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**CROP PRODUCTION, PLANT PROTECTION,  
AND BIOTECHNOLOGY**

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## **Ecological Aspects of the Productivity of Nigella Varieties under the Conditions of the Middle Volga Region**

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**Abstract**—The article presents a comprehensive assessment of the varieties of *Nigella sativa* and *Nigella damascena* under the agro-climatic conditions of the forest-steppe zone of the Middle Volga region. The experimental work was carried out in 2019–2021 on the experimental field of FSBRI the Penza Research Institute of Agriculture. Climatic conditions during the years of study of *Nigella* were characterized as dry. The hydro-thermal coefficient ranged from 0.67 in 2019 to 0.92 units in 2021. The duration of the growing season of *nigella* averaged 98–113 days. The number of capsules per plant and the seed weight per plant had the greatest influence on the formation of the seed yield of *nigella*, the share of influence of which was 27.6 and 29.2%. The productivity indicators of one plant were in the range of 1.36–2.32 g, and the variability of this trait was 33.4%. The highest weight of seeds from one plant 2.23 and 2.32 g was noted in the Iskra and Chernyi Barkhat varieties. The 1000 seed weight varied from 2.58 (Diva) to 3.53 g (Iskra). The highest yield in the conditions of the Penza oblast was noted in the varieties Vitol'dina, Yalita, and Znakharka, the yield of which was 1.22–1.25 t/ha. The average oil content in *Nigella* seeds was 38.89%. According to the fat content, the varieties Yalita and Vitol'dina stood out; their oil content was 41.82 and 40.95%. The varieties Yalita, Znakharka, and Krymchanka were characterized by the greatest stability over the years, and the value of the variety stability indicator (VSI) for them was 1.41–1.45. In the composition of the oil, the largest share was linoleic and oleic acids, the content of which reached 47.98–64.27 and 16.91–29.52%. In addition, the fatty acid composition of *nigella* contained two more saturated fatty acids: lauric and capric. Their content was 0.18–0.46 and 0.04–2.30%, respectively.

**Keywords:** *nigella*, varieties, yield, growing season, crop structure, oil content, fatty acids

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### INTRODUCTION

The expansion of the range of biological diversity of the crop industry of each region, taking into account its bioclimatic potential, is possible by introducing and cultivating such a set of crops and varieties most adapted to various environmental conditions [1]. In turn, the distribution of varieties resistant to adverse environmental factors is the most accessible and cheap way to increase agricultural production [2].

The development of various industries and the creation of new directions for the use of crop products now determines the need for a wide range of oilseeds and essential oil crops, which can be expanded by using *nigella* [3]. *Nigella*, also known as black cummin, is mainly represented by two species of the Ranunculaceae family: *Nigella sativa* L. and *Nigella damascena* L., which have high oil, essential oil, melliferous, and medicinal properties [4, 5].

The uses of *nigella* are extremely diverse, primarily as an oilseed raw material, since its seeds contain up to 40% oil and up to 1.5% essential oil [5, 6]. *Nigella* oil is rich in unsaturated fatty acids (approximately 80%)

as well as relatively rare saturated lauric and capric fatty acids [7, 8].

In addition, black cummin oil contains a large number of different biologically active substances, which opens up opportunities for the use of *nigella* in medicine for the treatment and prevention of various diseases [9, 10]. There are currently a large number of studies devoted to the study of the pharmacological activity of plant raw materials of this culture [11, 12]. For example, Australian scientists found that *nigella* seeds contain the active ingredient thymoquinone, which, due to its neutralizing properties, prevents the development of pneumonia, which can be used against coronavirus infection [13]. Nevertheless, *nigella* belongs to plants whose medicinal potential has not been fully disclosed.

The biological features of this crop allow to grow it in a wide range of soil and climatic conditions [4, 6, 14]. Black cummin is most popular in Africa, India, Pakistan, and Afghanistan [10, 15]. For the forest-steppe of the Middle Volga region, in particular the Penza oblast, *nigella* is an unconventional culture;

**Table 1.** Variation of hydrothermal conditions during the growing season of nigella (2019–2021)

Indicator	Sowing–shooting	Shooting–flowering	Flowering–ripeness	Shooting–ripeness
Accumulated temperature $\geq 10^{\circ}\text{C}$	137.0–213.0	815.0–1251.0	884.0–996.0	1811.0–2191.0
Mean daily temperature, $^{\circ}\text{C}$	10.9–19.4	18.3–20.9	17.0–21.9	17.6–21.4
Precipitation amount, mm	1.4–22.9	50.0–103.9	50.4–100.7	133.5–202.4
HTC	0.07–1.54	0.75–0.83	0.57–1.05	0.67–0.92

therefore, it is important to study the features of its growth and development under local conditions with subsequent introduction.

The purpose of the study was a comprehensive assessment of productivity of *Nigella sativa* L. and *Nigella damascena* L. varieties under the agro-climatic conditions of the forest-steppe zone of the Middle Volga region.

## MATERIALS AND METHODS

Experimental study was carried out in 2019–2021 on the experimental field of the division of the Federal Scientific Center of Bast Crops Penza Research Institute of Agriculture. The object of research was *Nigella sativa* and *Nigella damascena* varieties: Znakharka, Iskra, Radasts' (Belarus); Chernyi Barkhat, Vitol'dina (Saratov oblast); Krymchanka, Yalita (Republic of Crimea); Diva (Krasnodar krai); Golubaya, Shakherizada (Moscow oblast).

The climate of the forest-steppe of the Middle Volga region, which includes the Penza oblast, is temperate continental, a distinctive feature of which is a pronounced contrast, characterized by variability and instability of heat and moisture resources. The effective temperature sum during the growing season of crops varies from 1750 to 2450 $^{\circ}\text{C}$ , and the annual precipitation amount was from 350 to 750 mm, while drought is a typical phenomenon for the region, in which 3 of 5 years are dry to varying degrees. The soil of the experimental plot was leached chernozem with a humus content of 6.2%. The reaction of the soil solution was slightly acidic, pH = 5.4, the content of easily hydrolysable nitrogen was 82.4 mg/kg (according to Tyurin and Kononova, GOST 26951–86), contents of mobile phosphorus and potassium were respectively 157.3 and 132.5 mg/kg (according to Chirikov, GOST 26204–91).

The field experiments, all observations, records, and analyzes were carried out according to generally accepted methodological recommendations [16]. Identification and determination of the content of fatty acids was performed by gas-liquid chromatography using a Khromatek-Kristall 5000 chromatograph.

The variety stability indicator (VSI) was calculated according to the method described by E.D. Nettevich (2001). Statistical processing of data, coefficient of variation (V %) of yield structure indicators, and the

share of their influence were determined according to the method of B.A. Dospikhov (1985).

## RESULTS AND DISCUSSION

The climatic conditions of the growing seasons of nigella during the years of research were characterized as arid to some extent, and the hydrothermal coefficient varied from 0.67 to 0.92 units. The most favorable conditions for the vegetation of the crop were formed in 2021, the HTC was equal to 0.92 at a mean daily temperature of 21.3 $^{\circ}\text{C}$  and precipitation amount of 202.4 mm (Table 1).

During the 2021 growing season, weather conditions changed from very dry to moderately humid. For example, from sowing nigella to the full emergence of its shoots, the precipitation was only 1.4 mm, and the hydrothermal coefficient was 0.07 at an average daily temperature of 19.4 $^{\circ}\text{C}$ . The duration of the sowing–shooting phenophase was 11 days (see Fig. 1).

Further, the period from shooting to flowering was characterized as moderately dry (HTC: 0.83) and lasted 60 days. The period from flowering to ripeness proceeded under moderately humid conditions, the precipitation was 98.5 mm at fairly high average daily temperatures of 21.9 $^{\circ}\text{C}$ , and the HTC was at the level of 1.5 units. In general, the duration of the growing season of nigella in 2021 was 103 days.

Spring 2020 was rainy and cold. Precipitation of varying intensity fell every day at fairly low average daily temperatures (10.9 $^{\circ}\text{C}$ ). The development of nigella from sowing to germination proceeded against the background of abundant precipitation (22.9 mm), and HTC was equal to 1.54. The seeds were in cold and moist soil for a long time, the duration of the sowing–shooting phase was 20 days. The periods of “germination–flowering” and “flowering–ripeness” proceeded, respectively, under arid (HTC: 0.61) and moderately humid (HTC: 1.01) conditions, and their duration was 43 and 55 days, respectively. In general, the growing season was characterized as moderately dry, the hydrothermal coefficient was 0.83, and its duration was 98 days.

The sowing–shooting period in 2019 proceeded in dry conditions (HTC: 0.31) and then they hardly changed. From germination to flowering, HTC was equal to 0.75; the duration of this period was 61 days. From flowering to plant ripeness (52 days), the mete-

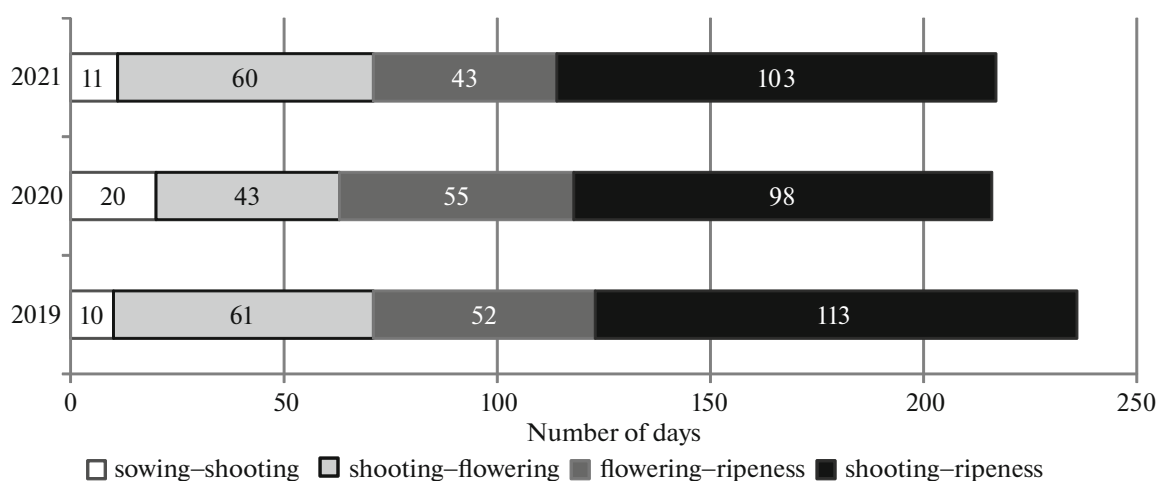


Fig. 1. Duration of phenological phases of nigella development.

orological conditions were very dry (HTC: 0.57). In general, the duration of the growing season of nigella was 113 days and it proceeded under dry conditions (HTC: 0.67). It should be noted that this was the longest growing season of the crop during the 3 years of study, probably due to low rainfall (133.5 mm) and average temperatures (17.6°C).

An important factor in the analysis of plant productivity is the assessment of the variability of the structural components of productivity. The number of capsules per plant and the seed weight per plant had the greatest influence on the formation of the seed yield of nigella: 27.6 and 29.2%, respectively (Table 2).

The capsules varied from 9.2 to 16.5 pcs./plant by varieties, and this trait was characterized by rather high variability; the coefficient of variation was 29.8%. The highest number of capsules (16.3 and 16.5 pcs.) was

formed on plants of the Shakherizada and Znakharka varieties, while the number of seeds in one capsule was 77.0 and 76.3 pcs., respectively. The highest number of seeds in one capsule was noted for Yalita, Krymchanka, and Radasts' varieties: 94.3, 98.3, and 89.3 pcs., respectively. However, it should be noted that the share of influence of this factor on the formation of yield was not high and comprised 20.3%.

The productivity of one plant was at the level of 1.36–2.32 g, and the variability of this trait was 33.4%. The highest seed weight per plant was noted for Iskra (2.23 g) and Chernyi Barkhat varieties (2.32 g), while the lowest values was revealed for Golubaya (1.36 g) and Radasts' varieties (1.38 g).

The 1000 seed weight varied from 2.58 (Diva) to 3.53 g (Spark), and the coefficient of variation was low and amounted to only 9.3%. The variability of this

Table 2. Indicators of the yield structure of nigella varieties (2019–2021)

Variety	Plant height, cm	Number of capsules, pcs.	Number of seeds per capsule, pcs.	Seed weight per plant, g	1000 seed weight, g
Znakharka	43.4	16.5	76.3	1.64	2.87
Chernyi Barkhat	56.9	12.2	66.7	2.32	2.98
Krymchanka	54.8	14.8	98.3	1.74	2.74
Diva	42.1	14.1	64.7	1.67	2.58
Golubaya	45.1	12.8	75.7	1.36	3.19
Iskra	46.7	11.1	71.1	2.23	3.53
Vitol'dina	49.4	12.3	69.7	1.75	3.52
Yalita	44.4	12.0	94.3	1.74	3.44
Shakherizada	50.1	16.3	77.0	1.52	3.19
Radasts'	42.6	9.2	89.3	1.38	3.46
Coefficient of variation, %	11.3	29.8	20.4	33.4	9.3
Share of influence, %	5.3	27.6	20.3	29.2	17.6
HCP05	0.94	1.25	4.89	0.13	0.31

**Table 3.** Productivity of nigella varieties (2019–2021)

Variety	Productivity, t/ha	Oil content, %	VSI
Znakharka	1.25	34.78	1.42
Chernyi Barkhat	1.11	39.83	1.23
Krymchanka	1.18	40.20	1.45
Diva	1.06	38.72	1.30
Golubaya	1.14	40.19	1.25
Iskra	1.19	37.18	1.32
Vitol'dina	1.22	40.95	1.38
Yalita	1.23	41.82	1.41
Shakherizada	1.09	35.20	1.29
Radasts'	1.18	40.08	1.35
Average of varieties	<b>1.17</b>	<b>38.89</b>	<b>1.34</b>
HCP05	0.04	1.25	–

structural element was probably determined in most cases by the genotype and, to a lesser extent, by the growing conditions [17]. The share of the contribution of the 1000 seed weight trait in the formation of the total yield was 17.6%,

The yield of nigella varieties under the conditions of the Penza oblast was quite high and varied from 1.6 to 1.25 t/ha, and the average varietal indicator was 1.17 t/ha (Table 3). It was the highest for Vitol'dina (1.22 t/ha), Yalita (1.23 t/ha), and Znakharka varieties (1.25 t/ha); the increase to the average value of this indicator was 0.05–0.08 t/ha. The lowest yield on average over 3 years was noted for Diva and Shakherizada varieties, it amounted to 1.06 and 1.09 t/ha and was lower than the average variety indicator by 0.08–0.11 t/ha.

The average oil content in *Nigella* seeds was 38.89%. Differences between varieties in terms of this indicator ranged from 0.9 to 7.0%. The highest fat content was noted in the Yalita (41.82%), Vitol'dina

(40.95%), Radasts' (40.08%), Golubaya (40.19%), and Krymchanka (40.20%) varieties which was by 1.19–2.93% higher than the average for all varieties. Low oil content (34.78 and 35.20%) was noted for Znakharka and Shakherizada varieties, which was by 3.69–4.11% lower than the average for the varieties.

The analysis of the results of the study of nigella varieties allowed us to identify the most ecologically stable genotypes with high VSI values. These varieties include Yalita, Znakharka, and Krymchanka with VSI values of 1.41, 1.42, and 1.45, respectively, which characterizes the complex of biological properties of genotypes and their adaptive capabilities under various climatic growing conditions.

The fatty acid composition of nigella oil was dominated by linoleic acid, the content of which varied from 47.98 to 64.27% depending on the variety. The proportion of linolenic acid was the smallest: from 0.28% in the Yalita variety to 1.02% in the Iskra and Golubaya varieties (Table 4). The lowest content of oleic acid (16.91%) was observed in the Chernyi Barkhat variety. In other genotypes, the value of this indicator exceeded 20% and amounted to 20.35–29.52%.

The proportion of saturated palmitic and stearic acids was 9.85–12.02 and 1.98–3.10% of the total, respectively. Moreover, the maximum content of palmitic acid in the experiment was noted for the Krymchanka variety (12.502%), the maximum content of stearic acid was revealed for the Yalita variety (3.10%). In addition, the fatty acid composition of nigella contained two more saturated fatty acids: lauric and capric, which accounted for 0.18–0.46 and 0.04–2.30%, respectively.

Thus, under the conditions of the Penza oblast, nigella can become a promising oilseed crop, including as a source of essential omega-6 and omega-9 fatty acids as well as valuable lauric acid. An evaluation of nigella varieties showed their high adaptability to the contrasting conditions of the forest-steppe of the Middle Volga region and the ability to form seed

**Table 4.** Content of fatty acids in nigella oilseeds (2019–2021), % of the total amount

Variety	Lauric	Capric	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Eicosadienoic
Znakharka	0.18	0.29	11.50	2.36	20.35	60.47	0.61	3.02
Chernyi Barkhat	–	0.18	11.11	2.15	16.91	64.27	0.44	3.56
Krymchanka	–	0.32	12.02	2.69	20.92	59.47	0.33	2.84
Diva	–	0.04	11.57	2.85	23.39	57.39	0.77	2.22
Golubaya	0.38	1.37	10.02	2.53	27.28	51.98	1.02	4.01
Iskra	0.26	1.53	10.56	2.44	26.93	50.40	1.02	4.74
Vitol'dina	0.31	1.58	10.12	2.74	28.06	52.24	0.37	3.55
Yalita	0.31	1.86	10.08	3.10	28.29	50.50	0.28	4.01
Shakherizada	0.18	0.94	10.90	1.98	26.06	53.21	0.34	4.88
Radasts'	0.46	2.30	9.85	2.92	29.52	47.98	0.70	3.79

yields up to 1.06–1.25 t/ha with an oil content of 34.78–41.82%. The Vitol'dina, Yalita, and Znakharka varieties were characterized by the highest productivity, the average yield of which was 1.22–1.25 t/ha. The Yalita, Znakharka, and Krymchanka varieties were characterized by the highest stability over the years, the VSI value of which was at the level of 1.41–1.45.

According to the fat content, Yalita and Vitol'dina varieties with an oil content of 41.82 and 40.95%, respectively, were distinguished. In the structure of nigella fatty acids, linoleic and oleic had the highest share; their content reached 47.98–64.27 and 16.91–29.52%.

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#### COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving animals or human participants performed by any of the authors.

#### CONFLICT OF INTEREST

The author declares that she has no conflicts of interest.

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