https://doi.org/10.61308/LZOM8934

Quantitative traits of productivity and yield of sesame varieties in steppe of Ukraine

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Citation: Aksyonov, I. (2025). Quantitative traits of productivity and yield of sesame varieties in steppe of Ukraine. *Bulgarian Journal of Crop Science, 62*(1) 57-68

Abstract: Sesame is an important oilseed crop. It has a cultivated area of about 9 million hectares in the world. At the same time, production of sesame in Ukraine remains low and unstable due to cracking of capsules, shedding of seeds from capsules, uneven ripening of capsules on the plant, low productivity. The purpose of the research was to evaluate the possibilities of creating highly productive varieties and varieties with non-cracking capsules and a determinate type of growth. The research was found that the non-cracking of capsules and the determinate type of growth have a recessive type of inheritance of the traits. The method of chemical mutagenesis and subsequent individual selection of plants made it possible to create sesame genotypes with complex of valuable agronomic traits. The traits are controlled by recessive genes in the homozygous state *idid* (non-cracking of capsules), *dt1dt1* (determinant type of growth). Determination of the type of inheritance of these traits in experimentally obtained mutants made it possible to create sesame varieties Boyarin and Ilona with non-cracking capsules and a determinant type of growth at variety Ilona. A change in the structure of the capsule leads to decrease of the number of seeds in the capsule, a decrease of the productivity compared to the new created highly productive varieties of sesame Gusar and Kadet with cracking capsules and an indeterminate type of growth. The weight of seeds per plant of the varieties Gusar, Kadet, Boyarin depended on the number of seeds of one plant and determined the level of the yield formation. The weight of seeds the one plant of the variety Ilona with non-cracking capsules was determined by the weight of 1000 seeds. The new variety Gusar with cracking capsules and indeterminate type of growth generated a maximum yield of 1.62 t/ha with the largest number of seeds (4207 pieces) and a maximum weight of seeds on plant of 11.7 g compared to other varieties. An increase of the weight of 1000 seeds to 3.0 g at the variety Ilona with non-cracking capsules ensures an increase of the weight of the seed of plant and the formation of a yield of 1.22 t/ha at the same level as at the variety Kadet with cracking capsules, which is a highly productive variety - 1.32 t/ha. The variety Boyarin with a modified structure non-cracking capsules and a minimum number 2664 pieces and weight of the seed in a capsules of the plant 7.9 g formed a minimum yield of 1.10 t/ha. The level of productivity and yield of sesame varieties Gusar, Kadet, Boyarin in the arid conditions of the Steppe of Ukraine is determined by the amount of precipitation during the growing season, and at the variety Ilona - by the temperature factor against the background of an increase of the average temperature of the growing season.

Keywoods: sesame; no-cracking of capsules; indeterminate type of growth; quantitative trait; variety; yield; variety reaction

INTRODUCTION

Vegetable oils are the basis for the production of many food products, raw materials for many industries, an exchange-traded food commodity and an important part of the food security of Ukraine. Among oilseeds, sunflower occupies the main place in the production of vegetable oils in Ukraine and ensures all the needs of the country in the domestic market. Oversaturation of crop rotations with sunflowers, non-compliance with crop rotations, unstable weather conditions of the Steppe of Ukraine, frequent droughts during the growing season, a small range of field crops for arid conditions pose the task of introducing the new oilseeds into agricultural production as an alternative to growing sunflowers in arid steppe conditions.

Sesame is one of the oilseed crops, which in terms of biological properties corresponds the conditions of growing in the arid conditions of the Steppe.

Sesame (*Sesamum indicum L.*) belongs to the genus *Sesamum* of the family *Pedaliaceae* and is an important oilseed crop cultivated in many countries around the world. The history of the introduction of sesame into agricultural production goes back about 5000 years. Sesame production is concentrated mainly in Asia and Africa (Weiss, 1984; Ram et al., 1990; Bisht et al., 1998).

The increasing demand in commercial seeds of a sesame is causing an increase the cultivated area under sesame in the world. The sown area of sesame in the world is about 10 million hectares. The main producers of commercial seeds of a sesame are Tanzania, Myanmar, India, Sudan (Aksyonov et al., 2020).

Sesame seed products are used in the food, pharmaceutical, cosmetic, feed industries, and medicine. The biochemical composition of the sesame seeds determines the most diverse and justified using of sesame oil and the seeds themselves as in human nutrition so and in a wide branch of economic activities (Lunogelo and Kazi, 2021).

The value of sesame is determined by the biochemical composition of the seeds of plants of this crop. The seeds of sesame contain the fats - up to 65%, the proteins - up to 22-30%, the carbohydrates - up to 16%; vitamins A, B, C, E; compounds, that speed the clotting of a blood. Sesame seeds contain lignans: sesamin, sesamolin, amino acids: histidine, tryptophan. Sesame is also characterized by a high content of the calorie in the seeds: 6355 kcal kg^{-1} (Zebib et al., 2015; Sanjay Kumar and Goel, 1994.).

The sesame seeds have very high content of fat. The seeds contain from 55 to 65% of one of the best edible vegetable oils. The oil of sesame contains from 40 to 48% oleic and from 37 to 44% linoleic acids. The organism of human does not produce these acids itself. The organism of human must receive these amino acids with food (Pathak et al., 2014; Eskandari et al., 2015; Aksyonov and Amelin, 2016).

The high content of oleic acid, as well as the almost equal 1:1 ratio of oleic and linoleic acids determine the uniqueness and high taste of oil of sesame (Abou-Gharbia et al., 1997).

Sesame is also cultivated in the world as an additional source of protein. The defatted flour of the sesame seeds contains up to 50% protein. Enriching wheat bread with the protein of the sesame seeds is possible and advisable. The quality of a flour is greatly improved when the seed coat of sesame seeds is removed before grinding of the seeds.

In India, sesame flour is an important food. Enriching of a flour with protein of sesame seed is a standard feature of production and processing of the sesame seed in the food industry (Aksyonov et al., 2020).

Due to the biochemical composition of the seeds, the sesame can be considered as a crop that can replace the animal proteins and the animal fats in the human diet as the rich source of vegetable protein and the healthy fats (Rahman et al., 2020).

The wide possibilities of using sesame in various areas of economic activity, and so in medicine and pharmacy, ensure a wide demand on the commercial seeds of the crop. In African and Asian countries, sesame is becoming an important alternative crop for small farmers. Growing sesame additionally solves the issue of employment and reduces poverty in rural areas (Pathak et al., 2017; Komivi et al., 2017).

Industrial using of sesame seeds, increasing the population in the world, changing models of food consumption and the awareness of consumer about their health are leading to an increase of volume of the sesame market.

In 2017, production in the world of sesame seeds was already about 5.5 million tons. In 2018, the global value of the market of sesame seeds reached 6.5 billion US$. With according of prognoses, the market of the sesame seeds will reach the volume of 17.77 billion US$ by 2025. The analytical data of the market of the sesame seeds shows that the production of the sesame seeds will reach 9.26 million tons by 2040, on comparison with 5.53 million tons in 2017. The expected demand on the seeds of the sesame only in China will reach of 2.56 million tons in 2040, on comparison with 1.3 million tons in 2016. Sesame is becoming the important significance in the economic, import-export relations of many countries. (Lukurugu et al., 2023; Sawadadkar et al., 2023).

The high demand for sesame poses a purpose for breeders on creating varieties which meet the requirements of agricultural production and the processing industry.

In the process of creating the varieties of sesame and introducing the crop into agricultural production, the breeder must take into account the climate zone of cultivation of this crop, the demands of plants on environmental factors in accordance with the biological properties of the varieties (Kharchenko, 2003). High drought resistance, the ability to generate yield in conditions of the deficiency of moisture in the soil expands the possibilities of growing crop in arid conditions, poses a problem for breeders on creating high-yielding, drought-resistant varieties (Aksyonov & Aksyonova, 1996; Cagurgan, 2006).

In this regard, unlocking the genetic productivity potential of varieties of any crop is solved through breeding work on creating varieties adapted to growing conditions. The creation of varieties of this direction is possible by analyzing the adaptive properties of plants, realized through the varieties manifestation of their quantitative characteristics (Zhuchenko, 2001; Klikov, 2010). The yield level of sesame varieties is determined by quantitative traits that determine the productivity of plants - the number of branches on a plant, the number of capsules on a plant, the number of seeds in a capsule, the weight of seeds per plant, the weight of 1000 seeds (Ojikpong et al., 2007; Sivagamy & Rammohan, 2013).

At the same time, the yield of sesame varieties remains low. The creation of adapted varieties based on the traits of productivity is hampered by insufficient study of the characteristics of the manifestation of quantitative traits and factors limiting the manifestation of traits (Mikhaylenko & Dragavtsev, 2010).

The unstable, arid nature of the weather conditions of the growing season, the different productivity of sesame varieties make relevant of research on the manifestation of quantitative traits and the level of yield formation in the steppe zone of Ukraine, with further determination of the possible using of varieties in soil-climatic zones of growing and as source of the initial material in breeding work.

The aim of the study was to establish the characteristics of the inheritance of the traits of "capsule non-cracking', "type of growth" of plant and to study the possibilities of creating highly productive sesame varieties with non-dehiscent capsules and a determinate growth type for cultivation in the steppe of Ukraine.

MATERIALS AND METHODS

The study was carried out in the conditions of the Department of Biology and Agronomy of the Institute of Natural and Agrarian Sciences of Lugansk National University named Shevchenko. The object of research was the productive traits of plants and the yield of sesame varieties Boyarin, Gusar, Kadet, Ilona.

The soil of the experimental plots was medium-humus chernozem. Characteristics of the soil layer 0...30 cm:

- the content of humus (according to I.V. Tyurin) is 3.9 %;
- the content of easily hydrolyzed nitrogen (according to I.V. Tyurin) is 9.1 mg per 100 g of soil;
- the content of mobile phosphorus (according to F. Chirikov) is 14.2 mg per 100 g of soil;
- exchangeable potassium content (according to F. Chirikov) is 6.5 mg per 100 g of soil.
- the soil solution has a reaction nearly to neutral - pH 6.5.

The experiments were carried out in a 7-field field crop rotation. The predecessor is winter wheat. The main method of tillage is plowing to a depth of 27-30 cm. In the spring the pre-sowing soil tillage consisted from the early spring cultivation of the soil and pre-sowing cultivation. The Harness® *(acetohlor*) MAX herbicide (2.5 l/ha) was applied for pre-sowing cultivation. Depth of pre-sowing cultivation - 4-5 cm. Depth of seed placement – 2.0-3.0 cm. Sowing period - soil temperature at the depth of seed placement is 12-14^0 C. Before and after sowing, the soil was compacted with the rollers. The row spacing is 70 cm. Sesame was harvested manually, followed by threshing of plant capsules in laboratory conditions. The plot area is 10.0 m^2. The experiment has 3-multiple of the replication.

Before harvest ten plants from 1 and 3 replications were selected randomly from each replication for determining on plant height, number of capsules on a plant, number of seeds per capsule, weight of seeds in capsule, weight of 1000 seeds, weight of seeds per plant, content of fat t in seeds. The content of fat in the seeds was determined using a Nuclear Magnetic Resonator (NMR).

Mathematical and statistical processing and determination of the reliability of experimental data were carried out according to the methods of Dospehov (1985), Aksyonov et al. (2023).

RESULTS AND DISCUSSION

The growing seasons of Steppe of Ukraine have weather conditions that correspond to the biological properties of sesame plants. The initial factor, that limits the cultivation of sesame in this climatic zone, is the instability of sesame plants to *Fusarium* ear blight. During the period when breeding work began on creating sesame varieties, was revealed that in the conditions of the steppe zone the plants of sesame are damaged by Fusarium with the great degree. The degree of plant damage ranged from 75 to 100%.

The completed ecological differentiation of collection and breeding samples of sesame and the selection of genotypes for resistance to Fusarium blight allowed to create of new varieties of sesame Nadezhda, Boyarin, Gusar, Kadet, Ilona. These created varieties of sesame are resistant to fusarium and have a high level of adaptability to growing conditions in the steppe and forest-steppe zones of Ukraine.

The disadvantage of the first variety, created in Ukraine, Nadezhda, is the low productivity of plants and the strong shattering of seeds from the capsules during their ripening period by reason of the strong cracking of the capsules.

New sesame varieties of Boyarin, Gusar, Kadet, Ilona have higher productivity. All new sesame varieties had a high level of resistance to Fusarium, ranging from 90-96%.

The varieties of sesame of Gusar and Cadet have cracking capsules and a simultaneous long period of flowering, the formation of new capsules in the upper portion of the plant and the ripening of capsules in the lower portion of the plant (indeterminant type of growth). These varieties have such features. Before the end of the growing season, with continued flowering and capsule formation, the capsules of the upper tier of the plant form and begin to ripen only, the capsules of the lower and middle tiers of the plant have already ripened and begin to crack. This leads to shattering of seeds from the capsules of the lower and middle tier of the plant and to a decrease in yield. Uneven ripening of seed capsules on the plant complicates mechanized harvesting with grain combines and delays the start of harvesting.

The Boyarin variety is characterized by the presence of no-cracking capsules. The variety of Ilona belongs to the group of varieties with slightly non-cracking capsules and has a less extended period of ripening of the lower and upper capsules on the plant, but a lower level of yield formation. The less extended period of ripening of the lower and upper capsules on the plant (determinant type of growth) ensured a more uniform ripening of capsules with seeds in the variety of Ilona (Figure 1).

The creation of varieties of Boyarin and Ilona with high technological properties was carried out in several stages.

The seeds of variety of Kubanets 55 were treated with the chemical mutagen ethylmethanesulfonate (EMS) in a concentration of 0.01%. Among the obtained mutant plants, the mutant plants of a sesame with indehiscent capsules were selected. The resulting mutant with no-cracking capsules was used in a combination of crosses with collection sample-90 of sesame with dehiscent capsules.

The trait of cracking capsules of collection sample-90 had a dominant type of inheritance. All plants of F_1 were with the dehiscent capsules (Table 1).

The plants of F_2 on the trait of capsule cracking had splitting on two types of capsules in ratio of 3 (capsule cracking): 1 (capsule non-cracking). The trait of non-cracking of capsules had a recessive type of inheritance. The resulting mutant with non-cracking capsules were inherited as a recessive and had a genotype with recessive genes in the homozygous state *idid*. The capsules of mutant plants, having the recessive gene *id* in the homozygous state *idid* did not were no-cracking. The action of a recessive gene *id* in a homozygous gene leads to structural changes in the shell mesocarp of the capsule and the capsules do not crack.

Figure 1. Sesame plants during the formation of capsules:
a) variety Gusar with simultaneous flowering and formation of capsules at the end of the growing season;
b) variety Ilona with uniform ripening, without flowering in the upper tier at the end of the growing season.

Table 1. Inheritance of the trait “non-cracking capsules of sesame” in the generations of F_1 and F_2 generations (average for 2019-2021)

Crossing combination		Phenotype F_1	Splitting on phenotype в F_2		Ratio splitting	χ2
♀	♂		cracking capsules	no-cracking capsules		
mutant with no-cracking capsules	collection sample-90	cracking capsules	368	124	3 : 1	0,71

Based on mutant plants, a line of NCS with non-cracking capsules was obtained. The line had low productivity. To increase productivity of the plants, the line NCS was involved in a combination of crossing with the variety of sesame Nadezhda. The assessment of plants for productivity and non-cracking of capsules was carried out in generation of plants F_2, obtained from crossing combination: mutant with no-cracking capsules × variety Nadezhda. Highly productive plants with homozygous recessive genes for the trait of non-cracking of capsules were selected. This work led to the obtaining of the sample PrNCM. On based of the genotype PrNCM, the variety Boyarin with a higher level of productivity and non-cracking capsules was created.

In parallel, work was carried out on obtaining genotypes with a shorter flowering period, while simultaneously ripening capsules on the sesame plant. Seeds of the variety sesame of Tashkentskiy 122 were treated with the chemical mutagen nitrosoethylurea at a concentration of 0.04%. By the indeterminate type of growth, the capsules with seeds at the base of the plant have already matured and are beginning cracking, and at this time at the top part of the plant flowering is still underway and the capsules are just forming. Treatment of seeds with a chemical mutagen allowed obtaining the plants mutant MTD with a determinant type of growth. Mutant plants (genotype *dt1dt1*) were characterized by a shorter flowering period and simultaneously ripening of capsules on the plant.

To establish the type of inheritance of the determinate type of growth, the mutant MTD with a determinate growth type was involved in a combination of crossing with the collection sample K-157 of the indeterminate growth type (genotype *DtDt*). In the plants generation F_1 a dominant type of inheritance of the trait - indeterminate type of growth (*Dtdt1*) was noted. The plants F_1 had a long flowering period and uneven ripening of seed capsules throughout the plant – indeterminate growth type (Table 2).

Analysis of the generation of plants of F_2, obtained from the hybridization of the mutant MTD (*dt1dt1*) and the collection sample K-157 (*DtDt*) showed splitting in the population of plants of F_2 in a ratio f 3 (indeterminate growth type, gene *Dt*) : 1 (determinate growth type, gene *dt1*). The gene *dt1*, which controls the trait of determinant type of growth, has a recessive type of inheritance. The determinant type of growth in sesame is inherited as a recessive (*dt1*) and the trait of a determinant type of growth is manifested by the homozygous state of the recessive gene *dt1dt1*.

After establishing the inheritance type of the gene d*t1dt1*, the sample PrNCM (*idid*) with non-dehiscent capsules was involved in a combination cross with the mutant MTD (*dt1dt1*). From this crossing combination, the generation F_1, F_2, F_3 was obtained. The plants F_1 on the traits non-dehiscent capsules and the determinant type of growth have a genotype *id dt1*. In the populations of sesame plants F_2, F_3, selection was carried out to select plants according to homozygous recessive traits in one genotype - non-cracking of capsules (*idid*) and determinant growth type (*dt1dt1*). The result of the selection made it possible to create the variety Ilona (genotype (*idid dt1dt1*) with

Table 2. Inheritance of the trait "determinate growth type" in the generations of F_1 and F_2 generations (average for 2019-2021)

Crossing combination		Phenotype F_1	Splitting on phenotype в F_2		Ratio splitting	χ2
♀	♂		indeterminate type of growth	determinate type of growth		
mutant MTD	K-157	indeterminate type of growth	675	224	3 : 1	0,80

good technological properties of plants - non-cracking of capsules, determinant type of growth (shorter flowering period, the capsules on the plant ripen simultaneously).

This increased the technological properties of the variety and led to a reduction in seed losses during harvesting. The decrease in seed shattering of varieties of Boyarin and Ilona is explained by the selection of forms on the basis of non-cracking of capsules.

The results of the study show that new sesame varieties have their own characteristics of growth, development and productivity formation.

Over the years of research, sesame varieties had different durations of growing season. The varieties with cracking capsules Gusar and Kadet belong to the early ripeness group and the middle ripeness group, respectively. The early ripening variety Gusar had a minimum growing season of 110 days (Table 3).

The growing season of the Kadet variety was 122 days. Late-ripening varieties Boyarin and Ilona had a longer growing season - 140 and 143 days, respectively.

In the conditions of the steppe of Ukraine, a variety of the early ripeness group Gusar and a variety of the the middle ripeness group Kadet had a slight variation in the duration of the growing season - 4.4 and 4.2%. The variation in the duration of the growing season in late-ripening varieties was more significant. The coefficient of variation in the duration of the growing season was 9.9% for a variety Boyarin and 9.4% for a variety Ilona. The varieties Gusar and Boyarin were harvested in mid-September at stable weather conditions on these days. Weather conditions did not influence on the changeability of the speed of ripening of plants of the varieties Gusar and Kadet and did not influence significant changes in the duration of the growing season.

The late-ripening varieties Boyarin and Ilona are harvested in the end September and early October at unstable weather conditions in years of the research. Weather conditions during harvesting contributed to changes in the length of the growing season for late-ripening varieties. In 2020 higher temperatures in period ripening of seeds of sesame than normal accelerated plant ripening and contributed to shortening the growing season. In 2020 higher temperatures in period ripening of seeds of sesame than normal accelerated plant ripening and contributed to shortening the growing season. In 2021 cool night temperatures in period ripening of seeds of sesame contributed length the phase of ripening and full maturity stage at late-ripening varieties Boyarin and Ilona.

Change in weather conditions during the growing season had virtually no effect on the height of plants of sesame varieties. The plant height of sesame varieties varied slightly over the years of the study. The coefficient of variation of plant height was between 3.0-5.4%. The maximum height of the plants of 124.5 cm with the maximum coefficient of variation of 5.4% was noted in the variety Gusar. The variety Ilona had the minimum height of plants of 110.7 cm with a minimum variation of this trait of 3.0%.

The created varieties with a lower level of seed shattering from capsules during the period

Table 3. Growing season and height of sesame plants (average for 2019–2021)

Variety	Period growing		Plants height	
	day	V, %	cm	V, %
Gusar	110	4.4	124.5	5.4
Kadet	122	4.2	120.1	4.3
Boyarin	140	9.9	116.3	4.0
Ilona	143	9.4	110.7	3.0

V, % - coefficient of variation

of ripening and seed formation had a lower level of productivity.

The trait of capsule cracking did not determine the number of capsules formed on the plant of sesame varieties. The maximum number of capsule per plant is 114 pcs noted in the variety Gusar with cracking capsules (Table 4).

The minimum number of capsules per plant is 94 pieces was formed in the variety Kadet with cracking capsules. The varieties Boyar in and Ilona with non-cracking capsules formed 101 and 104 capsules per plant during the growing season.

More significant differences at varieties with cracking and non-cracking capsules were noted in the manifestation of such quantitative traits as the number of formed seeds on the plant, the weight of the seeds of one plant, the weight of 1000 seeds.

The maximum number of formed seeds on 1 plant of 4207 and 3356 pieces noted in varieties with cracking capsules - Gusar and Kadet. The varieties with non-cracking capsules Boyarin and Ilona formed fewer capsules on the plant - 3664 and 3031 respectively.

The maximum weight of seeds of one plant corresponded to the maximum number of seeds on the plant. Seed weight increased with increasing number of seeds on the plant. The varieties Gusar and Cadet with cracking capsules had the maximum number of seeds per plant: 4207 and 3356, respectively. The variety Gusar formed the largest weight of seeds per plant 11.7 g. A decrease in the weight of seeds per plant was noted to the level of 9.6 g per plant in the variety Kadet. A decreasing of the number of seeds per plant in the variety Kadet resulted the decreasing of the seeds weight by 2.1 g compared with the variety Gusar.

A decrease in the number of seeds to 3031 pcs and 2664 pcs seed weight on the plant to the level of 7.9 and 8.9 g was noted in the varieties Boyarin and Ilona with non-cracking capsules. Changing the structure of the partitions in capsules and using the trait of non-cracking of capsules in the creation of varieties Boyarin and Ilona leads to a decrease in the formation of the number of seeds in the capsule. The varieties Boyarin and Ilona formed the number of seeds in one capsule within the range of 26-29 pieces. At the same time, the varieties Gusar and Kadet with cracking capsules had a larger number of seeds in one capsule, ranging from 36-37 seeds. Reducing the number of capsules on a plant to 94 pieces caused a decrease in the weight of seeds of one plant to 9.6 g in the variety Cadet. The maximum weight of 1000 seeds of 3.00 g was observed in the variety Ilona. An increase of the weight of 1000 seeds of the variety Ilona ensured the formation of a seed weight of one plant of 8.9 g, as well as at the level of the variety Kadet with cracking capsules of 9.6 g ($SMD_{0.05}$ 0.8).

The formed plant productivity, determined by quantitative traits, predetermined the level of the yield of sesame varieties.

The maximum weight of the seeds of one plant ensured the formation of the highest yield level of 1.62 t/ha in the sesame variety Gusar with crack-

Table 4. Quantitative traits and yield of sesame varieties (average for 2019–2021)

Variety	Number of capsules per 1 plant, pcs	Number of seeds per 1 plant, pcs	Weight of seeds per 1 plant, g	Weight of 1000 seeds, g	Yield of seeds, t/ha
Gusar	114	4207	11.7	2.79	1.62
Kadet	94	3356	9.6	2.89	1.32
Boyarin	101	2664	7.9	2.99	1.10
Ilona	104	3031	8.9	3,00	1.22
Smallest Average Difference $(SMD)_{0.05}$	7.2	157.5	0.8	0.05	0.11

ing capsules and an indeterminate growth type. Reducing the seeds weight of one plant had the effect of reducing the yield level of the variety Cadet with cracking capsules to 1.32 t/ha. The maximum weight of 1000 seeds and the same weight of seeds on the plant ensured the formation of almost the same yield level of 1.22 t/ha ($SMD_{0.05}$ 0.11) in the Ilona variety with non-cracking capsules (with fewer seeds per capsule) and determinant growth type, as in the variety Kadet with cracking capsules and indeterminate growth type 1.32 t/ha. The minimum yield level is 1.10 t/ha formed by the variety Boyarin with non-cracking capsules. The decrease of the seeds shedding at the variety Boyarin with non-cracking capsules, due to changes in the structure of the partitions, did not compensate the level of decrease in yield, that this variety formed in the arid conditions of the Steppe.

The manifestation of traits of plant productivity and the resulting level of yield was predetermined by the prevailing weather conditions of the growing season and the individual adaptive properties of varieties to growing conditions. The formation of the yield of the variety Ilona was least dependent on the amount of precipitation during the growing season. Precipitation did not determine the yield of the Ilona variety under dry conditions. With precipitation ranging from 128-229 mm during the growing season, the correlation coefficient for the variety Ilona between the yield and the amount of precipitation was completely insignificant and amounted to 0.04 (Table 5).

The manifestation of adaptive properties to conditions of growing season at the varieties Gusar, Kadet and Boyarin was different than at the variety Ilona. The formation of the yield of the varieties Gusar, Kadet, Boyarin, regardless of the type of capsules, was determined in a greater degree of the amount of precipitation during the growing season and was limited by less amount of the precipitation. An increase of the amount of precipitation contributed the formation of higher yields of varieties. A direct correlation was established between the yield of these varieties and the amount of precipitation, the correlation coefficients between these indicators were r = 0.76-0.84.

The variety Ilona with non-cracking capsules was more demanding of increased temperatures during the growing season. The variety Ilona had a direct positive correlation between yield and the average temperature of air of the growing season r = 0.68. An increase in temperature of air during the growing season contributed to an increase in the yield of the Ilona variety. In the unstable conditions of the Steppe, this reaction of the variety Ilona to temperature factors is very important. A biological feature of the variety is a slowdown of the processes of growth when the air temperature during the growing season drops below 20^0-15^0C.

At the same time, the yield of the varieties Kadet and Boyarin varieties was limited by high temperatures of air. An increase in temperature in the arid conditions of the Steppe caused a decrease in the yield of these sesame varieties to a certain degree. The correlation between yield and average temperature air was negative; the coefficient of correlation between these indicators was r = -0.77 for the variety Kadet and r = -0.59 for the variety Boyarin. The varieties Kadet and Boyarin had lower requirements for higher temperatures and tolerated low temperatures well during the growing season.

Table 5. Correlation matrix of the dependence of the yield level of sesame varieties and the weather conditions of the growing season, r (average for 2019–2021)

Meteorological indicators	Yield			
	Gusar	Kadet	Boyarin	Ilona
Growing season precipitation	0,76	0,84	0,81	0,05
Average air temperature during the growing season	0,09	-0,77	-0,59	0,68

The response of the variety Gusar to the temperature factor during the growing season had a neutral character. The correlation coefficient of the variety Gusar between yield and average temperature of air of growing season was near to zero and was equaled r = 0.09. The variety Gusar has the environmentally resistant to temperature factors during the growing season and stably tolerates the low temperatures of air during plant growth and development.

Analysis of plant productivity, the correlation matrix of the relationship between yield and weather conditions of the growing season shows the different ecological dependence of sesame varieties in the manifestation of quantitative traits that determine plant productivity on the weather conditions of the growing season and at the same time the possibility of growing them in accordance with the varietal environmental characteristics in different soil and climatic zones.

Analysis of the productivity and yield of the plant, determination of a correlation between yield and parameters of weather conditions during the growing season show different ecological adaptability of sesame varieties in the formation of yield, show the possibility of growing varieties in different soil-climatic zones in accordance with the environmental characteristics of the varieties.

CONCLUSIONS

The use of the chemical method of mutagenesis in sesame breeding solves the problem of obtaining genetic variability of traits that was not available in the germplasm collection – genotypes with traits of "non-cracking of sesame capsules", "determinant type of growth of sesame".

The gene that controls the trait "non-cracking of sesame capsules" (*id*) and the gene that controls the trait "determinant type of growth of sesame" (*dt1*) have a recessive type of inheritance. The manifestation of the traits "non-cracking of capsules" and "determinant type of growth" is observed in genotypes with a homozygous state of the recessive genes *idid* and *dt1dt1*. This indicates monogenic recessive control of the technological traits of sesame varieties. The identified genes *id* and *dt1* in a homozygous recessive state can serve as markers in the breeding of sesame and can be used to transfer desired traits to other genotypes of a sesame.

The presence of genetic variability among selected varieties of sesame for chemical mutagenesis and the identification of genes of non-cracking of sesame capsules and determinant type growth were key to the creation of varieties with valuable agronomic traits of the plants.

The resulting mutants are characterized the improved preservation of seeds in the capsule, non-cracking of capsules, altered anatomical structure of capsules, determinant type of growth, more uniform period of ripening. The created mutants provided an opportunity to create new varieties of sesame with improved technological characteristics of plants.

New created epy varieties of sesame are characterized by different levels of productivity and yield. Productivity and yield are determined by the unequal ability of varieties to show their quantitative signs of productivity, different levels of yield formation by varieties with cracking and non-cracking capsules and different types of growth.

Anatomical changes in the structure of the partitions in capsules and the use of the trait of non-cracking of capsules in the creation of varieties Boyarin and Ilona lead to a decrease in the formation of the number of seeds in the capsule.

The number of seeds on a plant determined the weight of seeds in the varieties Gusar and Kadet with cracking capsules, a indeterminant type of growth and in the variety Boyarin with non-cracking capsules and a determinant type of growth.

The maximum number of seeds on a plant, 4207, allowed the formation of the highest weight of seeds 11.7 g and the maximum level of yield 1.62 t/ha in the variety Gusar with cracking capsules.

Reducing the number of capsules on a plant to 94 pieces caused a decrease in the weight of seeds of one plant to 9.6 g in the variety Kadet

At the decreasing the number of seeds in non-cracking capsules and on the plant, the maximum weight of 1000 seeds of 3.00 g ensured the formation of the weight seed of one plant 8.9 g and the yield 1.22 t/ha as at the level of yield 1.32 t/ha with the variety Kadet with a large number of seeds in cracking capsules and on the plant.

Paired correlation analysis showed that the formation of yield is determined by the relationship between the varietal response of each individual variety and the weather conditions of the growing season. In arid conditions of steppe, the yield of the variety Ilona is predetermined by higher temperatures of air during the growing season with a possible decrease in precipitation; for varieties the Kadet and Boyarin – by a large amount of precipitation with a possibly lower average temperature of air during the growing season; for the variety Gusar – by a large amount of precipitation at neutral reactions to changes in average temperature during the period of growth and development of plants.

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Received: November, 05, 2024*; Approved:* December, 15, 2024*; Published:* February, 2025