ahat soybean variety. The variety has been included in the State Register of Plant Varieties Suitable for Spreading in Ukraine since 2000. The approbation group is *sordida*. The plant height is 60–70 cm. The weight of 1000 seeds is 197–218 g. The duration of the vegetation period is 135–150 days. Yield in the Forest-Steppe of Ukraine is 2.3–2.7 t/ha. The protein content in grain is 39.5–41.4%, fat – 22.1–23.0%. It is a variety of grain type of use, late maturing, capable of forming a favorable optical-biological structure of the leaf apparatus, highly productive, resistant to major diseases. It is recommended for growing in the southern Forest-Steppe and Steppe of Ukraine. The new high-yielding Ahat soybean variety, on average, formed 2.98 t/ha in 2006–2007. If the main requirements for growing the variety are met, it is possible to obtain soybean grain yield on non-irrigated lands at the level of 2.3–3.2 t/ha.

Artemida soybean variety. The approbation group is *abenaria*. The plant height is 78–90 cm; the height of attachment of the lower bean is 12–14 cm. The weight of 1000 seeds is 154–175 g. The duration of the vegetation period is 120–125 days. Grain yield in the Forest-Steppe of Ukraine is 2.2–2.7 t/ha, in the Northern Steppe – 2.2–2.7 t/ha. The variety is medium maturing, grain-type of use, relatively sensitive to moisture deficiency during the formation of generative organs, resistant to major diseases and pests, technological and suitable for mechanized harvesting. The protein content in seeds is 38.2–39.2%, fat – 18.8-20.4%. It is recommended for the Forest-Steppe and Steppe of Ukraine. In the conditions of the Left-Bank Forest-Steppe of Ukraine it is resistant to acid soils (pH 5.3–5.5).

Almaz soybean variety. The approbation group is *abenaria*. The plant height is 60–70 cm; the height of the lower bean is 12–14 cm. The weight of 1000 seeds is 190–220 g. The growing season is 100–105 days. According to the results of the State examination, the grain yield in Polissia is 2.6 t/ha,

in the Forest-Steppe – 2.6 t/ha. It has a high content of crude protein in seeds 37–39% and especially fat – 24–26%. The variety has a high resistance to lodging and cracking of beans; it is resistant to major diseases and pests. It is recommended for growing in the Forest-Steppe and Steppe zone of Ukraine. The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 2).

Table 2

The results of the study of economically valuable traits of Almaz variety in the areas of ecological variety testing (2005–2007)

Variety	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Forest-Steppe (2005–2007)						
Almaz	2.7	112	186.1	15.3	35.8	23.6
Almaz	1.23	110	180.4	10.8	32.0	23.9
Almaz	1.78	105	166,3	10.0	35.2	22.6
Steppe (2005–2007)						
Almaz	2.69	109	178.6	11.0	30.0	25.5
Almaz	2.39	106	165.0	12.3	37.1	23.8
Almaz	2.81	107	170.3	12.2	35.9	23.7

Antratsyt soybean variety. It has been listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine since 2012. The approbation group is *nigrooculata (Mikh.)*. It is a variety of grain type of use. The height is 80–100 cm. The weight of 1000 seeds is 180–200 g. The protein content in the grain is 37–39%; the fat content is 24–26%. The variety is early maturing. The stable growing season is 95–105 days. Potential grain yield in the Steppe and Forest-Steppe of Ukraine is 3.0–4.0 t/ha. The resistance against lodging and cracking of beans for a long stay is high. The variety is resistant to bacterial and viral diseases, weakly damaged by pests; it is a guaranteed predecessor to winter wheat.

The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 3).

The yield of Antratsyt variety during the years of study in Polissia varied from 1.75 to 1.96 t/ha, the deviation from the standard was 0.9–1.1 t/ha. For

Table 3

The results of the study of economically valuable traits of Antratsyt variety in areas of ecological varietal testing (2009–2011)

Variety	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Polissia (2009–2011)						
Antratsyt	1.75	126.0	186.8	9.0	36.8	21.0
Antratsyt	1.96	123.0	162.2	8.9	39.2	22.6
Antratsyt	1.76	127.0	207.8	13.5	41.0	20.5
Forest-Steppe (2009–2011)						
Antratsyt	1.99	107.7	161.9	9.9	37.5	23.4
Antratsyt	1.98	103.3	174.6	10.2	39.1	22.3
Antratsyt	3.04	112.0	197.4	10.0	35.1	24.2
Steppe (2009–2011)						
Antratsyt	1.67	104.8	148.4	10.9	37.7	24.7
Antratsyt	2.16	110.5	158.7	9.0	40.7	22.4
Antratsyt	2.18	105.0	169.9	9.2	35.7	25.8

the Forest-Steppe – 1.98 to 3.04 t/ha, the deviation from the standard was 0.35–0.17 t/ha. For the Steppe, respectively, 1.67–2.18 t/ha and 0.29–0.26 t/ha.

Vinni soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2010. The approbation group is *sordida*.

The variety is of determinant type of growth; the plant height is 80–95 cm. The height of attachment of the lower bean is 13–17 cm. The weight of 1000 seeds is 135.8 g. The duration of the vegetation period is 112–127 days; the average yield in the conditions of the Forest-Steppe of Ukraine is 8 t/ha. The content of crude protein in the seeds is 38.53%, fat – 20.04%. The variety is medium maturing, resistant to major fungal and viral diseases. It is a grain-type variety. It is recommended for growing in the Forest-Steppe and Steppe zones.

Vezha soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2010. The approbation group is *oculata (Mikh.)*. It is a variety of determinant type of growth; the plant height is 85–100 cm. The height of attachment of the lower bean

is 14–19 cm. The weight of 1000 seeds is 185–195 g. The duration of the vegetation period is 104–120 days, the average yield in the Forest-Steppe of Ukraine is 2.4–2.7 t/ha.

The content of crude protein in grain is 39.3%, fat – 19.6%. The variety is medium-early maturing, resistant to major fungal and viral diseases. It is a grain-type variety. It is recommended for growing in the Forest-Steppe and Polissia areas.

Adamos soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2013. The approbation group is *agr. oculata (Mikh.)*. The type of growth is intermediate, from semi-determinant to indeterminate, with a height of 91–110 cm. The height of attachment of the lower bean is 14–16 cm. The root system is well developed. The weight of 1000 seeds is 190–200 g. The protein content in the seeds is 38–40%, and the fat content is 22–25%.

The variety is early maturing. It is an absolutely reliable predecessor for winter crops. The duration of the period from emergence to flowering is from 35 to 40 days. The stable vegetation period is 95–100 days. Potential grain yield in the Steppe and Forest-Steppe conditions of Ukraine is 3.2–3.5 t/ha. It is a grain-type variety.

The resistance against lodging and cracking of beans for a long stay is high. In the case of harvesting seeds in hot weather, it is possible to grind the grain with a combine (recommended harvesting is in the morning). The variety is resistant to bacterial and viral diseases, pests are poorly damaged. The variety responds well to seed inoculation with biological products. It is characterized by increased adaptability to adverse growing conditions, including growing on acidic soils (pH 4.5–5.5).

The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 4).

Aleksandryt soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2013. The approbation group is *agr. oculata (Mikh.)*. The type of growth is intermediate, semi-determinant. The plant height is 71–90 cm. The height of the attachment of the lower bean is 13–15 cm. The weight of 1000 seeds is 170–190 g. The protein content in the grain is 37–39%; the fat content is 19–22%. The variety is early maturing. It is a reliable predecessor for winter crops. It successfully combines high productivity and seed quality with a short growing season.

Table 4

The results of the study of economically valuable characteristics of Adamos variety in areas of ecological variety testing (2010–2012)

Variety	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Polissia (2010–2012)						
Adamos	2.10	133.0	177.3	10.9	37.5	22.3
Adamos	1.90	129.0	192.7	12.5	39.8	19.8
Adamos	1.90	120.5	166.5	12.6	38.6	20.9
Forest-Steppe (2010–2012)						
Adamos	1.87	111.3	168.8	15.0	39.7	21.7
Adamos	3.10	118.3	187.2	10.7	36.6	22.6
Adamos	2.05	103.6	156.4	9.6	38.5	22.2
Steppe (2010–2012)						
Adamos	2.09	112.8	171.5	9.2	42.5	20.1
Adamos	2.40	106.0	174.4	11.2	38.3	28.8
Adamos	147	103.6	150.1	7.2	37.8	21.0

It has a stable growing season of 95–100 days. Potential grain yield in the Steppe and Forest-steppe conditions of Ukraine is 2.7-3.3 t/ha.

A feature of the variety is its high drought resistance and resistance to sudden temperature fluctuations during the day. It is a grain-type variety. The resistance to lodging and cracking of beans is high. The variety is resistant to bacterial and viral diseases; it is slightly damaged by pests. It responds positively to fertilizer application and pre-sowing inoculation of seeds with biological products. It is characterized by increased adaptability to adverse growing conditions, including growing on acidic soils (pH 4.5–5.5). It is recommended for growing in the Steppe and Forest-Steppe of Ukraine.

The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 5).

Avantiuryn soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2015. The approbation group is *agr. Oculata (Mikh.)*. The type of growth is intermediate. The plant is 71–90 cm high. The height of the lower bean attachment is 12–15 cm. The weight of 1000 seeds is 170–190 g. The content of protein in seeds is 38%,

Table 5

The results of the study of economically valuable traits of Aleksandryt variety in areas of ecological variety testing (2010–2012)

Variety	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Polissia (2010–2012)						
Aleksandryt	2.06	131.8	163.4	7.9	39.2	20.5
Aleksandryt	2.10	128.3	185.0	11.8	37.0	19.4
Aleksandryt	1.67	120.0	167.8	10.8	34.7	22.0
Forest-Steppe (2010–2012)						
Aleksandryt	1.80	106.8	142.7	11.4	40.5	19.7
Aleksandryt	3.02	113.3	156.5	12.6	35.1	20.7
Aleksandryt	1.96	104.4	153.4	12.1	36.7	21.9
Steppe (2010–2012)						
Aleksandryt	2.07	110.5	160.2	9.7	41.7	19.1
Aleksandryt	2.42	106.4	158.8	10.3	34.9	21.7
Aleksandryt	1.46	102.0	148.5	10.6	38.6	19.7

fat is 22%. The maturing period is very early. It is a guaranteed predecessor for winter crops. It has a stable growing season of about 100 days. Potential grain yield in Ukraine is 3.0–3.2 t/ha. The variety is resistant to bacterial and viral diseases; it is slightly damaged by pests. The resistance to lodging and cracking of beans is high. The variety responds well to fertilization and pre-sowing inoculation of seeds with biological products. It is recommended for growing in the Steppe and Forest-Steppe of Ukraine. In the conditions of the LLC KHOROL-AGRO farm (Poltava oblast) in production crops, it forms 3.0–3.5 t/ha of seeds.

The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 6).

Akvamaryn soybean variety. It was listed in the State Register of Plant Varieties Suitable for Spreading in Ukraine in 2015. The approbation group is *agr. Oculata (Mikh.)*. The type of growth is intermediate. The plant is 71–90 cm high. The attachment height of the lower bean is 15 cm. The weight of 1000 seeds is 170–180 g. The protein content is 43%, fat – 22%. There is a guaranteed predecessor for winter crops. It has a stable growing season of about 100 days.

Table 6

The results of the study of economically valuable traits of Avantiuryn variety in the areas of ecological variety testing (2013–2014)

Variety	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Polissia (2013–2014)						
Avantiuryn	1.61	123.5	166.5	11.3	38.6	20.7
Avantiuryn	2.35	120.0	186.7	11.1	38.0	20.5
Forest-Steppe (2013–2014)						
Avantiuryn	2.18	108.1	171.2	11.3	39.5	19.9
Avantiuryn	2.33	115.7	167.3	9.8	37.0	22.0
Steppe (2013–2014)						
Avantiuryn	1.71	90.8	168.9	6.3	38.5	21.2
Avantiuryn	1.62	108.0	157.5	8.0	38.1	23.3

Potential grain yield in the Steppe and Forest-Steppe conditions of Ukraine is 3.0–3.2 t/ha. It is a grain-type variety. The resistance to lodging and cracking of beans is high. The variety is resistant to bacterial and viral diseases; it is slightly

Table 7

The results of the study of economically valuable traits of Akvamaryn variety in the areas of ecological variety testing (2013–2014)

Variety, standart	Yield, t/ha	Vegetation period, days	Weight of 1000 seeds, g	Height of attachment of the lower bean, cm	Grain quality, %	
					protein	fat
Polissia (2013–2014)						
Akvamaryn	1.76	135.0	157.5	11.2	40.9	20.2
Akvamaryn	2.34	123.3	148.2	12.4	40.0	20.0
Forest-Steppe (2013–2014)						
Akvamaryn	2.23	112.9	166.8	12.0	41.5	19.8
Akvamaryn	2.37	115.1	162.2	12.0	38.4	22.1
Steppe (2013–2014)						
Akvamaryn	1.63	97.3	146.7	10.0	40.5	20.8
Akvamaryn	1.65	108.3	148.8	7.3	39.7	21.7

damaged by pests. The variety responds well to fertilization and pre-sowing inoculation of seeds with biological products. It is characterized by increased adaptive ability to unfavorable growing conditions, including for growing on acidic soils (pH 4.5–5.5). It is recommended for growing in the Steppe and Forest-Steppe of Ukraine.

The study of economically valuable traits in areas of ecological varietal testing showed the following results (Table 7).

4. Conclusions

The variety remains the main reserve of resource conservation and intensification of agro-industrial production in Ukraine. The efficiency of growing a crop increases significantly if it is included in the State Register of Plant Varieties Suitable for Spreading in Ukraine of high-yielding drought-resistant soybean varieties, adapted against a complex of unfavorable factors. The primary task of breeding is to create varieties that combine high yields with relatively high resistance to adverse soil and climatic conditions and have a sufficiently high level of adaptability of the variety to the conditions of the growing region.

Breeding of drought-resistant soybean varieties should be carried out in the region where frequent droughts occur during the growing season. In Poltava oblast, these phenomena against the background of climate change are observed more and more often. Poltava breeding center annually conducts ecological variety testing of created soybean varieties. Thus, the highest value are early maturing varieties – Almaz, Antratsyt, Adamos, Aleksandryt, Akvamaryn, Avantiuryn, which are recommended for cultivation in the Steppe (Ametyst, Antratsyt, Adamos) and Forest-Steppe (Ametyst, Almaz, Avantiuryn, Akvamaryn) of Ukraine.

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