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SUGAR BEET HYBRIDS BASED ON CYTOPLASMIC MALE STERILITY AND THEIR USEFUL PROPERTIES

Abstract. The study was made during 2017–2020 in Central Black Earth (as basis), some Russian regions and in Kazakhstan. The main indicators were "yield", "sugar content", "sugar yield", which were determined by traditional methods. To improve sowing properties of male sterile (MS) component, seeds were treated with synthesized organic compounds: 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline and 2-benzylamino-4-methylpyrimidine-5-carboxylic acid. An increase of seed germinative energy, seed germination, seedling length, and mass of 100 seedlings in the experiment as compared to the control (%) were calculated. A positive effect from seed treatment on their sowing qualities and a stimulation of growth indicators was revealed in all variants of using the dihydroquinoline and the pyrimidine-carboxylic acid. A high level of monogermity (98–100 %) was noted in obtained hybrids. Studied hybrids show a higher level of main indicators: "yield", "sugar content", "sugar yield" compared to the standard. The treatment of uncoated sugar beet seeds with the pyrimidine-carboxylic acid provides an increase in seed germination energy by 29–55 %, seed germination by 25–53 %, average seedling length by 43–70 %, weight of 100 seedlings by 61–80 % compared to the control. Studied substances can be accepted as growth stimulants for sugar beet in laboratory and in field. Using CMS allows to create heterotic hybrids with the complex of economically valuable properties quicker compared to the traditional selection. This research provides obtaining hybrids on a sterile basis and study their useful properties. The results presented in the paper can be applied in the production process of sugar beet hybrids.

Keywords: male sterile forms, heterosis, monogermity, sugar beet, hybrid

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ГИБРИДЫ САХАРНОЙ СВЕКЛЫ НА СТЕРИЛЬНОЙ ОСНОВЕ И ИХ ПОЛЕЗНЫЕ СВОЙСТВА

Аннотация. Исследование проводилось в течение 2017–2020 гг. в некоторых регионах России (в Центрально-Черноземном как основном) и в Казахстане. Основными показателями были «урожайность», «сахаристость», «сбор сахара», которые определяли традиционными методами. Для улучшения посевных свойств мужскостерильного компонента (МС) семена обрабатывали синтезированными органическими соединениями: 6-гидрокси-2,2,4-триметил-1,2-дигидрохинолином и 2-бензиламино-4-метилпиримидин-5-карбоновой кислотой. Рассчитывали увеличение энергии прорастания семян, всхожести семян, длины проростка и массы 100 проростков в опыте по сравнению с контролем (%). Положительный эффект от обработки семян на их посевные качества и стимуляцию ростовых показателей выявлен во всех вариантах применения дигидрохинолина и пиримидинкарбоновой кислоты. Отмечен высокий уровень односемянности (98–100 %) полученных гибридов. В исследуемых гибридах выявлен более высокий уровень основных показателей – «урожайность», «сахаристость», «сбор сахара» – относительно стандарта. Обработка недражированных семян сахарной свеклы пиримидинкарбоновой кислотой обеспечивает повышение энергии прорастания семян на 29–55 %, всхожести семян на 25–53 %, средней длины проростка на 43–70 %, массы 100 проростков на 61–80 % относительно контроля. Исследуемые вещества могут быть приняты в качестве стимуляторов роста сахарной свеклы в лабораторных и полевых условиях. Использование цитоплазматической мужской стерильности (ЦМС) позволяет быстрее, чем при традиционной селекции, создавать гетерозисные гибриды с комплексом хозяйственно ценных признаков. Это исследование способствует получению гибридов на стерильной основе и изучению их полезных свойств. Представленные результаты могут быть применены в производстве гибридов сахарной свеклы.

Ключевые слова: мужскостерильные формы, гетерозис, односемянность, сахарная свекла, гибрид

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Introduction. Sugar beet is the most important industrial crop providing raw material for the sugar industry not only in Russia but also in many countries such as France, Germany, Spain, Sweden, the Netherlands, the UK and the USA. In this regard, research is being widely conducted to improve the elements of the technological process of growing sugar beets, which ensure stable yields. Development of monogerm sugar beet hybrids based on cytoplasmic male sterility (CMS) is the most progressive breeding method which makes it possible to fulfill plant biological potential. The creation of such hybrids provides the presence of male sterile forms, pollinators – maintainers of O-type sterility, selection of highly heterotic polyspermous pollinators. They are responsive to high doses of fertilizers, resistant to biotic and abiotic environmental factors with an optimal shape of roots [1–3]. A change to hybrids on sterile basis has caused significant change of seed-growing methods, the main of which is separate sowing of seeds, separate storage of beet roots, separate planting of components by alternating rows (strips) in different ratios and separate harvesting of the components. For example, methods of a hybrid components planting on a sterile base, and their impact on the basic indicators of productive properties have been developed and scientifically grounded [4].

Climate changes, especially water deficits and increasing temperatures impact on the sugar beet crop [5]. The search for genetic sources of drought tolerance has already being conducted [5–7]. India's first beet processing factory was opened in 2004 and further development work was currently being carried out in Sudan, Pakistan and Kenya [5, 8]. For instance, growing of sugar beet hybrids on a sterile basis in conditions of unreliable moisture in Central Black Earth has been studied [4]. There are lots of agricultural practices, agrotechnological methods and modes to improve yield, sugar content of mother roots and sowing properties (germinating capacity) of seeds [9–12]. Organic or inorganic compounds are used for seed treatment [11–15]. New compounds of the quinoline series were applied as growth and yield stimulants of agricultural crop [14]. Other compounds of the quinoline and pyrimidine-carboxylic acids series can be used as growth regulators [13–14].

Recently, the use of heterosis is considered the most effective in CMS-based breeding [16–20]. The maximum heterosis effect is achieved by hybridization of a sterile monogerm component with a fertilized (multigerm) pollinator [17]. But there is a problem to maintain high monogermity level in male sterile components of heterotic hybrids.

The creation of sugar CMS-based heterotic hybrids depends on the genetic diversity of the linear material used in the breeding process [16–22]. Successful use of monogerm sugar beet hybrids based on CMS depends on a series of factors. Level of hybrids' heterosis making them competitive, as well as ecological factors and effective breeding methods to produce and maintain the components (MS – male sterile, OT – O-type, HP – heterosis pollinator, MM – multigermity). Taking into account that sugar beet is a two-year allogamous crop, breeding of hybrids based on CMS takes about 15–16 years. On the whole, a principle scheme of breeding-seed-growing process is divided into three basic stages: the first stage – maintenance of MS analogues by crossing with related lines of O-type (super-elite); maintenance of pollinators separate from MS forms. This stage takes three years: 1 – growing root crops (MS-1, MS-2, etc.), (OT-1, OT-2, etc.), (pollinators A, B, etc.), 2 – reproduction of components in order to obtain superelite seeds, 3 – growing root crops from superelite seeds. The second stage – obtaining of simple MS hybrids (elite seeds) by crossing with not related lines and lines of O-type, reproduction of pollinators maintaining their purity, obtaining of synthetics-pollinators (father form) by method of several multigerm lines' hybridization. This stage takes two years. The third stage – formation of hybrid seeds having heterosis effect by crossing simple MS hybrids (mother form) with a multigerm synthetic pollinator of beet (father form). It takes two years. Before the second and third stage, evaluation of components according general and specific combining ability is necessary. At these two stages, plants of mother and father components are planted at a 2 : 1 ratio, sometimes 3 : 1 and other ratio variants, but indispensable condition is to remove father form plants after flowering. If balls of father form are possible to select by counting, the joint planting is used. In this case, percentage of father plants is reduced to 10–15 %, otherwise, separation costs of balls and fruits become unjustified.

The purpose of this research was to study economically valuable traits of sugar beet hybrids on a sterile basis and to improve seed sowing qualities. Seed sowing qualities are meant to be seed germinative energy, laboratory seed germination, seedling length, and mass of 100 seedlings.

Material and Methods. The studies have been conducted during 4 years in 2017–2020, those include the perennial data to observe hybrids development in Russia. The plant material was in the same conditions in each location (without additional moistening). Some trials were conducted in Kazakhstan (in dry climate). For Russia, monitoring of drought phenomena is particularly relevant, since significant part of the agricultural land relies in the zone of unstable and insufficient moisture [23]. Central Black Earth belongs to the 5th soil-climate zone (region of the admission) according to FSBI "State Variety Commission". The base research was carried out in "A. L. Mazlumov All-Russian Research Institute of Sugar Beet and Sugar" (Central Black Earth) to develop observed hybrids. Other trials were conducted in different regions. Global climate changes are often reflected in the determined soil-climate zone as water deficits and increasing temperatures. Various definitions for the reflection of climate changes are applied. For example, the Hydrothermal coefficient (HTC) of G. T. Selyaninov, characterizing the ratio of heat and moisture, is widely used as a measure of droughts. Coefficient is calculated according to the formula:

HTC = R / 0.1 · T > 10 °C, where T > 10 °C is the sum of average daily air temperatures for the period with air temperatures above 10 °C, R is the amount of precipitation for the same period [23]. Drought classification based on HTC [23] is presented here: 0.8 < HTC ≤ 1 weak (low); 0.6 < HTC ≤ – 0.8 moderate; 0.3 < HTC ≤ 0.6 strong; HTC ≤ 0.3 extreme. Drought intensity was determined according to HTC and drought classification [23] in Central Black Earth based on the data of "A. L. Mazlumov All-Russian Research Institute of Sugar Beet and Sugar" (Table 1).

T a b l e 1. **Hydrothermal coefficients in Central Black Earth**

Year	April	May	June	July	August	September	October	Average for growing season
2017	1.7	0.2	1.4	0.9	3.9	1.0	3.5	1.8
2018	0.4	1.8	0.5	1.1	0.5	3.6	1.2	1.3
2019	1.8	0.7	1.5	0.1	0.6	0.1	0.7	0.8
2020	4.0	0.75	1.1	1.5	0.33	0.32	3.1	1.0
Perennial data	2.4	1.0	1.1	1.1	0.9	1.6	5.6	2.0

Methodology of the field experiment was used according to traditional recommendations [4]. Standard agricultural practices were applied for growing plants including pollinators, hybrids [17, 24]. As a soil preparation, plowing, cultivation and fertilization were carried out in autumn. Then cultivation and application of herbicides were carried out in spring. Sowing, mechanized weeding (about 2–3 times with the depth of 2–6 cm), manual weeding (2 times) and examination were carried out. Harvesting of hybrids and their components, as well as estimation of useful properties were carried out in autumn. Experiments were carried out in four replications, including experiments of FSBI "State Variety Commission".

As a pre-sowing preparation, seeds were cleaned and calibrated. Sowing seeds fraction was 3,5-4,5 cm. Some uncoated seeds were treated with water solutions of chemical compounds. Seeds were soaked in water solutions of synthesized compounds: 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (Figure 1) and 2-(benzylamino)-4-methylpyrimidine-5-carboxylic acid (Figure 2). 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline was synthesized by dealkylation of commercially available 6-ethoxy-2,2,4-trimethyl-1,2-dihydroquinoline (ethoxyquin) using hydrobromic acid (Figure1) according to well-known method [25].

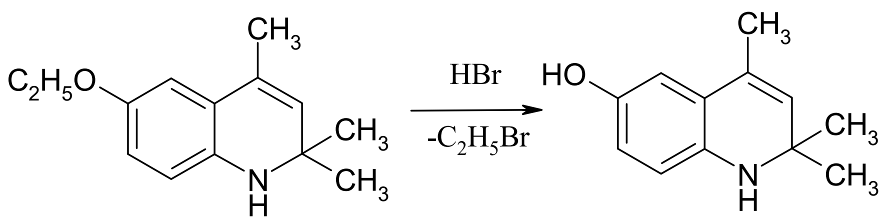

Fig. 1. The synthesis of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline

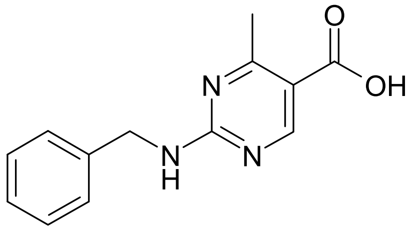

Fig. 2. 2-(benzylamino)-4-methylpyrimidine-5-carboxylic acid

To prepare 0.1 % solution, 1 g per 1000 g of water was used. Then the solution was diluted to 0.05 and 0.01 % concentrations. The seeds were kept in water solutions of the above chemical compounds at concentrations of 0.01, 0.05, and 0.1 % for 18 hours. As a traditional stimulator, the commercial preparation Epin-extra (of the Russian producer NNPP NEST, Moscow) in a use concentration according to the instructions for use – 0.05 %. Seeds were sprouted on a filter paper in plastic containers in four replications with 100 seeds per replication. The containers were kept under laboratory conditions at a constant temperature range of 22–25 °C. As a control, seeds of the same line were used. They were soaked in tap water. Analysis of the solution influence on sugar beet seed sowing qualities – germinative energy, laboratory seed germination, seedling length, mass of 100 seedlings – were carried out. To study the germinative energy of seeds, seedlings were counted four days after the beginning of seed sprouting according to Russian Standards of seed germination (GOST 22617.2-94). To study the seed germination, seedlings were counted ten days after the beginning of seed sprouting (GOST 22617.2-94). The seedling length was measured with the help of a ruler ten days after the experiment start. The seedling mass was determined in ten days using an electronic balance. Statistical processing of the results was conducted using the Stadia software package. Average values of seedling lengths and mass of 100 seedlings were compared using Student's *t*-test. The germinative energy of seeds, seed germination in control and experimental variants were compared using Z-test for equality of frequencies [26] (Kulaichev, 2006). An increase in sugar beet germinative energy of seeds, seed germination, length of seedlings, and mass of 100 seedlings in the experiment as compared to the control (%) were calculated. The influence of the factor "treatment with the chemical compound" in different concentrations upon the listed traits was determined using a one-way analysis of variance. SSD is used for characterizing parameters "yield", "sugar content", "sugar yield" [24]. The resistance to black leg, root rots, powdery mildew, cercosporosis and root crop storage diseases was estimated by V.N. Shevchenko scale [27].

Early, RMS-46, RMS-70 and RMS-73 were used as a standard in Russian researches (originator "A. L. Mazlumov All-Russian Research Institute of Sugar Beet and Sugar"). In our researches, RMS-46 was also used as a standard. Origin of material applied for obtaining of standard hybrids is Russian. Currently, Russian breeders often apply hybrids of foreign selection. The standard was the foreign hybrid Bakkara (originator "Mezon Florimond Desprez").

A comprehensive assessment of the technological quality of test hybrids was carried out in the laboratory for storage and processing of raw materials using the method of P. M. Silin, which includes the production of beet juice by pressing, its purification with milk of lime and carbon dioxide. The sugar content in root crops was determined by the method of cold water dehydrogenation [17].

Results and Discussion. 1) mm MS-line 1x mm O-type line 1 = mm MS-1 (maintenance of the MS-component); 2) mm MS-line 1x mm O-type line 2 = mm MS-1, 2 (obtaining a simple MS-hybrid); 3) mm MS-line 1, 2 x MM = F1 mm MS (creating a heterosis hybrid).

In our studies, most of heterotic hybrids of sugar beet (RMS-46, RMS-60, RMS-70, RMS-73, RMS-90) were obtained according to the simple scheme.

For example, hybrid RMS-90 is based on the MS component RS-106, pollinator of O-type RF-2113 and the multiple pollinator OP-14840. The author's certificate has been obtained for this hybrid. According to ecological tests results new hybrid is superior to the standard hybrid of Ramon single-germ 47 in sugar content by 5.29 t/ha and the group standard by 7.27 t/ha, by 0.28 and 0.31 % respectively, in sugar yield by 0.98 and 1.36 t/ha. Damage of hybrid with black leg (at 6.8 %) and root rots (at 2.2 %) was below the standard. The hybrid is resistant to drought. RMS-90 has a high fertility rate – up to 99.5 %.

This hybrid is responsive to a high level of agricultural technology. It has a high safety of root crops during storage. The high productivity of the hybrid is combined with increased sugar content (Table 2).

At present, the main task of sugar beet breeding is to develop highly productive hybrids meeting the requirements of modern agricultural industry.

T a b l e 2. **Productivity of the sugar beet hybrids in Central Black Earth**

Hybrid	Yield, t/ha	Sugar content, %	Sugar yield, t/ha	Compared to the standard variety, %		
				Yield	Sugar content	Sugar yield
Standard RMS-46	46.7	18.5	8.64	100.0	100.0	100.0
RMS-60	50.6	17.8	9.0	117.8	96.2	104.2
RMS-90	65.6	18.4	12.1	140.5	99.5	140.0
SSD*	2.6	0.2	0.54	–	–	–

* $P = 0.05$.

Special attention is given to suitability for mechanized harvesting of seed-bearing plants that is connected with a form of seed-producing plants and simultaneous maturing of seeds. Besides, development of hybrids and their components resistant to diseases has become a sore problem last years. More frequent cercosporosis epiphytoties and intensive development of rhizomania have revealed insufficient resistance of varieties and hybrids. Issues of technological qualities and resistance to bolting improvement are still urgent.

High-quality seeds are the basis to obtain steady sugar beet yields. During the last years, production of beet seeds in the majority of seed-growing companies has been sharply reduced because of yield decrease till 0.6–0.8 t/ha and sharp reduction of areas to grow seed-bearing plants.

Search of way out from crisis for the industry branch should be aimed not at return to initial state, but change to a more perfect production level corresponding to the world one. In addition, one of the important elements to improve productivity of beet fields is to cultivate not varieties-populations, but heterosis hybrids on sterile basis that are notable for greater productivity (additional yield makes 4.0–8.0 t/ha) and high level of monogermity (98–100 %). Placement of beet root heads relative to soil surface is much more uniform in MS-hybrids. This reduces raw material losses when harvesting. The form and uniformity of beet root surface allow their harvesting under conditions of high soil moisture without considerable increase of soil pollution.

During the last years, hybrids on sterile basis have been developed by scientific research institutes of sugar beet. The hybrids do not yield to foreign ones or even surpass them in basic parameters, for example, resistance to root rots. Some hybrids are characterized by great precocity, i. e. are good for early harvesting, for example, the hybrids: RMS-90, Ramnes and Ruslan (Table 3).

T a b l e 3. **Productivity of hybrids at collective farms**

Hybrid	Yield, t/ha	Sugar content, %	Sugar yield, t/ha
Standard Bakkara	43.40	17.20	7.46
RO-117	47.00	17.20	8.08
Ruslan	48.50	17.30	8.39
Aksu*	58.80	16.20	9.52
Ruslan*	53.34	16.10	6.59
Ramnes*	51.70	17.10	8.84
RMS-90*	56.60	16.30	9.22

* Trials conducted in Kazakhstan (dry climate).

Last years, foreign hybrids, many of which are entered in the State Register List of Russian Federation, have been propagandized intensively and unreasonably for sugar beet production (Table 4). Results of State Variety Trials show that our hybrids do not yield to foreign ones in productivity (%, compared to the standard variety). The standard was the hybrid Bakkara (originator "Mezon Florimond Desprez").

Table 4. **Results of State Variety Trials in productivity (%, compared to the standard variety)**

Region*	Hybrid	Yield	Sugar content	Sugar yield
3	RMS-46	109.4	101.7	110.6
3	Inter	108.3	101.7	110.0
5	LMS-29	108.7	103.0	112.0
5	Galla	110.6	101.2	111.8
5	RMS-90	140.5	99.5	139.7
5	RK-1	160.0	98.4	157.4
6	line MS 05	109.0	102.0	112.7
6	Lena	113.3	100.0	113.6
7	RMS-70	110.0	102.7	112.7
7	Kiva	101.2	102.9	104.0
10	RBMS-17	107.5	100.5	108.0
10	Kira	117.9	95.6	112.7

Note: Standard Bakkara; * – number of the soil-climate zone (region of the admission) according to FSBI "State Variety Commission"; 3 – Central region of the admission; 5 – Central Black Earth; 6 – Middle Volga; 7 – Nizhnevolzhsky; 10 – West Siberian.

The hybrid RMS-46 was tested in France. Among 20 foreign hybrids, it took the 5th place in sugar yield, and its sugar content was above the average values. Our hybrids surpass foreign ones in resistance to diseases as evidenced by data of the last years, especially those in which an epiphytoty of rots affected up to 90 % of foreign sugar beet fields (in comparison to 8–10 % for the domestic ones) and caused practically total death of this important technical crop plants. For effective work of sugar beet industry, it is reasonable to have 2–3 hybrids in each soil-climate zone. Additionally, part of them is to be of sugar type thus ensuring early start (from 25 of August) of sugar beet factories. And another part is to be hybrids providing the highest sugar yield when harvesting starts on 20 of September (high-yield type hybrids, for instance, RMS-90 and RK-1). Compared to other data, there are some periods for the assessment of main indicators in productivity. Different types of hybrids had definite characteristics and were more effective in the certain period. The chemical composition of standard Bulgarian cultivars of sugar, fodder and table beet from the gene pool of the Agricultural Institute in Shumen was studied at two harvest periods (in August and in October) [28].

Superagro, a new sugar beet hybrid developed on MS basis in the Centre "Bioengineering", meets these requirements. Superagro was obtained by crossing the line LBS-16 with not related line of O-type LBO-19. Preliminary variety trials (2017–2018) showed that this hybrid was superior to the standard hybrid of RMS-73 in beet root yield by 145.8 %, sugar content by 100.3 % and sugar yield by 146.8 %. Average yield of the hybrid Superagro was 62.9 t/ha in 2018, with sugar content of 19.1 % and sugar yield of 12.02 t/ha. The hybrid was resistant to bolting and beet yellows virus (BYV), weakly affected by black leg (17 %), root rots and powdery mildew (10 %). The cercosporosis disease was not noted. Results of State Variety Trials of the hybrid Superagro are presented in Table 5.

Table 5. **Productivity of hybrids according to test results of FSBI "State Variety Commission"**

Hybrid, zone	Yield, t/ha	Sugar content, %	Sugar yield, t/ha	Compared to the standard variety, %		
				Yield	Sugar content	Sugar yield
Standard Bakkara	43.4	17.2	7.5	100.0	100.0	100.0
Superagro, maximum in original region 5*	63.1	18.6	11.7	145.4	108.1	156.8
Superagro, in tested regions (5, 9*)	51.0	17.8	9.1	117.5	103.5	122.0
RK-1, in tested regions (5, 9*)	44.3	18.1	8.0	102.1	105.2	107.2
RMS-107, in tested regions (5, 9*)	39.3	15.4	6.1	90.6	89.5	81.9
RMS-120, in tested regions (5, 9*)	48.6	17.3	8.4	112.0	100.6	112.6

Note: * – number of the soil-climate zone (region of the admission) according to FSBI "State Variety Commission"; 5 – Central Black Earth; 9 – Ural region of the admission.

The seed treatment has been used in order to improve the quality of MS hybrids components and sowing properties (germinating capacity) of seeds. Analyzing Table 6, an increase in the germination energy and germination of sugar beet seeds is noted after seed treatment with dihydroquinoline and pyrimidine-carboxylic acid in the studied line in comparison with the control ($P < 0.05$, $P < 0.01$), and in comparison with the standard growth stimulant (the Epin-extra group) ($P < 0.05$, $P < 0.01$).

T a b l e 6. **Quantitative characteristics of sugar beet after seed treatment with synthesized organic compounds**

Concentration, %	Seedling length, cm	Mass of 100 seedlings, g	Germinative energy, %	Seed germination, %
Control (water)	5.8 ± 0.1	5.2 ± 0.1	58	64
Epin-extra 0.05	6.9 ± 0.1	6.7 ± 0.1	67	75
6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline				
0.01	11.3 ± 0.1**[2]	11.7 ± 0.1**[2]	85**[2]	90**[2]
0.05	10.7 ± 0.2**[2]	10.8 ± 0.2**[2]	85**[2]	90**[2]
0.1	8.9 ± 0.2**[2]	8.8 ± 0.1**[2]	80*[1]	85*[1]
2-(benzylamino)-4-methylpyrimidine-5-carboxylic acid				
0.01	7.8 ± 0.1**[1]	8.4 ± 0.2**[1]	75*[1]	80*[1]
0.05	9.5 ± 0.1**[2]	9.2 ± 0.2**[2]	80*[1]	90**[2]
0.1	9.8 ± 0.1**[2]	9.4 ± 0.2**[2]	90**[2]	98**[2]

Note: * – differences with the control group are reliable ($P < 0.05$); ** – differences with the control group are reliable ($P < 0.01$); [1] – differences with the Epin-extra group are reliable ($P < 0.05$); [2] – differences with the Epin-extra group are reliable ($P < 0.01$).

Table 6 shows the positive effect from treatment of non-coated sugar beet seeds with water solutions of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline and 2-benzylamino-4-methylpyrimidine-5-carboxylic acid on the length of the seedling and the weight of 100 seedlings. There is an increase in the average values as compared to the control group and the Epin-extra group ($P < 0.05$, $P < 0.01$). The concentration of 0.1% proved to be the most effective for pyrimidine-carboxylic acid. All tested compounds at a concentration of 0.01 %, 0.05 % and 0.1 % had a stimulating effect on the germinative energy, laboratory seed germination, seedling length and mass of 100 seedlings compared to the control. The best stimulating effect on the seedling length and mass of 100 seedlings was revealed in the variant of the dihydroquinoline at the concentration of 0.01 % (see Table 6, 7).

T a b l e 7. **Increase in quantitative characteristics of sugar beet after seed treatment with synthesized organic compounds compared to the control (in %)**

Concentration, %	Seedling length, cm	Mass of 100 seedlings, g	Germinative energy, %	Seed germination, %
6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline				
0.01	94.8	125.0	46.6	40.6
0.05	84.4	100.8	46.6	40.6
0.1	53.4	69.2	37.9	32.8
2-(benzylamino)-4-methylpyrimidine-5-carboxylic acid				
0.01	43.5	61.5	29.3	25.0
0.05	63.8	76.9	37.9	40.6
0.1	70.0	80.8	55.2	53.1

Table 7 shows the increase in the quantitative characteristics of sugar beet after seed treatment with 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline and 2-benzylamino-4-methylpyrimidine-5-carboxylic acid compared to the control (in %). A positive effect from seed treatment on their sowing qualities and a stimulation of growth indicators is noted in all variants of using the dihydroquinoline and the pyrimidine-carboxylic acid (see Table 7). The results of one-way analysis of variance confirm the influence of the factor "treatment with the chemical compound" in different concentrations on biometric indicators: seedling length ($P < 0.01$) and mass of 100 seedlings ($P < 0.01$).

The seed treatment increases sowing qualities of other plants [13, 14]. For example, it was found that the synthesized organic compounds of pyrimidine-carboxylic acids series increased the growth of seedlings of some annuals [14]. Obtained results support earlier studies by R. G. Gafurov and co-workers on carbon N- and O-benzyl-containing compounds that have bright auxin activity, which is ensured by the presence of a benzyl group at the nitrogen or oxygen atom [29]. In addition, these substances were stress protectants in field experiments [29]. As 2-benzylamino-4-methylpyrimidine-5-carboxylic acid contain similar fragment, so it also shows bright auxin activity. In comparison with other data, the synthetic cytokinins are the matter of the utmost importance and the subject of highly intensive studies due to the high activity in prevention of leaves fading, mobilization of nutrients, stem growth, etc. [30]. The results of frost resistance of winter wheat tested in the presence of the synthetic cytokinins revealed their activity substantially exceeding the control. Thus, the new regulators seem to be very promising candidates as plant growth regulators and stress protectants [30].

Treatment of uncoated sugar beet seeds with the dihydroquinoline provides an increase in seed germination energy by 37–46 %, seed germination by 32–40 %, average seedling length by 53–94 %, weight of 100 seedlings by 69–125 % compared to the control. Dihydroquinolines at concentrations of 0.05 and 0.1 % proved to have the strongest effect for perennial woody plants after seed treatment with their water solutions [13]. Studied substances can be accepted as growth stimulants for sugar beet.

Conclusion. Thus, using CMS allows to create heterotic hybrids with the complex of economically valuable properties quicker compared to the traditional selection. Development of monogerm sugar beet hybrids based on CMS is the most progressive breeding method which makes it possible to fulfill heterosis effect and, correspondingly, plant biological potential. CMS satisfies requirements of intensive resources-economy technology of cultivation. A high level of monogermity (98–100 %) was noted in obtained hybrids. Studied hybrids show a higher level of main indicators: "yield", "sugar content" and "sugar yield" compared to the standard. Treatment of uncoated sugar beet seeds with the pyrimidine-carboxylic acid provides an increase in seed germination energy by 29–55 %, seed germination by 25–53 %, average seedling length by 43–70 % and weight of 100 seedlings by 61–80 % compared to the control. Studied substances can be accepted as growth stimulants for sugar beet in laboratory and in field. This research allows to obtain hybrids on a sterile basis and to study their useful properties.

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