Volga Region Farmland

Scientific and theoretical as well as practical journal for scientists and specialists

WEBSITE: http://www.niva-volga.ru
ADDRESS of editorial office, publisher, printing house: 30 Botanicheskaya St., Penza, 440014
TELEPHONE: (8412) 628380;
FAX: (8412) 628354
E-MAIL: niva-volga@mail.ru

FOUNDER: Federal State Budgetary Educational Institution of Higher Education "Penza State Agrarian University"

Printed in the printing house of Penza SAU. Older №
Signed for publication on 20 Jun. 2019. Format 60x84 1/8.
Paper writing. C. p. s. 10,93. Print run 500 copies.
Over 16 years of age. In accordance with the Federal law 136.
Flexable price.

The journal is registered by the Federal Service for Supervision of Communications, Information Technology and Mass Communications – registration number ПИ № ФС77-74148 from 29 Oct. 2018.

Content

2(2)'2019

AGRICULTURAL SCIENCES

Agronomy

DOI: 10.26177/VRF.2019.2.2.001

DUST STORMS IN THE VOLGOGRAD REGION, THEIR MANIFESTATION AND PREVENTION

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The article presents long-term observational materials on the frequency and intensity of dust storms on the territory of the Volgograd region. A map chart of the number of dust storms in the designated territory is made, and the reasons for their occurrence are also considered. It is shown in which cases the damage from them will be great, the thought about the necessary measures to prevent dust storms is clearly carried out. It is indicated how forest-reclamation measures should be tied to the danger that exists for this part of the region with specific soil and climatic conditions. The structure of the territory according to the wind-erosion potential is given in detail. Map charts on the soil erodibility of the Volgograd region will also be useful for choosing measures for protecting the soil from wind erosion. The dust storm climatology and the volume losses due to deflation, that were identified during dust storm manifestation in 1969, 1972, 1984 and 2015, as well as summary results of this article, undoubtedly expand and specify knowledge about deflation patterns, about mechanisms of deflationary adverse natural phenomena, reveal a number of previously unclear questions about the role of forest reclamation in areas prone to deflation and reveal how the parameters of forest belt systems need to be adapted to the specific conditions of the wind erosion development.

Keywords: soil deflation, dust storms, climatology, forest shelter belts, distribution, factors, orography, number, recurrence rate, erodability.

Introduction

The Volgograd region, already through its location and the nature of the atmospheric circulation processes, belongs to a territory potentially prone to deflation [14]. The fact is that in this area weather conditions are largely determined by the effects of cyclones of the polar front and the invasion of arctic dry air, as well as the formation of an extensive and sedentary anticyclone centered over the southern Urals. The interaction of these atmospheric formations often leads to the occurrence of strong and storm winds, periodic droughts, dry winds and other adverse events, including dust storms.

Methods and materials

The studies used generally accepted methods of analysis and processing of scientific materials of meteorological services and original experiments on the study of the aerodynamic properties of the soil.

Research results

As a rule, the most apparent dusty storms appear in the spring, but most often they occur in the dry summer period (Fig. 1).

Dust storms in the Volgograd region occur with a prolonged absence of precipitation and a sharp increase in wind, when an extensive and slow-moving blocking anticyclone is established

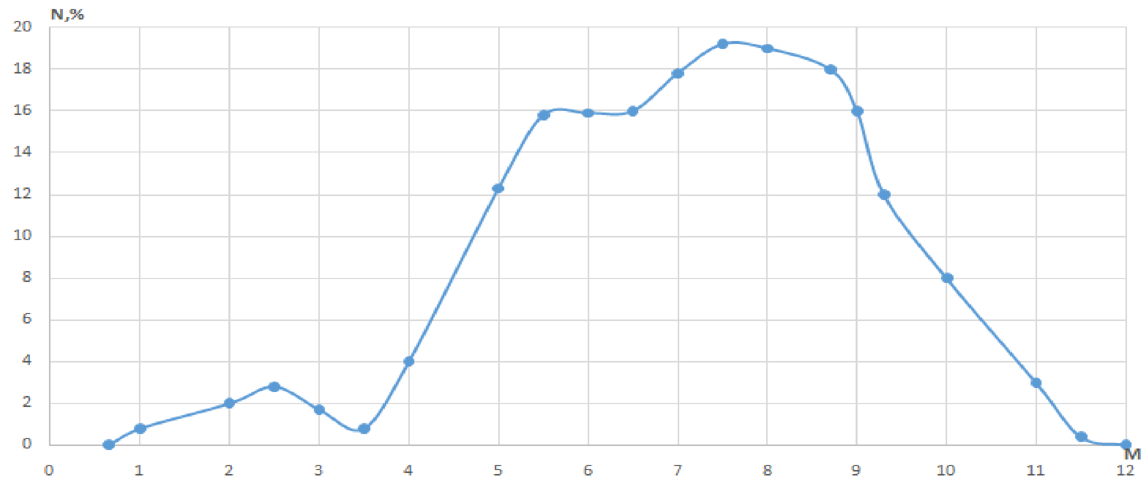

Fig. 1. Kecurrence rate of dust storms (N, %) by months (M) of the year on the territory of the Volgograd region

over the southern Urals, which sometimes retains its influence for several synoptic periods. Cyclones, leaving the Atlantic or the Mediterranean, when they encounter a blocking anticyclone, are accompanied by dust storms [3, 14]. Human activities contribute to this phenomenon as well.

The predisposition of the Volgograd region territory to the formation of dust storms is aggravated by the drought of the soil and the orography of the area. The soils of the region under irrational nature management are easily subjected to deflation processes [6]. This, naturally, leads to their degradation, since, as a rule, particles ≤ 1 mm in size, containing much more humus than all other aggregates, are blown out [15]. The greatest difference in the content of humus in blown fine particles < 1 mm and aggregates > 1 is observed in soils of a lighter grain size distribution. In other words, these soils, so poor in humus already, with the loss of deflation-hazardous aggregates of size ≤ 1 mm, become even poorer, their structure is more destroyed, they are more eroded by the wind. The presented schematic diagram (Fig. 2) shows the great diversity of this indicator in spatial terms.

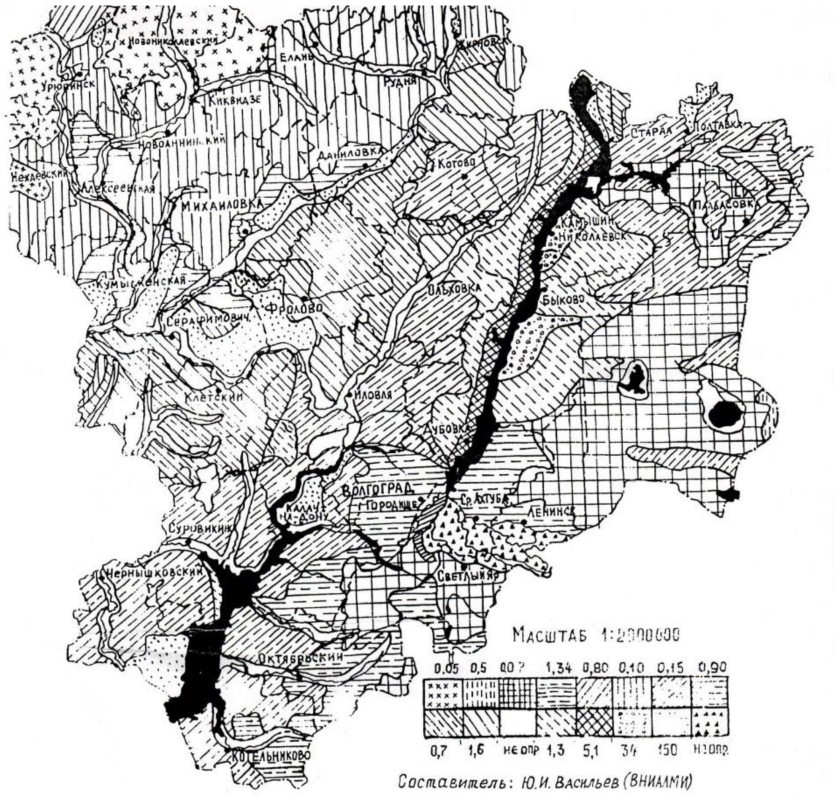

Fig. 2. Erodiability (t/ha•h) of the soils of the Volgograd region

But one thing is undeniable, soils of heavier particle size always erode less [16-18]. This suggests that they suffer, in degradation terms, less. The emphasis is on the soil of a lighter grain size distribution. One more point should be emphasized. Soil erodibility is an integral indicator. It includes both dynamic wind indicators and structural characteristics of the soil. Moreover, this indicator, as a rule, determines the deflation potential, if, of course, to take into account the duration of dust storms.

Using survey data after dust storms of 1969, 1972, 1984 and 2015, we attempted to assess the territory of the Volgograd region by the potential of dust storms manifistation (Fig. 3).

Studies have shown that the soils of the Volgograd region are already subject to deflation processes in 70% of the territory, especially in the areas of lighter particle size distribution. At the moment, the area of degraded arable land is 930-1300 thousand hectares. As for the regularity of the spatial distribution of dust storms in 2015, they generally correspond to long-term observations about their number and spatial distribution (Fig. 4) [2, 8, 10].

Wind speeds in 2015 (March 27-31) in the Volgograd region were at a maximum of 22-24 m/s. Topsoil was over dried.

Dust storms in the period noted were observed in the zone of chestnut soils of Surovikinsky, Chernyshkovsky, Serafimovichsky, Kletsky, Frolovsky, Olkhovsky, Kotovsky, Kamyshinsky and Ilovlinsky districts. In the north of the region, in the zone of chernozem soils, wind erosion and dust storms were observed in Novonikolayevsky, Kikvidzensky, Yelansky, Zhirnovsky regions, but farms along the Buzuluk river (the Bolshevik village) suffered the most. It was found that the demolition and transport of soil particles from the fields was caused by the underdeveloped vegetation cover (winter wheat). In a number of farms in the Oktyabrsky and Kotelnikovsky districts, fields of more than 50 thousand hectares were damaged. Fine earth was deposited at all sorts of obstacles, including in the remaining afforestation. The height of the loops in them averaged 15-85 cm.

The analysis showed that the active development of deflation was facilitated, on the one hand, by the weather conditions of February and March, and on the other, by the inefficiency of environmental management. The relief component of the territory also contributed to the formation of a deflationary situation [7, 15].

Conclusion

Of course, the forest belt on arable land is a powerful protective shield. But, as shown by years of research [7, 9], it works effectively only when it is properly planned. Surveys after dust storms of 1969, 1972, 1984 and 2015 found that those regulatory inter-band distances that were developed for areas where there is no deflation, should be significantly adjusted depending on

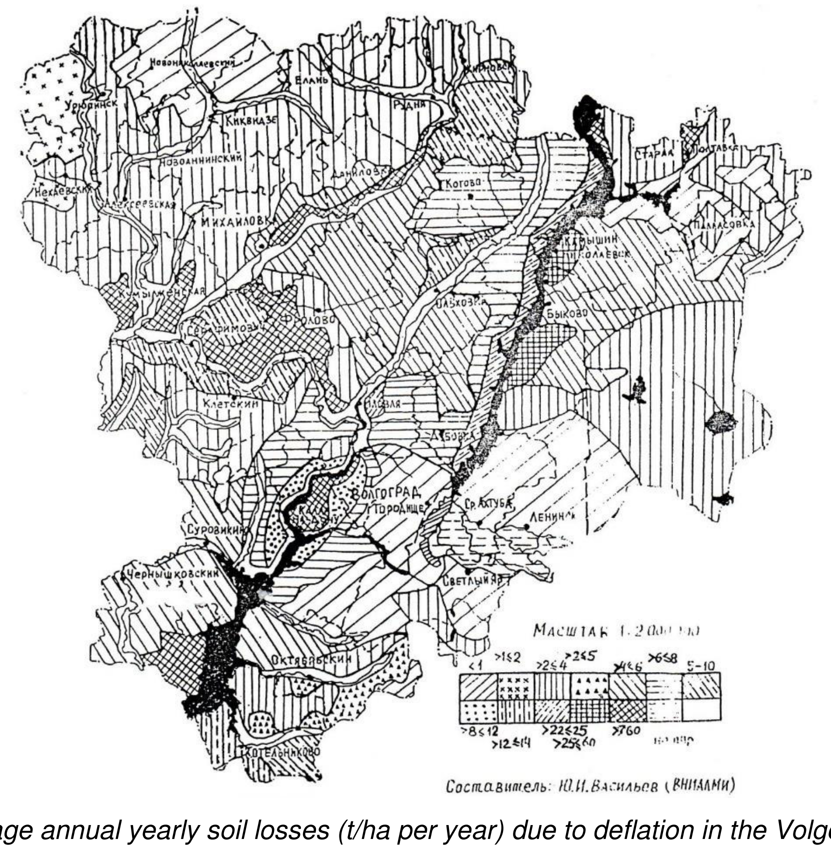

Fig. 3. Average annual yearly soil losses (t/ha per year) due to deflation in the Volgograd region

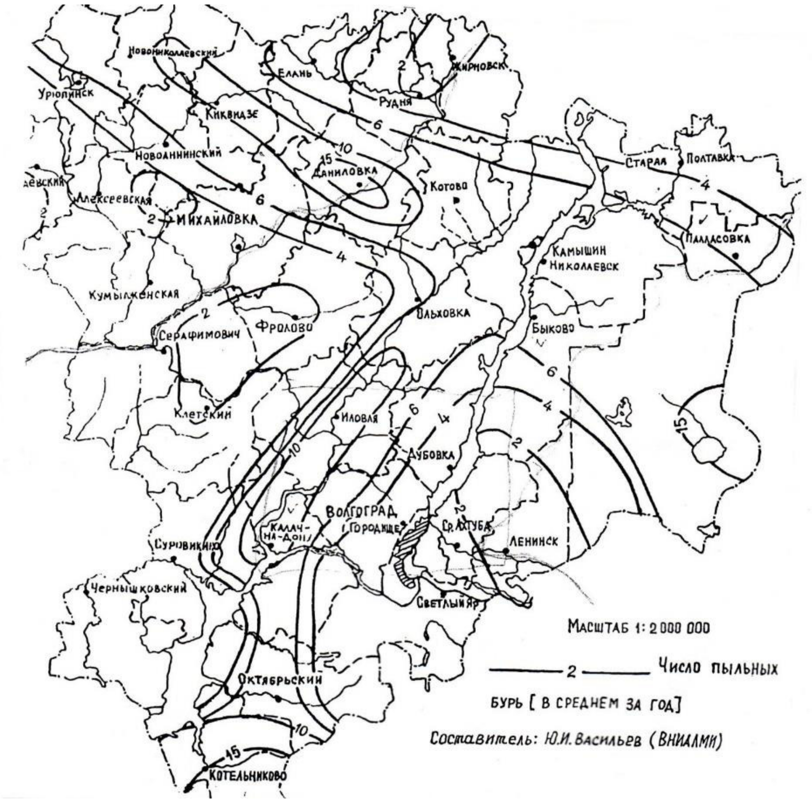

Fig. 4. The number of dust storms on average per year in the Volgograd region (according to long-term data of meteorological stations)

the potential of wind erosion of the soil in areas with active wind erosion. The following costs are given in the work [13]. In the zone of very weak deflation, it is possible to design the dimensions of inter-band spaces the same as recommended by the instructions [11]. In the zone of weak deflation, instructive dimensions should be reduced by 10-16%. In the zone of moderate and strong deflation, this decrease should be 22 and 23-35%, respectively. As for the zone of very strong deflation, there should be a reduction of 36-50% [7, 13]. These guidelines are for open ground. As for the use of forest strips against the background of agrotechnical methods of protecting the soil from blowing, it is necessary to solve the issue separately in each case here. For this purpose, there is a specific computer program [4], which can be delivered by private order.

And one more thing is to be noted. When examining the effects of dust storms of 1969, 1972 and 1984, as well as 2015, it was found that steam fields suffer most (especially with dump processing), fields with very late sowing and weak shoots, areas with a large wedge of tilled crops and with a non-compliance moisture regime during treatments. To prevent the factors contributing to the development of deflationary processes, it is necessary to strictly implement agrotechnical measures and apply agro-techniques that meet the soil and climatic conditions of each specific region [1, 2, 5].

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DOI: 10.26177/VRF.2019.2.2.002

INFLUENCE OF AVAILABLE MOISTURE ON THE STRUCTURAL INDICATORS AND YIELD OF WINTER WHEAT AND SPRING BARLEY DEPENDING ON THE METHODS OF MAIN SOIL TREATMENT UNDER ADAPTIVE PLANTS GROWTH SYSTEMS OF THE NORTHERN CASPIAN SEA REGION

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The article presents research materials obtained in the Northern Caspian conditions, which allowed to enrich the studied problem with new knowledge and to prove that the maximum supply of spring moisture was accumulated in variants of chisel processing with the working bodies of the “Rancho” with loosening up to 0.35 m and plowing with a PN-4-35 plow to a depth of 0.20-0.22 m, which averaged over the years of the experiments was 48.3 and 47.7 mm, respectively. The minimum stock of productive moisture was accumulated in the variant of surface tillage and amounted to 44.6 mm. By the end of the summer, these differences became almost equal. Thus, in the variant of chisel processing with the working bodies of the “Rancho” with loosening up to 0.35 m in August, on average, 39.2 mm remained for the research years, and in the variant of the surface tillage with a BDT-3 to a depth of 0.10-0.12 m – 31.8 mm. In the variant of chisel processing with the working bodies of the “Rancho” with loosening up to 0.35 m, all individual indicators of winter wheat and spring barley were the greatest. Also, in this variant of tillage, the maximum yield was obtained both for winter wheat and spring barley, and on average for the research years it was 1.82 and 1.41 t/ha, respectively. In the variant of surface tillage with BDT-3 to a depth of 0.10-0.12 m, it was minimal and amounted to 1.29 and 0.76 t/ha, respectively.

Key words: adaptive farming systems, methods of basic tillage, biometric indicators, yield, winter wheat, spring barley.

Introduction

For the arid regions of southern Russia, including the Northern Caspian Sea region, the optimal increase in the productivity of agricultural land has been developed on the basis of improved agrotechnical measures. At the same time tillage is the most simple and affordable technique aimed at improving the growing conditions of cultivated plants [2, 3, 5-7]. The methods of tillage vary depending on the type of soil, terrain features, climate, characteristics of the crops grown, fertilizing system, the nature of the weediness of the fields, and many other conditions [8].

Materials and methods

The studies were conducted on the experimental field of the Caspian Research Institute of Arid Agriculture, located in the south-east of the European part of Russia in the Northern Caspian region on the territory of the Chernoyarsk District of the Astrakhan Oblast.

The following variants of tillage were included in the experiment scheme: a) mouldboard with a PN-4-35 plow to a depth of 0.20-0.22 m (control); b) subsurfacewith a SibIME plow leg to a depth of 0.20-0.22 m; c) chisel with the working bodies of the “Rancho” with loosening up to 0.35 m; d) surface with the BDT-3 to a depth of 0.10-0.12 m.

The repetition of the experience was threefold, with a randomized placement of variants. The area of the plots was 60 x 7.2 m, with a total area of 432 m^2. The area of accounting plots was 56 x 4.2 m, with a total area of 235 m^2.

Field experiments were carried out in a three-field grain-fallow crop rotation: black steam - winter wheat - spring barley. Soil treatment was carried out in four variants, both on a black fallow field and on a barley one. Thus, the saturation method was used.

The experiments began to be carried out in the autumn of 2010 with the main treatment of black fallow for the studied variants. In 2011, in the spring-summer period, the fallowing of experimental plots were carried out. The plots were treated the same. In the autumn of 2011, winter wheat was sown. On the second research field with winter wheat as a predecessor, the options for the main tillage for barley were laid. In 2012, in early spring, the first barley sowings were made. At the end of June 2012, winter wheat and spring barley grain was collected. In 2011, in the third research field after the harvest of the predecessor grain (barley), in the autumn period the main treatment of black fallow was carried out according to the studied variants. In the summer of 2012, black fallow was treated, and in autumn winter wheat was sown. In early spring of 2013, spring barley was sown at the first research field, and it was harvested in the third decade of June. After collecting the grain in mid-September, the main tillage was carried out with various implements according to the studied variants of the experiment. In the same year, in the spring-summer period, fallowing was done on the second research field, and in early October winter wheat was sown. In mid-September, after the harvest of winter wheat at the third research field, the main tillage of the studied options was carried out. In 2014, the first research field remained fallow. Winter wheat was harvested at the second research field, and in the third decade of March, barley was sown at the third research field and harvested in the third decade of June.

The soil of the experimental field was represented by light chestnut solonetzic soils without spots of solonetz. The humus content in the topsoil was 0.91-1.1%, pH 6.7-7.2, the amount of absorbed bases was 18.4-18.7 mg/eq. per 100 g of soil, the content of NO_3 was 0.47, P_2O_5 was 2.29 and K_2O was 25.03 mg/100 g of soil. The equilibrium density of the soil in the layer of 0.0-0.2 m was 1.25-1.30 and increased lower in layers to 1.49-1.50 t/m^3. The density of the solid phase of the soil varied from 2.73 to 2.77 t/m^3.

Years of research during the life of spring barley were characterized by high temperature and uneven precipitation. In 2011, during the period of its life, 236 mm of precipitation fell, and the average monthly air temperature was 0.5 °C lower than the average annual value. In 2012, conditions were less favorable. Thus, the amount of precipitation that fell during the life of the plants was 57 mm lower than the average long-term values, and the average annual temperature indicator was 1.2 °C lower. In 2013, the weather conditions for the plants were most favorable. Thus, the annual amount of precipitation and average monthly air temperature were higher than the average annual values by 28 mm and 0.8 °C, respectively. In 2014, before harvesting barley grain, 132 mm of precipitation fell, and the average monthly temperature was characteristic for this zone.

Field experiments were accompanied by observations, counts and measurements made while observing the requirements of the field experience techniques [1, 4, 9].

Results

The value of moisture in autumn in the years of the research depended on the amount of precipitation during this period, and the differences in the main treatment methods at this moment were insignificant (Fig. 1).

Observations on the dynamics of moisture in the fallow research field showed that the maximum amount of moisture in spring was accumulated in chisel variants with working parts of the "Rancho" with loosening to 0.35 m and plowing with the PN-4-35 plow to a depth of 0.20-

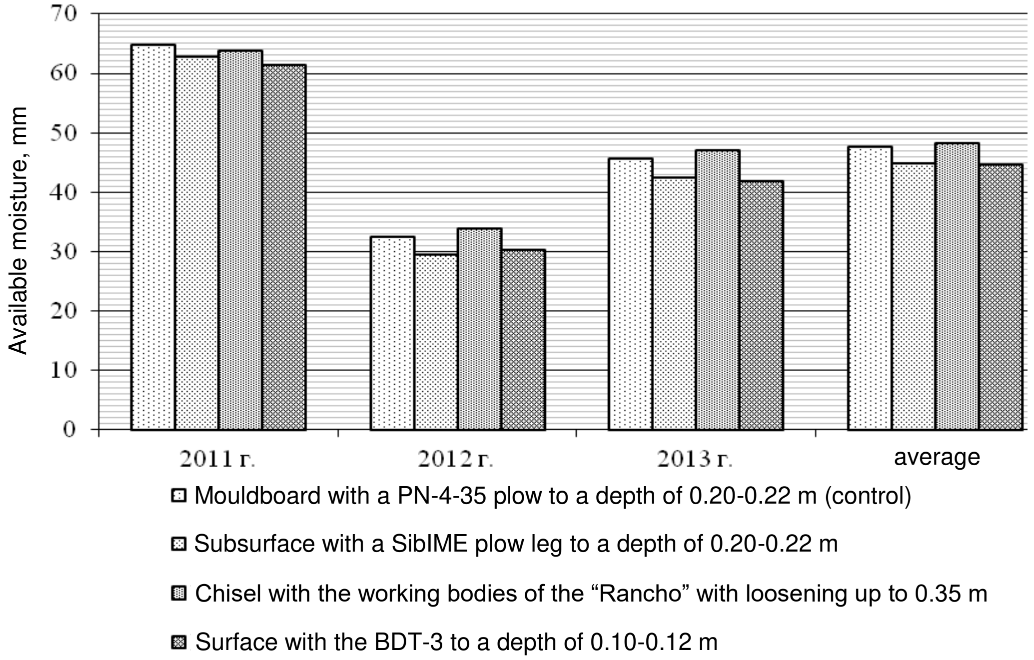

Figure 1. The amount of available moisture in the layer of 0.0-1.0 m after the main treatments of black fallow, mm (October, 15)

0.22 m and for the research years was 48.3 and 47.7 mm, respectively. The minimum stock of productive moisture was accumulated in the variant of surface tillage and amounted to 44.6 mm (Fig. 1).

During the research years, in the period of spring-summer treatment of the black fallow, there was a decrease in productive moisture in a meter-thick layer of soil. The difference was in the values by years, which depended on the amount of precipitation that fell during this period, and the dynamics of the decrease in soil moisture remained. By the end of the summer, these differences became almost equal. Thus, in the variant of chisel processing by the working bodies of the "Rancho" with loosening up to 0.35 m in August, on average, for the research years of epy experiments, 39.2 mm remained, and in the variant of surface tillage with BDT-3 to a depth of 0.10-0.12 m – 31.8 mm.

The number of productive stalks of winter wheat per 1 m2 ranged from 210 pcs. with disc surface tillage up to 246 pcs. when chisel processing, and the height ranged from 0.77 to 0.95 m depending on the years of the research. The difference in variants in some years reached 0.11 m.

The maximum tillering (both general and productive) was carried out during the chisel treatment by the working bodies of the "Rancho" with loosening up to 0.35 m and amounted to 1.41 and 1.26, respectively. In the variant where the treatment was carried out with a BDT-3 to a depth of 0.10-0.12 m, it was less by 0.23 and 0.15, respectively.

The largest number of grains in the ear was formed in the variant of mouldboard processing by the PN-4-35 plow to a depth of 0.20-0.22 m and amounted to 23.8 pieces during the research years, and the smallest – 20.2 pieces when processed with BDT-3. The maximum mass of 1000 grains was obtained in the varint of chisel treatment by the working bodies of the "Rancho" with loosening up to 0.35 m and during the research years amounted to $34.2 \cdot 10^{-3}$ kg. When processed by the PN-4-35 plow to a depth of 0.20-0.22 m, it was lower by 0.6·10-3 kg. In the variant where the processing was carried out by a SibIME plow leg to a depth of 0.20-0.22 m, the mass of 1000 grains decreased to $0.4 \cdot 10^{-3}$ kg than in the control, but it was by $0.8 \cdot 10^{-3}$ kg more than in the variant of surface tillage with a BDT-3 to a depth of 0.10-0.12 m.

The maximum height of spring barley plants during the research years (0.59 m) was noted in the variant of chisel treatment by the working bodies of the "Rancho" with loosening up to 0.35 m, and the minimum (0.49 m) with surface tillage with a BDT-3.

The number of productive plant stand of spring barley per 1 m^2 varied from 185 to 212 pcs.

The maximum number of grains per ear was formed in the chisel processing variant and averaged 18.9 pieces during the research years.

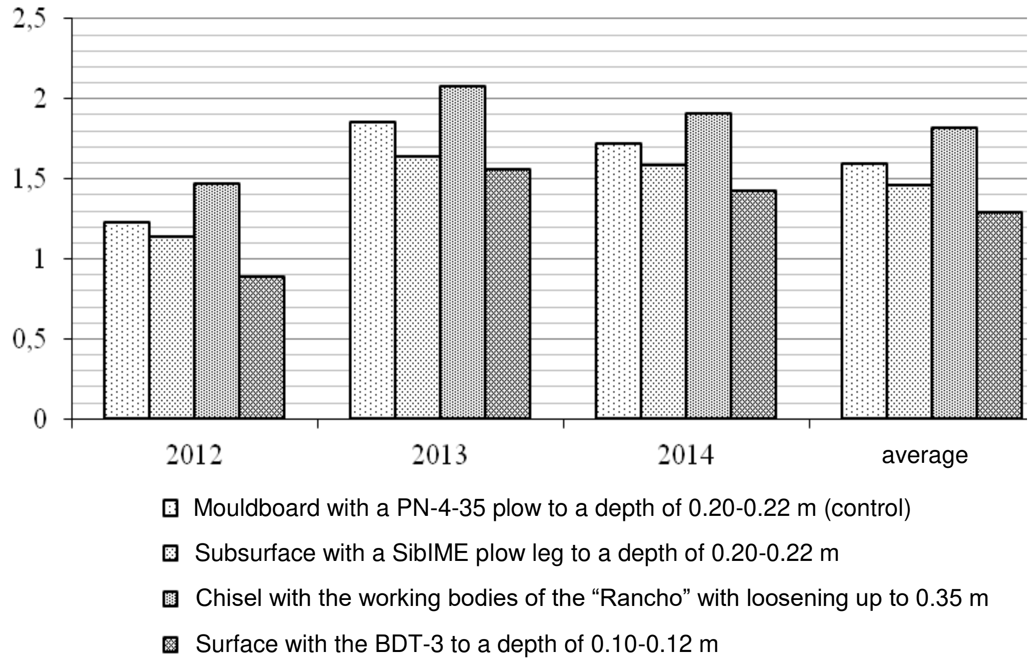

Figure 2. The influence of the methods of the main processing of light-brown soil on the yield of winter wheat, t/ha (HCP_{05} = 2012 – 0,011, 2013 – 0,022, 2014 – 0,04)

Also in this variant, the mass of 1000 grains was maximum and amounted to $33.4 \cdot 10^{-3}$ kg. The minimum number of grains was obtained in the variant of surface tillage with a BDT-3 and averaged 12.7 pieces during the research years, and the weight of 1000 grains was $31.0 \cdot 10^{-3}$ kg.

The maximum yield was formed in the variant of chisel treatment by the working bodies of the "Rancho" with loosening up to 0.35 m, which in average during the research years amounted to 1.82 t/ha of grain, and in the variant of surface tillage with a BDT-3 to a depth of 0.10-0.12 m it was lower by 0.22 t/ha, but it was higher by 0.04 t/ha of grain than in the variant of a subsurface tillage with a SibIME plow leg to a depth of 0.20-0.22 m.

The minimum grain harvest was formed in the variant of surface tillage with a BDT-3 to a depth of 0.10-0.12 m, which during the research years amounted to 1.29 t/ha.

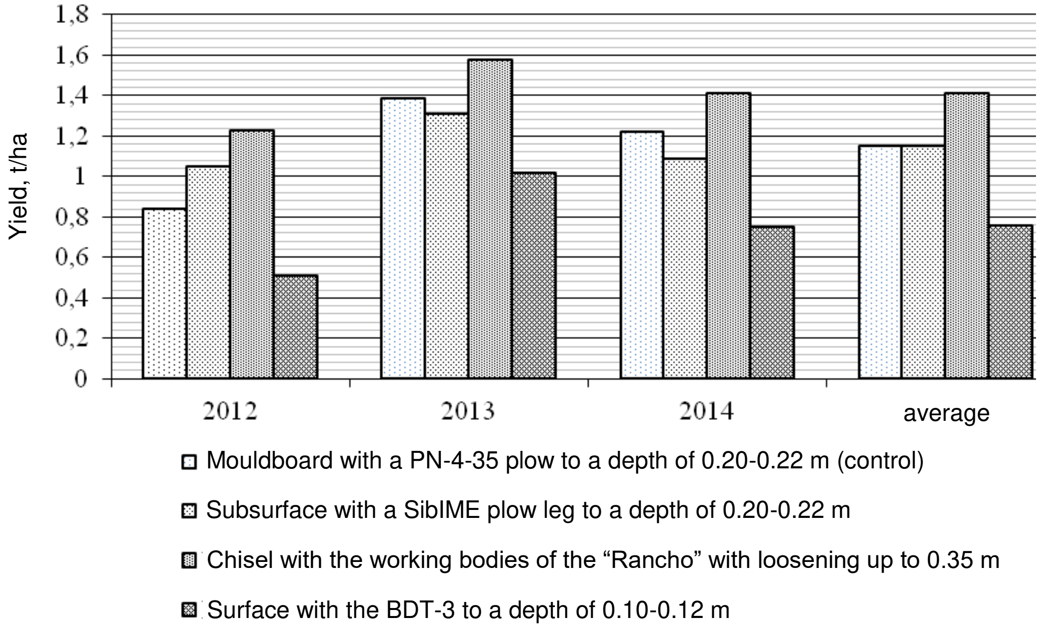

Figure 3. The influence of the main methods of processing light-brown soil on the yield of spring barley, t/ha (HCP_{05}= 2012 – 0,031, 2013 – 0,023, 2014 – 0,016)

From Figure 3 it can be seen that the collection of grain in the variant of chisel treatment by the working bodies of the “Rancho” with loosening up to 0.35 m, in comparison with other variants of processing, was maximum and from 2012 to 2014 amounted to 1.41 t/ha.

In the variants of mouldboard processing by the PN-4-35 plow to a depth of 0.20-0.22 m (control) and a subsurface with a SibIME plow leg to a depth of 0.20-0.22 m, the yield of spring barley decreased during the research years and amounted to 1.15 tons of grain per ha. In the variant of surface tillage with a BDT-3 to a depth of 0.10-0.12 m, the minimum grain harvest was formed and amounted to 0.76 t/ha.

Conclusion

Research materials obtained in the Northern Caspian conditions allowed us to enrich the problem under study with new knowledge and to prove that the maximum spring moisture accumulated in variants of chisel processing with working elements of the “Rancho” with loosening up to 0.35 m and plowing with a PN-4-35 plow to a depth of 0.20-0.22 m, which averaged over the years of experiments was 48.3 and 47.7 mm, respectively. The minimum stock of productive moisture wasw accumulated in the variant of surface tillage and amounted to 44.6 mm. By the end of the summer, these differences became almost equal. Thus, in the version of chisel processing by the working bodies of the “Rancho” with loosening up to 0.35 m in August, on average for the research years it remained 39.2 mm, and in the variant of the surface tillage with a BDT-3 to a depth of 0.10-0.12 m – 31.8 mm. In the variant of chisel treatment by the working bodies of the “Rancho” with loosening up to 0.35 m, all the structural indicators of winter wheat and spring barley were the greatest. Also, in this variant of tillage, the maximum yield was obtained both for winter wheat and spring barley, and on average for the research years it was 1.82 and 1.41 t/ha, respectively. In the variant of shallow tillage with a BDT-3 to a depth of 0.10-0.12 m, it was minimal and amounted to 1.29 and 0.76 t/ha, respectively.

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DOI: 10.26177/VRF.2019.2.2.003

INFLUENCE OF PLACEMENT METHODS ON PRESERVATION AND QUALITY OF JERUSALEM ARTICHOKE TUBERS WHEN STORING IN CONDITIONS OF A VEGETABLE STOREHOUSE

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The article presents data from two years of research to identify the most optimal of traditional methods of storing Jerusalem artichoke tubers of the Skorospelka variety. As part of the study, the following methods of storage tubers were studied: a polypropylene bag, a plastic box, and a bulk in a vegetable storehouse with unregulated conditions. Shelf life was 102 and 194 days. In the first year of storage, the weight loss of the tubers was 16.4-22.5%. In the second year, the highest storeability of the tubers was recorded when stored in bags; the weight loss was 5%. The method of storage of Jerusalem artichoke tubers in polypropylene bags in some years provided less damage from diseases and the storeability was 49-64% higher compared with storage in a bulk and in plastic boxes. The method of storing tubers of Jerusalem artichoke in a bulk contributed to their wilting by 1.7-5.8% compared with storage in bags and boxes. During storage of Jerusalem artichoke tubers in boxes, their carbohydrate complex was destroyed to a lesser extent. The fiber content in terms of absolutely dry matter was reduced by 0.2-2.5%, or 0.9-1.1% less than when stored in bags and in a bulk. The content of water-soluble carbohydrates was 2.5-4.8%, which was 3.3-7.4% less than during storage in a bulk. According to the results of research, the most optimal of the traditional methods of Jerusalem artichoke tubers storage was the storage in bags.

Key words: Jerusalem artichoke tubers, method of storage, habit, storeability, biochemical composition.

Introduction

Today Jerusalem artichoke is widely studied as a highly productive fodder crop. High feed quality of green mass and tubers of Jerusalem artichoke make it possible to use this culture in fodder production [1]. The culture does not require the use of pesticides, it is frost-resistant, and is also balanced in micro- and macro-elemental composition, contains a large amount of magnesium, potassium, phosphorus, calcium, iron [5, 7, 11, 15]. The tubers are a complete and environmentally friendly food product that can perform preventive functions [2, 5, 10, 12]. To date, the problem of its poor storeability has not been solved [9]. Due to the low keeping quality of the tubers, the possibility of their use in the development and introduction of new dishes at catering establishments is exclusively seasonal [3]. Traditionally, this culture is stored in containers, boxes, bags, bulk in storage and ground pits. There is a method of storage in trenches with the installation of forced-air ventilation [8, 14]. Also, the authors investigated an unconventional method of storing tubers - in regulated gaseous media (RGM) – N_2 (70%) + CO_2 (30%); O_2 (75%) + CO_2 (25%). Regardless of its composition, RGM lead to germination of the tubers in 73 days after storage, as well as to a significant reduction in quality indicators, which allowed considering this storage method for a short period of time [4]. The most promising ways are storage at negative temperatures, in the form of a powder, and storage in a fresh, untreated form (in a plastic bag with holes) [6, 13].

The purpose of the study was to determine the optimal method of storing Jerusalem artichoke tubers in a vegetable storehouse.

Objectives of the study:

1. To assess external changes in the quality of Jerusalem artichoke tubers during storage.
2. To determine the keeping quality of the tubers.
3. To analyze the biochemical composition of Jerusalem artichoke tubers after storage.

Methods and materials

To solve the tasks, in 2016 and in 2017 a one-factor experiment was laid out according to the following scheme: 1 – storage in plastic boxes, 2 – storage in polypropylene bags, 3 – storage in a bulk. The object of study was the tubers of Jerusalem artichoke of the Skorospelka variety. A non-ventilated vegetable pit without regulation of temperature and humidity conditions was used for the experiment. Air temperature during storage was 1-3°C. The method of preparation of a tuber included cleaning from the ground and drying. The repetition was threefold. The mass of a sample deposited was 3000 g. The date of laying the experiment in the first year of the study was 29.11.2016, the date of the extraction from the pit was 11.03.2017. The total storage period was 102 days. The date of laying the experiment in the second year of the study

was 21.10.2017, the date of the extraction from the pit was 02.05.2017. The total storage period was 194 days. The storeability, the habit of the tubers and their biochemical composition were analyzed according to generally accepted methods and state standards.

Results

An analysis of external changes in the state of tubers during storage showed that in the first year of the research, none of the storage methods made it possible to preserve the custom look of tubers. After storage, spoiled tubers afflicted with diseases in all three storage methods were observed. In the second year of research, the tubers stored in bags, after 194 days of storage, fully preserved the custom look and met the requirements of GOST 32790-2014 "Fresh Jerusalem artichoke. Technical conditions" (Table 1).

According to the results of the first year of research, the weight loss of tubers was 16.4-22.5%, depending on the method of storage. A significant difference in this indicator between the studied methods of storage was not observed. There was a tendency to increase the storeability of tubers when stored in bags. According to the results of the second year of research, tubers stored in bags, had a better storeability; weight loss was 5%, which was significantly lower (by 64.2%) than during storage in bulk. More than half the weight of the tubers (53.8%) was lost during storage in boxes (Table 2). One of the main causes of poor storeabil-

Table 1. Dynamics of changes in the external condition of Jerusalem artichoke tubers during storage

Control date	Method of storage		
	Box	Bag	Bulk
2016 год			
29.11.2016	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.
05.01.2017	Habit – there are tubers with black spots. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit – there are tubers with black spots. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.
11.03.2017	Habit – there are tubers with black spots. Tuber turgor – high. Disease contamination – there are tubers with mold. Sprouted and frozen tubers were not found.	Habit – there are tubers with black spots. Tuber turgor – high. Disease contamination – there are tubers with mold. Sprouted and frozen tubers were not found.	Habit – there are tubers with black spots. Tuber turgor – high. Disease contamination – there are tubers with mold. Sprouted and frozen tubers were not found.
2017 год			
21.10.2017	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.
02.01.2018	Habit is typical. Tuber turgor – high. Disease contamination – there is fungal mold. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit – atypical, dried tubers. Tuber turgor – low. Disease contamination – there is fungal mold. Sprouted and frozen tubers were not found.
24.02.2018	Habit is typical. Tuber turgor – high. Disease contamination – the beginning of the process of decay. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit – atypical, dried tubers. Tuber turgor – low. Disease contamination – there is fungal mold. Sprouted and frozen tubers were not found.
02.05.2018	Habit is typical. Tuber turgor – high. Disease contamination – there are tubers affected by fungal diseases. Sprouted and frozen tubers were not found.	Habit is typical. Tuber turgor – high. Disease contamination is absent. Sprouted and frozen tubers were not found.	Habit – atypical, dried tubers. Tuber turgor – low. Disease contamination – there are tubers affected by fungal diseases. Sprouted and frozen tubers were not found.

ity of Jerusalem artichoke tubers stored in boxes and in bulk in the second year of research was increased air humidity, which caused a high defeat of the tubers with pathogenic microorganisms in these variants [8].

Table 2. The weight loss of tubers of Jerusalem artichoke during storage

Storage method	Weight loss of tubers, %	
	2016	2017
Box	21,6	53,8
Bag	16,4	5,0
Bulk	22,5	69,2
HCP_{05}	$F_{fac} \leq F_{05}$	60,6

In the first year of research, a significant increase in the dry matter content was observed during storage in bulk by 1.7% (HCP_{05} = 1.3%) compared with the indicators obtained during the laying of the experiment (Table 3).

And in the second year of research, a significant increase in dry matter was observed in all the investigated storage methods, due to the drying of the tubers. However, the highest dry matter content in the tubers (30.4%) was also noted during storage in bulk, which was 5.2-5.8% higher than with the other methods of storage. A significant decrease in the content of crude fiber in the first year of research was noted during storage in a bag (by 1.1%) and in bulk (by 0.9%), in the second year of research – during storage by all the studied methods. A significant decrease in the content of water-soluble sugars was observed when using all the investigated storage methods. The deterioration of the biochemical composition of the tubers during storage can be explained by the consumption of carbohydrates for respiration – the main process of metabolism, as well as under the influence of fungal and bacterial infections.

Table 3. Biochemical composition of Jerusalem artichoke tubers

Indicator	Year	Before the laying	Storage methods			HCP_{05}
			Box	Bag	Bulk	
Dry matter content, %	2016	20.8	20.2	22.0	22.5	1.3
	2017	22.2	24.6	25.2	30.4	0.2
Crude fiber content, % per d.m.	2016	2.6	2.4	1.5	1.7	0.7
	2017	5.3	2.8	1.0	3.5	0.6
Water-soluble sugars content, % per d.m.	2016	23.1	20.6	19.4	17.3	1.2
	2017	24.4	19.6	19.5	12.2	2.2

Conclusion

1. The method of storage of Jerusalem artichoke tubers in polypropylene bags in some years provides less damage from diseases and storeability is 49-64% higher compared to storing them in bulk and in plastic boxes.

2. The method of storing tubers of Jerusalem artichoke in bulk contributes to their wilting by 1.7-5.8% compared with storage in bags and boxes.

3. During storage of Jerusalem artichoke tubers in boxes, their carbohydrate complex is destroyed to a lesser extent. The fiber content in terms of absolutely dry matter is reduced by 0.2-2.5%, or 0.9-1.1% less than when stored in bags and in bulk. The content of water-soluble carbohydrates is 2.5-4.8%, which is 3.3-7.4% less than during storage in bulk.

4. According to the research results, the most optimal of the traditional methods of storing Jerusalem artichoke tubers is storing in bags.

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DOI: 10.26177/VRF.2019.2.2.004

INFLUENCE OF PLANTING TIME AND TYPES OF THE PLANTING MATERIAL ON THE SURVIVABILITY AND PRODUCTIVITY OF COMMON HOP (*Humulus lupulus L.*)

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In hop production, the time of the planting and the type of planting material are of great importance, mainly because the condition of the hop plant and the care technology during the growing season in the first and subsequent years depend on the time of the planting and the material used. The article presents data on the results of research when planting new hopyard with different types of planting material and the time of their planting. Under production conditions, shortening the period of low market fruiting and obtaining a good harvest of cones in the second year are possible only when using annual seedlings as planting material. In the first year, the survivability and yield of plants during the autumn planting by annual seedlings is higher than during the spring one. In the second and third years of planting, the dependence of the crop on the type of planting material used was maintained. In less favorable years survival rate decreased, and in more favorable years it increased. The best option for planting hopyards was the autumn planting of annual seedlings in the first and second decades of October, which allowed us to maintain survivability at a high level.

For novice farmers and enterprises, in order to save money, stem cuttings can be used as planting material when laying hopyards. During the period prior to the beginning of abundant fruiting of hops, the

duration of which is two years from planting, it is possible to resolve the issues of acquiring the necessary hop growing equipment, ensuring the production of a hop harvester and a dryer.

Key words: planting material, stem cutting, annual seedlings, spring and autumn planting, survivability, yield, fruiting.

Introduction

In hop production, the time of the planting and the type of planting material are of great importance, mainly because the condition of the hop plant and the care technology during the growing season in the first and subsequent years depend on the time of the planting and the material used [1, 3, 4].

Under production conditions, the planting of hops is usually carried out by stem cuttings or annual seedlings [5-7, 13, 14].

The most progressive, reliable and providing high survivability method is setting up hopyard with annual seedlings in the autumn period – in the second decade of October [2, 5, 6]. Such hopyards have full-fledged seedlings in the spring of the following year and provide for obtaining up to 5-8 centners of hop per hectare. Spring planting of hopyards with stem cuttings, especially in a dry year, is a risky operation. Often, in such conditions, the survival rate of stem cuttings is reduced to 50%. Such hopyards are later difficult to bring in density to a full-fledged state and, as a rule, from year to year they remain low-yielding [10].

Under favorable weather conditions, it is possible to set up hopyards with stem cuttings. With proper agrotechnical measures, ensuring the survival of plants and creating conditions for the growth and development of the root system, such hopyards are able to produce up to 2-6 centners of hop per hectare in the first year of fruiting [11, 12].

For novice farmers and enterprises, in order to save money, planting new hopyards with stem cuttings is the most profitable option. During the period before the beginning of the abundant fruiting of hops, the duration of which is two years from planting, it is possible to purchase the necessary hop growing equipment, to solve the issues of ensuring the production of a hop harvester and a dryer.

The purpose of the research is to study the effect of planting time and types of planting material on the main economic and valuable signs of common hop.

Materials and methods

The studies were carried out on Podvyazny variety, according to the planting dates of stem cuttings harvested on pure-grade queen plants and annual seedlings grown in a reproduction nursery using a method of counting, visual assessments and field observations of plants [8, 9]. The soil of the site was grey forest heavy loamy, the availability of essential nutrients (P_2O_5, K_2O) was average, the response of the soil environment – slightly acid. The weather conditions of the vegetation period were different in humidity and air temperature. The studies were carried out on the newly laid hopyard in the Chuvash Research Institute of Agriculture and Federal State Budget Educational Institution of Higher Education Chuvash State Agricultural Academy. Soil preparation before planting was carried out in accordance with the recommended agrotechnical methods. In July-August, disking was carried out in two directions with heavy disc harrows for embedding herbs and leveling the site. The mouldboard plowing was carried out along using the PN-3-35 plow to a depth of 28 cm, and the boardless plowing (with removed boards) – across the site to a depth of 40 cm. Such a scheme of deep loosening does not turn the low-productive loamy upper illuvial horizon to the surface, it cuts the soil well along the line of placement of hop footholds. Pre-loosening before planting with simultaneous harrowing with a PRVN-2.5A or PRVM-3X plow was carried out in two directions: along the plantation to a depth of 22 cm and across to a depth of 30 cm. Stem cuttings and annual seedlings were planted semi-mechanized. First, the front section of the plow PRVM-3X with a furrow cutter mounted on the frame cut furrows to a depth of 28 cm. Planting material was planted with a bush feeding area of 2.5 x 1.2 m. All the methods of soil preparation and planting were the same during spring and autumn planting [16].

Results of the research

The survivability of planting material depended on both the species and the time of their planting (Table). In the variant of the autumn bookmark with annual seedlings, the average survival rate was 90%, that of the spring one with stem cuttings – 80%. And also when using stem cuttings and annual seedlings, as compared with spring, it increased by 4.5%, respectively. Weather conditions had a significant effect on survivability. In 2014, in May-June, there was not enough rainfall (with a need of at least 80 mm it was only 60 mm). The reserves of productive moisture in the arable layer decreased to 3-4 mm. The survival rate in the variant of spring planting with stem cuttings was 75%, and in other studied plots up to 80-89%. In 2015, in the first decade of May, the rooting period of stem cuttings and annual seedlings was characterized by insufficient precipitation (total absence in the first decade of May) and high air temperature – 4.2°C higher than normal. Rooting took place in

Table. The main indicators of hops, depending on the time of planting and the type of planting material

Variant	Survivability, %					Yield, c/ha				
	2014	2015	2016	2017	aver-age	2014	2015	2016	2017	aver-age
Spring planting with stem cuttings – control	75	78	80	87	80	5.1	5.5	6.0	7.0	5.9
Spring planting with annual seedlings	83	82	85	90	85	8.0	8.0	7.8	9.0	8.2
Autumn planting with stem cuttings – control	80	82	84	90	84	6.0	6.3	6.5	8.0	6.7
Autumn planting with annual seedlings	89	88	87	96	96	8.0	8.4	8.0	10.0	8.6
HCP_{05}	3	2	3	2		0.8	0.7	1.0	1.1	

conditions of low soil moisture. In 2016, the weather conditions were characterized by aridity and high air temperature up to + 30-35 °C. 2017 was more favorable, with heavy precipitations and air temperatures below +20 °C, and as a result, the survival rate of planting material on options increased by 2-7%.

In the first year after planting with stem cuttings, the yield was lower than in the variants with one-year seedlings. In the second and third years of planting, the dependence of the yield on the type of planting material used remained. The average yield, when planting annual seedlings, was higher by 0.8-1.9 centners/ha compared with stem cutting planting. This dependence remained over the years of research. The content of alpha-acids in the cones was 7.1-8.3% and did not depend on the timy and type of planting material.

In 2017, variants of the previously cited studies were studied under production conditions when planting hopyards with standard stem cuttings and one-year seedlings of the Podvyazny variety in the Chuvash State Agricultural Academy. The survival rate of planting material in the hopyard was 75-88%, respectively. In the conditions of the dry summer of 2018, the yield was at the level of 1.0-1.5 metric centner/ha, a significant part of the hop stems reached only the middle, and only a few reached the top of the trellis, the cones were small. In some farms of the Chuvash Republic on young plantings the height of the stems was only two meters, and the yield on the second year of hops was only five centners per hectare.

Consequently, under production conditions, reducing the period of low marketable fruiting and obtaining a good harvest of cones in the second year is possible only when using annual seedlings as planting material. The survival rate and yield of plants depended on weather conditions and the type of planting material used. The best option for planting hopyards was the autumn planting of annual seedlings in the first and second decades of October, which allowed to maintain survivability at a high level.

Conclusion

For hop-growing enterprises of the Chuvash Republic, it is recommended to plant annual seedlings in autumn in the first and second decades of October. This allows to maintain survivability on average up to 90% and get in the second year of the growing season, depending on weather conditions, up to eight centners of cones per hectare.

For novice farmers or enterprises with a lack of working capital, in order to save on planting, it is necessary to use stem cuttings, which, until the beginning of heavy commercial fruiting of hops, gives a certain amount of time for production support with hop machines and hop harvesting equipment.

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DOI: 10.26177/VRF.2019.2.2.005

ASSESSMENT OF WINTER WHEAT VARIETIES AT DIFFERENT LEVELS OF MINERAL NUTRITION

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The introduction of varieties, that are capable of maximizing the resources of the technology of their cultivation into production, is a promising, environmentally safe and economically beneficial direction of development of grain production. The aim of the work is to assess and identify winter wheat varieties that can realize the potential of grain yield at various levels of intensification of mineral nutrition. To achieve this goal, two factorial field experience was carried out. Factor A – varieties of winter wheat, factor B – levels of mineral nutrition. As a result, it was found that, on average, over the years of the research, the highest grain yield of winter wheat varieties was formed with a combination of applying fertilizer N_{16} P_{16} K_{16} in autumn when sowing and N_{68} in top dressing in spring. Over the years of research the Skipetr and Moskovskaya 56 varieties formed higher yields – 6.1 and 6.0 t/ha, respectively. The yield of varieties Nemchinov 57 and Clavdia 2 was lower and amounted to 5.6 t/ha. The grain yield of the Bezenchukskaya 380 and Fatinya varieties was formed somewhat lower – 5.4 and 5.1 t/ha, respectively.

Key words: winter wheat, varieties, yield, mineral nutrition, fertilizer.

Introduction

Variety is one of the means of agricultural production. Varieties, from an economic point of view, differ primarily in the fact that they can form different yields under the same conditions. In modern agriculture, variety acts as an independent factor in increasing crop yields and, along with technology, is of great, and in some cases crucial importance for obtaining high and sustainable yields [1-5].

In modern economic conditions, variety is one of the most important elements of the technology of cultivation of any agricultural crop, including winter wheat. The role of winter wheat varieties in the production of grain is very significant, and the contribution of the variety to the yield increase of this crop according to various data can be from 30 to 60% [6-10].

The intensification of farming places special demands on varieties of agricultural crops. In assessing the ability of varieties to realize the potential of yield, the creation of various growing backgrounds plays an important role. It is almost impossible to identify all the characteristics of a variety in homogeneous conditions, since the severity of the signs of crop structure in this case does not reflect the overall balance of the studied genotype, which, ultimately, will be characterized by a certain fitness [12-16].

Thus, the assessment of winter wheat varieties at different levels of mineral nutrition scientifically substantiates the introduction of varieties, optimally adapted to specific soil and climatic conditions, capable of maximally implementing the resources of the technology of their cultivation into the production.

Materials and methods

To achieve the goal, a two factorial field experience was laid as follows:

Factor A – varieties of winter wheat: Bezenchukskaya 380, Nemchinovskaya 57, Skipetr, Moscovskaya 56, Fatinya, Clavdia 2.

Factor B – levels of mineral nutrition: 1 – Without fertilizers; 2 – N_{34} in top dressing; 3 – N_{68} in top dressing; 4 – N_{16} P_{16} K_{16} at sowing; 5 – N_{16} P_{16} K_{16} when sowing + N_{34} in top dressing; 6 – N_{16} P_{16} K_{16} when sowing + N_{68} in top dressing.

On the plots of the first order there were sown varieties of winter wheat (factor A). The plot area – 540 m^2. Fertilizers were applied to the second-order plots to create different levels of mineral nutrition (factor B). Plot area – 90 m^2.

The repetition of the experiment was threefold. The location of the plots was systematic. The predecessor was pure fallow.

All varieties of winter wheat were grown against a single background of complete plant protection from weeds, diseases and pests. The following drugs were used as remedies: Herbicide Ballerina, SC (0.5 l/ha), Borei insecticide, SC (0.1 l/ha), Colosal PRO fungicide, CME (0.4 l/ha).

Results

Features of the growth and development of winter wheat varieties at different levels of mineral nutrition determine the unequal realization of the elements of grain productivity, respectively, predetermining the different formation of yield (Table).

Table. Grain yield of winter wheat varieties at different levels of mineral nutrition arranged by the years, t/ha

The level of mineral nutrition (factor B)	Variety (factor A)					
	Bezenchukskaya 380	Nemchinovskaya 57	Skipetr	Moskovskaya 56	Fatinya	Clavdiya 2
2017						
1 – Without fertilizers	4,1	5,6	5,6	4,9	5,5	5,2
2 – N_{34} in top dressing	4,7	5,9	6,7	5,7	5,6	6,0
3 – N_{68} in top dressing	5,2	5,9	6,6	6,0	5,5	6,9
4 – N_{16} P_{16} K_{16} at sowing	5,5	5,7	6,5	5,9	5,7	6,4
5 – N_{16} P_{16} K_{16} at sowing + N_{34} in top dressing	6,5	7,0	6,8	6,5	5,9	6,8
6 – N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing	6,8	6,9	7,5	7,4	6,1	6,7
2018						
1 – Without fertilizers	3.0	3.3	3.2	3.1	3.0	3.2
2 – N_{34} in top dressing	3.3	3.5	3.6	3.5	3.2	3.5
3 – N_{68} in top dressing	3.5	3.7	3.8	3.8	3.4	4.0
4 – N_{16} P_{16} K_{16} при посеве	3.4	3.4	3.5	3.4	3.2	3.4
5 – N_{16} P_{16} K_{16} at sowing + N_{34} in top dressing	3.7	4.2	4.4	4.2	3.7	4.3
6 – N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing	4.0	4.3	4.6	4.6	4.1	4.5
2017 HCP_{05} for Factor A – 0.20 HCP_{05} for Factor B – 0.20 HCP_{05} for interaction of factors AB – 0.10			2018 HCP_{05} for Factor A – 0.25 HCP_{05} for Factor B – 0.25 HCP_{05} for interaction of factors AB – 0.15			

Assessing winter wheat varieties according to grain yield at various levels of mineral nutrition, it can be noted that higher rates were obtained in 2017. Favorable weather conditions during the growing season of the crop contributed to the fullest realization of the potential yield of the varieties. In favorable conditions of the year, a high differentiation of varieties according to the yield properties was observed on the variant without fertilizer application. Thus, the difference between the lowest yield of the Bezenchukskaya 380 variety (4.1 t/ha) and the largest of the Nemchinovskaya 57 and the Skipetr varieties (5.6 t/ha) was 1.5 t/ha.

Analyzing the grain yield in 2017 according to the fertilization options, it is clear that the varieties did not react equally to changes in the conditions of mineral nutrition.

The Bezenchukskaya 380 variety responded well to the introduction of a higher dose in top dressing in spring and when sowing in autumn. The highest grain yield was obtained in the variant where N_{16} P_{16} K_{16} was introduced when sowing + N_{68} in top dressing – 6.8 t/ha.

In the Nemchinovskaya 57 variety an increase in the doses of mineral fertilizers in top dressing in spring did not contribute to an increase in yield. Higher yields were formed when N_{16} P_{16} K_{16} was introduced at sowing + N_{34} in top dressing – 7.0 t/ha.

The Skipetr variety reacted positively to spring top dressing, but without fertilizing in autumn when sowing, increasing the spring dose to the dressing did not increase the yield. When applying N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing, the maximum yield of the variety was obtained – 7.5 t/ha.

Significant responsiveness to increasing the dose in top dressing was observed in spring at the Moscovskaya 56 variety. The variety also reacted positively to fertilization in autumn at sowing. As a result, the maximum yield (7.4 t/ha) was formed with a combination of fertilizer application N_{16} P_{16} K_{16} in autumn at sowing and N_{68} in top dressing in spring.

The variety Fatinya did not react to an increase in the dose of spring top dressing. However, when fertilizers were applied in autumn at sowing and increasing the dose of spring top dressing of plants had a positive effect on yield formation. On variant N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing, the highest yield of the variety was 6.1 t/ha.

Clavdiya 2 was characterized by high responsiveness to increasing the dose of spring top dressing. The combination of autumn fertilization with spring top dressing did not lead to an increase in grain yield. The maximum grain yield of 6.9 t/ha was obtained on the variant where N_{68} was applied to top dressing in spring.

Assessing the yield of the varieties in 2018, it should be noted that weather conditions were less favorable for the growth and development of the crop. The main limiting factor in the implementation of plant productivity was low moisture availability in the spring and summer period. Accordingly, a lower yield of winter wheat varieties was formed.

In relation to the previous year, the difference in yield between varieties on the variant without fertilizer was significantly leveled and amounted to 0.2...0.3 t/ha.

The Bezenchukskaya 380 variety responded to the introduction of a higher dose in spring top dressing and at sowing in autumn. The higher grain yield, as in the previous year, was obtained on the variant where N_{16} P_{16} K_{16} was introduced at sowing + N_{68} in top dressing – 4.0 t/ha.

In 2018, in the Nemchinovskaya 57 variety, an increase in the doses of mineral fertilizers in the top dressing in spring contributed to an increase in yield. Higher yields were formed when N_{16} P_{16} K_{16} was introduced at sowing + N_{68} in top dressing – 4.3 t/ha.

The Skipetr, as in the previous year, responded well to spring top dressing, but without adding fertilizer in autumn at sowing, increasing the spring dose to the dressing increased the yield. When applying N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing, the highest yield of the variety was obtained – 4.6 t/ha.

High responsiveness to an increase in the dose in the top dressing was observed in spring at the Moscovskaya 56 variety. In contrast to the previous year, the variety reacted to a lesser degree to fertilization in autumn at sowing. The maximum yield (4.6 t/ha) was formed with a combination of fertilizer N_{16} P_{16} K_{16} in autumn at sowing and N_{68} in top dressing in spring.

The Fatinya variety, in contrast to the previous year, reacted to an increase in the dose of spring top dressing and reacted to a lesser extent to the application of fertilizers in autumn at sowing. However, when fertilizers were applied in autumn at sowing and increasing the dose of spring top dressing of plants had a positive effect on yield formation. As a result, on variant N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing, the highest yield of the variety was obtained – 4.1 t/ha.

In the Clavdiya 2 variety, as in the previous year, there was a high responsiveness to increasing the dose of spring top dressing. The combination of autumn fertilization with spring top dressing led to an increase in grain yield. A higher grain yield of 4.5 t/ha was obtained on variant N_{16} P_{16} K_{16} at sowing + N_{68} in top dressing.

Conclusion

The varieties of winter wheat, depending on the year of cultivation and variants of the experiment, implement the yield properties in different ways. However, in general, it can be noted that, on average, over the years of research, the varieties of winter wheat have formed the highest grain yield with the combination of application N16 P16 K16 fertilizer in autumn at sowing and N68 in top dressing in spring. The average yield of the varieties in this variant differed significantly. Thus, the higher yields for the years of research were formed by the varieties Skipetr and Moskovskaya 56 – 6.1 and 6.0 t/ha, respectively. The yield of the varieties Nemchinov 57 and Clavdiya 2 was lower and amounted to 5.6 t/ha. The grain yield of the Bezenchukskaya 380 and Fatinya varieties was slightly lower – 5.4 and 5.1 t/ha, respectively.

Further research involves the assessment of grain quality and the determination of the economic efficiency of cultivating winter wheat varieties at various levels of mineral nutrition.

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DOI: 10.26177/VRF.2019.2.2.006

INFLUENCE OF COMPLEX SULFUR-CONTAINING MICROELEMENT FERTILIZERS ON THE YIELD AND QUALITY OF MILK THISTLE (SILIBUM MARIANUM) IN CONDITIONS OF THE FOREST-STEPPE OF THE MIDDLE VOLGA REGION

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The article presents the results of studies on the influence of exogenous seed treatment and foliar dressing of grass stand with complex sulfur-containing microelement fertilizers on seed productivity, technological and biochemical properties of the fruit of the milk thistle of the variety Debut. The greatest positive effect was achieved with the exogenous treatment of milk thistle seeds with a complex sulfur-containing fertilizer Megamix-Zinc, the fruit yield – 1.23 t/ha, increase – 0.34 t/ha (38.2%); the content of oil – 35.9%; of protein – 29.8 and 7.0%; in relation to the control it increased by 7.6%, the content of essential amino acids was 149.5 mg/g of DM (dry matter) (in control – 124,0 mg/g of DM). With double foliar top dressing of milk thistle crops during the rosette and budding phase, the fruit yield amounted to 1.06-1.19 t/ha, in relation to the control it increased by 0.17-0.3 t/ha; oil content – by 2.9-7.0%, protein – by 1.4-2.9%. The highest yield of milk thistle seeds of 1.47 t/ha was obtained with foliar dressing of plants and seed treatment with Megamix-Zinc. The oil content was 35.3%, protein – 25.4%, flavonolignans – 3.06%, acid number – 0.28.

Key words: milk thistle, complex sulfur-containing microelement fertilizers, yield, seed productivity, technological and biochemical properties.

Introduction

D.N. Pryanishnikov (1952) indicated that sulfur is on a par with nutrients such as nitrogen, phosphorus, and potassium [1]. The studies of many authors revealed a close correlation of sulfur use with high crop productivity [2-10].

L.D. Slutskaya (1972), A.N. Aristarkhov (2001), B.A. Yagodin (1985) conclude that sulfur is a component of proteins, essential amino acids, it is involved in the formation of most enzymes, vegetable oils, esters, and plays an important role in redox reactions. Sulfur increases photosynthesis and the use of other nutrients by plants. In its specific significance for physiological processes in a plant, sulfur is an indispensable element and cannot be replaced by any other, even selenium, which is related to it [2, 9, 10].

According to the data of I.U. Valnikov (1981), G.N. Popov et al. (1984), negative sulfur balance is formed in the agriculture of the Middle Volga region [4-11].

The lack of sulfur nutrition of plants is accompanied by a significant decrease in the yield and quality of agricultural products. This is because earlier the composition of fertilizers (simple superphosphate, potassium sulfate and ammonium, etc.) contained a large amount of sulfur. With the transition of agriculture to the use of concentrated fertilizers, and of enterprises to the use of electricity, gas and oil products, the influx of sulfur into the soil from fertilizers and the atmosphere has sharply decreased, as well as the high use of nitrogen fertilizers and a significant increase in productivity. The main replenishment of sulfur reserves in soils is possible only through special sulfur-containing fertilizers [1].

The literature contains numerous information about the high efficiency of introducing sulfur and its compounds in perennial herbs, oilseeds, legumes, corn, vegetables and other crops.

A large number of experiments with the introduction of sulfur and sulfur-containing fertilizers for crops was carried out. The yield of grain crops (winter and spring wheat, winter rye, barley, oats) increased by 2.0-6.0 c/ha; that of legumes (peas, vetch, oats) – by 1.6-2.8 c/ha; of clover, alfalfa (hay) – 6-23 centner/ha; of flax (seeds) – by 1.1-3.2 c/ha; of corn (green mass) – by 10.0 c/ha [3].

It follows from the work of a number of authors that, under the influence of sulfur-containing fertilizers, the yield of spring wheat and rapeseed increases [12].

In the conditions of the Ulyanovsk region, early spring dressing of winter wheat plants of the Saratovskaya 17 variety with sulfur-containing fertilizers ensured a yield increase of 3.7 t/ha, the gluten content increased by 2.1% [13].

Sulfur contributes to the better development of nodules and the accumulation of more nitrogen in the soil [14].

Milk thistle is included in the list of medicinal plants approved for use in wide medical practice. Milk thistle fruits have a unique composition:

flavolignans, 32% of fat, 0.1% of essential oils, 17% of protein, water-soluble (groups B) and fat-soluble (A, D, E, K, F) vitamins, mono- and disaccharides, microelements (copper, zinc, selenium), fiber and enzymes that include sulfur [15-17].

Currently, researchers pay much attention to various methods of seed stimulation and foliar plant nutrition. An important role in the mineral nutrition of medicinal plants is played by microelements, the deficiency of which in the soil can impede the effective use of basic mineral fertilizers and lead to the disruption of the most important processes in plants. One of the promising areas for the use of microelements is their introduction in chelated form [18-20].

In this regard, the purpose of the research was the scientific justification and experimental confirmation of the use of sulfur-containing complex fertilizers for optimization the production process, increase the yield and quality of the fruits of milk thistle in the forest-steppe of the Middle Volga.

Methods and materials

The studies were conducted on the experimental field of LLC Agrofirm Biokor-S of the Mokshansky district of the Penza region in 2016-2018. The soil was leached heavy loamy medium humus black soil. The humus content in the arable layer – 6.5%, the content of mobile phosphorus – 103 mg/kg of soil, of exchange potassium – 160 mg/kg of soil, the availability of mobile forms of molybdenum, boron, manganese, copper, zinc, cobalt and sulfur was low, the reaction of the soil solution was slightly acidic – pH_{salt} 5.4. Soil density – 1.18-1.20 g/cm^2, the total soil porosity was 55-60%.

The forecrop was winter wheat. The plot area was 25 m^2, the repetition was fourfold, the allocation of plots was systematic. The cultivation technology – generally accepted for oilseeds in the region.

L.D. Slutskaya (1972) concludes that the early application of sulfur-containing fertilizers always have an advantage over the later application [9].

G.N. Popov, A.N. Aristarkhov et al. (1984) say that in the conditions of the arid Volga region, the need for foliar dressing during the formation of reproductive organs, flowering and fertilization is more due to the fact that the number of readily available microelements for plants due to frequent drying of the upper soil layer in June-July decreases sharply [11].

M. Campfer, E. Zegler (1969) also indicate that in acute sulfur deficiency, foliar dressing of plants with a 0.5–2% sulfate solution is recommended [21].

The object of research is milk thistle of the variety Debut.

The field experiment was carried out in four repetitions, the allocation of plots was systematic. Mineral fertilizers in a dose of $N_{60}K_{60}P_{60}$ were introduced in the pre-sowing cultivation. The concentration of preparations was taken in accordance with established recommendations. During the research, the methods of laying and conducting experiments generally accepted in agronomic science were used [22, 23].

Over the years of research, the following experiments were performed:

Experiment 1. The effect of pre-sowing seed treatment with complex fertilizers on the yield and quality of seeds of Milk Thistle. Scheme: 1. Control (seed treatment with water); 2. Processing of seeds wiht Megamix-Semena (0.4 kg/t); 3. Megamix-Profi (0.4 l/t); 4. Humate K/Na + microelements (0.15 l/t); 5. Green-Go (2 kg/t); 6. Cytovit (1 l/t); 7. Albite (30 ml/t); 8. Agrica (1 l/t) + Humate K/Na with microelements (0.15 l/t); 9 Agrica (1 l/t) + Humate K/Na with microelements (0.15 l/t) + Azotobacter (1 l/t).

Experiment 2. The effect of foliar dressing with complex sulfur-containing micronelement fertilizers on the productivity of milk thistle. Scheme: 1. Without processing (control); 2. Foliar top dressing with Megamix-Nitrogen (1l/ha); 3. Megamix-Profi (0.4 l/ha); 4. Megamix-Zinc (1 l/ha); 5. Cytovit (1 l/ha); 6. Albite (20 ml/ha).

Results

In the process of research it was found that complex sulfur-containing fertilizers acted positively (to varying degrees) on the formation of the production process of agrocoenosis of milk thistle. On average for 2016-2018, the area of leaves in the phase of budding-beginning of flowering, according to the experimental variants, was 41.2-56.7 thousand m^2/ha, in control – 29.8 thousand m^2/ha. The largest leaf surface was formed during exogenous seed treatment with Megamix-Zinc – 56.7 thousand m^2/ha, an excess of 26.9 thousand m^2/ha or 1.9 times compared to the control variant. The indicators of net productivity of photosynthetic potential also increased. Moreover, higher rates were observed when using the multifunctional preparation Albite, Megamix-Zinc, Humate K/Na with microelements and enriched sodium selenate, Megamix – Semena.

The positive effect of complex sulfur-containing fertilizers on the growth and development of milk thistle ensured an increase in yield, an improvement in the technological and biochemical properties of seeds (Tables 1, 2).

The seed yield on average for three years according to the experimental variants was 1.01-1.23 t/ha, a reliable increase in the yield was 0.12-0.34 t/ha (13.5-38.2%). The highest yield of 1.23 t/ha was obtained by treating seeds with a

Table 1. The effect of complex sulfur-containing fertilizers on the yield, technological and biochemical properties of the fruit of the milk thistle of the variety Debut (2016-2018)

Variant	Yield, t/ha	Content, %			Microelements, mg/kg		
		of oil	of protein	of flavonolignans	Fe	Cu	I
Control (seed treatment with water)	0.89	28.3	22.8	2.75	164	10.8	0.19
Megamix-Semena	1.19	35.8	29.6	3.79	190	13.4	0.34
Megamix-Profi	1.08	31.8	27.3	3.49	178	12.2	0.27
Megamix-Zinc	1.23	35.9	29.8	3.81	192	13.6	0.35
Cytovit	1.14	35.8	29.4	3.79	190	13.5	0.34
Albite	1.18	35.9	30.4	3.80	192	134	0.34
Humate K/Na with microelements	1.05	32.8	27.5	3.58	183	13.2	0.30
Humate K/Na with microelements + Agrica	1.08	33.1	27.8	3.60	1.86	13.4	0.32
Humate K/Na with microelements + Agrica + Azotobacter	1.12	35.5	38.2	3.64	189	13.6	0.34
Humate K/Na with microelements + Agrica + Se	1.13	35.7	29.0	3.75	188	134	0.33
Green-Go	1.01	30.2	24.6	3.49	178	12.7	0.28
HCP_{05}, t/ha	0.11						

sulfur-containing Megamix-Zinc preparation, the increase was 0.34 t/ha, or 38.2%.

Milk thistle oil is widely used in medicine, food industry and as a component of cosmetic products. In this regard, the method of increasing its quantity and quality in the fruits of milk thistle is of practical interest. An analysis of the biochemical composition of the oil showed that the treatment of seeds with sulfur-containing preparations improved the technological and biochemical parameters of milk thistle.

Thus, the oil content in the fruits of milk thistle increased in relation to the control by 1.9-7.6% and amounted to 30.2-35.9% (control – 28.3%), the protein content ranged from 24.6 to 29, 8% (control – 22.8%).

F.N. Gilmiyarova, V.M. Radomskaya (2001) insist that flavolignans have unique abilities to exert hepatoprotective and antioxidant effects [24]. According to our data, sulfur-containing fertilizers increased the number of flavolignans in milk thistle fruits from 3.49 to 3.81% (control – 2.75%) (Table 1).

Under the influence of complex sulfur-containing fertilizers during exogenous seed treatment, an increase in the content of vitamins B1-B12, A, D, E was observed, as well as a more intense accumulation of iron, zinc, manganese, cobalt and iodine (Table 1). At the same time, there was a decrease in the accumulation of heavy metals and radionuclides in the fruits of milk thistle.

Table 2. The content of essential amino acids in the seeds of milk thistle, mg/g of DM

Variant	Threonine	Lysin	Histidine	Arginine	Valine	Methionine	Isoleucine	Leucine	Phenylalanine	Tryptophan	Total amount of amino-acids
Control (seed treatment with water)	9,5	10,9	7,9	26,3	14,9	4,8	10,6	21,1	14,2	3,8	124,0
Megamix-Semena	10,8	12,5	9,0	32,3	17,4	5,9	12,3	25,2	16,5	4,7	146,6
Megamix-Profi	10,2	11,6	8,5	29,2	16,3	5,2	11,6	23,8	15,3	4,2	135,9
Megamix-Zinc	10,9	12,7	9,3	32,6	17,8	6,2	12,6	25,7	16,8	4,9	149,5
Cytovit	11,2	12,6	9,2	32,5	17,7	6,1	12,5	25,6	16,4	4,8	148,6
Albite	10,9	12,6	9,1	32,4	17,5	6,1	12,5	25,3	16,7	4,8	147,9
Humate K/Na with microelements	10,4	11,8	8,7	29,6	16,5	5,4	11,8	24,0	15,5	4,5	138,2
Humate K/Na with microelements + Agrica	10,6	12,1	8,8	29,7	16,7	5,6	11,9	24,3	15,7	4,5	139,7
Humate K/Na with microelements + Agrica + Azotobacter	10,7	12,4	8,9	30,6	16,9	5,8	12,1	24,8	16,2	4,6	141,2
Humate K/Na with microelements + Agrica + Se	10,9	11,8	8,7	30,8	17,2	5,8	12,3	25,2	16,7	4,8	144,2
Green-Go	9,8	11,4	8,5	29,1	16,4	5,3	11,7	23,7	15,4	4,1	135,4

Table 3. Productivity, biochemical and technological properties of the seeds of milk thistle with foliar feeding of plants with complex sulfur-containing fertilizers (2016-2018)

Foliar dressing (rosette+budding)	Yield, t/ha	Content, %			Acid number, mg KOH
		of oil	of protein	of flavo-nolignans	
Without treatment (control)	0.89	28.3	22.8	2.75	0.19
Megamiz-Nitrogen	1.06	31.2	24.2	2.97	0.23
Megamix-Profi	1.12	33.2	24.6	2.86	0.25
Megamix-Zinc	1.19	35.3	25.7	3.06	0.28
Cytovit	1.05	34.2	25.1	3.02	0.26
Albite	1.13	33.6	24.5	2.95	0.25

The total amount of the essential amino acids in the experimental variants was 135.4-149.5 mg/g of DM, in the control – 124.0 mg/g of DM. The highest number of amino acids in the protein of milk thistle fruit – 149.5 mg/g of DM was when using the Megamix-Zinc preparation; in relation to the control variant, their content increased by 10.6% (Table 2).

An important factor in obtaining high yields with product quality that meets the standards is the regulation of vital processes at all phases of plant growth and development. Matskov F.F. (1957) concludes that by applying top dressing to vegetative plants it is possible to strengthen weak nutrition links, change the focus of enzymes, and therefore the nature of intracellular metabolism, thereby affecting the growth and development of the plant organism, i.e. to manage the process of crop formation [25].

The studies showed that a twofold leaf dressing of plants of milk thistle in the rosette and budding phase with complex sulfur-containing fertilizers contributed to a significant increase in the assimilation apparatus of agrocenoses. The size of the leaf area depended on the type of preparation and on the sulfur content. Foliar top dressing extended the functioning of the leaf surface, its area increased to 42.3-54.8 thousand m^2/ha (control – 30.2 thousand m^2/ha).

The maximum photosynthesis rates were observed during foliar dressing with the Cytovit preparation – 54.8 thousand m^2/ha, which was 24.6 thousand m^2/ha or 1.81 times higher than the control. At the same time, the indicators of photosynthetic potential and net productivity were also the highest and amounted to 3.06 million m^2d/ha, 2.83 g/m^2 per day, respectively.

The use of sulfur-containing fertilizers for double foliar dressing in the phase of rosette and budding is an effective way to increase the productivity of milk thistle. At the same time, optimal conditions for the formation of elements of the structure of the milk thistle crop were formed: the number of fruits in the heading according to the experimental variants was 110-124 pcs., on a plant – 148-159 pcs., plant productivity – 1.16-1.28 g, the weight of 1000 seeds – 22.6-25.8 g. The seed yield according to the experimental variants ranged from 1.06 to 1.19 t/ha (control – 0.89 t/ha), additionally 0.17-0.30 t/ha was obtained from each hectare. The highest yield increase was obtained with a double foliar dressing with Megamix-Zinc – 0.53 t/ha, or 33.7%. At the same time, there was a high oil content – 35.3%, an increased level of protein – 25.1%, of flavonolignans – 3.26%, the acid number – 0.28 mg KOH (Table 3). Similar indicators of yield (1.15 t/ha) and the quality of milk thistle fruits were observed when using the Cytovit for foliar dressing: the oil content in the fruits was 34.2%, of protein – 25.1%, of flavonolignans – 3.02%, the acid number – 0.26 mg KOH.

Conclusion

The greatest positive effect was achieved with the exogenous treatment of milk thistle seeds with a complex sulfur-containing fertilizer Megamix-Zinc: fruit yield was 1.23 t/ha, the increase – 0.34 t/ha (38.2%); the content of oil – 35.9% and of protein – 29.8% increased by 7.6 and 7.0% in relation to the control; the content of essential amino acids – 149.5 mg/g of DM (control – 124,0 mg/g of DM).

The highest yield of milk thistle seeds (1.19 t/ha) was obtained with foliar dressing of plants with Megamix-Zinc. The oil content increased by 35.3%, of protein – by 25.5%, of flavonolignans – by 3.06%.

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DOI: 10.26177/VRF.2019.2.2.007

YIELD AND QUALITY OF SPRING TRITITICALE GRAIN WHILE USING NANOKREMNIY AND SILIPLANT IN CONDITIONS OF FOREST-STEPPE OF THE MIDDLE VOLGA REGION

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NanoKremniy and Siliplant preparations stimulated growth processes, which contributed to an increase in the parameters of photosynthesis of spring triticale agrocenoses. The maximum values of the leaf surface – 34.6 thousand m^2/ha, of the photosynthetic potential – 1.82 million m^2 days/ha, of the net productivity of photosynthesis – 3.26 g/m^2 per day, of the ear grain size – 36-38, of grain weight per spike – 1.2-1.3 g were observed during seed treatment and double foliar top dressing in the tillering and heading phase with the NanoKremniy preparation. When presowing seed treatment was used, the highest grain yield of triticale (4.05 t/ha on average over three years) was obtained using the preparation NanoKremniy. A reliable increase in the control amounted to 0.8 t/ha (32.5%). Silicon-containing preparations NanoKremniy and Siliplant contribute to improving the technological properties of spring triticale grains. Indicators of the grain unit on the variants of experience amounted to 776-781 g/l. The greatest indicator of the grain unit (781 g/l) was when the preparation NanoKremniy was used for seed treatment. The grain hardness in relation to the control increased by 4.0-11.0%, the content of raw gluten – by 1.5-2.1%, of protein – by 2.7-3.1%. Foliar plant nutrition with silicon-containing preparations in different phases of the growing season had a significant impact on increasing yields and improving the technological properties of spring triticale Ukro grain. On average, over three years, the yield of grain according to the variants of the experiment was 34.4-4.49 t/ha, the increase relative to the control was 0.39-1.43 t/ha (12.5-48.6%). The highest grain yield (4.49 t/ha) was obtained by double feeding with the preparation NanoKremniy during the tillering and heading stages, the grain yield increase was 1.43 t/ha (48.6%). The maximum indicators of the technological properties of spring triticale grain were obtained by double foliar fertilization of plants with the NanoKremniy preparation: grain unit – 792 g/l, hardness – 62%, raw gluten – 26.2%, protein – 15.8%.

Key words: spring triticale, microelement fertilizers Siliplant and NanoKremniy, yield, technological properties of grain.

Introduction

V.I. Vernadsky (1967) called silicon an element of exceptional importance in the universe [1].

Silicon is among the necessary biophilic elements, it forms the skeletal part of plants, strengthens the stem, it is necessary for the metabolic processes of a living organism, and is actively involved in the metabolism of calcium, phosphorus, chlorine, fluorine, sodium, sulfur, aluminum, molybdenum, manganese, cobalt [2-9].

L.I. Kudinova (1975), V.K. Bakhnov (1979) reported silicon to have a stimulating effect on the development of the root system, leaf area, growth rate, the final dry weight of plants, contributed to increasing the drought resistance of plants, resistance to fungal diseases, pests, lodging, low temperatures [4, 9].

M.L. Shkolnik (1974), M.G. Voronkov et al. (1978); N.E. Aleshin, E.R. Avanyan (1978) noted the agroecological aspect of silicon in plant protection to reduce the pesticide load in agrocenoses, to limit nanobiotics in the environment, to increase plant resistance to mutations [7, 10].

Wheat, barley, oats, millet, corn, and rice are referred to as silicophilous, more than half of the mineral substances that grains absorb from the soil make up silicon dioxide. Cereals absorb silicon 10-20 times more than legumes [10, 12, 14, 15].

Researches of A.M. Bakhnov (1979) found that silica eliminated the toxic effect of iron, aluminum, manganese, copper, arsenic, strontium-90 and phenols, it also stimulated the flow of nitrogen, potassium, calcium, magnesium, carbon dioxide into the plant [9].

When diatomites, tripoli, slags, sapropel, superphosphate production waste rich in silicon are used as a fertilizer, barley yield increases by 19-36%, oats yield – by 40% [14].

L.I. Kudinova (1975), Joshida Schochi (1965) noted in their works that foliar nutrition with easy digestible inorganic silicon compounds accelerated plant growth and metabolic processes, increased the weight and area of the leaf apparatus, of roots, increased productivity, resistance to drought, frost, promoted assimilation of phosphorus and other nutrients from soil [4, 23].

A.H. Kulikova (2013) noted that natural silicon sources – diatomites and usolites – were widely used as silicon fertilizers in Russia [6].

Researches of A.V. Kamsky, V.N. Kapranov (2006), B.A. Sushenitsa (2009) found diatomite to be an effective agrochemical means of increasing the yield of grain crops in direct action and afteraction. When treating seeds with diatomite, 0.5 t/ha of barley variety Vladimir, 0.3 t/ha of winter wheat Moscowskaya 36 were received in addition to the control [16].

In the experiments of D.Yu. Ivanov and L.A. Dorozhkina (2004), with the combined use of the herbicide Epin-Extra (50 ml/ha) with the silicon-containing preparation Siliplant on barley crops, the yield increased and the weed infestation decreased by 20-37% of annual weeds, by 44-80% of perennial weeds [17].

According to A.N. Kshnikatkina, S.A. Kshnikatkin, P.G. Alenin (2014), with double treatment of winter triticale plants in the phase of tillering and heading with Siliplant, the yield increase was 0.97 t/ha [18].

When agro-ecological evaluation of the effectiveness of the use of tank mixtures of herbicides Korsar and Agrika together with the silicon-containing preparation Siliplant on cowgrass crops, it was found that the seed yield increased by 18.6% [19].

I.F. Borodin (2007) concluded that silicon-organic biostimulants (NanoKremniy, etc.) increased productivity, cold resistance, heat and drought resistance, increased the plant's protective functions against diseases and pests, reduced the sedative effects of plant protection chemicals [20].

The purpose of the research was to provide scientific substantiation and experimental confirmation of the effectiveness of the use of silicon-containing preparations Siliplant and NanoKremniy in the technology of spring triticale cultivation.

Methods and materials

The object of research was spring triticale of the variety Ukro. The agrotechnology – generally accepted for spring grain crops. The forecrop was the cowgrass. Sowing was carried out in an ordinary way, with a row spacing of 15 cm, in the first decade of May. The seeding rate was 4.5 million seeds per hectare. Mineral fertilizers N_{60} P_{60} K_{60} were introduced into presowing cultivation. The area of the plots – 25 m^2, the repetition was fourfold, the placement of plots was systematic. The harvest accounting was carried out to 14% of humidity.

The methods common in agronomic science to establish and carry out experiments were used in this work [21].

Experiment 1. The effect of presowing seed treatment with NanoKremniy and Siliplant preparations on the yield and technological properties of spring triticale grain. Scheme: 1. Control (water treatment of seeds); 2. Seed treatment with NanoKremniy (400 g/t); 3. Seed treatment with Siliplant (1 l/t).

Experience 2. The effect of foliar fertilizing with silicon-containing preparations on the productivity of spring triticale. Scheme: 1. Control (without processing); 2. Foliar fertilizing with NanoKremniy in the tillering stage (200 g/ha); 3. Foliar fertilizing with NanoKremniy in the earing phase (200 g/ha); 4. Foliar fertilizing with NanoKremniy in the tillering stage (200 g/ha) + in the earing phase – (200 g/ha); 5. Foliar fertilizing with Siliplant in the tillering stage (1 l/ha); 6. Foliar fertilizing with Siliplant in the earing phase (1 l/ha); 7. Foliar fertilizing with Siliplant in the tillering stage (1 l/ha) + in the heading phase – (1 l/ha).

Results

The analysis of the formation of spring triticale agrocenosis of the Ukro variety showed that with exogenous treatment of seeds with silicon-containing drugs NanoKremniy and Siliplant, field germination of seeds in relation to the control increased by 1.8 and 10.6%, the safety of plants for harvesting – by 3.5 and 11.2%. The most stimulating effect was shown by the drug NanoKremniy, the field germination rates increased by 10.6%, the safety of plants for harvesting – 11.2%.

NanoKremniy and Siliplant preparations stimulated growth processes, which contributed to an increase in the parameters of photosynthesis of spring triticale agrocenoses. Spring triticale crops formed the highest indices of photosynthetic activity in the treatment of seeds with the NanoKremniy preparation. The maximum values of the leaf surface – 34.6 thousand m^2/ha; of photosynthetic potential – 1.82 million m^2/ha; and of the net productivity of photosynthesis – 3.26 g/m^2 per day were observed when the plants were twice treated with the NanoKremniy in the tillering and earing stages.

Pre-sowing seed treatment and foliar nutrition of vegetative plants with the studied preparations had a positive effect on the formation of elements of the structure of spring triticale yield. The greatest grain content of the spike (36-38 pcs.) and the greatest mass of grain per spike (1.2-1.3 g) were observed during seed treatment and double foliar feeding with the NanoKremniy preparation.

The integral indicator that characterizes the influence of various factors on the growth, morphogenetic and physico-biochemical processes occurring in plants is the yield. In the presowing treatment of seeds, the highest grain yield of spring triticale (on average for three years – 4.05 t/ha) was obtained using the preparation Nano-

Table 1. The influence of silicon-containing preparations NanoKremniy and Siliplant on yield and technological properties of spring triticale grain (2016-2018)

Variant	Yield, t/ha	+/- to the control		Grain unit, g/l	Hard-ness, %	Raw gluten, %	Protein, %
		t/ha	%				
Control (water treatment)	3.06	-	-	762	48	22.8	11.5
Seed treatment with NanoKremniy	4.05	0.80	32.5	781	59	24.9	14.6
Seed treatment with Siliplant	3.57	0.52	16.8	776	57	24.3	14.2
HCP_{05}, t/ha	0.16						

Kremniy. A reliable increase in the control amounted to 0.8 t/ha (32.5%). A sufficiently high reliable yield increase (0.52 t/ha) was provided by exogenous seed treatment with Siliplant (Table 1).

Silicon-containing preparations NanoKremniy and Siliplant contributed to improving the technological properties of spring triticale grains. Indicators of the grain unit according to the variants of experience were 776-781 g/liter, which corresponded to the basic standards (not less than 750 g/l). The highest indicator of the nature of grain (781 g/l) was when the NanoKremniy preparation was used for seed treatment. The hardness of the grain in relation to the control increased by 4.0-11.0%, the content of raw gluten – by 1.5-2.1%, and the content of protein – by 2.7-3.1%. The NanoKremniy preparation turned out to be the most effective for exogenous seed treatment (Table 1).

Foliar nutrition of plants with silicon-containing preparations in different phases of the growing season had a significant impact on increasing yields and improving the technological properties of spring triticale grain of the variety Ukro. Thus, on average over three years, the yield of grain according to the variants of the experiment was 34.4-4.49 t/ha, the increase relative to the control – 0.39-1.43 t/ha (12.5-48.6%). The highest grain yield of 4.49 t/ha was obtained by double feeding in the tillering and heading stages with the NanoKremniy preparation. Additionally, from each hectare, the grain yield increase amounted to 1.43 t/ha (48.6%) (Table 2).

The problem of increasing the grain production of triticale is inextricably linked with the improvement of its quality. Our research established that the NanoKremniy and Siliplant preparations used in foliar feeding of triticale plants provided an increase in yields and improved the grain quality. Indicators of the nature of the grain ranged in variants of experience from 780 g/l to 792 g/l (control – 762 g/l); grain hardness increased by 7.0-14.0%; the content of raw gluten in the grain – by 0.61-1.5%; protein in the grain was accumulated 2.6-4.3% more than in the control.

The maximum indicators of the technological properties of spring triticale grain were noted on the variant with double foliar nutrition of plants with the NanoKremniy preparation – grain unit was 792 g/l, hardness – 62%, raw gluten – 26.2%, protein – 15.8% (Table 2).

Table 2. The effect of the NanoKremniy and Siliplant preparations on the yield and technological properties of spring triticale grain (2016-2018)

Variant	Yield, t/ha	+/- to the control		Grain unit, g/l	Hard-ness, %	Raw gluten, %	Protein, %
		t/ha	%				
Control (no treatment)	3.06	-	-	762	48	22.8	11.5
Foliar nutrition in the tillering stage with NanoKremniy	3.72	0.67	21.6	783	58	24.7	14.3
Foliar nutrition in the earing stage with NanoKremniy	3.64	0.59	18.9	786	60	25.9	15.2
Foliar nutrition in the tillering + earing stages with NanoKremniy	4.49	1.43	48.6	792	62	26.2	15.8
Foliar nutrition in the tillering stage with Siliplant	3.54	0.49	15.8	776	55	24.5	14.1
Foliar nutrition in the earing stage with Siliplant	3.44	0.39	12.5	780	56	25.3	14.8
Foliar nutrition in the tillering + earing stages with Siliplant	4.32	1.26	41.3	784	58	25.8	15.2
HCP_{05}, t/ha	0.18						

The main indicator of the nutritional and feed value of cereal grains is not only the protein content, but also its amino-acid composition. Grain of spring triticale compared with other cereals contains and has the best amino acid composition, in particular, significantly more lysine and tryptophan.

On the basis of biochemical analysis, it was found that silicon-containing preparations NanoKremniy and Siliplant contributed to an increase in the number of amino acids in the grain of spring triticale. The total number of amino acids increased in the variants of the experiment to 12.64-16.78 with 11.35 mg/g of dry matter in the control. The maximum level of amino acids (16.78 mg/g of dry matter) was noted in triticale grains with a double foliar nutrition with NanoKremniy, while the limiting lysine amino acid was 0.65 mg/g of dry matter (control – 0.41 mg/g of dry matter).

During exogenous seed treatment and foliar feeding of spring triticale plants, there was a tendency for more intensive accumulation of iron, zinc, manganese, and cobalt in the grain. The grain of triticale had the best trace element composition when the NanoKremniy preparation was used in the technology of cultivation.

Conclusion

Exogenous treatment of seeds and double foliar nutrition of plants in the tillering and heading stages with a silicon-containing preparation NanoKremniy increased yields and improved the technological qualities of the properties of spring triticale grain of the variety Ukro. The highest grain yield – 4.49 t/ha, and the increase – 1.43 t/ha (48.6%) were obtained with double foliar nutrition in the tillering and earing stages, the gluten content increased by 3.4%, the protein content – by 4.1 %, glassiness – 14%.

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DOI: 10.26177/VRF.2019.2.2.008

THE FORMATION OF SAFFLOWER AGROCOENOSIS IN THE CONDITIONS OF FOREST-STEPPE OF MIDDLE VOLGA REGION

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The purpose of the research was to study the formation of productive agrocoenosis of safflower in the conditions of the Middle Volga region. The studies were conducted in 2015-2018 on the fields of the Penza Institute of Agriculture. The growing season of safflower in 2015 proceeded in insufficiently moistened conditions with HTC – 0.76, with an average daily temperature of 21.3 °C. In 2016, the vegetative period of safflower proceeded in moderately moistened conditions with HTC – 1.1 and an average daily temperature of 20.1°C. The vegetation period of 2017 was characterized as insufficiently moistened with HTC – 0.82 units. The conditions of 2018 were severe, HTC was only 0.4. The seedlings of the culture appeared in nine days. After 71 days, the flowering phase began, it lasted on average about 30 days. The duration of the period from flowering to ripeness of safflower was 36 days. The growing season of safflower in the conditions of the Middle Volga region averages 116 days. Field germination of safflower varied within 71.2-77.6%, the safety of plants for harvesting ranged from 93.6 to 96.5%. The largest leaf area of safflower was formed during the flowering phase (22.9-26.8 thousand m²/ha). The value of the photosynthetic potential ranged from 1.98 to 2.55 million m² × day/ha. The highest net productivity of photosynthesis was observed in 2018 and 2016 and amounted to 2.95 and 2.99 g/m² × day, respectively. Safflower, on average over four years, formed a fairly high and stable yield: 1.19 and 1.32 t/ha. The maximum yield of safflower seeds was obtained in 2016 and averaged 1.32 t/ha.

Key words: safflower, yield, growing season, field germination, photosynthetic activity.

Introduction

Safflower (Carthamus tinctorius L.) is a valuable oil-bearing crop of many uses.

Safflower is a rather new crop for Russian agricultural producers. Its market is only being formed, but it is developing at a fast pace. Statistics on safflower has been maintained since 2011, when the crops were 7 thousand hectares. Since then, they have grown more than 20 times. The main cultivation area falls on the steppe zone and semi-deserts [1, 15].

Until recently, the history of safflower was associated with the use of its flowers, from which the dye cartamine was extracted [13].

Now, speaking of the advantages of safflower, firstly, it should be noted its importance as one of the sources of world production of vegetable oil. Safflower contain up to 50-56% oil in seeds, and up to 25-36% oil in fruits, which is widely used in the food and technical industry [4, 6].

Safflower is an annual herb with pronounced morphological and biological signs of xerophyte, which refers to the short-day plants. At the same time, it reacts relatively poorly to the lengthening of the day when planted northward [12].

Safflower seeds germinate at 4-5ºC. Shoots in the rosette phase can stand frosts down to minus 15-17ºC. This biological feature of safflower allows the culture to be used for underwinter and winter sowings in the South-East of the European part of Russia and, in particular, in the Volga region [2, 10].

Safflower is a plant that is most adapted to the truly continental climate of the Lower and Middle Volga region. It is one of the most heat-resistant and drought-resistant crops [3, 11].

Safflower stands air and soil drought. Dry years for safflower are more favorable than years with prolonged rainy weather. Safflower sharply reacts to an increase in the humidity of the air and a decrease in the amount of heat by reducing the yield and the fat content of the seeds. Under such conditions, the mass of empty seeds increases due to low fertilization, and the heads become rotten [5, 14].

Resistance of safflower to drought is favored by a well-developed tap root (up to 2 m) deep in the soil. It is strongly branched and extracts moisture from the lower layers, thereby protecting the plants from heat and dry winds [1].

The requirements of safflower to moisture during the growing season is uneven. It has relatively large demands on moisture in the period of swelling and seed germination, and therefore it responds positively to the early sowing period. The level of yield of safflower is in direct proportion to the presence of soil moisture in the critical phase of its development that falls on the branching – budding.

Safflower is undemanding to soils and suitable for cultivation in broad soil conditions. It normally grows on marginal lands, including saline lands, on sandy soils, fairly rich in lime, and on dry soils, formed on highly weathered limestone. However, the greatest yields of safflower are obtained on black earth and chestnut soils [1, 2].

The complex of biological peculiarities we have described defines safflower as a drought-resistant, heat-resistant field crop not demanding on soils, capable of producing relatively high and stable yields in various climatic conditions.

Despite this, safflower is not yet widespread in the forest-steppe of the Middle Volga region, namely in the Penza region. In this regard, the aim of our research was to study the formation of productive agrocoenosis of safflower in the Middle Volga region.

Materials and methods

The object of the research, which was conducted in 2015-2018, was the safflower variety Aleksandrit.

The vegetative period of safflower in 2015 proceeded in insufficiently humidified conditions with HTC – 0.76 and an average daily temperature of 21.3°C. In 2016, the vegetation period proceeded in moderately wet conditions with HTC – 1.1 and an average daily temperature of 20.1°C. The vegetation period of 2017 was characterized as insufficiently moistened with HTC – 0.82 units. The conditions of 2018 were severely arid, HtC was only 0.4 with average daily temperatures of 19.3°C.

Phenological observations and biometric evaluations were carried out during the growing season in accordance with the Methodology of the State variety testing of agricultural crops [8].

Accounting and evaluation of productivity were performed according to the methodological recommendations [7].

Determination of photosynthetic parameters (leaf area of plants, photosynthetic potential of crops (PP) and net photosynthesis productivity (NPP)) was carried out according to the method described by A.A. Nichiporovich [9].

Results

It is known that each plant is an integral morphogenetic structure with its own peculiarities of growth, organ formation and productivity formation at each stage of development, where regular changes in the body occur: seed germination, growth of vegetative organs; flowering and fruit formation in specific environmental conditions.

During the years of research, the meteorological conditions of the seasons largely influenced the growth and development of safflower, which basically determined the duration of the interphase periods and the total vegetation period of the crop.

Safflower shoots, on average over the years of research, appeared after nine days. The “sowing-seedlings” period proceeded mainly under severe dry conditions, the HTC was 0.4 units (Table 1).

Flowering usually occurs in 65-70 days and it lasts on average about 30 days. It takes 35-40 days from flowering to ripening.

The period from germination to flowering of safflower, on average for 2015-2018, lasted 71 days and was characterized as dry (HTC – 0.6) with average daily temperatures of 16.9°C and with a sum of effective temperatures of 1008.3°C.

The period from flowering to ripeness of safflower averaged 36 days over the years and proceeded under dry conditions with HTC – 0.5 and with average daily temperatures of 20.1°C. The greatest need for heat was noted in the period of flowering-ripening.

In general, the vegetation period of the crop proceeded at an average daily temperature of 19.8°C, and moderate moistening (HTC – 0.9) and was 116 days.

Temperature is the most important factor determining the overall duration of the safflower growing season. The higher the average daily

Table 1. Meteorological indicators for the growing season of safflower, on average for 2015-2018

Interphase period:		Hydrothermal conditions:			
development phase	number of days	average daily temperature, °C	∑ temperatures ≥ 10°C	∑ precipitation, mm	HTC
Sowing-shoots	9	14.3	98.9	7.4	0.4
Shoots-flowering	71	16.9	1008.3	59.1	0.6
Flowering-ripeness	36	20.1	981.8	46.7	0.5
Sowing-ripeness	116	19.8	2089.0	113.2	0.9

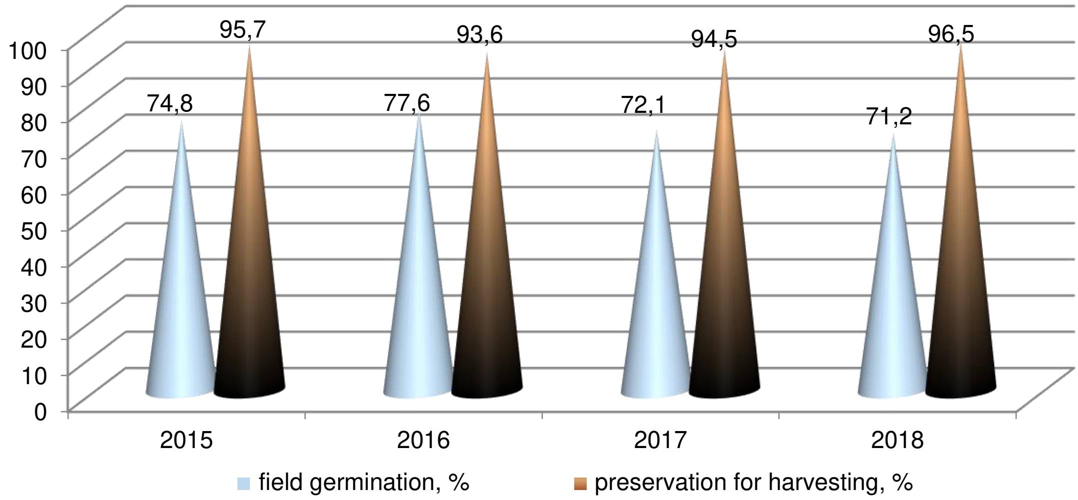

Figure 1. Formation parameters of safflower productive agrocoenosis

temperatures during the growing season, the faster the safflower matures.

Mathematical analysis showed that the vegetation period had a high positive correlation with air temperature (r = 0.91) and with HTC (r = 0.81).

To obtain high yields, safflower needs to form crops with an optimal density of plant stand, which is determined by field germination and the safety of plants for harvesting.

Field germination and preservation of plants for harvesting varied depending on the influence of meteorological factors. On average, over the years of the study, the field germination of safflower was rather high and varied within 71.2-77.6% (Fig. 1).

The lowest field germination was in 2018, with zero HTC in the sowing-seedling phase. With more favorable conditions of 2015 and 2016 with HTC – 0.8-1.0, there was a tendency to increase the percentage of field germination by 3.6-6.4%, respectively.

For an average of three years, the safety of safflower plants for harvesting was high and ranged from 93.6 to 96.5%.

A promising direction of increasing the productivity of safflower crops is the integrated use of the biological potential of the crop, and in particular, the photosynthetic productivity of agrocoenosis, which is due to the size of the leaf surface.

In the initial period of growth, in the stooling phase of safflower, the area of leaves grew very slowly, and their assimilation surface was small and amounted to 10.9–13.4 thousand m²/ha (Fig. 2).

The largest leaf surface area was formed in the flowering phase, on average over the years of the research it was 22.9-26.8 thousand m²/ha. It should be noted that the leaf surface area was the largest in 2018, when there were the most favorable conditions for the growing season of the crop.

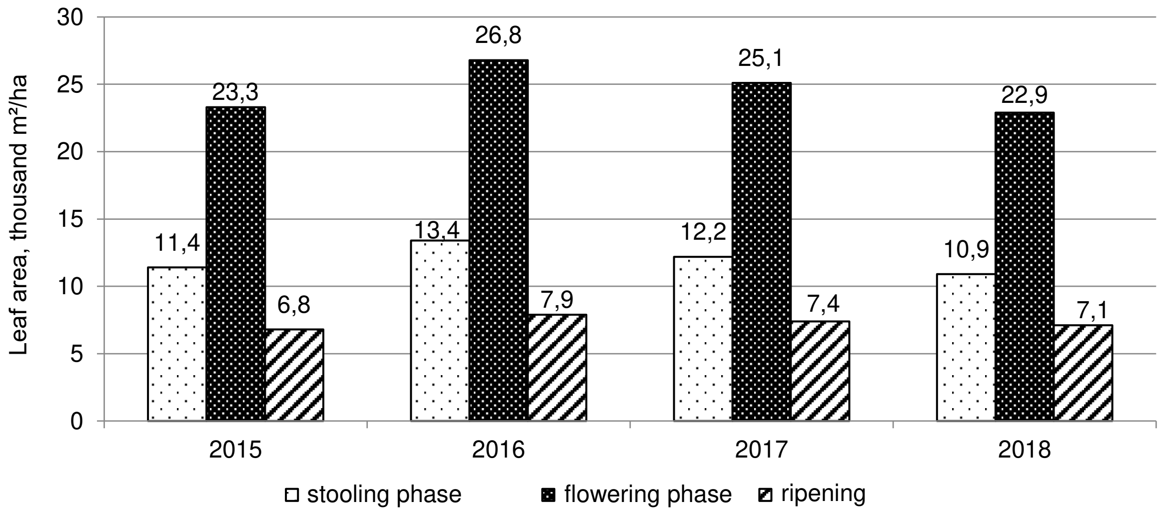

Figure 2. The dynamics of the increase in the area of safflower leaves

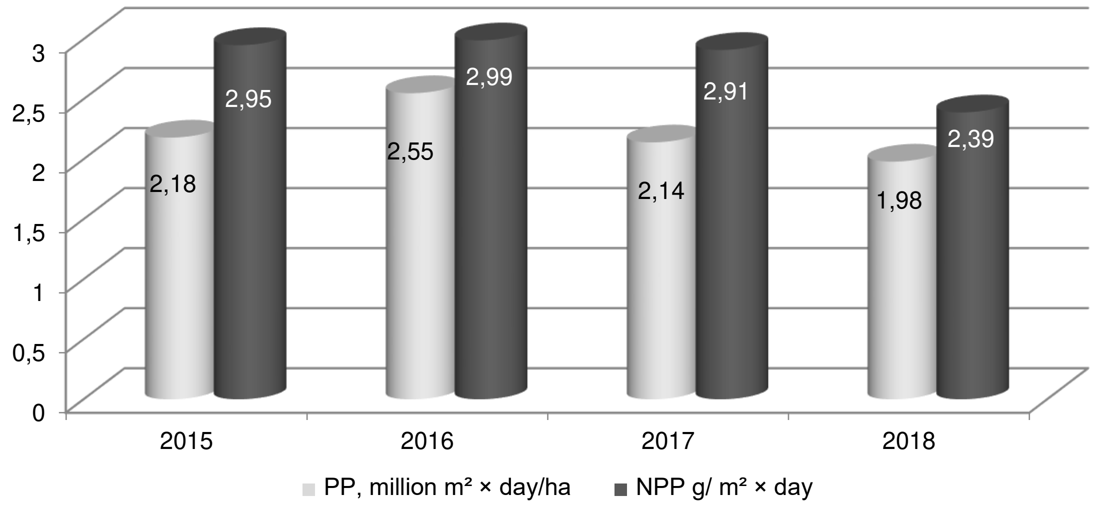

Figure 3. Indicators of photosynthetic activity of safflower

Further, in the phenological phase of "ripening", there was a decrease in the leaf area of safflower plants. On average, this figure ranged from 6.8 to 7.9 thousand m²/ha.

The amount of the yield was in close connection not only with the size of the leaf apparatus, but mainly with the duration of its work during the growing season, which was characterized by the photosynthetic potential of the crops.

The value of the photosynthetic potential (PP) of safflower agrocoenosis varied from 1.98 to 2.55 million m² × day/ha (Fig. 3).

The net productivity of photosynthesis (NPP) is a very plastic and the most stable indicator of photosynthesis, less than others, depending on the conditions of the growing season.

The highest net productivity of photosynthesis was observed in 2018 and 2016 and amounted to 2.95 and 2.99 g/m² × day, respectively. A low rate of NPP was observed in 2018 – 2.39 g/m² × day.

The end result in the formation of agrocoenosis of crops is the crop yield – an integral indicator of the interaction of all the quantitative traits of a plant with environmental conditions.

The average yield of safflower seeds for 2015-2018 amounted to 1.19-1.32 t/ha. The maximum yield of safflower seeds was obtained in 2016 and amounted to 1.32 t/ha (Fig. 4).

Safflower formed low yields in 2018 and 2015 (1.19 and 1.20 t/ha) under dry growing conditions with HTC – 0.4 and 0.7, respectively.

Conclusions

Thus, the length of the growing season (up to 116 days) is one of the main biological characteristics of plants in the formation of their high agrocoenosis. Field germination, plant leaf apparatus work and photosynthesis productivity determine safflower in general as a promising oil-bearing crop capable of producing relatively high and stable seed yields up to 1.28-1.32 t/ha in contrasting climatic conditions of the Middle Volga region.

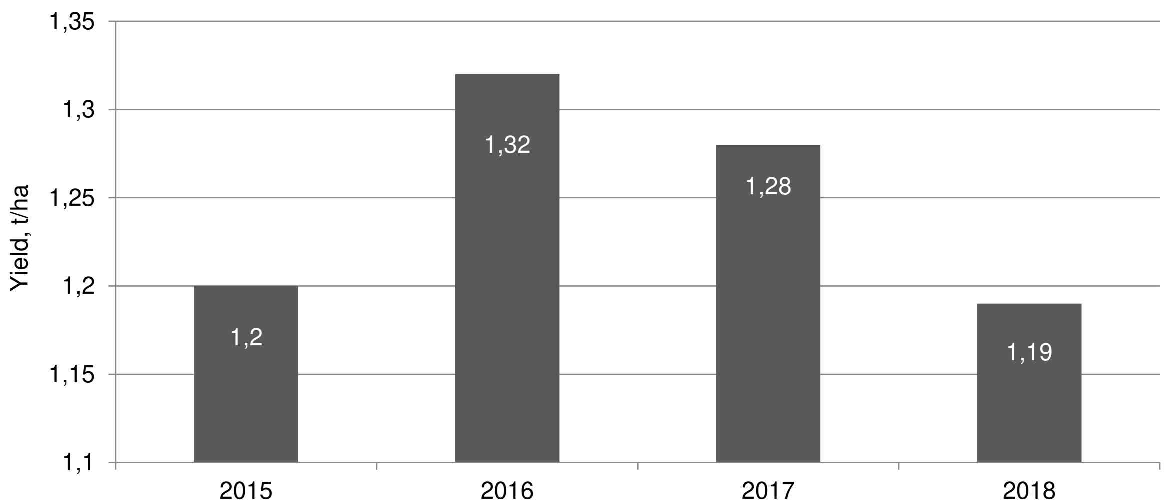

Figure 4. The yield of safflower, 2015-2018

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DOI: 10.26177/VRF.2019.2.2.009

USAGE OF A NEW PLANT PRODUCTIVITY INDEX FOR EVALUATION OF WINTER WHEAT BREEDING MATERIAL

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An important problem in the selection process is to increase the efficiency of selection of a selection material on the basis of productivity using selection indexes. We used the most popular indexes in breeding practice (Mexican, Canadian, spike linear density index, as well as a new modification of the index – plant productivity index (PPI)) to determine the most effective and informative index indicators to determine the breeding value of winter wheat genotypes in various environmental conditions. The studies were conducted on 120 varieties of winter soft wheat in the foothill zone of the Central Caucasus. As a result of the conducted research, it was established that the greatest information content on productivity in the “genotype-environment” relationship was obtained during the assessment by the PPI index. The correlation analysis revealed reliable relationships between the yield of winter wheat variety samples and the plant productivity index, which showed the highest value, r = 0.93. Reflecting productivity as a result of genotype-environment interaction, PPI helps to identify resistant genotypes for bio- and

abiostressors, which allows preliminary assessment of the adaptive properties of the breeding material, and using the index itself as a marker of adaptability.

Keywords: winter wheat, variety, productivity, selection indexes.

Introduction

The main task of selection is the creation of varieties that can realize their potential productivity in a wide range of soil and climatic conditions, in other words, to be environmentally plastic and stable [1]. The implementation of the program of creating adaptive varieties at each stage of the selection process is accompanied by a comprehensive assessment of the breeding material on the basis of the main economically valuable characteristics and constitutes a specific system. Each link of the selection process has its own methodological approach, which must meet certain requirements: first of all, be informative, accurate, objectively reflect the properties of the genotype of the breeding material and, if possible, be labour saving [3, 13].

Evaluation by productivity retains its value both in the early stages of the selection process, when elite plants are selected and their offspring are tested, and later, when it becomes possible to determine the yield of selection numbers. To assess the grain productivity, the search for a method by which the selection of highly productive plants can be carried out most fully and objectively is relevant.

Selection indexes are integrated indicators of a comprehensive assessment of productivity, reflecting the patterns between productivity and plant characteristics or between individual components involved in the formation of the crop. They are most suitable for such a criterion. The advantage of selection by indexes lies in the ability to evaluate the breeding material not one by one, but by a combination of characteristics closely interconnected with the parameters of productivity [8, 14].

The aim of our research was the development and validation of a new selection plant productivity index (PPI) on the example of assessing the grain productivity of breeding material from a collection, represented by variety samples of winter wheat from the world collection of N.I. Vavilov Research Institute of Plant Industry and zoned varieties.

Methods and materials

The studies were conducted in 2016-2018 in the laboratory of selection and seed production of grain crops of North Caucasus Research Institute of Hill and Foothill Agriculture – a branch of the Federal State Budgetary Institution of Science of the Federal Scientific Center. The material for the research was 100 varieties of winter wheat from the world collection of N.I. Vavilov Research Institute of Plant Industry and 20 zoned varieties.

The soil of the experimental plot was represented by medium-heavy heavy-loamy leached black soil, underlain by pebble stone.

Meteorological conditions in the years of research differed in temperature and moisture supply.

The climatic conditions of 2016 were characterized as favorable for grain crops, the hydrothermal coefficient (HTC) was 1.5.

The climatic conditions of 2017 (HTC 1.62) was hotter and more humid than usual since the spring vegetation period, which contributed to the development of diseases, including spike fusarium and septoria.

In 2018, the moisture availability of crops in early March-April was lower than usual (HTC 1.73), the productive moisture reserves in the soil were 20-27 mm in the arable layer, which was insufficient for plants during the period of ear budding. In May, the amount of precipitation exceeded the norm by 135%. The crops were well supplied with heat and moisture.

When evaluating the genotype-environment interaction, different selection indexes were used [2, 5]: Mexican index (Mx) – grain mass per spike / plant height; spike linear density index (SLD) – the number of grains in the ear / ear length; Canadian index (Ki) – grain weight per spike / spike length; as well as a new plant productivity index (PPI), which is the ratio of the product of the number of grains of an ear, and the weight of grain from an ear to an ear length.

Mathematical processing of experimental data was performed according to B.A. Dospekhov [4]. Field experiments, phenological observations, surveys and measurements of plants were carried out in accordance with the method of state variety testing [12].

Results

There are many selection indexes that differ in their informativeness and accuracy. They can be divided into three groups: characterizing the productivity of the leaf, the attraversa ability of the ear, the productivity of the ear. The first two reflect the potential of the plant during crop formation. For example, there are indexes that use biochemical and physiological parameters that are related to productivity, but, undoubtedly, indexes that include parameters of real productivity will be more accurate and more informative, which is more significant for selection evaluation [6].

The productivity of winter wheat has a complex polygenic nature. The signs differ in the range of the reaction norm or modification variability; they are divided into vegetative (plant

height, length of internodes, length of spines, leaves, plant mass, etc.) and generative (ear length, number of grains per ear, 1000 grain weight, weight of grain per ear) and etc.). The accuracy and information content of the index depends on what parameter is a part of it. If the index includes slightly varying characteristics, having regular links between themselves with changes in environmental conditions, then the index will more accurately reflect the real productivity of the plant, and vice versa. The slightly varying characteristics include: spike length, number of grains per ear, grain weight, mass of 1000 grains, etc. [7]. Strongly varying characters include: plant height, length of internodes, leaf area, weight of stems or plants, etc.

For example, in some paired indexes, the number of grains of an ear or their mass is compared with highly variable linear parameters:

– length of internodes – Poltava index;
– plant height – Mexican index;
– spit length – index of the spike linear density;
– specific yield of the spike – Canadian index.

Obviously, there is an indirect connection between these indicators, and the information content and accuracy of such indices is low.

For more reliable selection by yield, such criteria are needed, which, on the one hand, will reduce the subjective assessment of the size of an indicator, and on the other, take into account the effect of the remaining indicators on the main one. The effectiveness of the selection work will be much higher if the signs are combined into one index. In this case the selection will be based on the complex of the combined characteristics [9, 10].

The proposed plant productivity index (PPI) is of practical interest, since it is calculated by the three main parameters of ear productivity: length, number of grains and grain weight per ear:

$$PPI = (NG \times GW) / SL,$$

where NG – number of grains, pieces,
GW – grain weight per spike, g,
SL – spike length, cm.

These indicators make the main contribution to the yield of the variety [11, 15]. Let us consider the possibility of using the PPI index in a comprehensive assessment of breeding material from a collection nursery.

Table 1 presents the studied breeding material, ranked by individual economically useful traits: plant height, number of grains per ear, weight of grains per ear, mass of 1000 grains, resistance to ear fusarium. The distinguished samples are marked in bold, on the basis of which the PPI index will be calculated.

Table 1. Selection-valuable features ranking of the breeding material of winter wheat

Indicator	Source
Plant height (90-105 cm)	Schedra nyva, Charodijka, Bilotserkivs'ka, Lazurna, Chygyrinka, Khmel'nychanka, Lymarivna, Zluka, Spasivka, Blago, Komertsijna, **Areal Yuvileinyj,** Nebokraj, Vatazbok, **Pylypivka, Zorepad**, Golubka odes'ka, Lebidka odes'ka, Lastivka odes'ka, Zhajvir (Zdobutok), Zolotoglava, Evklid, Areal, Alacris, Astella, Bona Dea, Ignis, IS Karpatia, Malyska, Markola, Stanislava, Sarlota, Vanda, Veldava, Venistar, Verita, Viador, Zerda, **Alekseich, Tvorets,** Kuma, Sharada, Bat'ko, **Tabor**, **Vid**, Antonina, Albatros odesskij, **Don 93, Zernogradka 6**
The number of grains in the ear, pcs (>40 pcs.)	Schedra nyva, Zluka, Blago, **Areal Yuvileinyj**, **Zorepad**, Evklid, Areal, Zhajvir (Zdobutok), Poveliya, Alacris, Bona Dea, Genoveva, Malvina, Malyska, Verita, Astella, IS Karpatia, Stanislava, **Pylypivka,** Hermes, PGMAR 1543, Deya, Zira, Sarlota, Vanda, Veldava, Verita, Zerda, Solara, **Alauda**, **Alekseich, Tvorets, Vid, F 228 H 1-3**, Ringo Star, Testo, Sumai aut, Kuma, Antonina, Albatros odesskij
Grain weight per spike (>1,5 g)	Areal, Gordovyta, Schedra nyva, Sarlota, RingoStar, Verita, Astella, Solara, **Areal Yuvileinyj,** Bona Dea, **Zorepad**, Zluka, Markola, **Pylypivka,** Hermes, Malyska**, F 228 H 1-3**, Poveliya, Malvina, Alacris, Testo, Vanda, Antonina, Zira, Albatros odesskij, **Vid, Alekseich, Tvorets, Don 93**
1000 grains mass (>35,0 g)	Genoveva, Verita, Sarlota, Ritter, Blago, Bona Dea, Zluka, Markola, IS Karpatia, Gordovyta, Hermes, Charodijka, Malyska, Al'yns, PG MAR 1543, Malvina, **Alauda**, Livius, Alacris, Antonina, Bat'ko, Deya, Schedra nyva, Lymarivna, **Areal Yuvileinyj**, Gestija, **Pylypivka,** Golubka odes'ka, Testo, Knyagynya Ol'ga, Lebidka odes'ka, **Zorepad,** Poveliya, List 25, **Alekseich**, Soloha, Zira, Albatros odesskij, **Vid, Tvorets**
Resistance to ear fusarium (up to 5% of ill grains)	Vatazbok, Hermes, **Alauda,** Ringo Star, Poveliya, Stanislava, Coker 9227, Malyska, Markola, Blago, Zluka, Al'yns, Alacris, Zolotoglava, Livius, Sumai aut, Areal, Kuma, **Zorepad, Pylypivka,** Sharada, Deya, Bat'ko, Schedra nyva, Lasurna, **Areal Yuvileinyj**, IS Karpatia, KS 8018-7-2, Ritter, Transilvania, Zerda Venistar, Malvina, Lebidka odes'ka, Knyagynya Ol'ga, Albatros odesskij, **Alekseich, Tvorets**

Table 2. Evaluation of the productivity of winter wheat varieties by various selection indexes (average for 2016-2018).

Variety sample	Plant height, cm	Productivity structure				Mx	Ki	SLD	PPI
		SL,cm	NG, pcs.	GW, g	kg/m^2				
Areal Yuvileinyj	75	12.0	58.0	2.3	1.13	0.031	0.19	4.8	11.1
Pylypivka	70	8.7	58.5	2.7	1.25	0.038	0.31	9.8	18.1
Tvorets	95	9.0	48.3	2.3	1.15	0.024	0.25	5.3	12.3
Alekseich	85	10.5	42.0	1.8	0.85	0.021	0.17	4.0	7.2
Zorepad	80	8.8	47.2	1.9	0.90	0.024	0.21	5.3	10.2
Vid	83	8.2	47.0	1.8	0.90	0.022	0.22	5.7	10.3
Don 93	85	8.6	38.2	1.8	0.77	0.021	0.21	4.4	8.0
F 228 H 1-3	70	8.1	47.2	1.6	0.80	0.023	0.18	5.8	9.3
Alauda	123	11.4	43.5	1.5	0.60	0.012	0.13	3.8	5.7
Tabor	70	9.1	36.5	1.4	0.66	0.020	0,15	4,0	5,6
Zernogradka 6	63	7.1	33.7	1.4	0.70	0.022	0,19	4,7	6,6
Correlation coefficient, r						0.37	0.83	0.74	0.93

Table 3. Classification of winter wheat varieties by productivity and selection index

Classification	Productivity, kg/m^2	Spike grain weight, g	PPI index
Low productivity	under 0,7	under 1,5	under 7,0
Medium productivity	0,7-1,0	1,5-2,0	7,0-11,0
High productivity	>1,0	>2,0	>11,0

Further processing of the data consists in calculating the index (PPI) using the formula. For comparison, calculations of other known indexes (Mx, Ki, SLD) were carried out, and the coefficients of correlation of these indexes with productivity (kg/m^2) were calculated. For clarity, breeding samples that differ in productivity were selected (Table 2).

All indexes had high indicators of correlation, but the greatest value was shown by the plant productivity index (PPI), r = 0.93.

According to the results of the calculations, the following variety samples showed high productivity: Pylypivka (PPI = 18.1), Creator (PPI = 12.3), Areal Yuvileinyj (PPI = 11.1), Vid (PPI = 10.3), Zorepad = 10.2), F 228 H 1-3 (PPI = 9.3), Don 93 (PPI = 8.0), etc. Having received an integral indicator of productivity, it became possible to group the breeding material relative to the values of the PPI index and productivity (Table 3).

Table 4 presents the grouping of the studied selection samples by indicators of productivity and the PPI index: low, medium and high.

The share of variety samples with low productivity was 22%, with high productivity – 19% and with average productivity – 59%. The variety samples with index values > 11.0 (Areal

Table 4. Ranking of winter wheat varieties from a collection nursery based on the weight of grain per spike

Low productivity	Medium productivity	High productivity
Khmel'nychanka, Lymarivna, Zluka, Viador, Sava, Zerda, **Alauda,** Coker 9227, Livius, KS 8018-7-2, Genoveva, Clemson, Sumai 3 aut, **Tabor**, Praskovya, Duplet, Yunnat odesskij, Olviya, Veha, **Zernogradka 6**, Mironovskaya sharozernaya	Gordovyta, Schedra nyva, Charodijka, Chygyrinka, Spasivka, Blago, Gestija, Komertsijna, **Zorepad**, Knyagynya Ol'ga, Lebidka odes'ka, Lastivka odes'ka, Zdobutok, Evklid, Poveliya, Astella, Bona Dea, IS Karpatia, Malvina, Malyska, Stanislava, Ignis, Sarlota, Solara, Vanda, Panna Venistar, Hermes, PG MAR 1542, Ritter, Transilvania, **F 228 H 1-3**, Ringo Star, Red River 68, KS90WGRC 1 N 89 L 356, Batum, Testo, Norin 10, **Don 93,** List 25, Bat'ko, Sharada, Antonina, Soloha, Ukrainka odesskaya, Kuma, Tanya, Zira, Bezostaya 1, **Alekseich, Vid**, Lidiya, Chigit, Dolya, Bezostaya 100, Graf, Don 107 (standart), Karavan, Rostovchanka, Karlik 1, Albatros odesskij, Leleka, Voyazh, Markiz	Al'yns, Lasurna, **Areal Yuvileinyi**, **Pylypivka,** Nebokraj, Vatazbok, Areal, Golubka odes'ka, Zolotoglava, Alacris, Markola, Veldava, Verita, Eltan, Vulcain, Svagor, **Tvorets,** Oksana, Trio

Yuvileinyi, Pylypivka, Tvorets) belong to the group of highly productive, the samples that have PPI index values from 7.0 to 11.0 (Zorepad, Vid, F 228 H 1-3, Don 93, Alekseich) belong to the group with an average productivity, the variety samples with the values of the PPI index up to 7 (Alauda, Tabor, Zernogradka 6) belong to the group with low productivity.

Conclusion

Selection of winter crops for the foothill zone of the Central Caucasus is aimed at adaptability of varieties to the conditions of cultivation, high and stable productivity. Adaptive, high-yielding varieties must be resistant to autumn-spring drought, lodging and diseases (ear fusarium). Despite the fact that the region is characterized by sufficient moisture, precipitation falls extremely unevenly, often there is a soil drought. During the critical period of wheat development, from booting to earing (IV-V stages of organogenesis), drought affects the formation of leaves and the number of germinated spikelets, which further reduces grain content and the weight of grain from the ear. Direct productivity losses are also observed when the ear is affected by fusarium, while the number of healthy grains and their weight decreases, the number of fusarium and lightweight grains increases.

Thus, grain productivity depends on the resistance of the variety to the bio-and abiostressors of the environment, and, consequently, breeding indexes reflecting the grain productivity directly or indirectly indicate the adaptive properties of the variety.

Advantages of the proposed PPI index:

1. It is calculated by the three main indicators of wheat productivity, it has a high correlation relationship with productivity, reflects the result of the genotype-environment interaction. Selection by this index will increase the proportion of grain relative to the vegetative mass of the plant, i.e. it will increase the harvest index.

2. Reflecting productivity as a result of genotype-environment interaction, PPI helps to identify resistant genotypes to bio- and abiostressors, which allows at least preliminary judging of the adaptive properties of the breeding material (adaptability marker).

3. The absolute values of the PPI index vary widely (for example, from 5 to 18). This increases its information content and increases the accuracy of the assessment, it is simple to perform.

Thus, our research allows us to recommend a plant productivity index (PPI) for the selection of winter wheat for productivity and adaptability.

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DOI: 10.26177/VRF.2019.2.2.010

YIELD OF MODERN CHICKPEA VARIETIES DEPENDING ON THE METHOD OF SEEDING AND FORECROPS

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The article presents the data of a field experiment on the study of yield of chickpea modern varieties selected at FSBSI RusRISC "Rossorgo" depending on the method of sowing and its forecrop. In the experiment it was found that, depending on a year of the research, the effect of factors in the overall variability of the chickpea varieties yield differed. In 2017, according to the results of a three-factor analysis of variance, it was found that the contribution of factor A to the total variability was 1.32%, that of factor B – 64.00%, of factor C – 4.66%, the interaction A*B – 7.11%, A*C – 2.05%, B*C – 12.23%, A*B*C – 4.80%, the remains (unrecorded factors) – 3.83%. The yield ranking of chickpea varieties was carried out in the following sequence: Benefis> Sfera> Bonus> Sharik> Sokol> Galileo. On the field variant with a 45 cm row spacing and with spring wheat as a forecrop, the Sharik variety formed the highest yield (7.34 t/ha). In 2018, it was found that the contribution of factor A to the overall variability was 8.97%, that of factor B – 43.19%, of factor C – 18.88%, the interaction A*B – 18.77%, A*C – 1, 65%, B*C – 2.03%, A*B*C – 3.97%, the remains (unrecorded factors) – 2.54%. The yield ranking of chickpea varieties was carried out in the following sequence: Bonus> Galileo> Benefis> Sfera> Sharik> Sokol. On the field variant with a row spacing of 70 cm, and with spring barley as a forecrop, the variety Sfera formed the highest yield (3.38 t/ha).

In 2017, chickpea varieties significantly differed in seed yield (Benefis, Galileo, Sfera (factor A)), but Bonus and Sokol varieties did not significantly differ in yield from Sharik. In 2018, the chickpea varieties Sharik, Sokol differed significantly, and the Benefis variety did not significantly differ in yield from the Sfera variety and the Galileo variety, and the Bonus variety from the Galileo variety.

Key words: chickpea, variety, factor, interaction, yield, row spacing, forecrop.

Introduction

Due to a significant increase in the area of sowing chickpeas, its development and improvement of sowing technologies is of great importance [1, 2]. Along with other agrotechnical methods, considerable attention in market crop production is also given to the choice of forecrops [9]. Optimal planting density is an essential requirement for obtaining high chickpea yields and depends on seed size, plant type and growing season. N.I. Germantseva in her works talks about seeding rates for various microzones [4, 5]. However, the spatial arrangement of plants is also very important in the technology of growing chickpeas [14]. It was established that with the same width between the rows, with increasing distances between plants, the height decreased, the number of branches and beans per plant increased, and the weight of 1000 seeds increased [4].

Chickpeas are sown mainly in rows, the distance between the rows varies depending on the time of sowing, soil type, chickpea shape, etc. In the chickpea production system of the Lower Volga region, the yield is considered to be higher when the distance between the rows is 15 cm [3, 7]. However, there are other studies in which the highest chickpea yield was obtained with a row spacing of 30-60 cm [12, 13]. It is believed that under certain conditions, an increase in chickpea yield when sown in narrower rows may be due to improved light capture during the critical period

of seed laying or at the end of the bean-filling period, with an increase in leaf surface index and more intensive photosynthesis [8, 18]. The distance between rows can affect both the productivity of the main stem and the branches of the first and second orders. It is believed that for sowing chickpea with wide row spacing, it is necessary to choose varieties with a large number of branches, and for narrow-row crops – a preference with weak branching [16, 17]. It is believed that increasing the plant density does not lead to an increase in the yield of chickpea seeds, as it reduces the efficiency of using solar radiation. On the practical side, high plant density implies a high seeding rate, that is, high production costs, and agricultural producers are more interested in net profit, not in the yield and gross seed collection [10, 11, 15].

The purpose of the research was to study the effect of sowing methods (factor B) and predecessors (factor C) on the yield of chickpea varieties (factor A) in a five-field grain-fallow crop rotation under conditions of the Lower Volga region.

Materials and methods

The research included chickpea varieties differing in the mass of 1000 seeds, selected at Federal State Budget Scientific Institution RusRISC «Rossorgo»: Benefis, Bonus, Galileo (> 350 g), Sfera (300-350 g), Sokol (240-300 g), Sharik (180- 260g).

Field experiments, phenological observations, recording the dynamics of biomass accumulation and leaf surface area according to development phases and yield recording were carried out upon generally accepted methodological recommendations [6].

The total area of experience was 1.39 hectares, the area of the accounting plot – 25 m^2, the number of options – 120, the repetition was fourfold.

Experimental studies were conducted on the experimental field of the FSBSI RusRISC «Rossorgo» in 2017-2018. The soil of the experimental plot was southern leached black soil. In the arable layer of soil the humus content was 3.3%.

Table 1. The yield of chickpea varieties with different row-spacing and forecrops (t/ha), 2017

Variety (factorp A)	Row spacing (factor B)	Forecrop (factor C)			
		Grain sorghum	Corn	Spring barley	Spring wheat
Benefis	15	2.02	1.55	3.69	2.86
	30	2.34	2.68	2.55	3.49
	45	6.27	5.97	4.52	6.55
	60	5.29	5.10	3.07	4.59
	70	4.24	3.83	2.87	5.06
Bonus	15	1.86	1.43	3.39	2.63
	30	2.15	2.47	2.35	3.21
	45	5.77	5.49	4.16	6.03
	60	3.92	3.29	3.92	4.32
	70	4.41	3.20	4.52	4.74
Galileo	15	1.80	1.38	3.28	2.55
	30	2.08	2.39	2.27	3.11
	45	5.58	5.31	4.02	5.83
	60	3.98	4.26	3.33	3.84
	70	5.03	2.66	1.79	2.81
Sfera	15	2.10	1.61	3.84	2.97
	30	2.43	2.79	2.65	3.63
	45	6.52	6.21	4.70	6.81
	60	1.79	4.07	4.76	4.40
	70	3.24	3.17	2.99	4.55
Sokol	15	2.20	1.69	4.02	3.12
	30	2.55	2.92	2.78	3.80
	45	6.83	6.51	4.93	7.14
	60	2.65	3.35	3.20	3.49
	70	2.33	2.93	2.45	2.92
Sharik	15	2.26	1.74	4.13	3.20
	30	2.62	3.00	2.86	3.91
	45	7.02	6.69	5.06	7.34
	60	3.47	3.80	2.08	3.25
	70	3.27	2.07	1.48	3.78
$F_{fact.}$ – factors: A − 37.80*; B − 19.94*; C − 21.74*; interact. − A*B − 44.30*; A*C − 19.16*; B*C − 14.26*; A*B*C − 11.20*					
$HCP_{0,05}$ − factors: A – 0.030; B − 0.084; C − 0.022; interact. − A*B − 0.18; A*C − 0.056; B*C − 0.095; A*B*C − 0.214					

The agricultural technology of chickpea cultivation was zonal, developed at FSBSI RusRISC «Rossorgo». Soil preparation included autumn plowing, early spring harrowing (BZSS-1.0) in two tracks across the plowing direction, two pre-sowing cultivations (KPS-4 + MTZ-82) – the first to a depth of 8-10 cm, the second to the depth of embedding of the seeds (6 -7 cm). Sowing was carried out on 4.05.2017 and on 17.05.2018 with the SZ-3.6 planters (inter-row spacing – 15 cm, 30 cm, 45 cm and 60 cm) and SON-4.2 (inter-row spacing – 70 cm). The seeding rate was 350 thousand seeds/ha. Rolling was carried out simultaneously with sowing, and on the third day after sowing, pre-emergence harrowing was carried out. Yield recording was conducted by trial sheaves. Weather conditions in the years of research corresponded to long-term average values. The hydrothermal coefficient (HTC) was: 2017 – 1.17; 2018 – 0.65.

Results

In 2017, according to the results of a three-factor analysis of variance, it was found that the contribution of factor A to the total variability was 1.32%, that of factor B – 64.00%, of factor C – 4.66%, the interaction A*B – 7.11%, A*C – 2.05%, B*C – 12.23%, A*B*C – 4.80%, the remains (unrecorded factors) – 3.83% (Table 1).

In general in 2017, a high seed yield was obtained in the cultivation of the variety Benefis. The ranking of chickpea varieties by yield was carried out in the following sequence: Benefis> Sfera> Bonus> Sharik> Sokol> Galileo. In the variant placed with a row spacing of 45 cm and with spring wheat as a forecrop, the variety Sharik formed the highest yield (7.02 t/ha).

In 2018, according to the results of a three-factor analysis of variance, it was found that the contribution of factor A to the total variability was 8.97%, that of factor B – 43.19%, of factor C – 18.88%, the interaction A*B – 18.77%, A*C – 1.65%, B*C – 2.03%, A*B*C – 3.97%, the remains (unrecorded factors) – 2.54% (Table 2).

In general in 2018, a high yield of seeds was obtained in the cultivation of the variety Bonus. The ranking of chickpea varieties by yield was carried out in the following sequence: Bonus> Galileo> Benefis> Sfera> Sharik> Sokol. In

Table 2. The yield of chickpea varieties with different row-spacing and forecrops (t/ha), 2018

Variety (factor A)	Row spacing (factor B)	Forecrop (factor C)			
		Grain sorghum	Corn	Spring barley	Spring wheat
Benefis	15	0.58	0.71	0.91	0.84
	30	1.11	1.58	1.68	1.61
	45	1.46	1.50	2.02	1.85
	60	1.74	2.36	2.78	2.43
	70	0.97	1.07	1.71	1.20
Bonus	15	0.64	0.81	1.34	1.18
	30	1.03	1.12	1.61	1.33
	45	1.41	1.43	2.31	1.99
	60	1.76	2.25	2.68	2.44
	70	1.17	1.18	1.91	1.46
Galileo	15	0.67	0.71	1.51	0.81
	30	0.86	0.93	2.34	1.26
	45	0.76	1.83	2.26	1.99
	60	1.51	2.26	2.61	2.39
	70	1.11	1.44	2.01	1.44
Sfera	15	0.68	0.92	0.97	0.95
	30	0.85	1.12	1.24	1.20
	45	1.00	1.17	2.08	1.34
	60	1.61	1.65	1.79	1.75
	70	2.14	2.16	3.38	2.22
Sokol	15	0.50	0.64	0.74	0.51
	30	0.32	0.41	0.77	0.46
	45	0.51	0.57	0.91	0.79
	60	0.94	1.63	2.19	1.67
	70	1.18	1.53	2.63	1.75
Sharik	15	0.51	0.66	0.93	0.87
	30	0.72	0.72	0.89	0.73
	45	0.68	0.81	1.31	1.10
	60	1.30	1.43	2.33	1.60
	70	1.62	1.87	2.92	1.95
$F_{fact.}$ – factors: A – 19.47*; B – 12.45*; C – 54.78*; interact. – A*B – 10.82*; A*C – 9.61*; B*C – 14.77*; A*B*C – 5.77*					
$HCP_{0,05}$ – factors: A – 0.047; B – 0.038; C – 0.038; interact. – A*B – 0.095; A*C – 0.093; B*C – 0.083; A*B*C – 0.204					

Table 3. Multiple comparisons of the yield of chickpea varieties according to the Duncan criterion (factor A)

Year	Variety					
	Benefis	Bonus	Galileo	Sfera	Sokol	Sharik
2017	3.93e	3.66c	3.37a	3.76d	3.59b	3.65bc
2018	1.50cd	1.55e	1.54de	1.48c	1.03a	1.25b

Note: Variants accompanied by the same Latin letters differ insignificantly according to the Duncan criterion.

Table 4. Multiple comparisons of the yield of chickpea varieties with different row spacing according to the Duncan criterion (factor B)

Year	Row spacing				
	D	E	F	K	L
2017	2.56a	2.79b	5.89e	3.72 d	3.35c
2018	0.82a	1.08b	1.36c	1.97e	1.74d

Note: D – 15 cm, E– 30 cm, F -45 cm, K – 60 cm, L – 70 cm; Variants accompanied by the same Latin letters differ insignificantly according to the Duncan criterion.

Table 5. Multiple comparisons of the yield of chickpea varieties with different forecrops according to the Duncan criterion (factor C)

Year	Forecrop			
	Grain sorghum	Corn	Spring barley	Spring wheat
2017	3.60c	3.45b	3.39a	4.20d
2018	1.05a	1.28b	1.81d	1.44c

Note: Variants accompanied by the same Latin letters differ insignificantly according to the Duncan criterion.

the variant placed with a row spacing of 70 cm and with spring barley as a forecrop, the variety Sfera formed the highest yield (3.38 t/ha).

In 2017, chickpea varieties significantly differed in seed yield (Benefis, Galileo, Sfera (factor A)), but Bonus and Sokol varieties did not significantly differ in yield from Sharik (Table 3). In 2018, the chickpea varieties Sharik, Sokol differed significantly, and the Benefis variety did not significantly differ in yield from the Sfera variety and the Galileo variety, and the Bonus variety from the Galileo variety.

In 2017-2018 the yield of chickpea varieties was significantly different when sown in all studied inter-row spacings (factor B) (Table 4). The yield ranking of different variants of inter-row spacings was in 2017 – F > K > L > E > D; in 2018 – K > L > F > E > D.

In 2017-2018 the yield of chickpea varieties was significantly different against all the studied forecrops (factor C) (Table 5).

The yield ranking of different variants of the forecrops was in 2017 – spring wheat > grain sorghum > corn > spring barley; in 2018 – spring barley > spring wheat > corn > grain sorghum.

Conclusion

The yeild ranking of chickpea varieties according to the year of study was: in 2017 – Benefis > Sfera > Bonus > Sharik > Sokol > Galileo; in 2018 – Bonus > Galileo > Benefis > Sfera > Sharik > Sokol; according to various inter-row spacings: in 2017 – F > K > L > E > D; in 2018 – K > L > F > E > D; and according to different variants of the forecrops: in 2017 – spring wheat > grain sorghum > corn > spring barley; in 2018 – spring barley > spring wheat > corn > grain sorghum.

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DOI: 10.26177/VRF.2019.2.2.011

ECONOMIC EFFICIENCY OF WINTER TRITICALE CULTIVATION IN AGRIBUSINESS ENTITIES

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Crop production is one of the fastest growing industries. The production of many types of crop products is profitable and provides positive financial results to agricultural enterprises. However, at present, negative trends continue to appear in the development of the crop growing industry: reduction of agricultural land and sown areas, the formation of their irrational structure, a decrease in the rate of renewal of fixed assets and capital supply, the instability of production volumes of most types of products, the level of profit and profitability of production. In the current natural and economic conditions of the Middle Volga region, the main gross grain harvest should be provided by winter crops. Achieving this goal is envisaged by increasing the sown area of winter grains, increasing their productivity by introducing more advanced cultivation technologies and introducing new promising varieties with stable productivity in different weather conditions. One of the promising crops, at present, is winter triticale – winter-resisting, high-yielding, resistant to a complex of abiotic and biotic environmental factors. Based on the materials of a particular entity of agribusiness, indicators of economic efficiency of production and sale of grain of winter triticale "Krokha" are determined.

Key words: grain crops, winter triticale, winter resistance, high yield, economic efficiency.

Introduction

Grain and its products are one of the main types of food for the population and the basis of the country's food security, characterized by the most stable demand. The state of the grain market is affected by gross production, sown areas, yield, domestic consumption in the country, the balance of supply and demand in the world market, product price, logistics during sales, and many other interrelated factors [1].

Figure shows the dynamics of gross grain harvests, productivity and sown areas in Russia over the past 15 years. An analysis of the data presented shows that over the past five years,

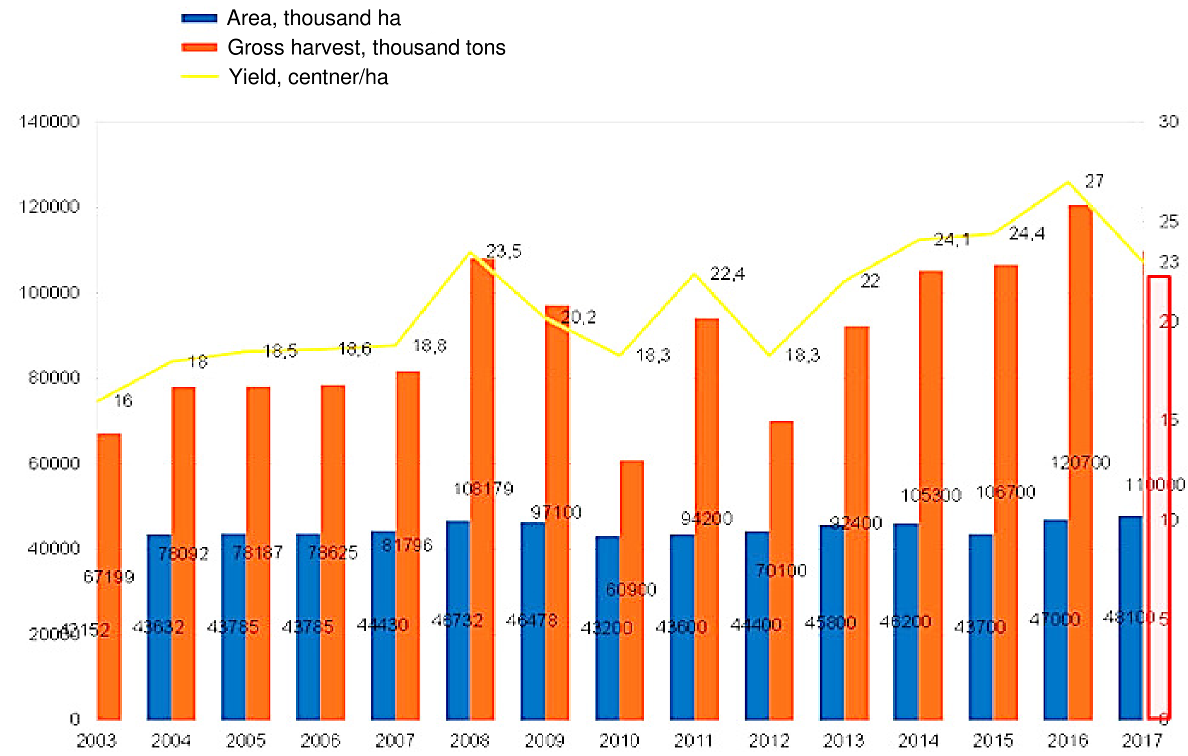

Figure. Sown area, gross harvest and grain yield in the Russian Federation

gross grain production has a steady tendency to grow and approach 105-110 million tons, and in 2016 it reached 120.7 million tons.

Only in recent years, sown area began to increase slightly. So, over the past five years, they increased by 3 million hectares and reached 48 million hectares. However, this indicator does not exceed the level of sown area sown with grain in 1990 (63.0 million hectares of sown area and gross grain harvest of 120 million tons with an average yield of one hectare of 19.5 centners). In this regard, it is relevant to expand the sown area of grain crops due to promising, high-yielding varieties. The variety of winter triticale “Krokha” belongs to this category [2, 3, 4].

Methods and materials

The object of a more detailed study was JSC “Uchkhoz “Ramzai” of Penza State Agricultural Academy” of Mokshan District, the dynamics of resource and effective indicators of which are presented in Table 1.

Resource indicators of the organization in the reporting year showed multidirectional dynamics. In 2017, the total agricultural land and arable land of the enterprise decreased by 31% and 25% compared to 2015 and 2016, respec-

Table 1. Dynamics of resource and effective indicators of JSC “Uchkhoz “Ramzai” of PSAA”

Indicator	2014	2015	2016	2017 to 2015, %
The area of agricultural land, ha	5546	5546	3834	69.1
including arable land	4925	4925	3694	75.0
The average annual value of assets, thousand rubles	105977	106759	112895.5	106.5
The average annual cost of equity, thousand rubles	78205.5	79215	80153.5	102.5
The average annual value of fixed assets, thousand rubles	48645	49907.50	51120.5	105.1
The average annual number of employees, people	137	144	112	81.7
The number of cattle at the end of the year, animals.	984	924	978	99.4
including cattle	420	420	422	100.5
Pigs-total, animals.	474	352	141	29.7
Revenue, thousand rubles.	89252	103448	91071	102.0
Profit (loss) from sales, thousand rubles	1440	-1109	1439	99.9
Profit (loss) before tax, thousand rubles	1918	2171	1797	93.7
Profitability (loss) of sales, %	1.61	-1.07	1.58	-
Profitability (loss) of expenses, %	1.64	-1.06	1.6	-

tively. The average annual number of employees throughout the analyzed period was constantly changing, but by 2017 the number had sharply decreased to 112 people. The average annual value of assets, equity and fixed assets has increased slightly over the past three years. The amount of revenue varies by years. Such productive indicators of the economy as profit from sales, profit before tax have negative development trends. The profitability of costs and sales in the reporting period at a low level (almost 1.6%).

The organization also has a grain focus, while an important aspect is the assessment of the efficiency of grain farming as one of the main objects of the implementation of the technological management functions in crop production (Table 2).

Table 2. Economic efficiency of grain production and sale

Indicator	2015	2016	2017
Yield of 1 ha, centner	24.5	22.7	30.8
Labor costs per 1 centner, mhrs	1.36	1.4	0.59
The total cost of 1 centner, rub.	875.3	828.6	627.9
Selling price of 1 centner, rub.	1086.7	942.8	604.7
Profit from sales per 1 centner, rub.	211.4	114.2	-23.5
Production profitability, %	24.1	13.7	-3.7

Many indicators of the efficiency of grain production are improving: grain yields have increased over three years, labor costs per centner have decreased, and the total cost per unit of production has decreased. But a sharp drop in sales prices in 2017 to the level of 604.7 rubles affected the loss from the sale of grain with a loss ratio of production – 3.7%. Thus, society needs to monitor all the negative aspects of reducing the efficiency of production and sales of grain, the use of land resources and take all measures to improve them. To achieve this goal, the following research methods were used in the research process: theoretical (logical analysis, comparative analysis); methods of quantitative data processing (comparative analysis; design and construction analysis; economic and statistical analysis).

Results

In the prevailing natural and economic conditions of the Middle Volga region, winter crops should provide the main gross harvest of grain. Achieving this goal is envisaged by increasing the sown area of winter grains, increasing their productivity with the introduction of more advanced cultivation technologies and introduction of new promising varieties with stable productivity in different weather conditions [5, 6].

In 2008, the Krokha winter triticale variety was submitted for state variety testing and passed the test in the Middle Volga, Volga-Vyatka and Ural regions. The variety is intended for cultivation for grain (feed and food) and green mass. It does not slough, does not lodge. The growing season is 302-309 days. The ear is productive, well-grained (the number of grains 33.0-50.0 pcs.). The density of the productive plant stand is 477-527 stems/m². The weight of 1000 grains is 30.0-38.7 g. The productivity is 28.0-66.7 kg/ha, depending on weather conditions [7, 8].

For the cultivation of this crop on the basis of JSC "Uchkhoz "Ramzai" of PSAA", all the necessary production capacities are available. The project will be implemented at its own expense in the amount of 2027.5 thousand rubles. They can be obtained from retained earnings, which in 2017 amounted to 7893 thousand rubles.

Table 3 shows the production program, i.e. volume of production and sales of winter triticale.

With an increase in cultivated areas to 300 hectares, almost 17 thousand centners of products intended for sale can be obtained. The projected production cost is presented in table 4.

The production cost per unit in the first year of the project is 360.8 rubles and tends to decline. Taking into account the costs of marketing, the full (commercial) cost of 1 centner of winter triticale will be almost 362 rubles. It is possible to sell the production to processing enterprises for the further use of processed products (flour) in the baking industry. Bakery products made from triticale flour are characterized by increased nutritional value, due to the higher protein content and essential amino acids, in particular, the main limiting acid – lysine [9, 10]. The combination of the positive properties of rye – a high content of biologically active aromatic substances and wheat – the rheological properties of the dough, makes it possible to produce a specific dietary product [11, 12].

Table 3. Production program for the use of winter triticale "Krokha"

Year	Yield, c/ha	Planned sown area, ha	Gross grain harvest, c	Seed fund, c	Grain for sale, c
1	56.2	100	5620	370	5250
2	56.2	200	11240	555	10685
3	56.2	300	16860	-	16860

Table 4. Calculation of production cost of 1 centner of winter triticale “Krokha”, rub.

Cost item	1 year	2 year	3 year
Material expenditures			
Including seeds and planting material	194250.00	133496.00	187634.62
fertilizers	364620.00	729240.00	1093860.00
oil products	280478.00	560956.00	841434.00
Labor costs with deductions for social needs	409221.60	818443.20	1227664.80
The content of fixed assets			
including depreciation of fixed assets	180954.10	361908.20	542862.30
repairs of fixed assets	170396.30	340792.60	511188.90
Works and services of auxiliary production	188472.80	376945.60	565418.40
Other expenses	44534.00	89068.00	133602.00
Total direct costs	1788392.70	3321781.60	4970063.02
General production and general business expenses	239121.00	478242.00	717363.00
Total production cost	2027514.13	3800023.60	5687426.02
Production cost per unit of production, rub.	360.80	338.08	337.33

Table 5. Project financial results

Indicator	1 year	2 year	3 year
Revenue, rub.	2545882.50	5181477.05	8175919.80
Gross profit, rub.	875675.61	2024049.59	3205856.78
Profit from sales, rub.	645537.45	1562661.86	2481733.78
Profit before tax, rub.	645537.45	1562661.86	2481733.78
Taxable profit, thousand rubles	814587.45	1906718.86	3024625.78
Single Agricultural Tax, rub.	48875.25	114403.13	181477.55
Net profit, thousand rubles	596662.20	1448258.73	2300256.23
Return on sales, %	25.4	30.2	30.4
Cost-effectiveness, %	34.0	43.2	43.6

Table 5 presents the financial results from the implementation of the project.

Production and sale of winter triticale grain will allow the company to receive a net profit of more than 2 million rubles by the third year of the project. Profitability of expenses and sales will increase to a level exceeding 43 and 30%, respectively. In all respects, the project is effective.

Conclusion

The increase in the economic efficiency of grain farming in the Middle Volga region is associated with variety exchange and variety renewal [13, 14]. In this context, we have developed a proposal for the introduction of an innovative crop of winter triticale of the variety “Krokha” on the basis of JSC "Uchkhoz “Ramzai" of PSAA”. The variety is winter-resisting, the crop is high-yielding, resistant to a complex of abiotic and biotic environmental factors, and can be used for grain and forage purposes [15]. We propose the organization of production of winter triticale and the sale of grain to processing enterprises for the purpose of further use in the baking industry to improve and enrich raw materials with high-protein material and lysine. The project will be implemented at its own expense in the amount of 2027514.13 rubles. With a planned yield of 56, 2 centners per hectare, it is planned to get almost 17 thousand centners of products by the third year of the project, and selling at a price of 484.93 rubles for 1 centner, it will make it possible to receive revenues in the amount of over 8 million rubles, with profitability of costs and sales of 34.0% and 25.4%, respectively.

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DOI: 10.26177/VRF.2019.2.2.012

PRODUCTIVITY OF GUIZOTIA ABYSSINICA DEPENDING ON SEEDING RATE UNDER CONDITIONS OF THE MIDDLE VOLGA REGION

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The aim of the research was to study the productivity of Abyssinian Guizotia depending on seeding rates under conditions of the Middle Volga region. The object of the research was Medea, the new variety of Guizotia. The study of seeding standards was carried out in 2016-2018. Five seeding rates were studied from 1.0 to 3.0 million viable seeds per hectare, with a pitch of 0.5 million viable seeds. The vegetation period of the crop proceeded under conditions of moderate moisture – HTC-1.2 and constituted 111-125 days. The productivity of Guizotia varied in the range of 1.63-1.75 t/ha, depending on the seeding rate. The highest seed yield was observed in the variant with a seeding rate of 2.0 million viable seeds per hectare and constituted 1.75 t/ha. Oil content of seeds ranged from 39.5-40.8%. The higher fat content was in the seeds in the variants with seeding rates of 2.0 and 2.5 million viable seeds per hectare and constituted 40.7-40.8%. Number of capitula per plant varied from 154.8 pieces per variant with a seeding rate of 3.0 million viable seeds/ha to 186.7 units – with a seeding rate of 1.0 million viable seeds/ha. The mass of 1000 seeds varied from 3.41 to 3.65 g. The largest seeds were the Guizotia when sown with a seeding rate of 2.5 and 2.0 million viable seeds per hectare. The optimal seeding rate of Guizotia under conditions of the Middle Volga region is 2.0 and 2.5 million viable seeds per hectare.

Keywords: Guizotia abyssinica, seeding rates, yield, oil content, crop structure

Introduction

Guizotia (or nug) Abyssinian (Guizotia abissinica Gass.), a new promising crop of the Aster family (Asteraceae), is an annual plant with a height of thirty centimeters to two meters. Its stem is branched, has simple lanceolate leaves. Its inflorescences are capitula (ranging from 2.2 to 6 cm in diameter), gathered in loose panicles. Nug seeds are glossy black [1, 8].

The Guizotia plant in the flowering phase is presented in Figure.

Guizotia seeds contain up to 43% oil, which is used for food and technical purposes, 20.9% crude protein, and a lot of iodine [6, 7, 14].

The content of linoleic acid is of great advantage in the composition of the oil, due to which the oil of Guizotia resembles sunflower seed oil in its qualities [4, 10].

Guizotia seeds are used to feed birds (crossbreds, parrots) [5, 12].

In addition, Guizotia is a good honey plant and can be used as green manure and silage, capable of forming up to 450 kg/ha of green mass [1, 6, 7].

According to its biological properties, Guizotia is characterized as heat resistant and drought resistant, as well as highly responsive to additional moisture [9, 15].

Now the Guizotia abyssinica is grown in Ethiopia, Nepal and India, mainly for edible oil [11, 13, 14].

In Russia, today, interest in it as an agricultural crop also grows, and it passes environmental testing in Lipetsk, Tambov, various districts of the Volgograd region, Astrakhan, Kazakhstan, Penza and other regions of Russia [1, 2, 3, 10].

The aim of the research was to study the productivity of Guizotia depending on the seeding rates under the conditions of the Middle Volga region.

Materials and methods

The object of the research was a new variety of Guizotia abyssinica, Medeya. The variety was created by breeding at the Penza Institute of Agriculture in 2018, has been included in the State Register of Breeding Achievements since 2019, and recommended for all growing zones.

The study of the elements of technology, namely the seeding rate of the crop, was conducted in 2016-2018. We studied five seeding rates from 1.0 to 3.0 million viable seeds per hectare, with a pitch of 0.5 million viable seeds.

Figure. A Guizotia plant grown under conditions of Penza Institute of Agriculture

The soil of the experimental plot is leached medium thick chernozem, with humus content of 6.35%, pH = 6.2.

All observations and counts were carried out in accordance with the methodological recommendations [16].

Research results

During the years of research, the meteorological conditions of the growing season of the Guizotia varied, but were generally favorable for the growth and development of the crop.

On average, for the years 2016-2018, the "sowing-seeding" phase proceeded in arid conditions. The amount of precipitation for this period was 19.5 mm, with an average daily temperature of 15.5°C. The period from sowing to germination was 8-11 days (Table 1).

The interfacial period of "seedling-flowering" proceeded under conditions of moderate moisture (HTC - 1.1), with average daily temperatures of 18.9°C. The length of this period ranged from 56-72 days. The duration of the phase from flowering to ripening was 50-64 days with HTC 1.1.

In general, the vegetation period of the crop proceeded under conditions with moderate moisture – HTC-1.2, with average daily temperatures of 20.9°C and the sum of effective tem-

Table 1. Weather conditions for the vegetation phases of Guizotia, on average in 2016-2018

Development phase	The sum of the temperatures ≥10°C	Average daily temperature, °C	The amount of precipitation, mm	HTC
Sowing-seeding	140.3	15.5	19.5	0.7
Seeding-flowering	890.9	18.9	105.3	1.1
Flowering-ripening	1195.9	21.5	136.9	1.1
Seeding-ripening	2227.1	20.9	261.7	1.2

Table 2. Efficiency of civilization, depending on seeding rates, 2016-2018.

Seeding rate, million viable seeds/ha	Productivity, t/ha	Oil content, %	Oil collection, t/ha
1.0	1.63	39.5	0.58
1.5	1.67	39.8	0.59
2.0	1.75	40.8	0.64
2.5	1.72	40.7	0.62
3.0	1.69	39.5	0.59
HCP_{05}	0.04	1.1	0.05

Table 3. Elements of the crop structure depending on seeding rates, 2016-2018

Seeding rate, million viable seeds/ha	Height, cm	Number of capitula, pcs	Number of seeds in 1 capitulum, pcs	Weight of seeds from 1 plant, g	Weight of 1000 seeds, g
1.0	108.9	186.7	21.7	8.87	3.41
1.5	107.9	156.9	26.8	9.99	3.61
2.0	109.5	175.9	32.9	11.03	3.65
2.5	109.6	166.9	28.9	10.96	3.64
3.0	108.6	154.8	26.9	8.98	3.56
V, %	14.6	41.3	28.9	34.4	8.9

peratures of up to 2227.1°C. The growing season of Guizotia amounted to 111-125 days.

The productivity of Guizotia varied within 1.63-1.75 t/ha, depending on the seeding rate. The highest seed yield was observed in the variant with a seeding rate of 2.0 million viable seeds per hectare and amounted to 1.75 t/ha. With an increase or decrease in the seeding rate, a significant decrease in crop productivity was noted, except for the variant with a seeding rate of up to 2.5 million, here the yield did not decrease significantly – to 1.72 t/ha (Table 2).

With a further increase in the seeding rate of up to 3.0 million, the yield has already decreased by 0.06 t/ha, which shows a greater competitiveness between plants and their lower tillering.

Oil content of seeds ranged from 39.5-40.8%. Greater fat content was in the seeds in the seed rates of 2.0 and 2.5 million viable seeds per hectare and was 40.7-40.8%. Oil collection did not differ significantly and varied in variants from 0.58 to 0.64 t/ha.

Structural analysis of the plant productivity showed that the plants of Guizotia were quite high, their height averaged 107.9-109.6 cm (Table 3).

The number of capitula per plant varied from 154.8 pieces on the variant with a seeding rate of 3.0 million viable seeds/ha to 186.7 pieces – with a seeding rate of 1.0 million viable seeds/ha, which, first of all, depends on the density of standing plants. When sowing seeds with a rate of 1.0 million viable seeds, the plants are more bushy and form more productive stems. However, this leads to uneven ripening of Guizotia and to decrease in the productivity of one plant (8.87 g) and in weight of 1000 seeds (3.41 g).

The number of seeds from one capitulum varied over a wide range from 21.7 to 32.9 pieces, the coefficient of variation here was high and amounted to 28.9%. The productivity of one plant was 8.87-11.03 g, the variability was 34.4%. The highest variation percentage, that is noted for the number of capitula on a plant, is 41.3%.

Guizotia formed the largest seeds when sowing with a seeding rate of 2.5 and 2.0 million viable seeds per hectare. The 1000 seed weight here was 3.64 and 3.65 g, respectively.

Conclusion

As can be seen from the above, the optimal rate of seeding of Guizotia under conditions of the Middle Volga region is 2.0 and 2.5 million viable seeds per hectare. At these rates, the highest seed yield of 1.75 and 1.72 t/ha with a high oil content of up to 40.7-40.8% was obtained. This is confirmed by the high indicators of the crop structure elements: the productivity of one plant (10.96-11.03 g) and the weight of 1000 seeds (3.64-3.65 g).

The inclusion of Guizotia Abyssinica into field crops will expand the possibilities for alternating crops of different nature and expand the oilseed and raw material conveyor.

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DOI: 10.26177/VRF.2019.2.2.013

PRODUCTIVITY OF THE SUNFLOWER DEPENDING ON THE CONDITIONS OF THE RELIEF, SOIL TREATMENT AND ORGANIC FERTILIZERS

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The purpose of the research was to identify the optimal combination of soil-protecting and medium-improving techniques in order to increase the productivity of sunflower when it is cultivated on the slopes of a 3-5° steepness of northern exposure in the formed environmentally sustainable agricultural landscapes of the Central Russian upland of the central black earth. A three-factor experiment was carried out: factor A (relief conditions): 1. Slope 0-3°, 2. slope 3-5° of north exposure; factor B: 1. Plowing (control) – PLN-4-35 to a depth of 25-27 cm, 2. Deep nonmoldboard cultivation – SunFlower to a depth of 25-27 cm, 3. without processing (No-till); factor C: 1. Without fertilizers; 2. Green manure (white mustard); 3. Straw compost (20 t/ha). As a result of research, the effect of differences in relief conditions on the productivity of sunflower was not established. Conducting the main tillage, regardless of the method (moldboard or nonmoldboard) contributed to a significant increase in the yield of sunflower (by 0.2-0.3 t/ha) and oil content of its seeds (by 1.2-1.4%). The positive effect of compost was revealed, especially

when it was applied when plowing, which ensured the highest yield of 3.21 t/ha and oil collection (1.66 t/ha). This gave grounds to continue research on other important aspects of sunflower cultivation on the slopes (3-5°) of the northern exposure, including the study of fertility indicators and soil erosion resistance, in order to expand its crops with such lands under the obligatory condition of full development of landscape farming systems.

Key words: sunflower, yield, oil content, tillage, organic fertilizers, landscape farming.

Introduction

Taking into account the long period of return of sunflower, the possibilities of increasing its acreage are very limited, despite the high profitability and competitiveness of the crop [8, 13]. Due to the rather high erosive risk factor of sunflower crops and a significant degree of decrease in its yield on washed-off soils, the refusal to grow it on slopes steeper than 3° was adopted [10]. The introduction of sunflower into crop rotations on slope lands is predetermined by a number of conditions, including the contour-strip distribution of crops [7].

High-performance technologies for creating ecologically sustainable agrolandscapes were successfully tested in the most severe conditions of erosion development – in the most eroded area (Krasnogvardeysky) of the most eroded Central Black Earth area (Belgorod region), which contributed to their development throughout the Belgorod region [1, 3]. The large-scale development of adaptive-landscape farming systems in the farms of the Belgorod Region, contributing to the prevention of erosion, creates the condition for more efficient use of slope lands. The use of resource-saving soil-protective methods of tillage and organic fertilizers for modern highly productive, environmentally sustainable sunflower hybrids can improve soil fertility and erosion resistance, and thus reduce the loss of sunflower productivity on weakly washed-off soils.

Previous studies established that the soils of the northern slopes have a higher potential fertility (even in virgin conditions) than the southern, and in some cases, hihger than lowlands with tilled soils [9, 16].

There is a number of studies on the influence of individual elements of sunflower cultivation technology on its productivity indicators [2, 4-6, 11-12, 14]. But for the most part, they concern the issues of choosing a hybrid, sowing dates, the system of mineral fertilizers and plant protection. There is currently no comprehensive information on the complex effect of the methods of basic tillage and organic fertilizers on the productivity of sunflower in various landscape conditions, which has led to the need and relevance of this study.

Methods and materials

The studies were conducted on the basis of ZAO (closed joint-stock company) Krasnoyaruzhskaya Grain Company (Belgorod region) in 2016-2018. Soil of the plots: typical non-washed black soil (0-3°): humus content 4.9% (average), pHsol. – 6.4, the content of mobile phosphorus and potassium (according to Chirikov), respectively, 134 and 234 mg/kg of soil; typical weakly washed-off black soil (3-5°): humus content 4.5% (average), pHsol. – 6.1, the content of mobile phosphorus and potassium, respectively, 210 and 190 mg/kg of soil. A three-factor experiment: factor A (relief conditions): 1. Slope 0-3°, 2. Slope 3-5° north exposure; factor B: 1. Plowing (control) – PLN-4-35 to a depth of 25-27 cm, 2. Deep subsurface tillage – SunFlower to a depth of 25-27 cm, 3. Without processing (No-till); factor C: 1. Without fertilizers; 2. Green manure (white mustard); 3. Straw compost (20 t/ha). The sown area of the plots was 100 m2, the reference area – 50 m2, the repeatition was threefold. Before sowing the green manure and introducing the compost, Amazone-Catros post-harvest plowing was carried out, excluding the option of zero tillage. The planting of sunflower seeds was made by the Massey Ferguson seeder with the seeds of the hybrid Nema Nek from the company Syngenta.

Results

The most favorable conditions for the growth and development of the crop were formed in 2016 and 2018, when the average yield level was 3.31 and 3.55 t/ha, respectively; in 2017 – 2.19 t/ha. There is a significant variability in the yield of the studied hybrid over the years of research. The coefficient of variation was 24.3%. The lowest yield was observed in the absence of the main tillage (No-till) and averaged over three years 2.85 t/ha (Table). The yield was significantly higher by 0.19 t/ha (7%) when using deep loosening. For plowing, the yield was 3.16 t/ha, which was significantly higher compared to No-till (by 0.31 t/ha or 11%) and compared to subsoil tilling – by 0.12 t/ha (4%).

The yield also depended on the use of organic fertilizers, but reliably only in favorable weather conditions in 2016 and 2018, when it was significantly higher when applying compost, and on average over three years the increase in this variant was 0.07-0.08 t/ha. The fact that green manures gave a full-fledged yield of green mass only in 2017 (for the sunflower crop of 2018) made no matter: the yield was significantly lower compared to compost – on average by 0.18 t/ha.

Table. Sunflower yield, t/ha

Factor A	Factor B	Factor C	2016	2017	2018	Average for 3 years
0-3°	Plowing	Without fertilizer	3.47	2.36	3.55	3.12
		Compost	3.53	2.24	3.87	3.21
		Green manure	3.46	2.28	3.56	3.10
	Deep loosening	Without fertilizer	3.26	2.25	3.51	3.01
		Compost	3.40	2.33	3.70	3.14
		Green manure	3.37	2.21	3.49	3.02
	No pro-cessing	Without fertilizer	2.99	1.99	3.48	2.82
		Compost	3.10	2.03	3.53	2.89
		Green manure	3.07	1.95	3.44	2.82
3-5°	Plowing	Without fertilizer	3.44	2.28	3.73	3.15
		Compost	3.56	2.32	3.75	3.21
		Green manure	3.43	2.34	3.57	3.11
	Deep loosening	Without fertilizer	3.31	2.18	3.48	2.99
		Compost	3.36	2.15	3.61	3.04
		Green manure	3.39	2.23	3.36	2.99
	No pro-cessing	Without fertilizer	3.01	2.04	3.35	2.80
		Compost	3.17	1.95	3.42	2.85
		Green manure	3.17	2.10	3.42	2.90
HCP_{05} for factors that had a significant impact			B. C – 0.05; AC – 0.07; BC – 0.09	B – 0.06; AC – 0.09; BC – 0.10	B. C – 0.15; AC – 0.22; BC – 0.26	B. C. D* – 0.06; AC – 0.08; BC – 0.10

* D – year conditions.

The effect of differences in landscape conditions on yield was not established. Only when assessing the interaction of the factors: the previously noted positive effect of compost on yield was only significant in a flat section with a steepness from 0 to 3° – 0.10 t/ha on average over three years. The effectiveness of the compost also depended on the method of primary tillage, i.e. a reliable increase was only when using the main treatment, regardless of the nonmouldboard or mouldboard tillage.

It was established that the oil content of sunflower hybrids can be influenced by elements of the cultivation technology [15]. This was confirmed by our research.

The oil content in sunflower seeds, cultivated with the use of primary tillage, regardless of the way of tillage, was significantly higher by 1.2-1.4% (HCP_{05} = 0.97%) compared to zero treatment (Fig. 1).

The influence of relief conditions (in the flat area the oil content was higher by 0.5%) and organic fertilizers (the increase was 0.1-0.5%) was insignificant (HCP_{05} = 0.8%) on average during the experiment. Nevertheless, a different combination of the studied factors revealed a significant variability of this indicator, the minimum value of which was noted on a slope of 3-5° when introducing compost to No-till: 49.5%. In general, the use of organic fertilizers did not improve this indicator for No-till neither on the flat area, nor on the slope.

The characteristic tendencies of the indicator variability when applying the main tillage depending on its method attract attention. When carrying out mouldboard processing, the oil content of seeds increased with the use of organic fertilizers, regardless of the slope steepness, reaching a maximum value when using green manure – 52.5% (0-3°) and 52.2% (3-5°). And the maximum value of the indicator in the experiment was observed when using a nonmouldboard processing of 53.0-53.2%, and, depending on the relief conditions, the influence of fertilizers was opposite: on the flat area they led to a decrease in oil content, to a greater extent on green manures, while on the slope plot the lowest oil content was observed without their use.

It should be noted that, in general, the variability of oil content for the studied factors was quite low: the coefficient of variation was within 2% on average over the study period. The variability of the indicator over the years of research was fundamentally different from the variability of yield and amounted to 0.9%, and

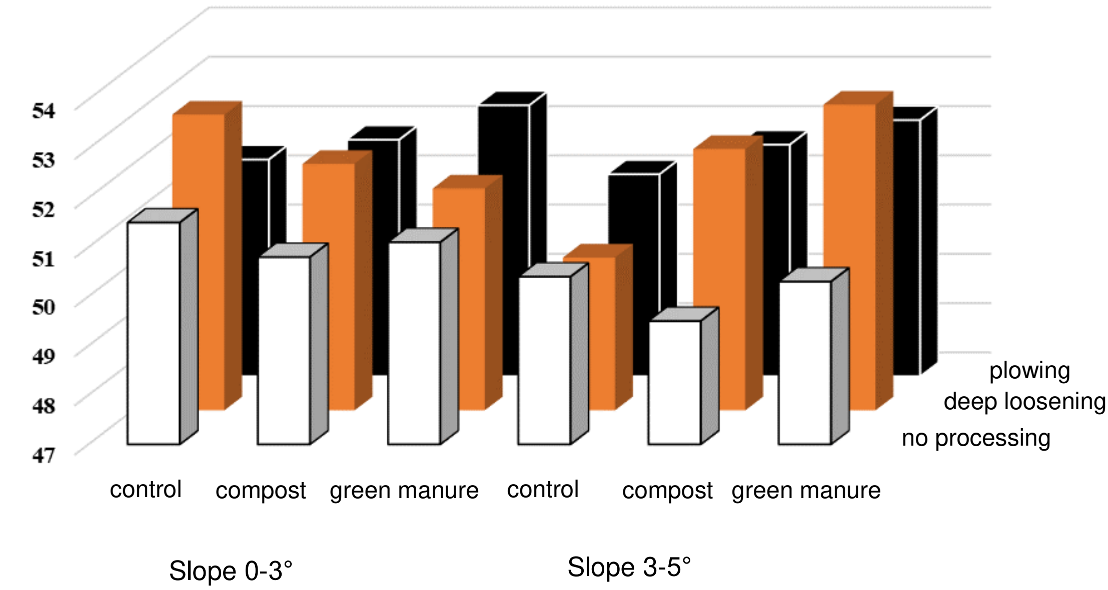

Figure 1. Oil content of sunflower seeds,% (2016-2018)

the difference between the maximum and minimum values was only 1.8%. This shows the high stability of this indicator in environmentally changing conditions and its high genetic determinacy in the NK Neom hybrid.

The resulting indicator of the productivity of sunflower is the gathering of oil, the value of which is determined by both the yield level and the oil content of the seeds. Assessing the variability of these indicators, it can be assumed that the yield of oil is mainly due to the influence of the studied factors on the crop yield and, above all, the conditions of the year. This is confirmed by the data presented in Figure 2. Indeed, the influence of landscape conditions on the collection of oil has not been established. Some advantage (0.02 t/ha) had a flat area, but it was unreliable (HCP_{05} = 0.04 t/ha).

The oil yield per unit area significantly depended on the method of primary tillage (HCP_{05} = 0.05 t/ha) and the use of organic fertilizers (HCP_{05} = 0.05 t/ha), and also the combination of the studied factors mattered (HCP_{05} = 0.11 t/ha).

The lack of tillage led to a decrease in oil collection on average to 1.44 t/ha or by 9.7% compared with nonmouldbord deep processing and by 13.2% compared with plowing. The differences between deep loosening and plowing, according to which the greatest amount of oil was obtained (1.63 t/ha on average), were also significant. Mouldboard tillage leveled the

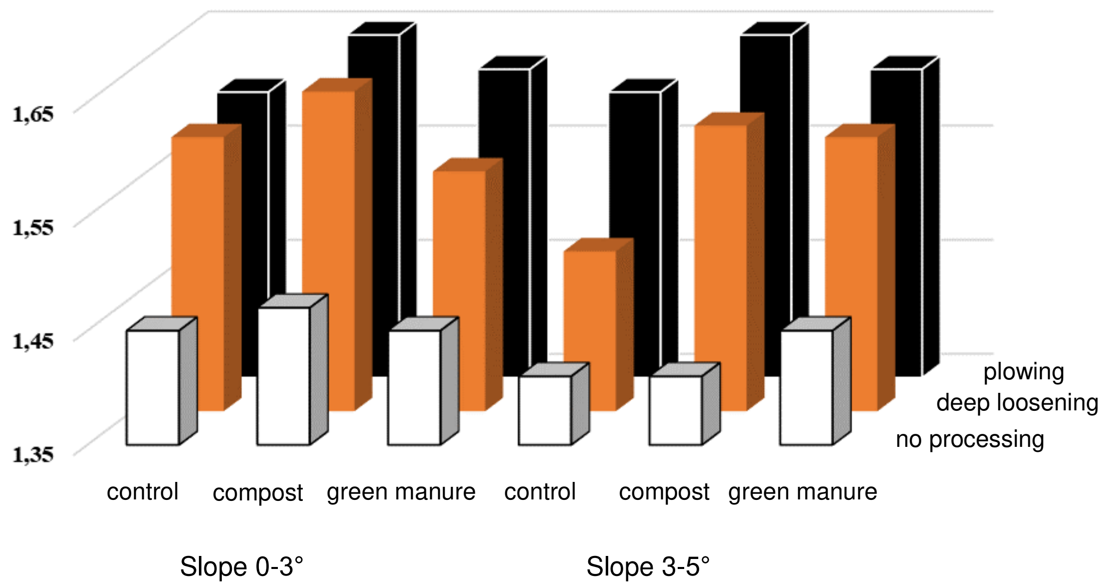

Figure 2. Oil collection depending on the relief conditions, the method of the main tillage and fertilizers, t/ha (2016-2018)

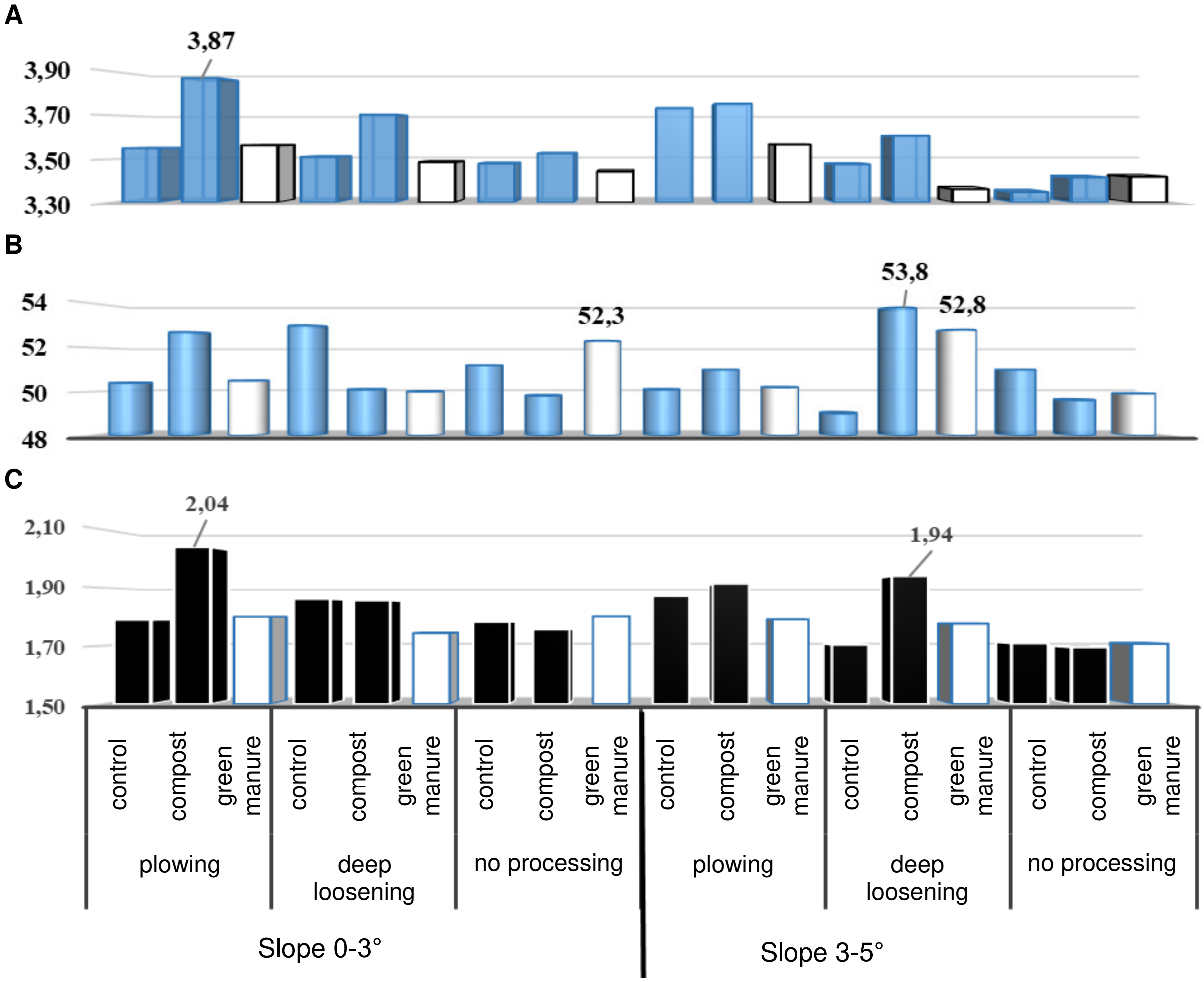

Figure 3. A) yield, t/ha B) oil content of seeds, % C) oil collection, t/ha 2018

conditions of the slopes, regardless of the steepness of which, without fertilizers, 1.60 t/ha was obtained, with the use of green manure – 1.62 t/ha and using compost – 1.66 tons of oil per ha.

The use of organic fertilizers contributed to the increase in oil; when introducing compost, it was significant – 0.05 t/ha. The introduction of compost in the main tillage had a positive effect, and even without treatment in the flat area there was a slight increase in the amount of oil. Compost was particularly effective in more favorable weather conditions of 2016 and 2018; in the latter, the maximum oil yield was obtained in the flat area when compost was introduced in plowing (2.04 t/ha), on the slope section – in deep loosening (1.94 t/ha) (Fig. 3, C).

The influence of green manure was unreliable due to the fact that a full-fledged harvest of green mass was obtained only in 2017 for the 2018 sunflower crop yield. Despite the low reliability of one-year data, their assessment is of interest for evaluating the effects of the green manure. Moreover, such a situation when green manures do not “succeed” every year is typical for the region of the research.

The yield data presented in Figure 3, A shows that when using the green manure, there was no increase in the yield of sunflower, on the contrary, quite often it was lower even compared to the control variant (without fertilizers). In relation to the oil content in the seeds of the crop (Figure 3, B), such an unambiguous picture was not observed. On the contrary, when using green manure on a flat stretch of No-till, and on a slope in deep loosening, the index value was one of the best this year – 52.3-52.8%. This allowed to significantly reduce the loss of oil in these options (Fig. 3, C).

Conclusion

The development of landscape farming systems, in which erosion processes are stopped, is a powerful factor in the regulation of the bioproduction process, reducing the differences between lowland conditions and slope conditions with a steepness of 3-5° of the northern exposure to an unreliable level. Conducting the main tillage, regardless of the method (mouldboard or nonmouldboard) contributed to a significant increase in the yield of sunflower (by 0.2-0.3 t/ha) and oil content of its seeds (by 1.2-1.4%). The positive effect of

compost was revealed, especially when it was applied for plowing, which ensured the highest yield of 3.21 t/ha and oil collection (1.66 t/ha). This gives grounds to continue research on other important aspects of sunflower cultivation on the slopes (3-5°) of the northern exposure, including the study of fertility indicators and soil erosion resistance, with the aim of expanding its crops with such lands under the obligatory condition of full development of landscape farming systems.

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DOI: 10.26177/VRF.2019.2.2.014

COMPLEX FERTILIZERS AS A FACTOR OF REGULATING THE PRODUCTIVITY OF CORN

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The article presents the results of studies of the effect of foliar treatment with complex water-soluble fertilizers with microelements on morphobiometric indicators and yield of corn, depending on the level of root nutrition. At the first level of improved root nutrition, the foliar treatment of corn with complex fertilizers made it possible to further increase the intensity of the linear growth of plants by 3.6-9.7%, and on the second – by 3.3-9.0% relative to the variants without treatment. The smallest linear increase in soil fertilization at both levels was obtained using Humate+7B. The largest number of developed cobs on fertilized agro-backgrounds were formed by plants with foliar treatment with Cytovit and EcoFus (an increase of 13.5-20.0%), and on an uncomfortable agrofone when using Siliplant universal (an increase of 9.0%). Against the background of natural soil fertility, with the use of complex fertilizers, the weight gain of one plant was 4.8-16.1%. Against the background of nitrogen-phosphorus fertilizers, an increase of 6.1-12.0% was obtained, and when applying N120P90K60, the increase varied from 6.2 to 14.7%. At all studied levels of root nutrition, the greatest stimulating effect was obtained during the treatment of crops with Cytovit. The best indicators of phytomass yield were recorded for all agricultural backgrounds plants with foliar treatment with Cytovit, the gain to the variants without complex fertilizer was 15.8-16.5%. EcoFus treatment turned out to be in the second place in terms of efficiency, an increase in green mass of 11.6-14.9% was obtained. The maximum yield of dry matter was formed with the complex use of Ecofus and Cytovit with mineral fertilizers – 17.4-18.0 t/ha.

Key words: corn, mineral fertilizers, microelements, cob, biomass, yield.

Introduction

Corn is a valuable fodder crop that is characterized by its versatility of use. One of the conditions for realizing the potential of corn hybrids is cultivation with an optimal degree of plant availability of nutrients [1-5]. In connection with the removal of agricultural crops during the harvest, the soil is constantly depleting the supply of nutrients, which must be constantly replenished. This is possible through the use of fertilizers. In ensuring the nutrition of plants, an important role is played by microelements – boron, manganese, sulfur, iron, copper, zinc, molybdenum, which are part of the most important enzymes and other physiologically active compounds. They participate in the synthesis of proteins, carbohydrates, fats and vitamins [6-8, 16]. Modern direction in the sphere of agriculture is the search and development of such methods that could increase the yield of cultivated plants without increasing the rates of fertilizer application. In this regard, the use of complex water-soluble fertilizers with microelements for foliar dressings is of great interest. They are distinguished by a high digestibility by plants and low doses of application [9-11]. Plants require a small amount of microelements, and that is why it is convenient to introduce them by spraying the leaves. Non-root dressings allow to quickly influence the plant during critical periods when the plants need microelements [12, 13, 17, 18]. Therefore, a detailed study of these forms of fertilizer is of scientific and practical interest in terms of saving energy and money for the cultivation of corn.

The aim of the research was to study the effect of foliar treatment with microelements on morphobiometric indicators and corn yield at various levels of mineral nutrition.

Methods and materials

The studies were conducted in 2015-2017 on leached medium deep black soil with a high content of nitrogen, phosphorus and potassium, the reaction of the soil solution – slightly acid. Field experiment was carried out in accordance with generally accepted methods [14-15] in quadruplicate using the method of split plots according to the scheme: factor A – fertilizer rate: $N_0P_0K_0$; 2 – $N_{120}P_{90}$; 3 – $N_{120}P_{90}K_{60}$; Factor B – foliar treatment of corn plants with microelements in the phase of 6-7 leaves: 1 – control (water treatment); 2 – EcoFus (2.5 l/ha); 3 – Green Go (1.5 kg/ha); 4 – Siliplant universal (1.0 l/ha); 5 – Gumostim (0.3 l/ha); 6 – Cytovit (0.5 l/ha); 7 – Humate+7B (0.5 l/ha). Organic mineral fertilizers with microelements (EcoFus, Gumostim, Humate+7B) and water-soluble complex fertilizers with microelements in chelate form (Green Go, Siliplant, Cytovit) were dissolved in water (at the rate of 200 l/ha).

The area of the first-order plots was 196 m^2, of the second – 28 m^2. The object of research was the early ripe hybrid of corn – ROSS 199 MV

(FAO 190). Sowing was carried out with 70 cm row spacing. Plant standing density (80 thousand/ha) was formed in the phase of full germination. The forecrop was winter wheat on a clean fallow. Mineral fertilizers (ammonium nitrate, nitroammophos, potassium chloride) were applied during the first pre-sowing cultivation. Weather conditions of the growing season varied during the years of the research. The hydrothermal coefficient (HTC) in June 2015 was 0.85, which corresponded to average arid conditions; in July – 1.67 and in August – 0.15. The HTC in June 2016 was 1.50, in July – 0.91 and in August – 1.17, i.e. the precipitation was distributed fairly evenly throughout the growing season, which contributed to obtaining high yields of both green mass and dry matter. The HTC in June 2017 was 1.14, in July it was 0.97 and in August it was 0.19, i.e. June and July were sufficiently moisture-treated, and August was arid.

Results

Plant height is an important morphological feature, the magnitude of which can determine the dynamics of plant growth, and which, to a certain extent, indicates the conditions of growth and development of plants. Improved mineral nutrition conditions contributed to enhanced linear growth. Measurements of plant height before harvest showed that, on average, over three years of research, when applying nitrogen-phosphate fertilizers in the norm of N120P90, the linear growth of plants increased by 27 cm or 14.0% compared to the uncomfortable background (Table). Supplementing the fertilizer with potassium contributed to the growth of plants in length by 31 cm compared with the level of natural soil fertility. The plants reacted differently to the foliar treatment with complex microelement fertilizers depending on the level of mineral nutrition. So, on an uncomfortable agricultural background, the largest increase was observed during treatment with Cytovit – 18.0 cm or 9.9%, compared with the variant without microelements. The height of the plants increased by 12-14 cm when they were treated with solutions of Green Go, Siliplant universal, Gumostim and Humate+7B, and using EcoFus – by 5 cm.

As shown by the measurements made, at the first level of an improved root nutrition, foliar treatment of corn with complex fertilizers allowed an additional increase in the intensity of linear growth of plants by 3.6-9.7%, and at the second level – by 3.3-9.0% relative to the variants without treatment. Moreover, the smallest linear increase in soil fertilization at both levels was obtained using Humate+7B.

The height of attachment of the lower developed cob is important for corn, since the higher the cob is laid on the plant, the less the loss of valuable generative organs during harvesting. On average, over three years of research, the application of mineral fertilizers contributed to an increase in the height of attachment of the lower developed cob by 12 cm or 18.0%. When the plants were treated with complex fertilizers on a natural agricultural back-

Table. Morphobiometric indicators of corn, average for 2015-2017

Fertilizer rate	Treatment with complex fertilizers	Height, cm		The number of cobs per 100 plants, pcs.	Weight of one plant, g
		of plants	of cob attachment		
$N_0P_0K_0$	Control	182	63	100	442
	EcoFus	187	67	102	494
	Green Go	194	73	101	463
	Siliplant universal	194	68	109	479
	Gumostim	194	54	103	483
	Cytovit	200	71	105	513
	Humate+7B	196	67	102	487
$N_{120}P_{90}$	Control	206	78	105	589
	EcoFus	226	84	126	660
	Green Go	224	78	118	629
	Siliplant universal	216	76	121	629
	Gumostim	220	75	111	625
	Cytovit	227	77	126	684
	Humate+7B	213	76	114	656
$N_{120}P_{90}K_{60}$	Control	210	78	111	617
	EcoFus	227	83	132	693
	Green Go	223	75	123	655
	Siliplant universal	228	80	114	671
	Gumostim	227	78	122	671
	Cytovit	229	79	126	708
	Humate+7B	217	75	116	678

ground, the cobs were formed 4.0-10.0 cm higher than in the version without microfertilizers. However, this effect was practically not observed against the background of improved root nutrition.

Recording developed cobs per 100 plants showed that more generative organswere formed in the conditions of 2015, and less – in 2016. When mineral fertilizers were applied, the number of cobs increased in all the years of research. But, if in 2015 their number increased by 24.0% when applying nitrogen-phosphate fertilizers, and from nitrogen-phosphorus-potassium fertilizers – by 30.0%, then in 2017 the increase was twice as low, while maintaining the same trend. In the growing season of 2016, due to the late planting dates and more rapid passage of development phases at elevated air temperatures, the number of generative organs from the use of mineral fertilizers increased by 4.7%. On average, over the years of research on the background of the natural fertility of the soil, the number of cobs per 100 plants was 103 pieces. The use of fertilizers in the norm of $N_{120}P_{90}$ contributed to an increase in the number of cobs by 13.6%, and with the introduction of $N_{120}P_{90}K_{60}$ the increase was 16.5%.

Foliar treatment with complex fertilizers also contributed to an increase in the number of generative organs. The greatest stimulating effect was obtained in the conditions of 2015. Against the background of nitrogen-phosphorus fertilizers, the growth of the cobs in the variants with the treatment of Humate+7B, Cytovit, Green Go and Siliplant universal amounted to 19.8-32.7%, and the best for this indicator was the variant using EcoFus, where the increase was 55.4 % With the introduction of a complete mineral fertilizer, this trend continued, but the increase in the generative organs varied from 6.6 to 9.1%. This pattern was noted in subsequent years of experiment. On average, over the years of research, plants formed the largest number of developed cobs on fertilized agricultural backgrounds when treated with Cytovit and EcoFus (an increase of 13.5-20.0%), and on an unfertilized agricultural background by using Siliplant universal (an increase of 9.0%).

Yield is an integral indicator of the effectiveness of crop cultivation. Corn yield for silage harvesting depends on the individual productivity of each plant and the number of plants per unit area.

The records showed that stronger plants were formed in conditions of sufficient moisture and moderate air temperatures in 2017. As shown by the results of our research, mineral fertilizers contributed to an increase in plant mass (Table). On average, over the three years of the experiment, the weight of one plant with the application of mineral fertilizers in the norm of $N_{120}P_{90}$ increased by 159 g or 33.1%. With the improvement of the root nutritional conditions, due to the addition of potassium to fertilizers, an increase in the weight of a single corn plant was noted, on average by 19.0 g or 39.6% in comparison with unfertilized variants.

The use of complex fertilizers with microelements stimulated the accumulation of raw plant biomass. On average, against the background of natural soil fertility, an increase in the mass of one plant was 4.8-16.1%. Against the background of nitrogen-phosphorus fertilizers, an increase of 6.1-12.0% was obtained, and when applying $N_{120}P_{90}K_{60}$ the increase varied from 6.2 to 14.7%. At all studied levels of root nutrition, the greatest stimulating effect was obtained during the treatment of crops with Cytovit. The efficiency of the variants with EcoFus and Humate+7B was slightly less.

An analysis of corn yield data showed that mineral fertilizers provided a larger increase in phytomass. On average, over the years of the experiment, the yield of green mass using nitrogen-phosphate fertilizers increased by 10.0-14.0 t/ha, or 26.1-35.35%, compared with similar variants against the natural agricultural background (Figure). The addition of potassium fertilizer made it possible to obtain an increase in phytomass of 13.3-15.2 t/ha or 34.9-39.8%.

Complex fertilizers stimulated the growth of phytomass, but their influence was weaker than that of macro fertilizers. The best indicators were recorded on all agro-plants with foliar processing with Cytovit, the gain to the variants without complex fertilizer was 15.8-16.5%. EcoFus treatment turned out to be in the second place in terms of efficiency, an increase in green mass of 11.6-14.9% was obtained. It should be noted that complex fertilizers showed their best on an uncomfortable agricultural background and when making full mineral fertilizer.

According to the obtained experimental data, on average over the years of the experiment, harvesting cobs with wrappers on an unfertilized agricultural background amounted to 12.2-17.7 t/ha or 31.8-44.5% of the green mass yield. Against the background of an improved root nutrition ($N_{120}P_{90}K_{60}$), their total mass increased by 18.2-46.9% or 2.5-8.4 t/ha, but the content in the green mass remained practically unchanged. The addition of potassium to the fertilizer did not contribute to a further increase in the generative organs.

The effect of complex fertilizers with microelements at different levels of root nutrition on the collection of cobs was rather questionable. On the natural agricultural background, the best variant was Cytovit, which provided an increase in cobs of 6.2 t/ha. The variants with EcoFus and

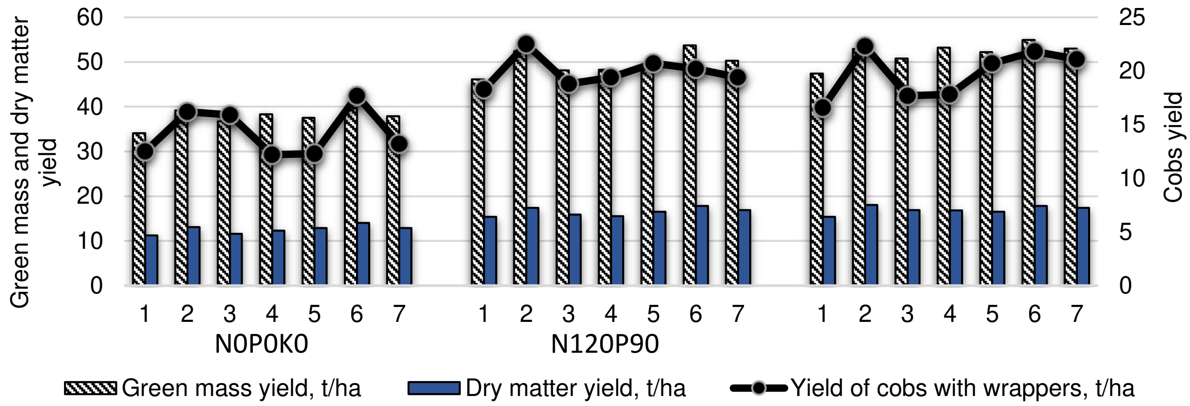

Figure. Yield of corn, average for 2015-2017: 1 – Control (water treatment); 2 – EcoFus; 3 – Green Go; 4 – Siliplant universal; 5 – Gumostim; 6 – Cytovit; 7 – Humate+7B

Green Go were slightly inferior to him, where an increase of 27.2-29.6% was obtained. Against the background of $N_{120}P_{90}$, the variant with EcoFus treatment stood out, the weight of corn cobs increased by 22.9% compared with 2.7-13.1% of the use of other microelement fertilizers. Against the background of complete mineral fertilizer, the largest increase in cobs with wrappers was obtained during foliar treatment of crops with EcoFus and Cytovit – 5.2-5.7 t/ha or 31.3-34.3% to the variants without microelement fertilizers.

Records for the dry matter yield showed that the maximum biomass yield was obtained in 2015-2016, mainly due to an increase in the dry matter content in the green mass. The biomass yield from the use of fertilizers increased with the application of $N_{120}P_{90}$ by 3.2-4.3 t/ha or by 26.0-37.5% compared to the background of natural soil fertility. With the increase in the use of fertilizers to $N_{120}P_{90}K_{60}$, the absolute increase in biomass was 3.6-5.3 t/ha, and the relative increase was 27.1-45.7% to the unfertilized background.

On average, over three years of the research, when applying mineral fertilizers in the norm of $N_{120}P_{90}$, the increase in dry biomass was 3.2-4.3 t/ha, or 26.0-37.1% to the non-fertilized agricultural background. Further improvement in root nutrition did not lead to a significant increase in dry biomass.

All studied complex fertilizers stimulated the growth of biomass. The maximum yield of dry matter was formed with the integrated use of EcoFus and Cytovit with mineral fertilizers – 17.4-18.0 t/ha. The treatment of crops with EcoFus and Cytovit contributed to an increase in biomass of 16.9-25.0% against the background of natural soil fertility, and with the introduction of mineral fertilizers the increase in similar variants was less and amounted to 13.0-16.9%.

Conclusion

The research results showed that when processing with complex fertilizers with microelements, biometric indicators improve and the yield of corn increases. It was found that in all agricultural backgrounds, the highest yield was obtained during the treatment of plants with Cytovit and EcoFus – the increase in green mass was 5.1-7.6 t/ha, in dry matter – 1.9-2.8 t/ha compared to variants without complex fertilizers.

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DOI: 10.26177/VRF.2019.2.2.015

COMPETITIVE VARIETY TRIAL OF PROMISING BREEDING MATERIAL OF INDUSTRIAL HEMP

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A three-year scientific research was conducted in the comparative assessment of perspective hybrid populations of Central Russian ecotype monoecious industrial hemp in competitive variety trials. The results are hereby presented.

The object of the research was three varieties of non-psychotropic industrial hemp, approved for use on the territory of the Russian Federation, and two promising breeding numbers, selected according to the results of preliminary trials of previous years.

The goal of the research is to create new highly productive varieties of non-psychotropic monoecious industrial hemp that are adapted to the agro-ecological conditions of the Middle Volga region and possess higher levels, in comparison to the existing varieties, of economically valuable traits, as well as stability of the monoecious property during reproduction, with content of less than 0.1% tetrahydrocannabinol (THC).

The main method of research works is multiple family-group selection according to a complex of selectively valuable features and properties. During the experiment, methods and schematic models generally accepted in breeding research institutions were used. The content of less than 0.1% THC in the upper parts of the inflorescences was taken as the main limiting feature of selection.

Following the results of 2018 competitive variety trial cycle of promising breeding numbers, an application was submitted for inclusion of breeding number GP-7/012m under the name “Milena industrial hemp variety” in the State Register of Breeding Achievements of the Russian Federation (RF). It is planned to perform the next stage of breeding improvement with a promising breeding number GP-13/012v in order to increase the yield of common and long fiber in the plant stems.

On the basis of the introduction of new breeding varieties of industrial hemp, it is planned to transfer scientific results to various regions of hemp-harvesting of the agro-industrial complex of the Russian Federation in order to increase their economic development rates, increase competitiveness of their products and ensure import substitution.

Key words: Cannabis sativa, non-psychotropic variety, breeding number, cannabinoid, tetrahydrocannabinol, competitive variety trial, economically valuable feature, oil content, fiber yield.

Introduction

Selection activity with Cannabis sativa involves a list of the main directions, focused both on increasing the parameters of productivity elements, and on optimizing of specific properties inherent only in this crop. These are the presence of cannabinoids in plant biomass and the presence of a dominant dioecy in plant. Therefore, the two above-mentioned negative qualities of the crop should be taken into account when implementing modern breeding programs [14, 22, 23].

The variety of monoecious hemp is a dynamic population consisting of various feminized and masculinized types, which, under conditions of reproduction under the influence of the dioecy dominance and high cannabinoid content, spontaneously turn to loss of monoecy and low cannabinoidness, which, in turn, require continuous maintenance in the seed-breeding process [12, 13].

The presence of psychoactive compounds in Cannabis sativa determines the many years of breeding work to reduce the content of cannabinoids in plants and, above all, THC [22, 25].

The systematic selection process to reduce the content of cannabinoids in the USSR began in 1973. The determining indicator of a single elite plant is the THC content of less than 0.1% in hemp plant inflorescences [3, 4].

The main method of selection of low cannabinoid hemp varieties is continuous family-group selection. Culling highly cannabinoid plants against the background of a wide polymorphism of Cannabis sativa varieties as a cross-pollinating culture indirectly contributes to narrowing of the genotype and reduces the heterozygosity of the population on this basis. On the contrary, homozygosity due to the low THC content increases. The first low-cannabinoid varieties of monoecious hemp were created by the method of family-group selection: YUSO-14, YUSO-16, Dneprovskaya odnodomnaya, YUSO-31 [5, 6].

Modern hemp varieties of the Central Russian ecotype of Surskaya, Vera, Nadezhda, selected in the Penza Research Institute of Agriculture, and varieties of the southern ecotype of Zenitsa, Kubanka, Omegadar 1, Maria, Victoria, created in the Krasnodar Research Institute of Agriculture, contain less than 0.1% THC [21].

The monoecy feature is unstable in the offspring, and this instability stems from interaction of a series of multiple alleles of sex chromosomes genes and genetic factors of male and female autosomes of different valences. The spontaneous process of population change in the sex characteristics of monoecious plants is constantly aimed at fimble segregation, i.e., at turning monoecious hemp into dioecious, as a result of reversal of recessive genes into dominant ones [12, 13].

The hybridization and selection methods, previously used to create the source material, in the selection of monoecious hemp did not allow obtaining such a population whose monoecy stability would allow it to do without fimble culling, the content of which is the main indicator characterizing the stability of this feature in specific form [1].

Modern hemp breeding programs rest on principle of plant selection, contributing to the reinforcement of monoecy in the offspring. Genetic analysis of different reproductive types of hemp showed that, for breeding purposes, it is necessary to select real feminized monoecious plants and feminized monoecious pistillate hemp from feminized monoecious hemp. Such a selection contributes not only to the reinforcement of the monoecious trait in the offspring, but also increases the seed productivity of the plant population [8, 9, 18, 19].

Guided by this principle, domestic breeders have created a number of varieties in which the segregation of usual fimble was reduced to less than 1%. However, it was concluded that the further decrease of fimble content in the offspring is difficult [18, 19].

A number of foreign researchers also determined feminized monoecious pistillate hemp as the base for the selection. As a result of selection, in 18 years of breeding, the Bernburg monoecious variety was obtained, whose fimble content was reduced from 36 to 0.008% [2, 20, 24].

The next stage in the development of breeding for the reinforcement of monoecious property was hybridization of dioecious samples with monoecious ones in various combinations. The most widespread hybrids were back-crossing ones of the type (dioecious hemp × monoecious) × monoecious. In the case of using the paternal variety, selected on the basis of monoecious property, it is possible to create a breeding material with a low content of fimble for a relatively short period [16, 18].

It has been proven that other effective hybridization methods can be used with hemp in order to obtain source material with a fixed monoecious feature. Those are forced self-pollination of the original plant and induced mutagenesis with the creation of haploids and polyploids [12].

Thus, the analysis of the available theoretical and practical data shows that, despite the progress achieved, the problem of fixing the monoecious property in the offspring remains relevant, since the methods used to create varieties and hybrids do not fundamentally solve the main problem – growing monoecious hemp without repeated sorting. To solve this problem, further searches are needed to obtain a qualitatively new source material based on the use of modern methods for changing heredity.

The breeding program for creation of new non-psychotropic varieties with no fimble segregation was launched in the Penza Research Institute of Agriculture in 2005. At the first stages (2005-2011), a fundamentally new breeding material was created based on self-pollinated lines. In 2012, a set of selected promising lines was hybridized and hybrid combinations were obtained with a wide range of economically useful traits and properties. In the course of 2013-2015, their complex study and selection improvement was carried out by the method of family-group selection. As a result, two populations of Cannabis sativa were created which have no fimble segregation and with THC content of less than 0.05% in the plant biomass. Between 2016 and 2018 these populations were competitively trialled with modern varieties included in the State Register of Breeding Achievements and approved for cultivation on the territory of the Russian Federation [17].

Along with the competitive variety trial, preliminary reproduction of promising breeding material was carried out. The task of preliminary reproduction was to obtain the required number of original seeds of new promising populations for industrial reproduction of seed material of higher reproduction.

The purpose of research is to create new highly productive varieties of non-psychotropic monoecious industrial hemp, adaptive to the agro-ecological conditions of the Middle Volga region and possess higher levels, in relation to existing varieties, of economically valuable traits, the content of tetrahydrocannabinol in plants of not more than 0.1%, as well as monoecy stability during reproduction.

Research tasks:

– to conduct competitive trials of promising breeding material and modern non-psychotropic varieties of monoecious hemp of the Central Russian ecotype, registered in the State Register of Breeding Achievements of the Russian Federation;

– to obtain experimental data on the comparative evaluation of economically valuable traits and properties of promising breeding numbers and of modern varieties of non-psychotropic industrial hemp approved for use.

The practical significance of the work lies in expanding the variety of non-psychotropic monoecious industrial hemp seeds, that combine stable productivity and product quality, adaptive to the conditions of the Middle Volga region, have improved, with respect to existing breeding varieties, economically valuable traits and properties.

Methods and materials

Research work was performed under field and laboratory conditions in the period of 2016-2018. The experiments used methods and schematic models generally accepted in breeding research institutions. The research work method is a multiple selection according to a complex of selectively valuable traits and properties. The main limiting feature of selection is less than 0.1% THC in the upper parts of the inflorescences.

The complex of research works, provided by the work program of the task, was carried out under field and laboratory conditions. Nurseries set-up and their study was performed in accordance with the guidelines [4, 11]. The sowing method of competitive variety trial (CVT) nurseries with an area of 0.06 hectares is mechanized, with a SN-16 seeder in a four-row version with a 50 cm row spacing and a seeding rate of 1.4 million pcs/ha.

Identification and quantitative determination of the content of the main cannabinoids were performed by GLC analysis on the gas-liquid chromatographic complex "Crystal 2000M" according to the methodological recommendations [10].

Quantitative processing of the chromatograms was carried out on the peak areas using the computer program "Chromatec Analytic 2.5". The number of analytical samples is 2. The calculation of the quantitative content of tetrahydrocannabinol (THC), cannabidiol (CBD) and cannabinol (CBN) was carried out using the internal standard method. A 0.5% solution of methyl stearate in ethanol was used as an internal standard.

Accounting for yields from plots was carried out by continuous harvesting. The seed and stem yield was led to standard (13 and 25% respectively) moisture. Analysis of the structure of the seed, stem and fiber yield was performed according to the methods of VNIILK [11].

The determination of the oil content in the seeds was carried out in the chemical-analytical laboratory of the Penza University of Agriculture – branch of the Federal State Budgetary Scientific Institution “Federal Scientific Center of Fibre Crops” according to a modified Lebedyantsev-Raushkovsky method [15].

Statistical processing of experimental data was performed using regression analysis according to the method of B.A. Dospekhova [7].

The experimental work was accompanied by the necessary observations, counts and estimates, including:

– observations of air temperature and precipitation during the growing season;

– phenological observations according to the VNIILK method [11];

–- counting of the fimble in the flowering phase;

– assessment of pest damage and disease damage on a five-point scale [11].

Results

The main agroclimatic indicators of the study period – humidification regime and thermal resources – are varied over the years of research.

The growing season of 2016 was sufficiently humidified (HTC 1.19), 2017 – not sufficiently humidified (HTC 0.76), 2018 – extremely dry (HTC 0.30). The contrasting vegetation conditions allowed us to compare the adaptive ability of the compared varieties and promising variety samples in terms of the formation of productivity elements of the main product types and their quality characteristics.

The amount of the main cannabinoids in nursery plants of competitive variety trials averaged 1,087-2,668%, incl. THC – 0.024-0.083% (Table 1).

The lowest THC content and amount of the main cannabinoids throughout the entire cycle of the competitive variety trials was the promising breeding number GP-13/012v (on average, respectively, 0.045% and -1147% to st). On average, THC levels of promising breeding numbers were 1.4–2.9 times lower than of standard variety plants and 2.1–4.2 times lower than of the legally permissible value (0.1%), although in extremely dry growing season of 2018 they had an increase in the parameters of the trait by 0.01-0.05%.

The height of plants, the technical length of the stem of the promising numbers did not significantly differ from the standard variety in a sufficiently humid growing season and was significantly inferior to it in years with insufficient humidity, being characterized by low trait parameters (Table 2). However, this circumstance has certain advantages for effective combine harvesting of the crops.

The diameter of the stem of promising numbers in the case of sufficient humidity supply either was inferior to the standard, or was at its level. In extremely dry conditions, the trait parameters did not differ from the standard.

The number of internodes in varying conditions of the growing season corresponded to the values of the standard variety. The average length of internode with sufficient moisture content also corresponded to the values of the trait in the standard variety, but was significantly inferior to it in the case of acute precipitation deficit.

The content of the fimble in the populations of promising numbers at the final stage of competitive variety trials was zero, due to the fact that selection improvement continued in the family-group selection nurseries.

A comparative assessment of the parameters of the economically valuable traits revealed that, by the criterion of harvest seed moisture,

Table 1. The content of THC and the amounts of the main cannabinoids in plants, %, 2016-2018

Breed/variety sample	THC				Σ			
	2016	2017	2018	average	2016	2017	2018	average
1. GP-7/012m	0.037	0.026	0.081	0.048	1.320	0.720	2.410	1.483
2. GP-13/012v	0.019	0.020	0.033	0.024	0.861	0.714	1.685	1.087
3. Vera	0.063	0.044	0.096	0.068	2.169	1.253	3.134	2.185
4. Nadezhda	0.072	0.055	0.121	0.083	2.437	1.629	3.939	2.668
5. Surskaya, st	0.066	0.048	0.092	0.069	2.259	1.556	2.888	2.234
HCP_{05}	0.019	0.018	0.024	–	0.353	0.298	0.559	–
m, %	8.6	13.9	8.3	–	5.4	8.4	6.1	–

Table 2. Parameters of biomorphometric characteristics of plants, 2016-2018

Breed / variety sample	Characteristic																	
	Plant height, cm			Technical length of the stem, cm			Stem diameter, mm			Number of internodes, pcs			Average length of internode, cm			Content of the usual count, %		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
GP-7/012m	136	200	133	114	165	107	4	7	5	9	9	9	14	19	12	3.8	0.1	0.0
GP-13/012v	167	199	136	135	164	106	7	8	6	9	9	9	15	19	12	0.4	0.1	0.0
Vera	149	229	150	128	195	129	6	8	6	9	10	8	14	19	16	4.3	2.8	3.1
Nadezhda	142	238	159	125	200	135	5	9	5	9	10	10	16	20	14	12.5	5.8	4.2
Surskaya, st	153	228	161	128	188	138	6	8	5	10	9	10	14	20	14	8.8	2.8	2.0
HCP_{05}	23	11	10	17	9	8	1.0	0.7	0.8	NS	NS	1.3	NS	NS	1.6	3.2	2.6	0.6
m, %	4.1	1.6	2.0	3.1	1.6	2.0	7.1	2.7	4.5	4.1	3.6	3.5	5.4	3.1	3.9	14.7	12.4	2.2

Table 3. Parameters of economically useful traits of plants, 2016-2018

Breed / variety sample	Trait														
	Harvest seed moisture, %			Seed productivity, g/plant			Average mass of the stem, g/plant			Weight of 1000 seeds, g			Oil content, %		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
GP-7/012m	23.5	20.5	15.4	3.8	5.6	1.7	5	13	6	13.9	16.4	14.6	29.9	33.1	33.4
GP-13/012v	24.3	25.5	14.3	2.4	2.9	2.0	7	24	7	14.6	14.5	14.5	28.6	31.0	30.9
Vera	21.3	24.6	13.3	2.3	3.0	1.8	7	21	9	15.9	17.0	15.6	27.6	31.4	33.6
Nadezhda	25.8	26.1	15.0	2.3	4.2	1.9	6	22	9	15.2	16.8	15.5	29.1	31.7	33.7
Surskaya, st	26.3	26.6	15.9	2.8	3.6	2.0	7	18	10	14.6	14.5	14.7	28.4	30.7	33.9
HCP_{05}	2.5	3.2	0.9	0.8	1.1	0.8	1.7	4.6	3.8	1.6	2.1	0.6	1.3	2.2	1.9
m, %	11.3	4.4	8.1	13.1	11.5	16.1	10.6	8.1	13.9	4.9	4.4	1.5	2.4	2.73	2.0

the breeding number GP-7/012m (19.7%) was the lowest by years, i.e. it had the highest precocity in relation to other numbers (Table 3).

Also this number was in the lead by seed productivity (average 3.7 g/plant or +0.9 g/plant to st) and by oil content in seeds (average 32.1% or +1.1% to st), significantly surpassing the indicators of the standard variety under conditions of sufficiently moist vegetation. However, this breeding number was significantly inferior to the standard variety in the average mass of the stem (–6 g/plant to st), and the average mass of 1000 seeds corresponded to its level.

The qualitative and quantitative characteristics of the stems and fibers of the competitive variety trial showed a multidirectional reaction to the conditions of the growing season. Thus, under conditions of insufficient humidity, there was an increase in the absolute values of the total/long fiber yield by 3.0–6.2%, with the highest total fiber yield parameter noted by the standard variety and the highest long fiber yield parameter by the Vera variety (table. 4).

Table 4. Qualitative indicators of the harvest of stems, 2016-2018

Breed / variety sample	Total fiber yield, %			Long fiber yield, %			Breaking load of combed fiber, kgf			Combed fiber flexibility, mm		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
GP-7/012m	19.8	25.2	23.0	13.3	11.7	15.2	16.3	13.4	7.5	15.3	13.2	12.6
GP-13/012v	18.5	22.7	27.0	12.3	9.7	19.4	19.8	17.6	8.2	22.4	12.3	11.7
Vera	22.7	32.1	27.8	17.7	15.0	19.1	14.5	12.7	10.3	18.5	19.6	15.3
Nadezhda	23.4	29.6	28.5	15.7	11.8	17.6	14.4	10.8	9.3	17.3	15.2	13.0
Surskaya, st	25.2	30.9	29.1	16.8	13.2	19.6	17.4	15.5	14.2	20.8	11.4	11.6
HCP_{05}	4.9	3.5	3.0	3.1	1.3	2.1	2.2	2.0	4.5	6.3	5.4	2.9
m, %	7.42	4.1	3.73	8.1	9.5	9.8	10.5	25.1	14.6	12.2	12.5	10.7

Table 5. Quantitative characteristics of the harvest of the main products, 2016-2018

Breed/variety sample	Indicator														
	Stem yield, t/ha			Total fiber yield, t/ha			Long fiber yield, t/ha			Seed yield, t/ha			Oil yield, t/ha		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
GP-7/012m	2.4	7.3	2.8	0.48	1.84	0.64	0.33	0.85	0.42	0.22	1.65	0.81	0.065	0.55	0.27
GP-13/012v	6.1	11.6	3.4	0.62	1.44	0.92	0.42	0.61	0.66	0.17	1.28	0.96	0.055	0.39	0.30
Vera	4.4	10.0	4.9	0.99	3.21	1.35	0.78	1.53	0.94	0.15	1.24	0.98	0.045	0.40	0.33
Nadezhda	3.7	9.4	5.1	0.84	2.80	1.45	0.58	1.11	0.90	0.15	1.33	1.15	0.043	0.42	0.39
Surskaya, st	4.5	8.6	6.2	1.14	2.66	1.81	0.78	1.13	1.20	0.16	1.17	1.27	0.051	0.36	0.43
HCP_{05}	0.82	2.7	2.4	0.27	0.84	0.81	0.21	0.49	0.57	0.05	0.47	0.31	0.013	0.15	0.10
m, %	7.28	11.2	13.9	10.70	12.1	17.7	11.9	16.1	18.5	12.26	11.3	11.3	10.43	11.5	11.68

The breaking load of combed fiber as a whole had the highest indicators under conditions of sufficient humidity, and the standard variety occupied the leading positions in this attribute.

The moist conditions of the vegetation as a whole ensured the formation of average indicators of the combed fiber flexibility and low under dry conditions. The largest values of the indicator are marked by the Vera variety.

The yield of the main product types of the competitive variety trial numbers also depended on the vegetation conditions (Table 5).

In general, for all indicators of the yield of the main product types, their highest values were noted with the insufficiently humid growing season of 2017 (HTC 0.76). This circumstance allows us to conclude that both the lack of moisture supply and its excess do not contribute to the realization of the potential for the formation of the productivity of breeding varieties of cannabis.

In the aspect of varietal differentiation of the intensity of individual quantitative characteristics of productivity, it was established that, on average, the GP-13/012v selection number had superiority in stem yield (+0.6 t/ha to st), the GP - 7/012m selection number in seed and oil yield (respectively +0.03 and +0.02 t/ha to st). In total fiber harvest and long fibers harvest, it was the Surskaya standard variety and the Vera variety that were in the lead.

Field evaluation of number plants for the presence of diseases and pests showed that under conditions of a sufficiently humid growing season of 2016, the plants mostly showed leaf spots (*Phyllosticta cannabis Speg., Macrosporium cannabinum, Septoria cannabis Sacc.*) – from weak to average. During the growing season, the plant population of the hemp flea (*Psylliodes attenuata Koch.*) was not observed. The four numbers indicated a weak presence of the stem moth (*Pyrausta nubilalis Hb.*) (Table 6).

Under conditions of an insufficiently humid growing season of 2017, only leaf spots were observed on plants (*Phyllosticta cannabis Speg., Macrosporium cannabinum*) – a low level of infestation. During the growing season, the plant population of hemp flea was average. On all the numbers, the presence of a stem moth was observed – from weak to average.

Under the conditions of the extremely dry growing season of 2018, leaf spots (*Phyllosticta cannabis Speg.*) of low level of affection were observed on the plants. During the growing season, an average infestation of hemp flea was observed. In all varieties, a weak presence of stem moth was noted.

Table 6. Evaluation of disease and pest damage, 2016-2018

Breed/variety sample	Disease (leaf spot), point			Pest (stem moth), point		
	2016	2017	2018	2016	2017	2018
GP-7/012m	3	3	3	3	3	3
GP-13/012v	3	3	3	3	3	3
Vera	5	3	3	1	5	3
Nadezhda	5	3	3	3	5	3
Surskaya, st	3	3	3	3	5	3

Conclusion

As a result of the research, experimental data were obtained on the results of the three stages of competitive variety trial of promising new breeding numbers of industrial hemp as to the complex of economically valuable traits and properties.

The best results on the quantitative assessment of the THC content and the amount of cannabinoids were shown by the promising breeding number GP-13/012v (on average, respectively –0.045% and – 1.147% to st), which was distinguished by the lack of fimble segregation, by higher precocity in relation to the standard variety and other numbers, by superiority of stem yields (+0.6 t/ha to st).

The GP-7/012m breeding number had the best seed productivity (average 3.7 g/plant or +0.9 g/plant to st), oil content in seeds (average 32.1% or +1.1% to st), seed yield and oil yield (respectively +0.03 and +0.02 t/ha to st), and by the weight of 1000 seeds on average corresponded to the level of standard variety.

The Surskaya standard variety and the Vera variety dominated in yield and harvest of total/long fiber. The Surskaya standard variety showed superiority in breaking load of combed fiber in general. The Vera variety demonstrated the highest values of combed fiber flexibility.

According to the results of competitive variety trial of promising breeding numbers in 2018, an application was submitted for inclusion of the breeding number GP-7/012m under the name of Milena hemp variety in the State Register of Breeding Achievements of the Russian Federation.

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DOI: 10.26177/VRF.2019.2.2.016

EFFICIENCY OF APPLICATION OF DIFFERENT PROTECTANTS ON HARD SPRING WHEAT DEPENDING ON THE PRECURSOR IN THE CONDITIONS OF THE SOUTH FOREST-STEPPE OF WESTERN SIBERIA

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The article presents the results of studies of the influence of chemical preparations (protectants), which preparative form contained various active substances, on the formation of the main elements of the structure of the harvest of hard spring wheat, depending on its precursor. The work makes it possible to evaluate the effectiveness of the use of a disinfectant on hard spring wheat, depending on its precursor in the conditions of the southern forest-steppe of Western Siberia. As a result of the research, it was established that the highest field germination of hard spring wheat sown on clean fallow and of spring rape was provided by the drug Scarlet (76.9 and 71.3%, respectively), and on spring wheat – by Vincite (56.5 %). The lowest intensity of plant damage by root rot was observed in all variants using the drug Lamador. The benefits of clean fallow, like its predecessor, remained unchanged. The lowest susceptibility of hard spring wheat plants to root rot was noted after the clean fallow and was 17%, while for other precursors, this indicator was 33...50%. The affection of plants with root rot had a negative impact on the formation of the main elements of the structure of the crop and as a result significantly reduced the amount of the yield.
Key words: hard spring wheat, root rot, precursor, protectant, yield structure.

Introduction

The result of the active use of resource-saving technology of cultivation of agricultural crops is the concentration of pests in the upper soil layer, including the causative agents of root rot [8]. At the same time, the composition of the pathogenic complex of the seeds themselves includes dozens of species of fungi, bacteria and viruses, among which the causative agents of Helminthosporium blight, Fusarium blight, various spots and molding of seeds predominate. The development of these diseases causes serious losses in the collection of grain [3, 6].

The period from germination to seedling formation (the phase of 1...3 leaves) is critical in the life cycle of spring wheat. During this period, the transition from heterotrophic nutrition of seed spare nutrients to autotrophic nutrition of young plants takes place [5]. The causative agents of Fusarium-Helminthosporium diseases transmitted through the seeds are the first to harm the germinating seeds and seedlings. They reduce field germination, inhibit the growth and development of the vegetation cone, weaken and reduce the competitive ability of seedlings to phytophages and weeds. Compared to soft spring

Table 1. Used protectants

Protectant	Drug consumption rate, l/t	Active substance
Lamador, KS	0.15	prothioconazole (250 g/l) + tebuconazole (150 g/l)
Scenic Combi, KS	1.25	clothianidin (250 g/l) + fluoxastrobin (37.5 g/l) + prothioconazole (37.5 g/l) + tebuconazole (5 g/l)
Insure Perform, KS	0.4	triticonazole (80 g/l) + pyraclostrobin (40 g/l)
Scarlet, ME	0.3	imazalil (100 g/l) + tebuconazole (60 g/l)
Vincite, KS	0.4	flutriafol (25 g/l) + thiabendazole (25 g/l)

wheat, hard wheat is more strongly affected by root rot and black grain germ caused by Bipolaris sorokiniana [11].

Agricultural producers are currently offered a wide range of chemicals to protect the seeds, which preparative form contains various active substances. In this regard, there is a need to study these drugs in certain soil and climatic conditions for specific field crops [9, 10].

The aim of the research was to identify the most effective protectant of hard spring wheat, depending on its precursor in the conditions of the southern forest-steppe of Western Siberia.

Methods and materials

Field experience was established in 2016-2018 on the training and experimental field of the training and experimental farm of Omsk State Agrarian University, located in the southern part of the forest-steppe of the Omsk region. The soil of the experimental field was medium-deep low-humus medium-loamy meadow-black soil. In all the years of research, seeds were pretreated before sowing, which was carried out in the first half of the third decade of May with the SSFK-7 seed drill with a seeding rate of 4.5 million germinating grains per hectare, seed embedding depth of 5-6 cm with subsequent rolling of the soil with ring-spur rollers [7].

The plot area was 20 m^2 (2x10). The precursors weer clean fallow, soft spring wheat, spring rape. The variety of hard wheat was Omskiy emerald. Used protectants and their brief characteristics are presented in table 1 [1].

The meteorological conditions of the growing season (May-September) were characterized: in 2016 as insufficiently moistened (HTC = 1.09); in 2017 as hot (HTC = 0,70) and in 2018 as wet (HTC = 1.21).

Results.

Field germination of plants is one of the very important indicators that determine the amount of yield. In our studies, this indicator ranged from 29.9 to 76.9% depending on the used protectant, precursor, and meteorological conditions. The highest rates of field germination were observed in the cultivation of hard spring wheat after a clean fallow, the lowest – after spring wheat. When hard spring wheat was cultivated after spring rape, the field germination was noted in the range from 53.8 to 71.3% depending on the protectant (Fig. 1).

When seed was treated with Scarlet, higher field germination rates for pure steam and spring rape were noted (76.9 and 71.3%, respectively), and Vincite was best for spring wheat – 56.5% compared to other studied drugs. Relatively re-

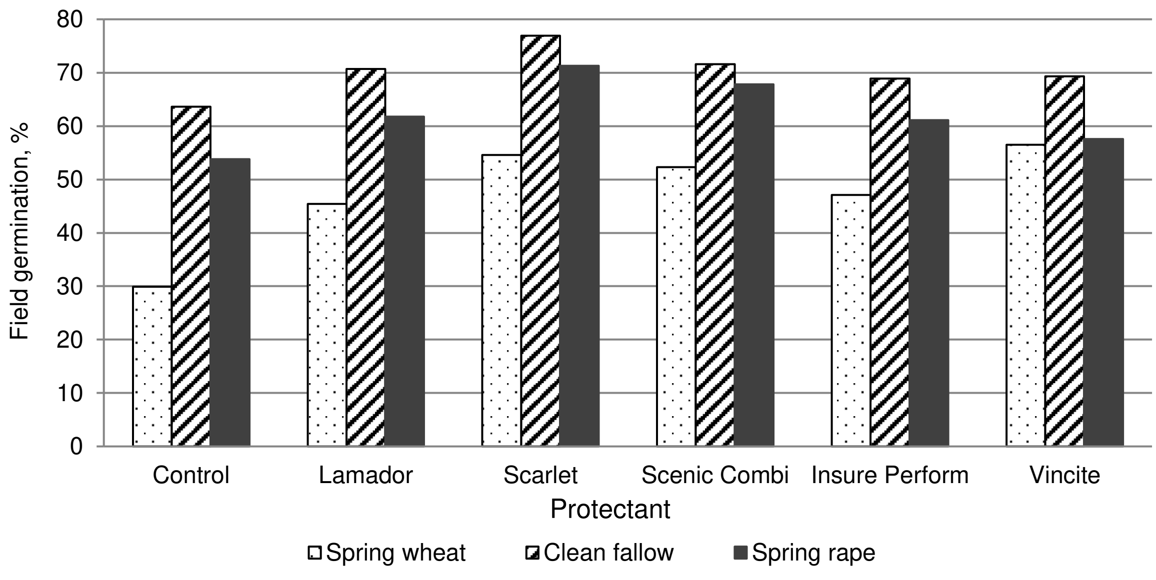

Figure 1. Field germination of hard spring wheat depending on the used protectant and its precursor, on average for 2016-2018

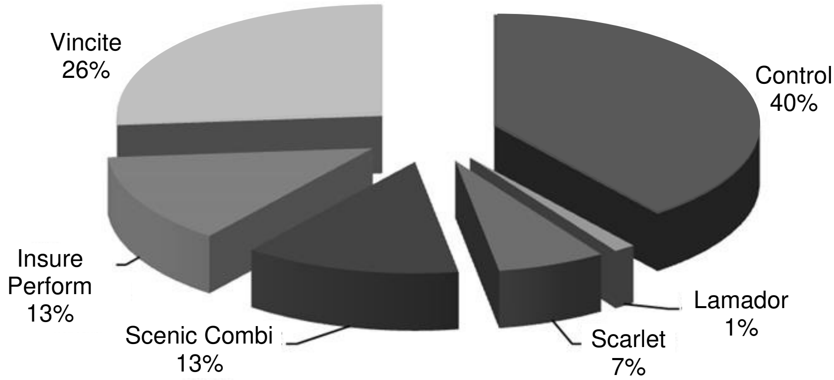

Figure 2. The intensity of hard spring wheat damage with root rot, depending on the protectant, on average for 2016-2018

duced indicators of field germination of a particular pattern were not identified. Thus, for spring wheat, the lowest rates of field germination were when the seeds were treated with Lamador (45.4%), for a clean pair – Insure Perform (68.9%) and for spring rape – Vincite (57.6%). It should also be noted that Control had the lowered indicators (29.9...63.6%).

Of the total infectious diseases of cereals, root rot occupies the first place in terms of its distribution and severity [15]. Helminthosorium fungus has a strong inhibition on the development of spring wheat seedlings [2]. In the conditions of Western Siberia, Helminthosporium and fusarium blight prevail on spring wheat [12]. The analysis of the hard spring wheat damage with root rot was carried out according to the 2002 VIZR method in the tillering stage of the crop. On average for 2016-2018 the most intensive root rot injuries were noted at Control – 40% (Fig. 2).

0 – healthy plants

1 – single strokes on a coleoptile or underground internode

2 – weak browning of a coleoptile or underground internode

3 – complete death of the seedling

In the variant with the use of the drug Vincite a high degree of plants damage with root rot was also noted – 26%. The lowest intensity of root rot damage was found in the variant with the use of the drug Lamador – 1%.

The most intensive damage of hard spring wheat plants with root rot were when this crop was sown after soft spring wheat – 50% (Fig. 3).

0 – healthy plants

1 – single strokes on a coleoptile or underground internode

2 – weak browning of a coleoptile or underground internode

3 – complete death of the seedling

The advantages of clean fallow as a precursor remain unchanged. So, the lowest susceptibility of hard spring wheat plants with root rot was after clean fallow – 17%.

The yield of spring wheat is determined by the number of productive stems per unit area [4]. The most complete picture of the productivity is given by a biometric analysis of plants, which consists of such elements as the length of the stem and spike rod, productive bushiness, the number of spikelets in the ear, the weight of 1000 seeds and the weight of grain from one ear. In this regard, it is extremely important to know under the influence of what factors a productive spike is formed. Particular attention should be paid to the influence of root rot pathogens on the development of the ear, since in large areas this indicator is still one of the powerful factors determining the height of the crop [13, 14]. Our observations showed that the highest indicators of the structure of the crop and yield were formed when sowing hard spring wheat on a clean fallow (Table 2).

When sown on spring wheat, the indicator of productive tillering was the lowest (1.0...1.5). On average, the plant height indicator varied significantly and ranged from 77.3 to 130.4 cm. This indicator was mainly influenced by both meteorological conditions during the growing season of the crop and the damage to the plants by root rot

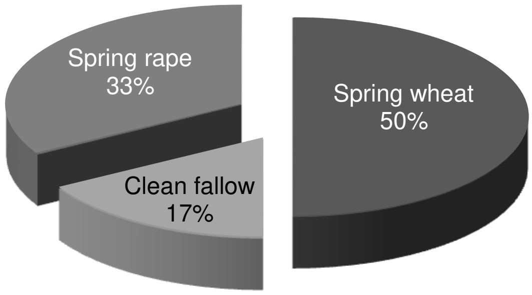

Figure 3. The intensity of hard spring wheat damage with root rot, depending on the precursor, on average for 2016-2018

Table 2. The main elements of the structure of hard spring wheat yield, depending on the protectant and precursor on average for 2016-2018.

Variant	Productive tillering	Plants height, cm	Amount, pcs		Grain weight per ear, g	Yield, t/ha
			spikelets in the ear	grains in the ear		
Precursor: Soft spring wheat						
Control	1.2	85.8	14.2	30.7	1.47	2.26
Lamador	1.2	99.1	14.7	28.8	1.94	3.48
Scarlet	1.2	99.1	14.7	28.8	1.51	3.12
Scenic Combi	1.0	93.3	13.7	25.7	1.41	2.87
Insure Perform	1.5	95.6	14.7	31.1	1.41	2.92
Vincite	1.3	94.2	11.5	23.0	1.37	2.66
					HCP_{05}	0.37
Precursor: Clean fallow						
Control	1.6	115.5	15.8	32.9	1.89	3.45
Lamador	1.9	126.6	19.6	42.9	2.15	4.05
Scarlet	1.6	109.5	16.8	37.5	1.90	3.85
Scenic Combi	1.7	121.8	17.8	38.2	1.97	3.80
Insure Perform	1.8	130.4	17.6	40.7	1.91	3.90
Vincite	1.6	117.7	16.2	30.8	1.41	3.65
					HCP_{05}	0.38
Precursor: Spring rape						
Control	1.2	83.9	12.8	31.0	1.96	2.97
Lamador	1.9	78.3	14.0	38.6	2.05	3.76
Scarlet	1.8	82.4	13.7	32.1	1.96	3.31
Scenic Combi	1.7	77.3	13.2	35.1	1.72	3.12
Insure Perform	1.6	81.7	13.5	36.9	1.96	3.48
Vincite	1.4	79.3	13.0	33.3	1.65	3.07
					HCP_{05}	0.27

(η = 0,60, $y = 0{,}0133x^2 + 0{,}2553x + 2{,}3473$). The productivity of the ear is a very complex element of the crop. On average, over three years, the largest number of spikelets in the ear (14.0...19.6 pieces) and, accordingly, the largest number of grains in the ear (28.8...42.9 pieces) had the variant using the drug Lamador. The lowest similar indicators were observed in the variants with the use of the drug Vincite (11.5...16.2 and 23.0...33.3 pcs, respectively). A significant relationship was established between the number of spikelets in the ear and the number of grains in the ear in all variants (r = 0.70...0.97). The lowest grain mass per spike and the lowest yield was noted in the variants with the highest intensity of plant damage by root rot.

We analyzed the relationship between the intensity of damage to plants of hard spring wheat by root rot with crop yield and the main elements of the crop structure. It was found that the crop yield naturally decreased with an increase in the susceptibility of plants by root rot (r = 0.77). With individual elements of the crop structure (productive tillering, the number of spikelets in the ear and the weight of grain from the ear), a direct dependence of the average degree was noted (r = 0.30...0.39). Due to the fact that the relationship between plant height, the number of grains per ear and the intensity of plant damage by root rot was significantly deviated from linear, i.e. weak contingency was noted, we established a curvilinear dependence of the average degree between these indicators (η = 0.56...0.60) (Fig. 4).

Conclusion

1. The highest field germination of hard spring wheat when it is sown on a clean fallow and spring rape is provided by the drug Scarlet (76.9 and 71.3%, respectively), and on spring wheat – by Vincite (56.5%).

2. On average, over three years of research, high efficiency (over 90%) in protecting hard spring wheat plants against root rot was provided by the drug Lamador.

3. Soft spring wheat is an unfavorable precursor for hard spring wheat due to the high intensity of root rot damage – 50%.

4. The highest indicators of the elements of the crop structure and the yield of hard spring wheat grain (4.05 t/ha) were noted when sowing seeds treated with Lamador on a clean fallow.

5. The yield of hard wheat grain naturally decreases with an increase in the susceptibility of plants by root rot (r = 0.77).

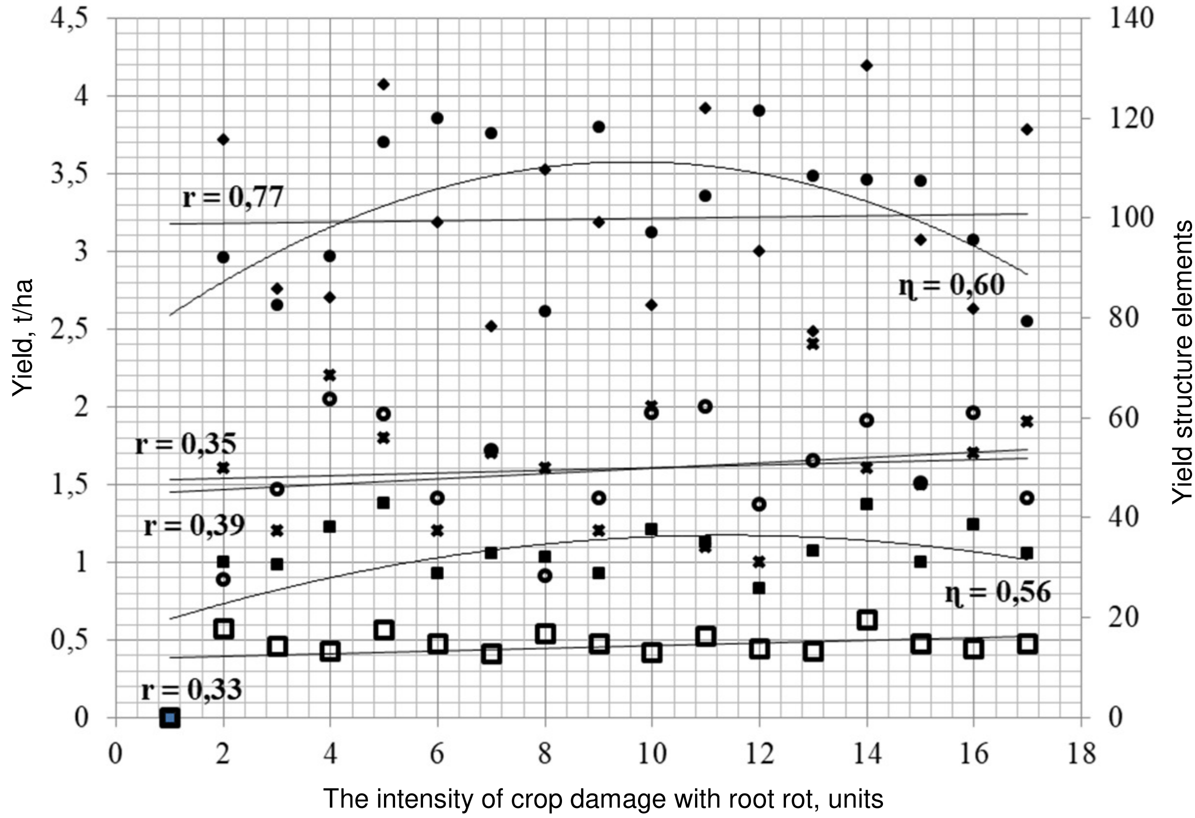

Figure 4. Correlation coefficients (r) or correlation relations (η) of the harvest of hard spring wheat grain and elements of the crop structure with the intensity of crop damage by root rot depending on the used preparation and its precursor for 2016-2018

6. The damage of plants by root rot has a negative impact on the formation of the main elements of the structure of the crop and as a result significantly reduces the amount of yield.

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Veterinary and zootechny

DOI: 10.26177/VRF.2019.2.2.017

ASSESSMENT OF THE FEMALE CHICKENS OF THE COBB-500 CROSS ON REPRODUCTIVE QUALITIES IN CONDITIONS OF THE MIDDLE VOLGA REGION

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In breeding work with meat poultry, great attention is paid to the hatching of eggs per layer, as the quantity of broilers produced depends on this indicator. Investigations were carried out in the production conditions of the second-order reproducer of the OAO (OJSC) Vasilievskaya poultry farm in the Bessonovsky district of the Penza region on female birds of the Cobb-500 cross. The parental group of the bird was completed with replacement chickens in the age of 17-18 weeks. We studied the main indicators of egg productivity (egg production on the initial layer for 50 weeks of productivity; weight of eggs, hatching eggs yield and hatching of young animals at the age of 350 days of life, yield of healthy chickens from one parent couple; safety of adult birds and live weight of layers) and morphological indicators of egg quality (weight of eggs, diameter of the air chamber, shape index, specific weight and shell thickness) of female hens at the age of 350 days of life. All indicators were compared with the standard of the Cobb-500 cross. As a result of the conducted research, the efficiency of breeding with the female birds of the Cobb-500 cross was established by reproductive qualities, which ensured more than 140 broilers from one parental pair, with 90.9% of hatching eggs and 83.4% of hatching. The productive qualities of the hens of the parent form of the Cobb-500 cross over all the studied parameters were not inferior to the standard of the cross.

Key words: female of cross Cobb-500, egg production, hatching eggs, egg quality, chickens hatchability.

Introduction

Modern poultry in Russia is one of the major sectors of the agro-industrial complex, and the production of eggs and poultry meat tends to increase. The success of the poultry industry in general, and broiler production in particular, is due to many indicators, namely, high preservation of young animals, the rapid increase in live weight of birds, low feed costs per 1 kg of egg mass and 1 kg of increase in live weight, high quality eggs and meat, high reproductive qualities of hens of pedigree flocks, high yield of hatching eggs and chickens obtained from one layer of a parent flock. [3]

Domestic poultry farms annually lack 10% of hatching eggs to provide the population with consumable goods. In the concept of the development of the poultry industry of the Russian Federation for the period 2013-2020, it is noted that with today's volumes of production of broiler meat for import supplies, about 500 million pieces of hatching eggs and 62 million hybrid day-old chicks must be imported annually. For the acquisition of parental day-old chickens of meat crosses, 4.7 million heads are needed, and of egg crosses – 800 thousand heads are needed [1, 6].

In the selection of modern crosses, the Cornish breed is used as the father form, and the Plymouthrock is used as the mother. This choice is due to the high live weight and excellent meat forms of Cornish young birds and good production performance of Plymouthrock poultry. The combination of these properties provides a high yield of meat from one parental pair [4].

An important direction when working with grandparent and parental flocks of poultry is the selection to improve the reproductive qualities of the bird. The main feature that determines the reproductive performance of the bird is egg production. With a high egg production rate of chickens of maternal lines and female forms from each parent pair, at least 130 broilers and about 300 kg of meat can be obtained. [10]

In the process of breeding female chickens, considerable attention is paid to the output of hatching eggs per one layer, as the number of broilers produced depends to a greater extent on this indicator. At the same time, the yield of hatching eggs depends on a number of factors, including the level of egg production of the layers, the period of puberty beginning, the age of the bird when selecting eggs for incubation, the quality indicators of eggs (size, shape,

components of the egg) and technology of poultry keeping [9].

Evaluation and selection of eggs for incubation must be carried out continuously. The first evaluation is carried out directly in the poultry house when they are examined – eggs with a clearly damaged or heavily polluted shell, two-yielded, small, notched, very large, severely deformed and with a bad shell are removed. The second selection is carried out in the egg warehouse of the hatchery, where the eggs are more carefully assessed and rejected, control over the belonging of the eggs to the line and the parent form is carried out [5].

The results of incubation, ensuring the production of the required number of healthy, full-bodied young animals play a large role in achieving the maximum economic indicators in the production of eggs and poultry meat. According to the statements of many scientists, the efficiency of incubation by 70% depends on the quality of eggs. An important condition for the production of eggs and poultry meat is a system for controlling the quality of the eggs, the development of the embryo, then the daily young chickens and thier safety in the first ten days of breeding [2].

General requirements for eggs for the reproduction of a selection flock include the determination of the mass, correctness of shape, the color intensity of the shell, the absence of notches and growths, blood and meat inclusions. Along with the evaluation and selection of eggs without violating the integrity of the shell, the assessment on the morphological and biochemical parameters of the egg content in different age periods is also carried out. For this purpose, eggs from each bird line are taken, their opening and evaluation is systematically performed. The quality of protein and yolk is determined by Hough units and the thickness of the shell. Before the eggs are opened, the shape and density indexes are determined. These indicators fully characterize their quality. Based on the results of weighing the constituent parts of the egg, the ratio between the protein and yolk is calculated. Such an assessment is necessary to monitor the state of the flock of chickens. Violations associated with bird feeding, planting density, sex ratio and other technological parameters always affect the quality of eggs, therefore full feeding of breeding birds should be strictly ensured [8].

The maximum hatchability of eggs, as well as high quality chickens, are obtained if the hatching eggs are in optimal conditions from the moment they are laid to the time they are put in the incubator. A fertilized egg consists of a multitude of living cells. After being laid, hatching eggs can only be saved, but not improved. The quality of hatching eggs largely depends on the mode of storage. Long-term storage of eggs leads to a decrease in hatchability of eggs and the quality of the hatchlings. Experimental data from domestic scientists have shown that warming incubation eggs from the chickens of 38 and 54 weeks of age for 2 and 4 hours increases egg hatching by 4.6% and 5.9%, respectively [7, 11].

In this regard, increasing the role of breeding work to improve the productive qualities of parental flocks of poultry is relevant.

All of the above served as the purpose of our work, namely, a need for a preliminary assessment of female chickens of the Kobb-500 cross on reproductive qualities at the age of 350 days of life in the conditions of OJSC poultry farm Vasilievskaya of the Bessonovsky district.

Methods and materials

The studies were carried out under the production conditions of a second-order reproducer of the OJSC Vasilievskaya poultry farm in the Bessonovsky district of the Penza Region on female birds of the Cobb-500 cross. The parental group of the birds was completed with replacement chickens at the age of 17-18 weeks, while using young birds (the first year of productivity) in the amount of 500 heads. The keeping of the bird was outdoor. The norms of layer density, light, temperature, humidity regimes, the front of feeding and watering in all periods of age corresponded to the recommendations of All-Russian Research and Technological Institute of Poultry Farming. The main indicators of egg productivity of hens of the above cross at 350 days of life were studied.

Results

An objective assessment of the egg production of female chickens of the Cobb-500 cross deserves a certain attention. The success of the breeding enterprise is largely determined by the number of breeding eggs from the parent pair.

As a result of purposeful breeding work carried out at the OJSC Vasilievskaya poultry farm, the egg production of the Cobb-500 cross layers is at a relatively high level and is 218.6 eggs per 50 weeks of productivity, with an average laying rate of egg-laying over the entire period of 62.5%, but inferior to the standard of the cross by 0.7 pieces or 0.33% (Table 1).

Based on the assessment of female birds of the Cobb-500 cross by meat forms of constitution, egg production, reproductive qualities, payment of feed by increase in live weight, the most productive individuals are allocated for further breeding work, and as a comprehensive indicator of the assessment of female birds of the cross studied and its selection in the future, a feature such as the transition from a chick to a layer for a biological period is used. The relatively tight selection of female birds of the Cobb-500 cross for further breeding work allows to

Table 1. Efficiency of hens of Kobb-500 cross

Indicator	Female birds	
	Fact	Standard
Egg production per hen housed during 50 weeks of productivity, pcs.	218.6	219. 3
The mass of eggs of birds of 350 days of life, g	67.4	67. 5
Hatching eggs productivity at 350 days of age, %	90.9	88. 6
The hatchability of young birds at the age of 350 days of life, %	83.4	83.6
The productivity of healthy chickens from one parent pair, heads	143.6	144.0
Safety of adult birds, %	92.2	92.0
Live weight of layers at 350 days of age, kg	3.85	3.82

achieve a significant consolidation of productive traits. The yield of chickens from one parent pair of the Cobb-500 cross made 143.6 heads.

In the process of breeding with female meat chickens, much attention is paid to the output of hatching eggs per one laying hen, as the quantity of broilers depends to a certain extent on this indicator.

Currently, there have been some changes in the feeding of meat chickens. Limited feeding of young animals and rationed feeding of adult birds are used practically in all farms in order to reduce their fatness and body weight and increase reproductive qualities. The use of limited feeding and differentiated light regimes while keeping breeding replacement chickens contributes to obtaining standard weight eggs and provides a reduction in the number of small ones.

The female chickens of the Cobb-500 cross in the conditions of the studied enterprise is characterized by a relatively high yield of hatching eggs – at the age of 350 days of life it was 90.9%, which exceeded the standard by 2.3%. In conditions of OJSC Vasilievskaya Poultry Factory of the Penza Region, great attention is paid to improving the productivity of hatching eggs and, ultimately, increasing the number of broiler chickens from each laying hen. The poultry factory carries out the timely transfer of replacement chickens from the growing room to the premises for adult birds. This is done when a layer reaches 17.5-18.0 weeks. The eggs are collected repeatedly during the day, with special attention paid to cleanness of the bedding. The observance of the daily routine and sanitary regime in the premises of the farm contributes to reducing the number of eggs laid on the floor, polluted, notched and broken.

The weight of eggs is one of the most important indicators of their incubation qualities. The task of breeding work is to increase the yield of hatching eggs due to an increase in the layers with an optimal egg mass (60-67 g). The poultry factory provides for a constant assessment of female chickens of the Cobb-500 cross by the weight of eggs.

Our studies on the mass of eggs of the hens of the Cobb-500 cross at the age of 350 days of life indicate that the size of the eggs of female chickens of this cross is at the level of 67.4 g; compared to the standard, the weight loss of the eggs is 0.1 g or 0 ,15 %.

To increase the size of eggs, it is necessary to carry out a more careful selection for this indicator in the period of onset of puberty. The size of the eggs depends on the sexual maturity of the hens. Between the age of the first eggs laid and the mass of the first ten eggs, a positive correlation coefficient was established, which was 0.8. Chickens that started egg-laying at an early age produce small eggs, which reduces the average weight of eggs in a one-year turnover, and, consequently, the economic efficiency of production. It is necessary for pullets to reach a live weight of at least 1300–1500 g at the start of egg laying. The mass of eggs varies depending on the age of the layers. During the first year of egg laying, hens reach the maximum egg mass at 13-15 months old. In the second year of productivity, hens lay 10-15% more eggs than on average in the first year of productivity.

In the conditions of OJSC Vasilievskaya Poultry Factory, sufficient attention is paid to the live weight of chickens. At the age of 350 days of life, this indicator is at the level of 3.85 kg, which exceeds the standard by 0.03 kg or by 0.52%. The control over the live weight of layers of the Cobb-500 cross contributes to an increase in the yield of hatching eggs, especially at the beginning of the laying.

The results of incubation of eggs of the Cobb-500 cross at the age of 350 days of life showed that the hatchability was 83.4%, compared with the standard, it was lower by 0.20%. The difference in hatchability of eggs between household data and the standard turned out to be unreliable.

The poultry factory regularly evaluates morphological indicators of egg content at different age periods. For this purpose, at least 30 eggs are systematically opened.

The quality of eggs characterizes biological, food and trademarks. Biological features include signs related to the developmental ability of an egg (fertilization of eggs, hatchability or embryonic viability), food features – determining

the nutritional value of yolk and protein; trade features include those related to the preservation of eggs as a commodity for buyers.

Numerous characteristics of egg quality can be divided into basic features (weight of egg, its shape, shell strength) and additional ones such as egg density, light transmission, marbling, shell color, Hough unit, protein and yolk index, egg fraction ratio, yolk pigmentation, chemical composition of protein and yolk, etc.

Characteristics of egg quality are genetically determined and differ in the parameters of heritability and variability. These signs are formed as a result of the interaction of the genotype and the environment. Therefore, raising the quality of eggs is achieved both by selection methods and optimization of environmental conditions.

A hatching egg must be rich in nutrients and vitamins, have a strong shell that can withstand transportation and long-term storage.

Improving the incubation qualities of eggs allows to increase the profitability of the industry and enforce the financial encouragement for poultry farmers.

Prior to incubating eggs, it is impossible to determine reliably if there will be a hatch from each individual egg or not, but this does not diminish the importance of determining the biological value of eggs intended for incubation according to their external features. Therefore, the selection of eggs for incubation by external signs is important as a method that improves the quality of eggs in the bred offspring.

The strength of the shell is determined indirectly by its thickness (there is a close correlation between the thickness of the shell and its strength), relative mass, egg density, and elastic strain. For direct measurement of the shell thickness, an indicator micrometer is used on a special stand that allows counting with an accuracy of 0.01 mm.

In special studies, to obtain an indicator characterizing the thickness of the egg shell on average, it is sufficient to measure pieces of the shell taken from the sharp and obtuse ends of the egg and its middle part. Before measurement, inner shell membranes are removed from the shell.

The shell thickness determines its strength and ranges from 0.20 to 0.60 mm. Strong and durable eggs have a shell thickness of 0.35 mm or more. A certain relationship has been established between the shell thickness and the quality of eggs. So, with a shell thickness of 0.28 mm, the proportion of the breakage and notches is 45.5%; 0.31 mm – 21.8%, 0.33 mm – 12.3%; 0.36 mm – 4.9%.

The strength of the shell depends on the characteristics of its structure, in particular on the number of pores and translucent areas (marbling). It should be noted that the pores on the shell surface are unevenly distributed: on 1 cm² of the sharp end of a chicken egg shell there is on average 100 pores, in the middle part – 142, at the blunt end – 151 pores. The porosity of eggshell of young laying hens is higher than of old ones. The gas permeability of the shell and the percentage of egg drying depend on the number and diameter of the pores.

The shape of the egg and the thickness of the shell affect its strength. Eggs with an average shell thickness can withstand a force of 2.5 to 4.5 kg.

The purity of the eggshell is one of the decisive factors determining their future use. Dirty shell spoils the marketable condition of eggs, dramatically reduces the duration of their storage, reduces their reproductive quality. The conditions of the poultry keeping is decisive for the cleanness of the shell.

The size of the air chamber characterizes the weight loss of the egg. Fresh eggs have a small air chamber, the diameter is about 1.5-1.8 cm. As the water from the egg evaporates, the volume of the air chamber increases. The season of the year has a definite influence on the size of the air chamber of the egg; in winter, the air chamber is larger than in summer, since at a low temperature the content of the egg reduces its volume more than at a high temperature.

When assessing the quality of eggs, an important indicator is the density of eggs, which characterizes the strength of the shell. The density of an egg is mainly due to the size of the air chamber and the thickness of the shell. This figure varies depending on the shelf life of eggs. The density of fresh eggs of chickens varies between 1.055-1.096 g/cm³, and during long-term storage it sharply decreases. Eggs with a density not lower than 0.907 g/cm³ are used in food.

With a shell thickness of 0.28-0.30 mm, the density of the egg is 1.071 g / cm³, with a thickness of 0.33-0.85 mm – 1.080 g / cm³ and 0.38-0.41 mm – 1.090 g / cm³.

The density of fresh chicken eggs averages 1,076-1,095 g / cm ³.

The assessment of eggs by morphological characteristics is necessary to monitor the state of the flock of hens of parental forms.

Studies carried out on the factory show that the incubation eggs of the hens of the Cobb-500 cross at 350 days of age generally comply with the requirements for the quality of hatching eggs (Table 2).

In order to improve the efficiency of breeding work with the Cobb-500 cross, much attention is paid to the male form of broilers. Strict selection of the male form of chickens is carried out on parameters of live weight and muscled

Table 2. Morphological quality indicators of eggs of the Cobb-500 cross at 350 days of age

Indicator	Standard	350 days of age	Difference
Weight of an egg, g	67.5	67.4	0.1
Diameter of the air chamber, cm	1.85	1.84	0.01
Shape index, %	82.9	82.9	0.3
Specific weight, g/cm²	1.080	1.080	0
Shell thickness, mm	0.32	0.33	0.01

breasts, leaving roosters only with high live weight and with excellent muscling of the lophosteon for subsequent reproduction of the flock. The determination of the musculature of the breast is carried out by visual inspection and palpation.

Conclusion

Experimental data showed that the increase in the reproductive qualities of chickens of the Kobb-500 cross in the conditions of the OJSC Vasilievskaya poultry factory is ensured through targeted breeding work and strict adherence to modern technology of poultry farming and keeping in a farm. The fulfillment of all the above measures made it possible to increase the productive qualities of the laying hens of the Cobb-500 cross, which were not inferior to the standard of the cross by almost all studied indicators.

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ENGINEERING SCIENCES

Processes and machines of Agroengineering systems

DOI: 10.26177/VRF.2019.2.2.018

A DEVICE FOR ADDITIONAL CLEANING OF SUGAR BEET ROOTS

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Materials of the article are devoted to the actual problem – improving the quality of cleaning sugar beet roots. In the conditions of the Middle Volga region, the harvesting of sugar beet begins in the second decade of September, which is characterized by a deterioration of the agro-physical properties of the soil, which leads to a sharp decrease in the quality of harvesting. Therefore, the sugar beet roots require additional cleaning from soil impurities after combine harvesting. The article presents the results of studies on the fractional composition of the heap and size-mass characteristics of the root crops after combine harvesting. A description of the design and principle of operation of the device for additional cleaning of root crops is given, its design and operating parameters are theoretically justified. A prototype has been manufactured and its production verification is given. It was established that at the operating speed of a feed conveyor of 2.0 m/s, the device's performance per hour of clean work was 28.0 tons, while the content of impurities in the cleaned pile did not exceed 8.0%.

Keywords: sugar beet, root crop, soil impurities, beet harvester, device for cleaning root crops, fractional composition of a heap, size-mass characteristic, rotary cleaner, elastic cleaners.

Introduction

Sugar beet is the main source of sugar in the Russian Federation, and Penza region is one of the major regions of its cultivation.

The most critical stage in the production of sugar beet is the harvesting of root crops. In the conditions of the Middle Volga region, the harvesting of this crop starts from the second decade of September, which is characterized by the deterioration of the agrophysical properties of the soil (moisture and stickiness increase). As a result, there occurs sticking of the soil to digging and separating working bodies of beet harvesters and root crops, which sharply reduces the quality of harvesting. Therefore, when harvesting sugar beets, the transshipment technology is mainly used, which involves the removal of root crops from the combine and their unloading at the edge of the field or on a specially prepared transshipment point into temporary field clamps for additional cleaning [2, 12, 14]. Therefore, the purpose of research was to reduce costs and improve the quality of cleaning of root crops; also the development and implementation of the device for additional cleaning of root crops.

The objectives of the research:

– to justify the design and technological scheme of the device for additional cleaning of root crops;

– to produce a prototype and carry out its production testing.

Methods and materials

To develop a device for additional cleaning of sugar beet roots, it was necessary to study the fractional composition of the heap entering the cleaning, and the size-mass characteristic of sugar beet roots. For this purpose, the studies were conducted on the fields of beet-growing farms of the Kamenka district of the Penza region. At the same time, a private method developed on the basis of state standards was used [4, 10].

The qualitative composition of the heap of sugar beet roots was determined from the results of sample analysis. The samples were taken from under the unloading elevator of the beet

harvester "Terra Dos" by the company "Holmer" (Germany). The number of samples was at least 30 in different parts of the field. Each sample was divided into fractions: roots, free soil, soil sticked to roots, vegetable and other impurities. The individual mass characteristic of each fraction was determined by weighing on a VTK-500 scales with an accuracy of 1.0 g. The results of processing the experimental data are presented in Table 1.

Table 1. Fractional composition of the heap of sugar beet roots

Indicator	Value		
	minimum	medium	maximum
The average mass of the heap, kg including	23.4	26.6	29.8
– root crops, %	73.2	77.1	80.9
– free soil, %	17.1	22.6	27.4
– sticked soil, %	1.6	4.8	8.2
– vegetable and soil impurities, %	0.4	0.8	1.2

Dimensional and mass characteristics of root crops were determined by the results of the analysis of samples taken in previous experiments.

The dimensions of the soil lumps that were in the heap of sugar beet roots were determined by measuring with a ShTs-11-250-0.05 caliper with an accuracy of ± 1.0 mm.

The individual mass of sugar beet roots was determined by weighing on a BJIP-1 scales with a division value of 1 g. The measurements were carried out in three replications. The results of processing measurements are shown in Table 2.

Table 2. The results of studies to determine the size-mass characteristics of root crops and soil

Indicator	Value		
	minimum	medium	maximum
Root length L, mm	120.0	212.6	260.0
Root diameter d, mm	32.0	87.3	152.0
Tail length L_2, mm	80.0	108.3	115.0
Diameter of soil lumps, mm	30.0	53.4	75.4
Root weight, g	130	910.5	1160.0

Based on the analysis of existing designs of devices for cleaning root crops [1, 3, 6, 9, 11, 13, 14, 16, 17, 18], on the results of studies on the fractional composition (Table 1) and the size-mass characteristics of sugar beet roots (Table 2), a stationary device for additional cleaning of root crops is proposed. It consists of a frame (1) (Fig. 1), on which a rotary cleaner (2) with a protective grid (3) is installed. The rotary cleaner (2) consists of a base, to which curvilinear rods (4) are radially and uniformly fixed, curved in a horizontal plane along an arc. Elastic cleaners (5) are installed on the guard grid.

A storage hopper (7) with a feeding conveyor (6) is also installed on the frame of the installation. For unloading root crops, there is a guide chute (14) and a discharge conveyor (15). The rotary cleaner (2) and conveyors (6, 15) are driven by gearmotors (10, 11) and chain drives (8, 9), which are switched on from the control panel (12). The rotational speed of the rotary cleaner (2) and the speed of the feed and discharge conveyors can be adjusted using interchangeable chain sprockets.

The device for additional cleaning of root crops works as follows. A heap of root crops after a beet harvester is brought and loaded into a storage hopper (7). When you turn on the installation from the control panel (12), the feed conveyor 6 evenly supplies the heap of sugar beet root crops to the rotary cleaner (2).

When the heap interacts with rotating rods (4) and elastic cleaners (5), root crops are cleaned, soil impurities fall into the impurity pool (13), and root crops go along the guide chute (14) to the discharge conveyor and go to the clamp.

The rotary cleaner consists of a flat disk (2) (Fig. 2) and curvilinear rods (1) that are cantilever-mounted to it and curved in an arc. The curved rods (1) are rigidly fixed to the disk (2).

Elastic cleaners are copronic fibers (1) (Fig. 3), fixed in the holes with the help of plates (2). The length of the fibers may vary.

According to studies of V.A. Khvostov and other authors [5, 7, 8, 15], the diameter of the rotary disk for cleaners made in the form of rotary disks which working surface is formed by curvilinear rods is set within $2R$ = 1.3...1.7 m, the angle inclination of the discs α = 15° is the angle of friction of the roots on the disc surface. Depending on the installation site and diameter, the rotational speed of the discs is 70...110 min^{-1}.

The working surface of the rotary disks is made of rods with a diameter of 16...18 mm. In this case, the radial rods, as a rule, are bent in the direction opposite to the direction of rotation.

The gap between adjacent rods in the central zone of the disk is 40 mm, and at the periphery – 60...80 mm.

In view of the foregoing, and based on design considerations, we take: the diameter of the rotary cleaner D = 1600 mm; the angle of rotation of the rotary cleaner α = 15°; the rod diameter d_{cm} = 16 mm; the gap between the rods t_{cm}: in the central zone – 30 mm; in the periphery – 60 mm.

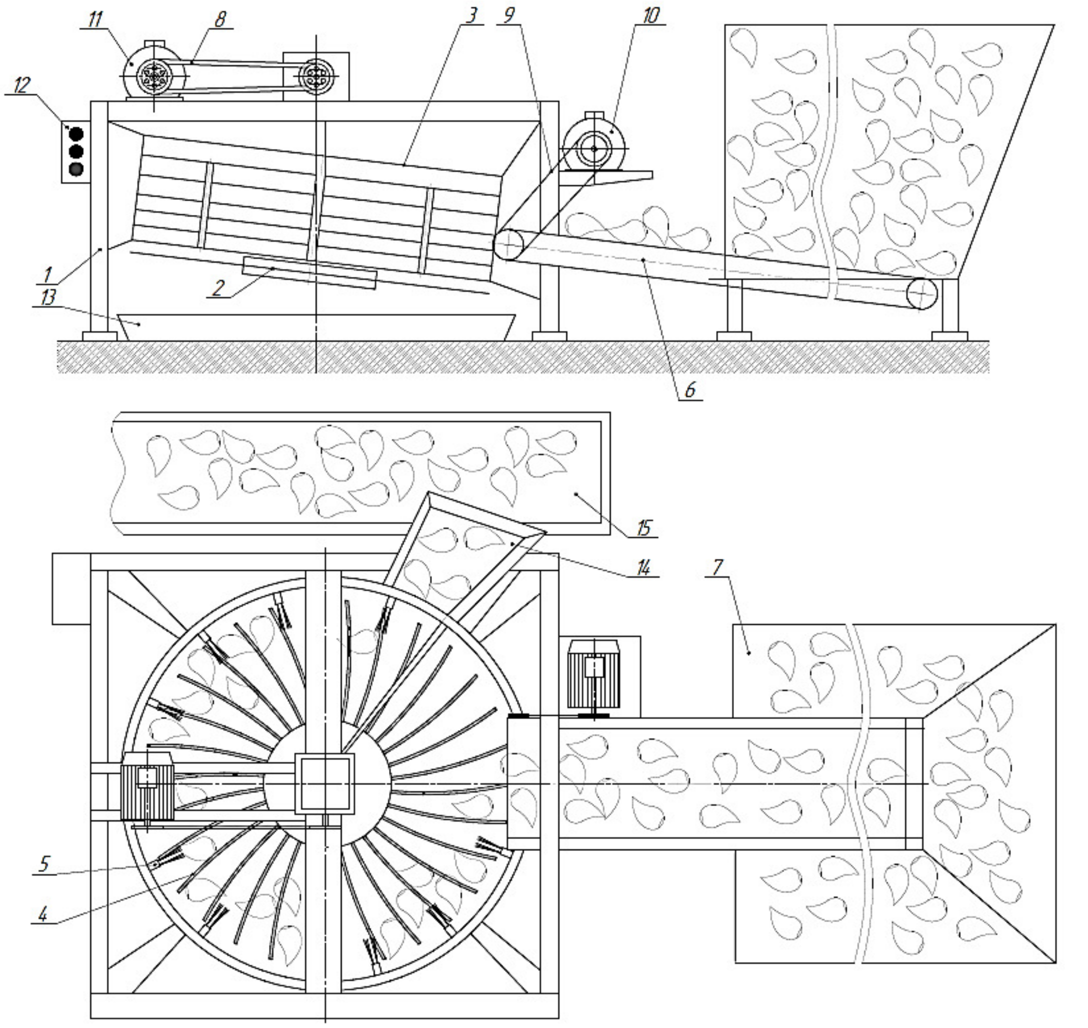

Figure 1. Diagram of the device for cleaning sugar beet roots:1 – frame; 2 – rotary cleaner; 3 – protective grating; 4 – curvilinear rod; 5 – elastic cleaners; 6 – feed conveyor; 7 – storage hopper; 8, 9 – chain drives; 10, 11 – gearmotors; 12 – control panel; 13 – impurity pool; 14 – guide chute; 15 – unloading conveyor.

The height h of elastic cleaners is taken with account to the maximum diameter of root crops:

$$h \geq d_{max}, \quad (1)$$

where d_{max} – maximum diameter of root crops (Table 1), m.

The length l of the fibers of the elastic cleaners is taken with account to the spanning of at least half of the maximum diameter of the root crop, i.e.

$$l \geq d_{max}/2. \quad (2)$$

In view of the foregoing and for constructive reasons, we assume h = 0.18 m; l = 0.08 m.

The production check of the device for additional cleaning of sugar beet root crops was carried out in real conditions during the harvesting of sugar beet. Contamination of the heap of root crops entering the additional cleaning was 22,8%, including soil impurities up to 17.8%. The rotational speed of the rotary cleaner was set to 53 min^{-1}, the number of elastic cleaners – 6 pieces. The working speed of the feed conveyor was regulated in the range from 1.2 to 2.4 m/s.

The contamination of the heap of the roots was determined by the method of sampling. Samples were taken from under the discharge conveyor of the device. The number of samples taken was not less than three on each mode. The analysis was carried out no later than 24 hours after the sampling, with protection from sun exposure, rain and possible damage.

To determine the total contamination of the heap of root crops, the sample was poured onto a tarpaulin and divided into fractions:

– pure root crops, G_o;
– vegetable impurities, G_1;
– soil impurities, G_2.

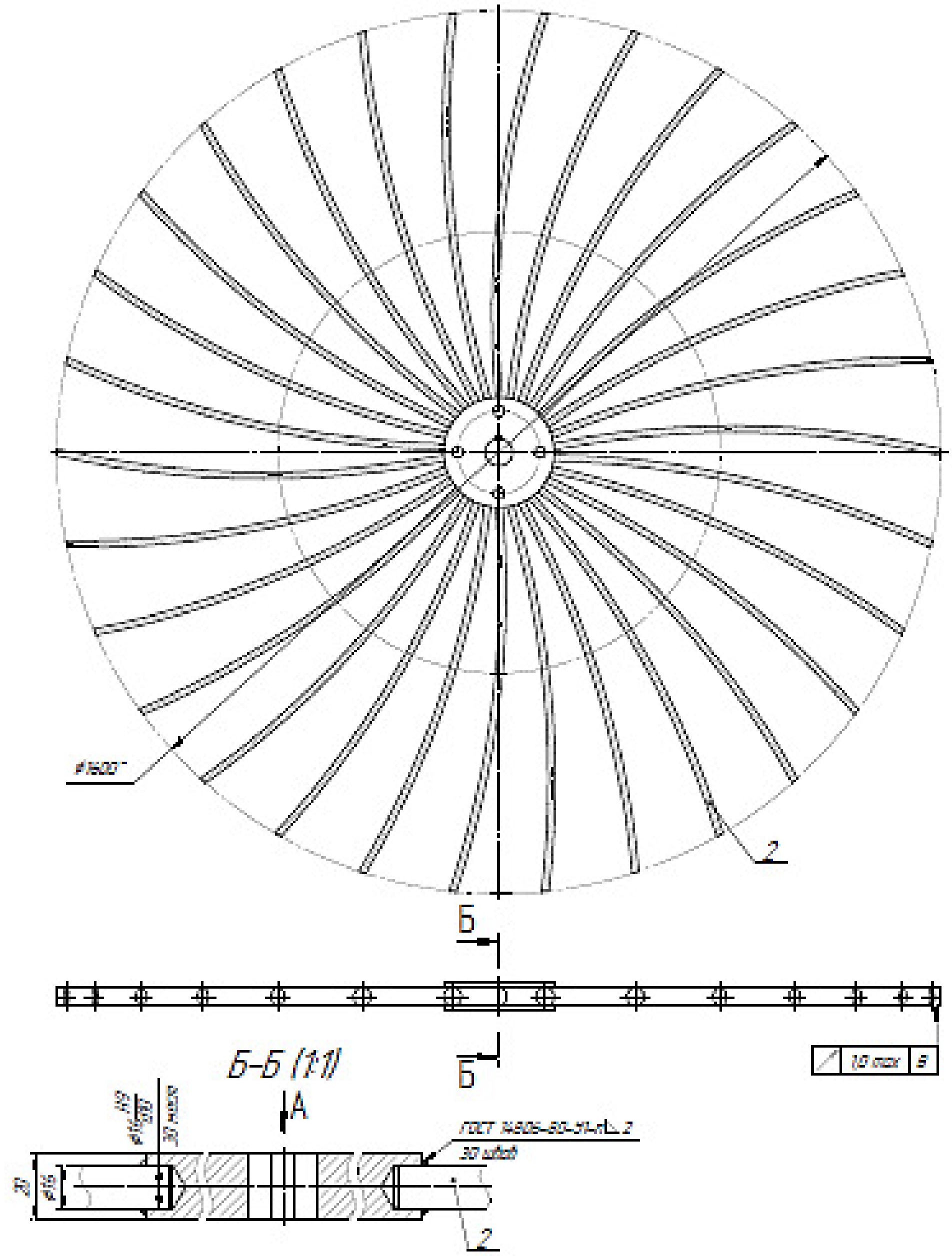

Figure 2. Rotary cleaner: 1 – disk; 2 – curvilinear rod

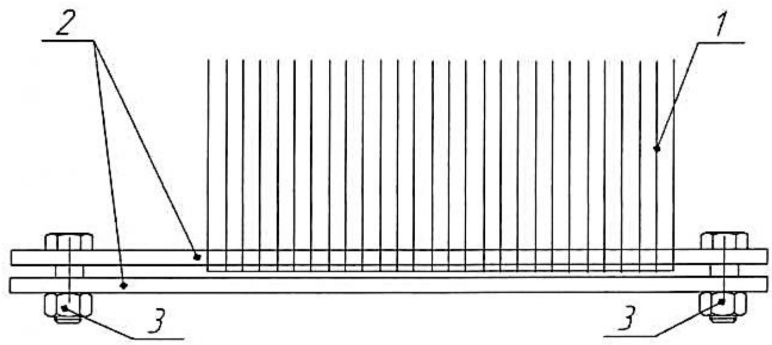

Figure 3. General view of the elastic cleaner (turned):
1 – nylon fibers; 2 – plates; 3 – bolted connections

The total mass of impurities $G_п$ (total contamination) was determined by the formula:

$$G_п = G_1 + G_2 \quad (3)$$

The mass fraction of impurities $\Delta G_п$, %, was determined by the formula:

$$\Delta G_{п} = \frac{G_{п}}{G} \cdot 10^2, \quad (4)$$

where G – the total weight of the sample, kg

$$G = G_0 + G_1 + G_2, \text{ kg.} \quad (5)$$

The mass fraction of soil impurities ΔG_2, %, was determined by the formula:

$$\Delta G_2 = \frac{G_2}{G} \cdot 10^2. \quad (6)$$

Results

As shown by the results of the studies on the fractional composition of the heap after a beet harvester, the amount of soil impurities in the heap of root crops was more than 30%, which indicated the need for additional cleaning of root crops.

As a result of the production check, it was found that at the operating speed of the feeding conveyor of the device of 1.4-2.4 m/s, the process of the post-cleaning of sugar beet roots was running stably. The disruption of the process was not observed. As the data given in Figure 4 show, with an increase in the operating speed of the feeding conveyor, the cleaning process for root crops deteriorates, which is associated with an increase in the mass of the heap entering the cleaning per time unit. The best quality of cleaning was ensured at the operating speed of the feeding conveyor of 1.4-2.0 m/s.

However, with a decrease in the operating speed of the feeding conveyor, the productivity of the device for additional cleaning of root crops decreases. So, at a working speed of 2.0 m/s, the hourly productivity of the device is 28.0 t/h,

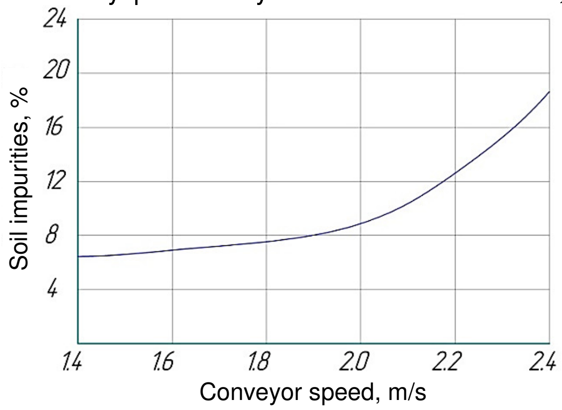

Figure 4. The dependence of the amount of impurities in the heap from the operating speed of the feed conveyor

and at a working speed of 1.4 m/s – 19.6 t/h. Therefore, for further research, we take the operating speed of the feeding conveyor as 2.0 m/s, while the amount of soil impurities in the purified heap does not exceed 8%.

Conclusion

As the research results show, the proposed device for additional cleaning of sugar beet root crops steadily performs the cleaning process at the operating speed of the feeding conveyor of 1.4-2.4 m/s. The best cleaning quality of root crops is ensured at a conveyor speed of 1.4-2.0 m/s. When the operating speed of the feeding conveyor is 2.0 m/s, the amount of soil impurities in the pile does not exceed 8.0%, and the device productivity is 28.0 t/h.

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DOI: 10.26177/VRF.2019.2.2.019

LABORATORY RESEARCH INTO SCREW FEEDER FOR SOWING GRAIN SEEDS

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The article presents the results of laboratory research into an experimental screw feeder conducted in order to optimize the proposed design, which influences the improvement of the quality of sowing grain seeds. The relevance of the study is due to the improved quality of sowing grain seeds because of the development of a new type of screw feeder and the justification of its design and operating parameters.

The main indicator characterizing the quality of sowing is the uneven seed distribution along the length of the row, since this indicator directly affects the yield of the cultivated crop. Conducting a multifactor experiment allowed us to find the optimal values of the outer diameter of the screw helix, pitch of the screw helix, and screw rotation frequency, at which the coefficient of variation of the uneven seed distribution along the row was the smallest. In coded and decoded form, the second order regression equations are presented, which establish the dependence of the coefficient of variation on the above-mentioned screw feeder factors.

A new type of screw feeder, capable of stacking grain seeds evenly, has been designed and manufactured. Screw feeder was installed and tested in laboratory conditions, based on generally accepted methods in accordance with regulatory standards.

Keywords: uneven seed distribution along the row, design and operating parameters, sowing quality, screw feeder, grain crops.

Introduction

A comparative analysis of different types of dispensers for sowing grain seeds made it possible to ascertain the need to develop a new type of dispenser capable of spreading seeds evenly along the length of a row [1-13, 23-25].

Based on exploratory research at the Penza State Agrarian University, an experimental screw feeder was manufactured and tested under laboratory conditions [14]. Tests of the screw feeder were carried out according to GOST R 52778-2007 and other recommended test methods [15-18] on the soil box, shown in Figure 1.

Methods and materials

Methods of laboratory research included:

– development and manufacture of an experimental screw feeder;

– use of a laboratory setup;

– conducting a multifactorial experiment to determine the effect of the optimal design and operational parameters of an experimental screw feeder unit of the laboratory setup, affecting the uneven distribution of grain seeds along the length of a row.

The optimization of the design and operating parameters of the experimental screw feeder

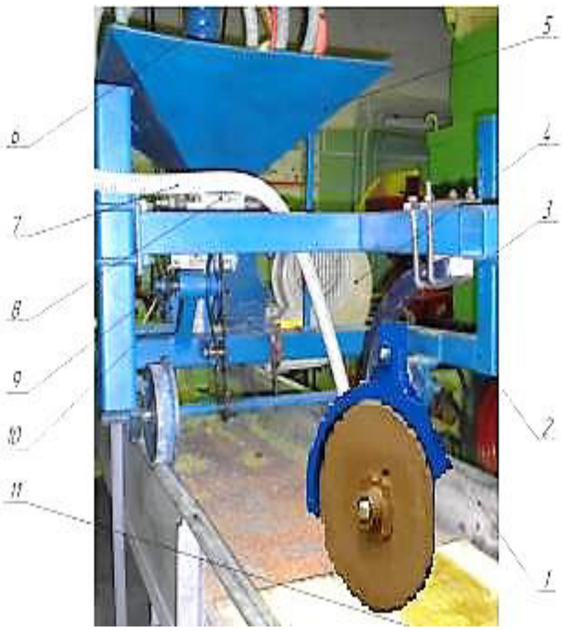

Figure 1. General view of the laboratory setup on the soil box: 1 – soil box; 2 – driven cart; 3 – disc coulter; 4 – pneumatic fan; 5 – bunker; 6 – distribution head; 7 – seed tube; 8 – experimental screw feeder; 9 – drive mechanism; 10 – electric motor; 11 – adhesive tape

(13) (Fig. 2) was carried out according to the criterion of uneven seed distribution along the row.

The bunker (16) is filled with the grain seeds. The driveline moves along the guide rails using a flexible cable (5), a tackle system (1), rollers (2), sprockets (3) and a chain transmission (4) from the gear motor (6).

When moving the cart, the rotation of the drive wheels shaft (24), due to the optimally selected sprockets (10) and chain drive (11), is transmitted on the experimental screw feeder (13), which doses the grain seeds, taking into account the seeding rate.

The airflow created by the fan (20) feeds the seed to the distribution head (15) and sends them through the seed tubes (14) to the disc coulters (8). At the same time, the number of grain seeds was determined in 5.0×5.0 cm squares of adhesive tape. Experiments were performed in triplicate, the number of squares studied was not less than 100.

Results

According to the results of processing experimental data obtained during a multifactor experiment using the Matlab 2018 program [19-22], we obtained a regression equation that adequately describes the dependence $y = f\,(D_{нв}, S_{ш}, n)$ in a coded form:

$$y = 34.8065 - 0{,}7547 \cdot x_1 - 0.2147 \cdot x_3 + 2.7917 \cdot x_1^2 + 1.3917 \cdot x_2^2 - 1.5917 \cdot x_3^2 - 0.6934 \cdot x_1 \cdot x_2 - 0.4684 \cdot x_1 \cdot x_3 - 1.7434 \cdot x_2 \cdot x_3 \qquad (1)$$

The multiple correlation coefficient and test criteria were accordingly $R = 0.957$, $F_{тест} = 0.94$.

Next, we found the differential of the variables x_1, x_2 and x_3. As a result we obtained a system of equations:

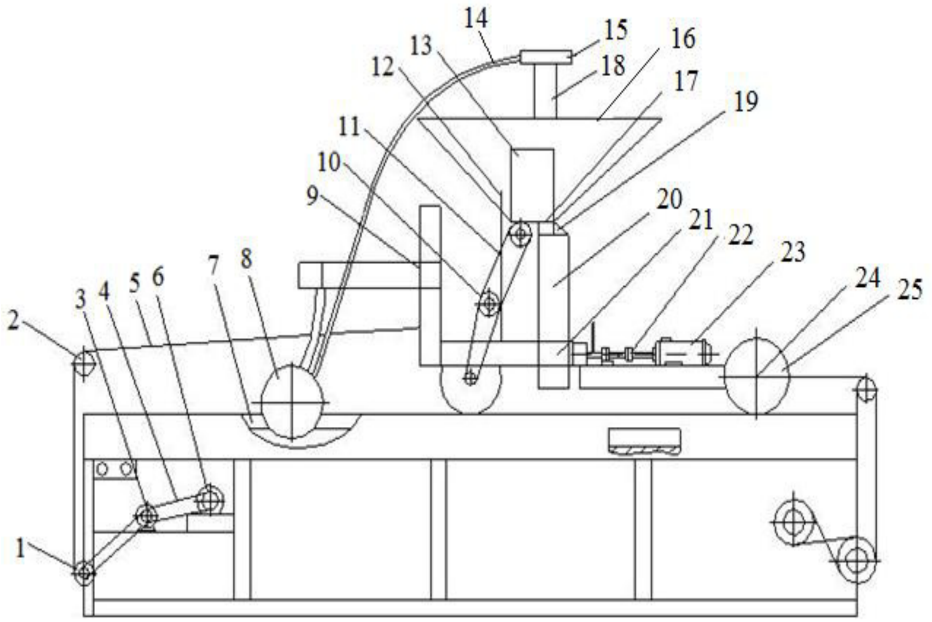

Figure 2. Diagram of the laboratory setup for the study of the process of sowing seeds: 1 – a tackle system; 2 – rollers; 3 – sprockets; 4 – chain drive; 5 – flexible cable; 6 – gear motor; 7 – soil box; 8 – disc coulter; 9 – adjusting bar; 10 – drive sprockets; 11 – chain drive; 12 – racks; 13 – experimental screw feeder; 14 – seed tube; 15 – distribution head; 16 – bunker; 17 – hopper flange; 18 – ejection; 19 – adapter; 20 – pneumatic ventilator; 21 – setup frame; 22 – bushing-pin coupling; 23 – electric motor; 24 – shafts; 25 – wheels

$$\begin{cases} \dfrac{dy}{dx_1} = 5.5834 \cdot x_1 - 0.6934 \cdot x_2 - 0.4684 \cdot x_3 - 0.7547 = 0; \\ \dfrac{dy}{dx_2} = -0.6934 \cdot x_1 + 2.7834 \cdot x_2 - 1.7434 \cdot x_3 = 0; \\ \dfrac{dy}{dx_3} = -0.4684 \cdot x_1 - 1.7434 \cdot x_2 + 3.1834 \cdot x_3 - 0.2147 = 0. \end{cases} \quad (2)$$

By solving the system of equations (2), we found the values of the variables x_1, x_2, x_3, at which the coefficient of variation of the seed distribution over the length of the row will be the smallest:

$$\begin{cases} x_1 = 0.1481; \\ x_2 = 0.0691; \\ x_3 = 0.0514. \end{cases} \quad (3)$$

To obtain a two-dimensional section of the response surface characterizing the seed distribution, instead of the screw helix pitch (x_2) and screw rotation frequency (x_3), the value $x_1 = 0$ was alternately substituted into equation (1), resulting in the following equation:

$$y = 34.8065 + 1.3917 \cdot x_2^2 + 1.5917 \cdot x_3^2 - 0.2147 \cdot x_3 - 1.7434 \cdot x_2 \cdot x_3 \quad (4)$$

Then we made a system of differential equations, which are partial derivatives for each of the other two factors.

$$\begin{cases} \dfrac{dy}{dx_2} = 2.7834 \cdot x_2 - 1.7434 \cdot x_3 = 0; \\ \dfrac{dy}{dx_3} = -1.7434 \cdot x_2 + 3.1834 \cdot x_3 - 0.2147 = 0. \end{cases} \quad (5)$$

By solving the system of equations (5), we found $x_2 = 0.0643$; $x_3 = 0.1027$. A two-dimensional section, characterizing the dependence of the coefficient of variation of seed distribution along the length of a row on the pitch of the screw helix ($S_ш$) and the screw rotation frequency (n), is shown in Figure 3.

By analogy, we substituted the x_2 factor with a zero value into expression (1) and obtained:

$$y = 34.8065 - 0.7547 \cdot x_1 - 0.2147 \cdot x_3 + 2.7917 \cdot x_1^2 + 1.5917 \cdot x_3^2 - 0.4684 \cdot x_1 \cdot x_3. \quad (6)$$

By solving a system of differential equations

$$\begin{cases} \dfrac{dy}{dx_1} = 5.5834 \cdot x_1 - 0.4684 \cdot x_3 - 0.7547 = 0; \\ \dfrac{dy}{dx_3} = -0.4684 \cdot x_1 + 3.1834 \cdot x_3 - 0.2147 = 0. \end{cases} \quad (7)$$

we found the coordinates of the center of the response surface in a coded form: $x_1 = 0.1426$; $x_3 = 0.0884$.

The corresponding two-dimensional section is shown in Figure 4.

Similarly, by equating to zero the x_3 factor and substituting it in the equation (1), we received:

$$y = 34.8065 - 0.7547 \cdot x_1 + 2.7917 \cdot x_1^2 + 1.3917 \cdot x_2^2 - 0.6934 \cdot x_1 \cdot x_2. \quad (8)$$

By solving the system of differential equations

$$\begin{cases} \dfrac{dy}{dx_1} = 5.5834 \cdot x_1 - 0.6934 \cdot x_2 - 0.7547 = 0; \\ \dfrac{dy}{dx_2} = -0.6934 \cdot x_1 + 2.7834 \cdot x_2 = 0. \end{cases} \quad (9)$$

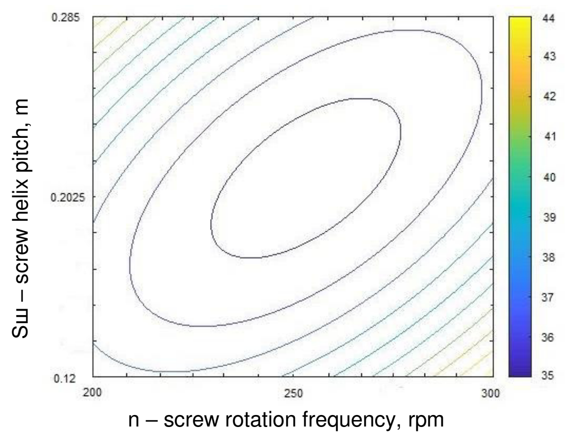

Figure 3. Two-dimensional section of the response surface, characterizing the dependence of the coefficient of variation of the uneven seed distribution along the length of the row on the screw helix pitch ($S_ш$) and the screw rotation frequency (n)

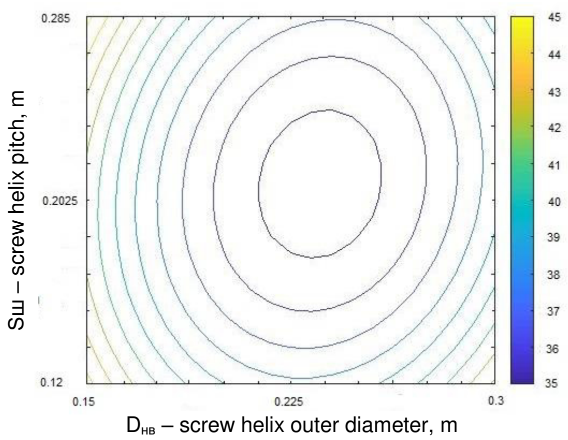

Figure 4. Two-dimensional section of the response surface, characterizing the dependence of the coefficient of variation of the uneven seed distribution along the length of the row on the screw helix pitch ($S_ш$) and the screw helix outer diameter ($D_{нв}$)

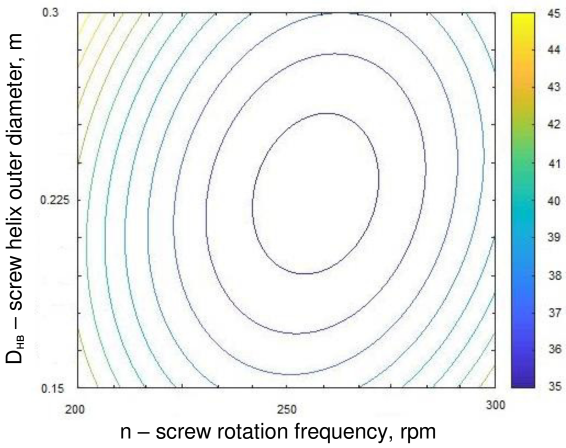

Figure 5. Two-dimensional section of the response surface, characterizing the dependence of the coefficient of variation of the uneven seed distribution along the length of the row on the screw helix outer diameter ($D_{нв}$) and the screw rotation frequency (n)

we determined the coordinates of the center of the response surface in a coded form: $x_1 = 0.1395$; $x_2 = 0.0347$.

A two-dimensional section, characterizing the dependence of the coefficient of variation of seed distribution along the length of the row on the screw helix outer diameter and the screw rotation frequency, is shown in Figure 5.

Analyzing graphic images of a two-dimensional section (Fig. 3, 4, 5), we can conclude that the optimal values of the studied factors are within: $D_{НВ}$ = 0.199-0.266 m, n = 229.5-277 rpm, $S_{Ш}$ = 0.17-0.243 m. In this case, the optimization criterion (y) is 35%.

In engineering calculations, the expression (1) is more convenient to use in a decoded form:

$$\nu = 92.2625\text{-}264.06 \cdot D_{НВ} - 0.1516 \cdot n + 25.14 \cdot S_{ш} + 496.3 \cdot D_{НВ}^2 - -0.00055 \cdot n^2 + 234.07 \cdot S_{ш}^2 - 0.184 \cdot D_{НВ} \cdot n - 75.7 \cdot D_{НВ} \cdot S_{ш} - 0.422 \cdot n \cdot S_{ш}. \quad (10)$$

Conclusion

As a result of the research, the range of optimal values of the design and operating parameters of the screw feeder $D_{НВ}$, $S_{Ш}$, *n,* was established, at which the optimization criterion – the coefficient of variation of the uneven seed distribution along the length – has the smallest value.

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DOI: 10.26177/VRF.2019.2.2.020

IMPROVING THE EFFICIENCY OF EXTRUDATE DEHYDRATION IN A VACUUM CHAMBER OF A MODERNIZED EXTRUDER

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The work of modern models of food extruders goes mainly with passing the extruded material into the environment, which, taking into account the processing of raw materials with high moisture content, leads to insufficient drying of the extrudate. Extrusion of raw materials in vacuum allows to eliminate this drawback. The article presents a theoretical justification for increasing the efficiency of extrudate dehydration in a vacuum chamber of a modernized extruder by computer simulation of the thermal vacuum effect. The Navier-Stokes equation averaged with the addition of Reynolds stresses and the laws of conservation of mass, moment, and energy were used to calculate the flow and heat transfer rates. Computer simulation of a simplified model of a vacuum chamber was performed using the SolidWorks Flow Simulation software module. Geometry was built in SolidWorks CAD. The data obtained by computer simulation of a simplified model of an extruder vacuum chamber confirmed the influence of the thermal vacuum effect on the characteristics of the extruded product. The created vacuum in the zone of ejection of the extruded vegetable raw material from the extruder matrix creates such fluid medium parameters that significantly increase the drying rate of the extrudate, increase its expansion index and contribute to more efficient removal of moisture from this zone.

Keywords: extruder, thermal vacuum effect, matrix die, explosion coefficient, vacuum chamber, volume flow rate.

Introduction

It is known that the working process of a single-screw autogenous extruder, from the standpoint of the thermodynamic characteristic, is carried out using heat generated directly in the machine path by dissipating the energy of the

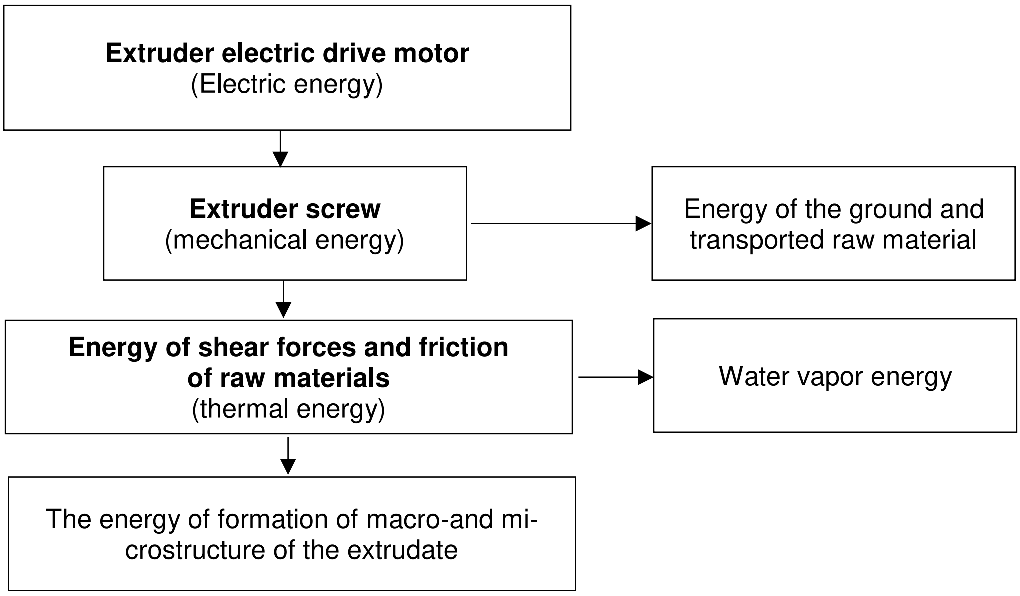

Figure 1. Energy transformation in extruder workflow

drive electric current. For this, special constructive solutions of the extruder's working parts (screw, chamber, die) provide resistance to the movement of raw material transported in the internal path of the machine, which leads to an increase in its temperature to 120–200°C.

The implementation of the technological process of such extruders is based on the multiple transformation of one type of energy into another (Fig. 1). As a consequence, the processing of raw materials using autogenous extruders refers to extremely power-consuming processes [1, 2].

Taking into account the fact that most of the energy expended on ensuring the working process of an autogenous extruder while processing phytogenic edible raw material, is spent on increasing its temperature, it should be recognized that the factor characterizing the heat consumption is dominant in technical solutions aimed at improving the energy efficiency of these machines types [6, 8].

The study of the basic laws of the formation of capillary-porous structure of the obtained extrudates allowed to theoretically substantiate a method for improving the energy efficiency of extrusion technologies due to the thermal vacuum effect on the resulting product at the time it leaves the machine matrix die [1, 5].

It has been established that the working process of an extruder that implements a thermal vacuum effect allows to obtain the desired result (explosion coefficient) at a lower pressure and, accordingly, temperature, which significantly saves power consumption [7–9, 15].

The theoretical analysis of the design and technological scheme of the proposed extruder with a vacuum chamber revealed a drawback that prevents the fuller realization of all the advantages of the thermal vacuum effect. This drawback shows itself during the processing of raw materials with an increased moisture content (30-35%) and, ultimately, in an insufficiently high air velocity at the surface of the extrudate. In turn, this air velocity limits the intensity of the transfer of liquid removed from the extrudate with the help of steam moving from the extruder's vacuum chamber to the vacuum cylinder, and necessitates the re-extruding or drying process of the resulting product to the point of required moisture using any kind of dryer [10, 12].

The purpose of the study is a theoretical justification for increasing the efficiency of extrudate dehydration in a vacuum chamber of a modernized extruder by computer simulation of the thermal vacuum effect.

The objective of the study is to obtain a mathematical model of the working process of a modernized extruder vacuum chamber.

The materials and methods are based on the finite volume method, calculated with the help of computer simulation of the workflow for a simplified model of a vacuum chamber. The Navier-Stokes equation averaged with the addition of Reynolds stresses and the laws of conservation of mass, moment, and energy were used to calculate the flow and heat transfer rates. The construction of three-dimensional geometry and the study of a computer model of an extruder vacuum chamber were carried out in SolidWorks Flow Simulation.

Results

In a modernized extruder, it is proposed to equip the vacuum chamber with an air valve for supplying a certain volume of air into it, which, in turn, intensifies the process of venting moist

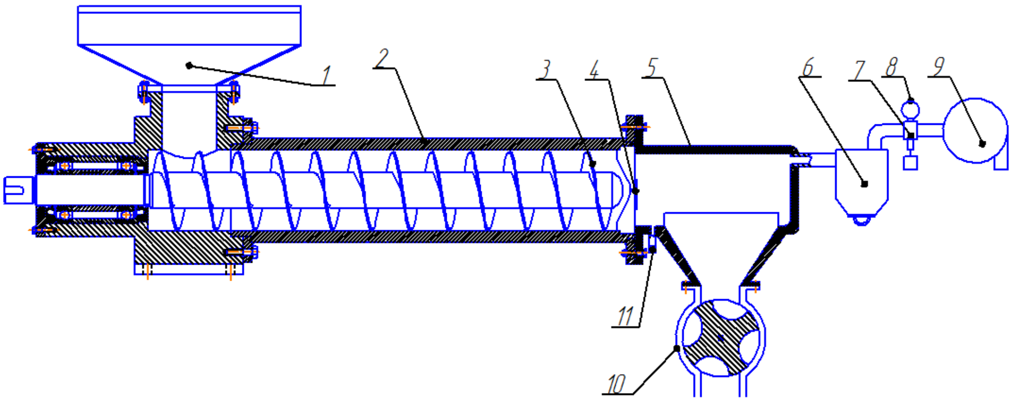

Figure 2. Constructive-technological scheme of the proposed extruder:
1 – loading hopper; 2 – body; 3 – screw; 4 – die; 5 – vacuum chamber; 6 – vacuum cylinder;
7 – vacuum regulator; 8 – vacuum meter; 9 – vacuum pump; 10 – lock gate; 11 – air valve

steam from the extrudate surface and its further transfer to a vacuum cylinder.

The design and technological scheme of the extruder includes a loading hopper (1) (Fig. 2), an extruder body (2), a screw (3), a die (4), a cutting device (not indicated in the scheme), and a vacuum chamber (5).

The vacuum chamber is attached to the body of the extruder and on the one hand is limited by the lock gate (10). It is equipped with a system of removal and condensation of moisture, consisting of a vacuum pump (9), a vacuum regulator (7), a vacuum meter (8) and a vacuum cylinder (6). At the bottom of the chamber there is an air valve that serves to supply a certain amount of air.

A lock gate (10) is designed to unload the obtained product without depressurizing the extruder vacuum chamber.

The workflow of the modernized extruder goes as follows. The processed raw material enters the loading hopper (1) of the extruder and moves to the screw (3), by means of which it sequentially passes through the pressing and dosing zones of the machine. Here, the raw material is heated to a temperature of 120-130°C and output through the die (4) into the vacuum chamber (5). When exiting the die, the extrudate is cut into particles of a given length by means of a cutting device.

Getting from the area of high pressure (in the internal path of the extruder) to the low pressure zone (in the vacuum chamber 5), the raw material is subjected to a powerful decompression explosion, which is the process of instantaneous transition of water in the raw material into steam.

The resulting hot steam is transferred by means of a vacuum pump (9) to a vacuum cylinder (6), where it condenses and flows as a liquid to its lower part. In order to intensify the removal of wet steam from the surface of the extrudate and its further movement into the vacuum cylinder (6) air is blown into the chamber (5) using the air valve (11).

The moisture content in the extruded product is controlled by the pressure in the vacuum chamber (5) using the vacuum regulator (7), as well as the amount of air coming in through the air valve (11) of the chamber (5).

Thus, the proposed technical solution will allow to increase the efficiency of dehydration of the extrudate and to process raw materials with high moisture content with the help of the claimed extruder.

Consider the conditions for implementing a technical solution of an extruder in a theoretical aspect using the method of computer simulation of the working process of its vacuum chamber.

Computer simulation of a simplified model of a vacuum chamber was performed using the SolidWorks Flow Simulation software module, geometry was built in SolidWorks CAD.

To calculate the flow and heat transfer in the Flow Simulation, the Navier-Stokes equation and the laws of conservation of mass, moment and energy are used:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_k}(\rho u_k) = 0;$$

$$\frac{\partial \rho u_i}{\partial t} + \frac{\partial}{\partial x_k}(\rho u_i u_k - \tau_{i,k}) + \frac{\partial p}{\partial x_i} = S_i;$$

$$\frac{\partial \rho E}{\partial t} + \frac{\partial}{\partial x_k}\left[(\rho E + p)u_k + q_k - \tau_{i,k} u_i\right] = S_k u_k + Q_H,$$

where ρ is the density, u is the speed, p is the pressure of the current medium, t is the time, S is the external mass forces acting on the mass unit of the current medium, E is the total energy per unit mass of the current medium, Q_H is the heat release (or absorption) per volume unit, q – distributed heat flow, τ – viscous shear stress tensor; subscripts denote summation over three coordinate directions.

For the calculation of turbulent flows, the Navier-Stokes equations averaged by Reynolds are applied, with the addition of stresses:

$$\tau_{ij}^{R} = \mu_t \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3} \frac{\partial u_I}{\partial x_I} \delta_{ij} \right) - \frac{2}{3} \rho k \delta_{ij},$$

where $\delta_{ij} = 1$ when i = j, $\delta_{ij} = 0$ for when i ≠ j is the Kronecker delta function, μ_t is the viscosity coefficient of turbulent eddies, k is the kinetic energy of turbulence. To calculate laminar and turbulent flows, the same system of equations is used, but with a laminar flow k and $\mu_t = 0$.

Within the k-e model of turbulence,

$$\mu_t = f_\mu \frac{C_\mu \rho k^2}{e},$$

where f_μ is a complex that takes into account turbulent viscosity, e is the dissipation rate.

The computer model of the extruder vacuum chamber in SolidWorks Flow Simulation was studied in the following sequence:

– creation of a 3D model;

– construction of the grid of the computational domain of the vacuum chamber model;

– the imposition of boundary conditions;

– visualization of the results.

The numerical calculation was carried out under the following assumptions: the processes of fluid flow and heat transfer are stationary; the heat flux density on the channel wall surface is constant; there are no internal sources of heat in the fluid flow; there is no heat exchange on the end surfaces of the channels.

Additional physical parameters of the calculation:

Heat transfer analysis: thermal conductivity in solids.

Flow type: laminar and turbulent.

Non-stationary type of analysis that takes into account gravity and heat radiation.

The following conditions were specified for the computable model:

physical conditions: the material of the vacuum chamber is steel (density: 7874 kg/m³, the diagram of specific heat capacity versus temperature is shown in Figure 3), steam is used as the fluid; the volume of the flow area is 0.325097 m³;

initial conditions:

thermodynamic parameters inside the vacuum chamber: static pressure – 101325 Pa; temperature – 20°C.

Boundary conditions (Fig. 4):

Mass flow rate at the inlet (outlet of the extruder matrix):

- flow parameters: the direction of the flow vectors is normal towards the surface; mass flow rate – 0.0900 kg/s.
- thermodynamic parameters: initial pressure estimate – 101325 Pa; the temperature of the initial components is 100°C.
- parameters of turbulence: the type of boundary layer is turbulent.

Volume flow rate on the outlet (outlet to the vacuum pump):

flow parameters: the direction of the flow vectors is normal towards the surface; volume flow rate – 0.0270 m³/s.

Global goals:

Total pressure is average; temperature (fluid) is average; speed is average.

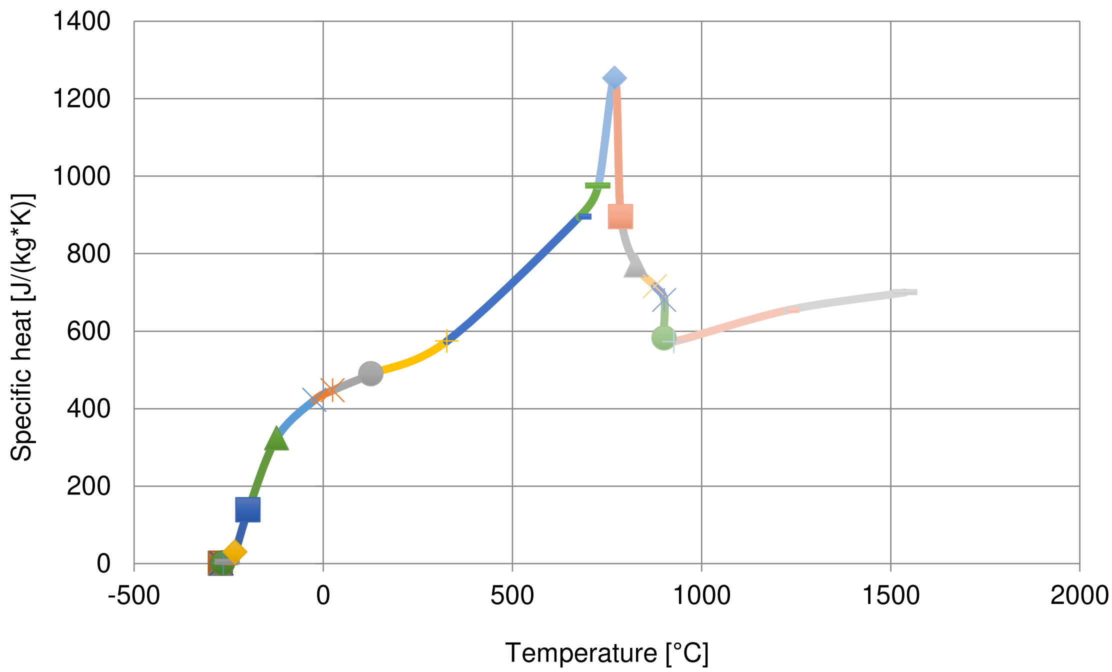

Figure 3. Diagram of dependence of the specific heat of the vacuum chamber material on the temperature

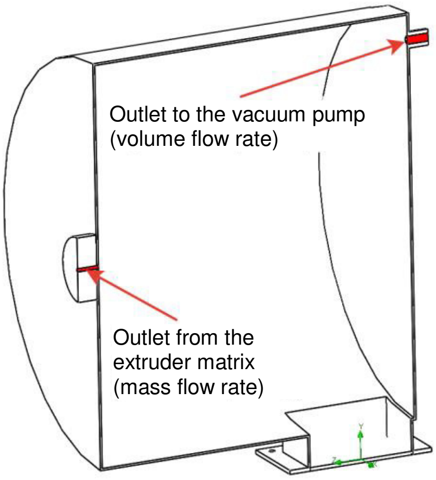

Figure 4. Boundary conditions in the extruder vacuum chamber

As a result of computer simulation, the fields of velocity, temperature and pressure were determined in the whole computational domain.

The average values obtained for global goals: the stabilizing temperature of the fluid inside the vacuum chamber is 25.87°C; The average flow velocity is 57.897 m/s.

The minimum and maximum values of the parameters obtained are shown in Table 1.

Analyzing the results of the distribution of absolute humidity inside the extruder vacuum chamber (Fig. 5), one can see a small zone near the extruder matrix, where the absolute humidity is low and then it begins to increase in the longitudinal axis to a small extent and in the periphery to the larger one.

That is, when steam is released into the discharged medium near the extruder matrix, instantaneous evaporation of water occurs, which will contribute to a larger extrudate rupture and loss of moisture. This statement confirms the distribution of the specific humidity of the fluid in the longitudinal section of the extruder vacuum chamber, shown in Figure 6.

Based on the results shown in Figure 7, we can conclude that the mass concentration of condensate is concentrated near the walls of the vacuum chamber, due to which there is a more complete removal of moisture from the extrusion zone and allows for accelerated drying of the extruded products.

To remove the point values of the thermodynamic parameters inside the extruder vacuum chamber, the measurements were made at the

Table 1. The minimum and maximum values of the parameters obtained when modeling steam flow in the extruder vacuum chamber

Parameter	Minimum	Maximum
Absolute humidity [kg/m^3]	1.56e-03	50.00
Pressure [Pa]	6.10	144883.34
Mass concentration of water	0.9999	0.9999
Mass concentration of dissolved gas	1.0000e-04	0.0001
Mass concentration of condensate	0	0.9999000
Density (fluid) [kg/m^3]	1.56e-03	50.00
Velocity [m/s]	0	47687.691
Temperature [° C]	-73.15	976.86
Temperature (solid) [° C]	-12.08	382.36
Temperature (fluid) [° C]	-73.15	976.86
Specific humidity [g/kg]	0	1000.000
Cell volume [m^3]	1.646220e-14	0.000225
Swirling [1/s]	3.80e-10	2475184.04
Peripheral velocity [m/s]	-452.921	2059.503
Axial velocity [m/s]	-47687.691	2.379
Radial velocity [m/s]	-215.835	623.316
Relative pressure [Pa]	-101318.90	43558.34
Dynamic viscosity [Pa*s]	9.1415e-06	13.0058
Condensate content in water	0	1.0000000
Relative humidity [%]	0	100.00
Adiabatic ambient temperature [° C]	-73.15	976.86
Heat flow noncollinearity indicator	1.4537283e-34	1.0000000
Thermal resistance indicator	2.8331226e-34	1.0000000
Heat transfer coefficient [W/(m^2*K)]	30.122	4.803e+07
Heat transfer coefficient (adiabatic temperature) [W/(m^2*K)]	0.116	2.485e+13
Surface density of the heat flux [W/m^2]	-1.430e+07	2069.215
Surface density of the heat flux (convection) [W/m^2]	-1.430e+07	3.245e+13
Thickness of the boundary layer (thermal) [m]	3.716e-05	1.148

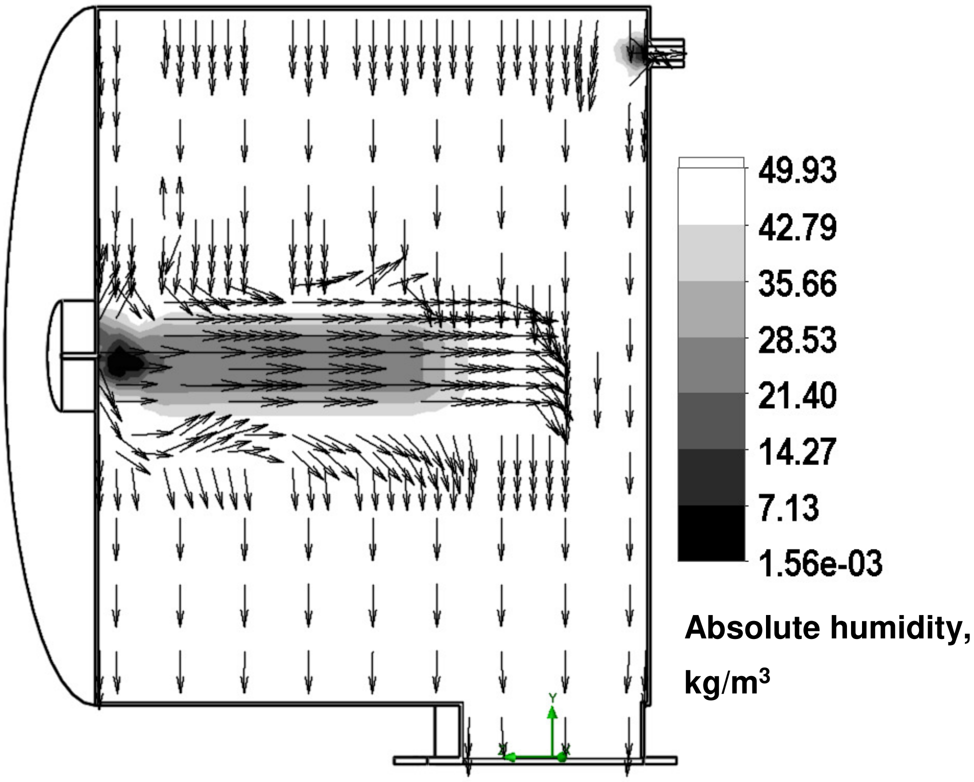

Figure 5. The distribution of the absolute humidity of the fluid in the longitudinal section of the extruder vacuum chamber

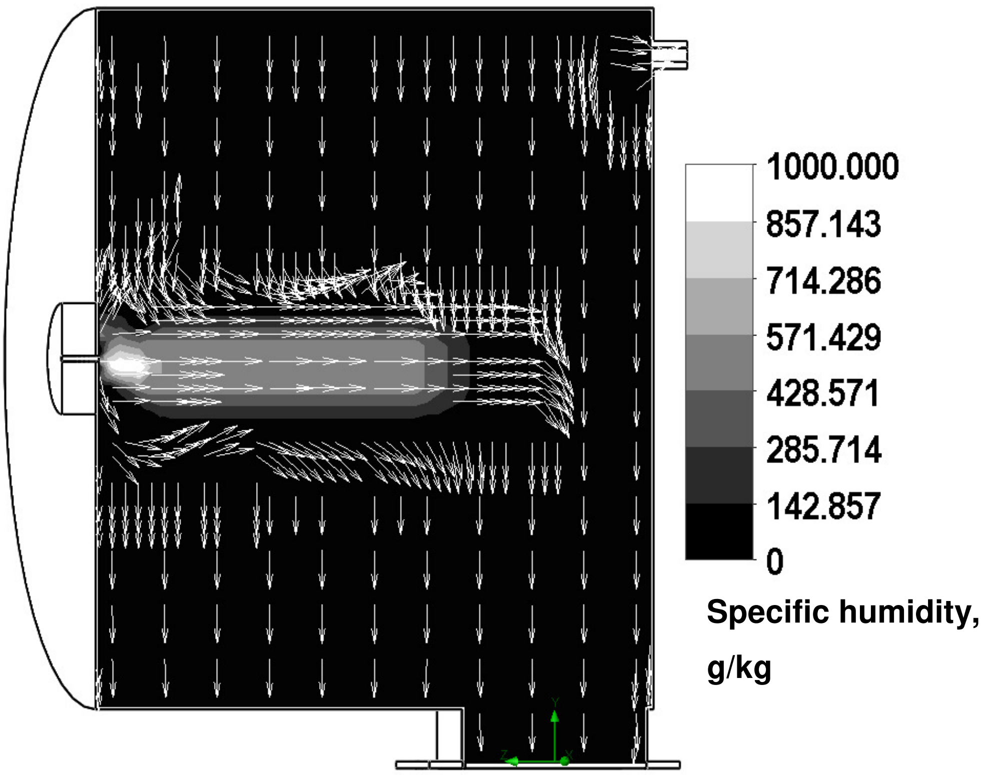

Figure 6. The distribution of the specific humidity of the fluid in the longitudinal section of the extruder vacuum chamber

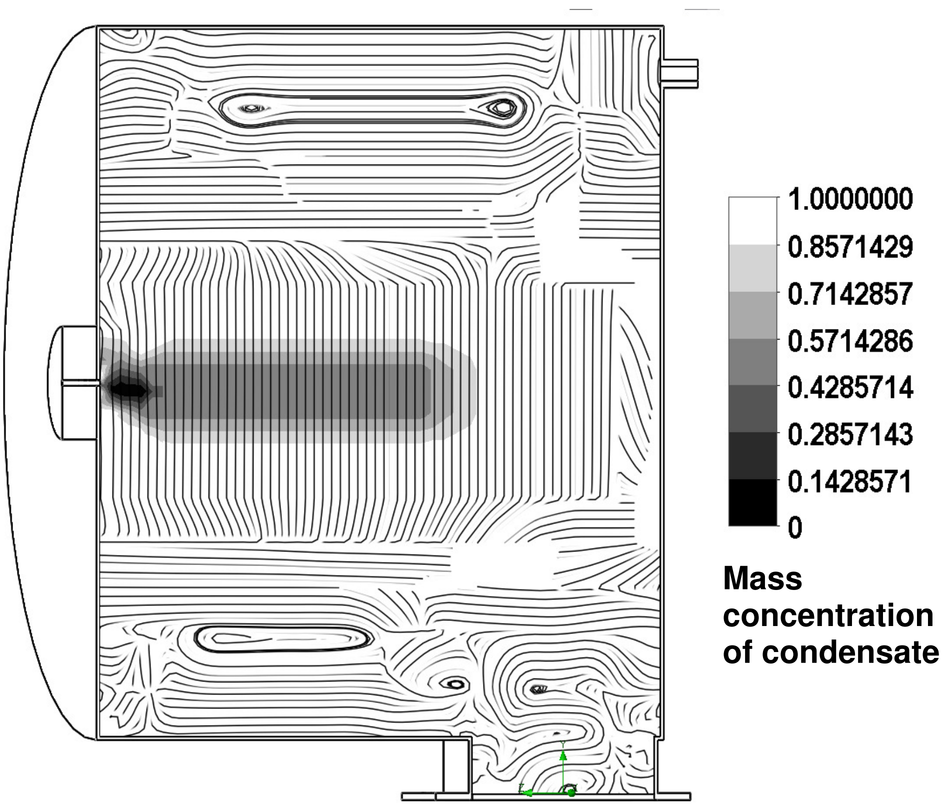

Figure 7. The distribution of the mass concentration of fluid condensate in the longitudinal section of the extruder vacuum chamber

initial time and after the start of the installation. The measurements were made at three points: at the lock gate discharge, at the outlet opening to the vacuum pump and in the matrix die opening. The obtained thermodynamic parameters are summarized in table 2.

The measurements of point thermodynamic parameters confirmed the general results shown in the figures. When using a vacuum chamber in the zone of ejection of extruded phytogenic raw material from the extruder matrix, the thermodynamic parameters (density, pressure, etc.) take on such values that significantly increase the drying rate of the extrudate, increase its expansion index and promote more efficient removal of moisture from this zone.

In the zone near the opening to the vacuum pump, the dynamics of the thermodynamic parameters of the state of the vapor-air fluid medium are as expected and confirm the effective removal of moisture from the vacuum chamber.

In the zone of extrudate ejection into the discharge opening, such parameters as absolute humidity, relative pressure help to maintain favorable drying parameters of the extruded phytogenic raw materials, which is confirmed by the obtained point parameters in this zone.

Table 2. Point thermodynamic parameters in the extruder vacuum chamber

Time, s	Absolute humidity, kg/m^3	Pressure, Pa	Mass concentration of condensate	Density (fluid), kg/m^3	Speed, m/s	Specific humidity, g/kg	Relative pressure, Pa	Relative humidity, %
Point 1 – Lock gate discharge								
0	998.31	101337.15	0.9999	998.41	0	0	12.15	100
5.09E-05	49.92	2794.87	0.9995	49.93	0	0.308582606	-98530	100
Point 2 – Outlet opening to the vacuum pump								
0	998.31	91834.71	0.9999	998.41	0	0	-9490	100
5.09E-05	0.14	644.00	0.93	0.14	174.94	61.71	-100680	100
Point 3 – Matrix die opening								
0	998.31	95813.97	0.9999	998.41	0	0	-5511	100
5.09E-05	4.01	102474.56	0.2928	4.01	4.54E-13	575.71	1149	44.87

Conclusion

The data obtained by computer simulation of a simplified model of an extruder vacuum chamber confirmed the influence of the thermal vacuum effect on the characteristics of the extruded product. The created vacuum in the zone of ejection of the extruded phytogenic raw material from the extruder matrix creates such fluid parameters that significantly increase the drying rate of the extrudate, increase its expansion index and contribute to more efficient removal of moisture from this zone.

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