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THE SEARCH FOR SOURCE MATERIAL OF PHACELIA TANACETIFOLIA BENTH FOR BREEDING FOR FODDER PRODUCTIVITY

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Abstract. The genetic resources of wild populations of the valuable forage crop *Phacelia tanacetifolia* Benth. in different ecological conditions of the southern Srednerusskaya Upland were studied. Selected source material for breeding for fodder productivity. In the Vorskla natural-territorial complex the individuals which on the average 6.9-27.7% exceeded the individuals in other cenopopulations by height and bush size. The forms with high potential fodder qualities are distinguished: low hairiness of leaves and stems, dry matter content - 20.9-21.6%, protein - 19.4-20.4%, crude fat - 2.1-2.3%, soluble carbohydrates - 34.6-36.5%, green matter yield - 2,32-2,44 kg*(m²)-1, seeds - 0,032-0,038 kg*(m²)-1. The seeds of the best forms were collected and transferred to the collections of Federal Williams Research Center for Forage Production and Agroecology, All-Russian Research Institute of Phytopathology, Belgorod State University for breeding of new disease resistant forage varieties.

Keywords: genetic resources, breeding, fodder crop, green manure crop, morpho-biological characters, biochemical composition.

1. Introduction

An important area of research is the expansion of the range of fodder crops used in agricultural production, which can be simultaneously used as green manure, honeybees, ornamental, etc. In the development and implementation of biological farming systems, perennial and annual leguminous and cereal grasses, cabbage (cruciferous) crops are used as green manure. *Phacelia tanacetifolia* Benth. has become widely known in recent years as a sider and melliferous crop. [1-4].

Ploughed green mass (approximately 20 t*(ha)⁻¹) is equivalent to the introduction of 20 t*(ha)⁻¹ of humus. Macronutrients in the amount of N 78 P 52 K 196 are accumulated in the soil. Due to the short vegetation period *Ph. tanacetifolia* can be sown 3-4 times per season, which allows the accumulation of a large mass of organic matter. *Ph. tanacetifolia* . grows well in the penumbra (for example, if the site is shaded by forest), under tree crowns. *Ph. tanacetifolia* . normalizes soil reaction and actively suppresses annual weeds [5,6].



The plant produces phytoncides that repel some pests (leafminer, fruit fly) and attract insects that eat their larvae [7-11].

Interest in phacelia as a promising agricultural crop of multifunctional importance is increasing worldwide. Its biochemical composition and genetic characteristics are actively studied [12-16].

In the Belgorod region, breeding work on the creation of new varieties of phacelia cinquefoil is carried out. Two new varieties with a number of valuable qualities for agricultural production, 'Militsa' (2017) and 'Dana' (2020), were created on the basis of local source material and included in the State Register of breeding achievements approved for use in the Russian Federation [17].

The methodological basis of the conducted studies is the concept of formation in the south of the Srednerussky Upland of a secondary anthropogenic microgenic center of the formation of certain synanthropic plant species [18-21].

Ph. tanacetifolia is also a promising fodder crop, although not as common as the generally recognized legumes and grasses. The technology of preparation of haylage and pelleted fodder from phacelia has been developed. However, *Ph. tanacetifolia* can be used as a green fodder only in the early stages of ontogenesis, since the whole plant is abundantly covered with stiff hairs, which coarsen as the stem and leaves age.

In this regard, it is relevant to search for the initial material of phacelia, which has a set of properties such as resistance to diseases, high quality forage mass, soft stems, the absence or reduced number of hairs on the stems and leaves, and seed productivity.

The aim of the work was to conduct research to find the source material of *Ph. tanacetifolia* in natural phytocenoses of the southern Srednerusskaya Upland for breeding for fodder productivity.

2. Methods and materials

Belgorod region is located on the southwestern slopes of the Srednerusskaya Upland. The climate is moderately continental. Duration of sunshine is 1900-2000 hours per year. Value of the radiation balance during the year reaches 1650 MJ*(m)⁻². The indicator of agroclimatic resources is heat availability, which is about 2755 °C. Average perennial reserves of productive moisture in arable layer of soil at the depth of 0-20 cm is 25-35 mm, and in a meter layer in spring - 135-190 mm. In some years this value can decrease to 100 mm.

According to the complex of natural and climatic features, Belgorod region is divided into three natural-territorial complexes (PTC) belonging to the typical forest-steppe subzone; and one district each, which belong, respectively, to the southern forest-steppe and northern steppe [22].

The studies were conducted in four different ecological zones of the Belgorod region:

- Vorskla PTC. All the rivers of the region flow through this area, flowing into the Dnieper River. During the year the territory of the PTC receives the maximum amount of precipitation for the region, on average, from 575 to 640 mm per year. The presence of soils is characteristic: gray forest soils and podzolized chernozems. The cenopopulation of *Ph. tanacetifolia* - CPPH 1 was studied.

- The Oskolo-Severskodonetsk PTC is an area with rather high indented and dissected ravine and gully complexes (the density of ravines and gullies is 1.5 km*(km)⁻², as well as the maximum elevation within the south of the Srednerusskaya Upland - up to 272-276 m above d.m. The amount of precipitation does not exceed 525-585 mm. Soils: gray forest, typical, leached and podzolized chernozems. Agricultural lands occupy about 60% of the area. Meadow steppes are preserved on the protected territories. On chalky slopes of some rivers relict pine forests are preserved. The cenopopulation of *Ph. tanacetifolia* - CPPH 2 has been studied.

- The Potudansko-Tikhososnensky PTC is the most eroded part of the Belgorod region: the density of the ravine and gully network reaches 1.5-2 km*(km)⁻². Due to the fact that the area occupies the eastern position, the climate here is continental: the absolute temperature amplitude reaches 80 C. The amount of precipitation does not exceed 525-585 mm. The background natural complexes of the interfluves are forest-field undulating loamy plains with typical and leached chernozems. The cenopopulation of *Ph. tanacetifolia* - CPPH 3 was studied.

- Kalitvinsko-Urayevsky PTC. Climatic conditions are more continental than in other areas. Summers here are hot and arid, winters are sparse and cold. The amount of precipitation is 470-500 mm per year. Soil erodibility is 57-64%. Soils are represented by ordinary chernozems, ploughed, in some places on slopes with impoverished tipchak steppes. Another type of landscape is sloping ravine and gully areas with birch forests, with washed away carbonate chernozems and sod soils on chalk rocks with calcareous vegetation. Price population of *Ph. tanacetifolia* - CPPH 4 was studied.

Each of the areas of research has its own geological-geographical, soil-climatic and environmental features that determine the manifestation of growth and metabolic processes in the studied plant objects.

Route studies were conducted in 2018-2020 while studying biological resources of wild relatives of cultivated plants in Belgorod region in the framework of joint research of scientists of Belgorod State University and Federal Williams Reserch Center for Forage Production and Agroecology, All-Russian Research Institute of Phytopathology.

To find and evaluate the feral forms of *Ph. tanacetifolia* in natural communities, we performed geobotanical descriptions according to generally accepted methods [23].

Sample areas were allocated ($S = 100 \text{ m}^2$; $n = 10$). To study morphological and biological features of plants, as well as to take samples for determination of biochemical composition, 10 recording plots of 1 m^2 each were randomly allocated on each hundred-meter sample plot. All observations and counts, as well as biochemical analyses were carried out according to standard methods. The results were statistically processed [24].

3. Results and discussion

The study of wild populations of *Ph. tanacetifolia* revealed both certain features of similarity and differences between them in morpho-biological characters, as well as productivity of aboveground phytomass and seeds and (Table. 1)

Table 1. Morpho-biological features and productivity of *Ph. tanacetifolia* in different ecological conditions

Trait	Cenopopulations			
	CPPH 1	CPPH 2	CPPH 3	CPPH 4
Plant height, cm	92-114	60-89	82-110	74-108
Shrub diameter, cm	47-56	33-47	45-50	35-54
Stem diameter, cm	0.8-1.2	0.9-1.1	0.9-1.6	0.9-1.8
Inflorescence: length, cm	9.6-15.0	5.2-11.6	12.1-17.7	11.5-16.4
Stem: pubescence, points	0-1	5-7	3-5	3-5
Leaf: pubescence, points	0-1	2-3	1-2	2-3
Stem coarseness, points	2-3	3-4	4-5	3-4
Yield of green mass, $\text{kg} \cdot (\text{m}^2)^{-1}$	2.44 ± 0.09	1.86 ± 0.14	1.98 ± 0.16	2.32 ± 0.19
Weight of 1000 seeds, g	2.12 ± 0.09	1.75 ± 0.08	1.95 ± 0.11	2.31 ± 0.12
Seed productivity, $\text{kg} \cdot (\text{m}^2)^{-1}$	0.038 ± 0.002	0.032 ± 0.001	0.024 ± 0.003	0.021 ± 0.002

In terms of height of individuals, forms from CPPH 1 had a stem height of 105.2 ± 3.01 cm and exceeded forms from CPPH 2 by 27.7%, from CPPH 3 by 6.9%, and from CPPH 4 by 11.7%. The coefficient of variation (Cv) was 75.4 %.

In terms of bush size, forms from CPPH 1 cenopopulation had a diameter of 53.8 ± 2.31 cm and outperformed forms from CPPH 2 by 22.3%, from CPPH 3 by 7.8%, and from CPPH 4 by 13.6%. The coefficient of variation (Cv) was 32.7%.

In terms of stem diameter, individuals of phacelia from cenopopulations CPPH 1 and CPPH 2 practically did not differ from each other - their stem size was at the level of 1.1 ± 0.23 cm. They were 20.0% smaller than individuals from CPPH 3 and 40.0% smaller than individuals from CPPH 4. The coefficient of variation (Cv) was 22.6 %.

Individuals of phacelia from CPPH 3 outnumbered the other populations in terms of inflorescence length. Their inflorescence length averaged 15.7 ± 2.41 cm. They surpassed individuals from CPPH 1 by 21.7%, individuals from CPPH 2 by 46.4%, and individuals from CPPH 4 by 11.1%. The coefficient of variation (Cv) was 41.3 %.

Important characteristics in the assessment of *Ph. tanacetifolia* as a fodder crop are such indicators as the degree of stem and leaf pubescence. Only individuals of Phacelia in cenopopulation CPPH 1 were found to have weak pubescence at the level of 1 point, and some individuals had practically no pubescence - 0 points. In cenopopulations CPPH 3 and CPPH 4, stem pubescence was expressed to a medium degree, and individuals in cenopopulation CPPH 2 expressed it to a strong degree.

A similar trend was observed for the trait "leaf pubescence". Only in individuals of cenopopulation CPPH 1 were found some individuals with practically bare leaf laminae - degree of pubescence 0 points. In the majority of individuals in this cenopopulation the pubescence was weak - at the level of 1 point. Also individuals of CPPH 3 had a rather weak expression of leaf pubescence. In other cenopopulations leaf pubescence varied from medium to strongly pronounced.

The trait "stem coarseness" is important from the point of view of fodder value. In individuals of cenopopulation CPPH 1 the trait was expressed to a medium degree. In individuals of the remaining populations, stem coarseness varied from moderately strong (CPPH 2 and CPPH 4) to strong (CPPH 3).

Evaluation of green mass yield of wild specimens of phacelia showed that there were no significant differences between CPPH 1 and CPPH 4 price populations. Price population CPPH 2 was inferior to CPPH 1 by an average of 23.7 %, and CPPH 3 by 18.8 %.

In the study of seed productivity, we evaluated the weight of 1000 seeds, an indicator that is genetically conditioned. Individuals of Phacelia from CPPH 4 outperformed the other populations by this indicator: individuals from CPPH 1 by 8.7%, individuals from CPPH 2 by 26.1%, and individuals from CPPH 3 by 17.4%. The coefficient of variation (Cv) was 16.8 %.

In terms of seed productivity, forms from CPPH 1 cenopopulation exceeded forms from CPPH 2 by 15.8 %, from CPPH 3 by 36.8 %, and from CPPH 4 by 44.7 %. The coefficient of variation (Cv) was 32.6 %.

We studied the biochemical composition of individuals of *Ph. tanacetifolia* depending on the place of growth in different natural and climatic zones of the Belgorod region (Table 2).

Table 2. Indicators of biochemical composition of *Ph. tanacetifolia* in different ecological conditions

Trait	Cenopopulations			
	CPPH 1	CPPH 1	CPPH 1	CPPH 1
Dry matter content, %	21.6±0.21	17.8±0.16	18.3±0.13	20.9±0.19
Crude protein content, %	20.4±1.20	16.5±1.33	17.6±1.11	19.4±0.97
Crude fat content, %	2.36±0.07	1.89±0.11	2.16±0.13	1.99±0.19
Soluble carbohydrate content, %	34.6±2.13	36.5±1.49	32.5±1.22	33.4±2.19

Dry matter content is an indicator that allows us to determine the potential collection of dry matter from a unit area of crops, and characterizes the potential fodder value of the crop.

In terms of dry matter content, no reliable differences were found in the forms from CPPH 1 and CPPH 4 cenopopulations. The individuals from CPPH 1 outperformed reliably the forms from CPPH 2 by 17.5 %, from CPPH 3 by 15.34 %. The coefficient of variation (Cv) was 37.1 %.

The forms from CPPH 1 and CPPH 4 had no significant differences in crude protein content. Individuals from CPPH 1 cenopopulation significantly exceeded the forms from CPPH 2 by 18.9 %, and from CPPH 3 by 13.7 %. The coefficient of variation (Cv) was 32.6 %.

No reliable differences between cenopopulations were found in crude fat content.

The content of soluble carbohydrates also differed insignificantly between cenopopulations. Only in CPPH 2 cenopopulation it was slightly (by 11.1-5.2 %) higher than in other populations.

Observations carried out on individuals of cenopopulations for three years allowed us to distinguish individuals differing in habitus, absence or low intensity of pubescence, seed productivity, as well as to evaluate in general the populations by indicators of fodder (biochemical) value and seed productivity. The founder effect is clearly traced in the price populations.

Seeds of individuals of local feral cenopopulations of *Ph. tanacetifolia* were collected. These seeds were transferred for inclusion in the collection of the Laboratory of Biological Resources and Plant Breeding of НИУ «БелГУ», as well as for the creation of a collection on the basis of FGBNU VNIIF to study disease resistance of wild forms of Phacelia and create disease-resistant breeding material.

4. Conclusion

1. In the course of route surveys carried out in various ecotopes of the south of the Srednerusskaya Upland, we studied cenopopulations of wild specimens of *Ph. tanacetifolia*. The cenopopulations differ in morphological and biological characters.

2. Cenopopulation of Phacelia from Vorskla natural-territorial complex is the most promising as a source material for breeding for fodder productivity. The individuals of CPPH 1 exceeded the individuals in other cenopopulations on the average by 6.9-27.7 % in height and bush size; weak pubescence of leaves and stems was noted in them. The forms with high potential fodder qualities are distinguished: low pubescence of leaves and stems, dry matter content - 20,9-21,6%, protein - 19,4-20,4%, crude fat - 2,1-2,3%, soluble carbohydrates - 34,6-36,5%, green matter yield - 2,32-2,44 kg*(m²)-1, seeds - 0,032-0,038 kg*(m²)-1.

3. Seeds of the best forms were collected and transferred to the collections of Federal Williams Reserch Center for Forage Production and Agroecology, All-Russian Research Institute of Phytopathology, Belgorod State University for breeding work to create new varieties of fodder resistant to diseases.

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