Productivity of a promising forage species *Poterium polygamum* Waldst. & Kit. in the conditions of North Ossetia-Alania

Productivity of a promising forage species *Poterium polygamum* Waldst. & Kit. in the conditions of North Ossetia-Alania

B G Tsugkiev[1], L Ch Gagieva[1], V I Cherniavskih[2,3,4] and E V Dumacheva[2,3,4]

[1]Gorskii State Agrarian University, 37, Kirov St., Vladikavkaz, Republic of North Ossetia-Alania, 362040, Russia;
[2]State Scientific Institution "All-Russian Research Institute of Phytopathology", Russian Agricultural Academy", St. Institute, own 5, Bolshie Vyazemy, Odintsovo distr., Moscow reg., 143050, Russia;
[3] Federal State Budgetary Scientific Institution «Federal Scientific Center for Forage Production and Agroecology named after V.R. Williams», 1 building, Scientific town, Lobnya, Moscow reg., 141055, Russia;
[4] Belgorod State University, 85, Pobedy St., Belgorod, 308015, Russia.

Corresponding author's e-mail: Laragagieva@yandex.ru

Abstract. The article presents the results of a long-term study of *Poterium polygamum* Waldst. & Kit. when introduced into culture in the collection nursery of plants of the Research Institute of Biotechnology in the Botanical Garden of the Gorsk State Agrarian University (Republic of North Ossetia - Alania) with the participation of the staff of the Botanical Garden of the Belgorod State University. The morphological features of *P. polygamum* are described: the structure of vegetative and generative organs. An assessment of the dynamics of the formation of aboveground phytomass, indicators of photosynthetic activity, productivity of the aboveground mass and seed productivity during the cultivation of *P. polygamum* under the conditions of culture is given. It has been established that the species *P. polygamum*, which is promising for fodder production, has a high bioresource potential under the conditions of North Ossetia-Alania and in culture can ensure the maintenance of the stability of cenopopulations throughout all the years of cultivation. The leaf area on average over four years of research was 48.5 thousand m^2 (ha^{-1}), photosynthetic potential - 1.3 million m^2 (ha^{-1}), net productivity of photosynthesis - 4.7 g (m^{-2}) per day, yield of aboveground phytomass - 321 q (ha^{-1}) (r = 0.39-0.91). On average, when cultivated in culture, individuals of P. polygamum formed generative shoots - 843.9 pcs. (m^{-2}) per day; heads on 1 shoot - 3.7 pcs.; seeds in 1 head - 10.1 pcs.; seeds from 1 shoot - 1.0 g; have a mass of 1000 seeds - 8.6 g; seed yield - 862.6 kg (ha^{-1}). Seed productivity of *P. polygamum* varied from 773.3 to 947.8 pcs. per 1 m^2. At the same time, the coefficient of seed productivity varied from 19.5 to 40.9%. Such stable productivity allows individuals of *P. polygamum* in natural conditions to withstand competition with other plants, and in culture makes the species promising for cultivation as a forage species.

1. Introduction

The introduction and reintroduction of promising forage plants is being actively pursued both in Russia and in the world. The introduction of new food species into culture is an important direction in the mobilization of biological resources [1 - 7].

The list of agricultural crops cultivated for fodder purposes does not currently exceed 25 species. This leads to certain problems: the lack of stability of the green conveyor, seasonal feed shortages, etc. [8 - 11].

In this regard, the search for new sources of protein, increasing the nutritional value of feed rations is being actively pursued. *Poterium polygamum* Waldst. & Kit is a very promising species for introduction. [12, 13]. In recent years, this perennial herb from the *Rosaceae* family has been increasingly considered as a source of valuable protein and biologically active substances for therapeutic and prophylactic animal feeding. It has been shown that *P. polygamum* improves the palatability and digestibility of nutrients in feed, and stimulates the reproductive function of animals [14–16]. Breeding work is underway to obtain new varieties of this valuable crop [17]. The technology of cultivation of *P. polygamum* is being developed [18, 19].

The aim of the research was to study the photosynthetic potential and productivity of *P. polygamum* in the Republic of North Ossetia-Alania during the introduction into culture.

2. Research methods

Research on the cultivation of *P. polygamum* in culture was carried out for four years in the collection nursery of plants of the Research Institute of Biotechnology of the Botanical Garden of the Federal State Budgetary Educational Institution of Higher Education "Mountain State Agrarian University" with the participation of the staff of the Botanical Garden of Belgorod State University.

The climate of the region is temperate continental, characterized by sharp fluctuations in temperature throughout the year: a rapid change in weather conditions from severe winter to hot summer, late spring and early autumn frosts, etc. During the research years, weather conditions were characterized as stable and favorable for the growth and development of *P. polygamum* - the hydrothermal coefficient was 0.75-1.0.

The soil of the experimental plot in the collection nursery is sod-gley with a slightly acidic reaction of the soil medium, pH = 4.9-5.2. The humus content in the topsoil is 6.5%, the mass fraction of total nitrogen is 0.62-1.17%, potassium is 30.3-51.0 mg (100 g^{-1}) of soil, mobile forms of phosphorus is 2.4-2.8 mg (100 g^{-1}) of soil, gross phosphorus - 0.32-0.35%.

The object of the study is *P. polygamum* Waldst. & Kit.

Sowing of *P. polygamum* was carried out in 2010. Experiments were set up, and *P. polygamum* specimens were taken care of and observed according to standard methods [20].

The photosynthetic potential and net productivity of photosynthesis of *P. polygamum* were determined by the size of the assimilation surface of leaves [21].

Potential, real seed productivity and productivity index of *P. polygamum* were assessed [22]. Potential seed productivity was considered as the maximum possible number of seeds that a plant can produce if all ovules in the flowers form mature seeds. Real seed productivity - as the number of normally developed seeds produced by a plant per individual or generative shoot. Productivity coefficient - as the ratio of the indicator of real seed productivity to potential seed productivity, expressed as a percentage.

3. Research results and their discussion

P. polygamum Waldst. & Kit. Is a perennial herb with a taproot system. The height of *P. polygamum* individuals ranges from 55 to 87 cm on average. The erect cylindrical stem is often glabrous, but may be covered with prominent hairs in the lower part. In the first year of life, forms a rosette of complex odd-pinnate basal leaves with long petioles. Leaves from 5 to 10 pairs. The leaflets are ovoid or obtuse, the edge is crenate or serrate-serrate, the petioles are long. Stem leaves are pinnate, the leaves have petioles.

Individuals of *P. polygamum* in North Ossetia-Alania bloom in June-July, the seeds ripen from July to September. Dense capitate inflorescences of *P. polygamum* of elliptical shape, up to 20 mm long, are located on long legs. *P. polygamum* flowers grow up to 25 mm in diameter. They have a four-leafed calyx-shaped perianth, petals are absent. Sepals are light yellow at the beginning of flowering, later they become brown in color. When fruits fall off.

Numerous stamens: in male flowers there are from 10 to 30 pcs., In bisexual flowers there are fewer of them; filaments are long, thin. There are two pistils, tassel-like stigmas of bright red color.

The nut-shaped, two-seeded winged fruit is 4-5 mm long and 2.5 mm wide. Wings up to 0.5 mm wide with wavy or slightly serrated margins located along the ribs, between the edges of the ribs they are coarse and deeply cellular, light brown or brownish.

Under the conditions of North Ossetia-Alania, *P. polygamum* grows on stony, gravel, sandy slopes and talus, is characterized by rapid growth and development, and a short growing season. The species is ecologically plastic - xeromesophyte, mesotroph.

As our previous studies have shown, under the conditions of North Ossetia-Alania, both under natural conditions and during introduction into culture, individuals of *P. polygamum* begin to vegetate early, quickly form above ground phytomass, and grow well after mowing. This makes it possible to obtain at least two cuttings annually [23].

The resistance of individuals to growing conditions, the productivity of the aboveground mass and seed productivity are primarily determined by the intensity of the photosynthetic processes. The results of assessing the photosynthetic potential and net productivity of *P. polygamum* photosynthesis during cultivation in culture are shown in Table 1.

It was found that the leaf surface area of *P. polygamum*, on average over the years, varied from 45.0 to 50.4 thousand m^2 (ha^{-1}), the photosynthetic potential - from 1.3 to 1.4 million m^2 (ha^{-1}), the net productivity of photosynthesis practically did not change and remained within 4.3-4.8 g (m^{-2}) per day (table 1).

Table 1. Indicators of photosynthetic productivity of *P. polygamum* in culture

Indicators	Years of research				
	2010	2011	2012	2013	In the average
Leaf area, thousand m^2 (ha^{-1})	50.1	50.4	48.5	45.0 [a]	48.5
Photosynthetic potential, million m^2 (ha^{-1})	1.4	1.4	1.3	1.3	1.3
Net productivity of photosynthesis, g (m^{-2}) per day	4.8	4.8	4.7	4.3 [a]	4.7

[a] differences are significant for $P < 0.05$

It was found that, when cultivated under culture conditions, *P. polygamum* forms a significant amount of aboveground phytomass, starting from the first year of life - the year of sowing - on average up to 174 c / ha of raw matter, in the second year - 335 c (ha^{-1}), in the third year - 413 centners (ha^{-1}), and in the fourth year - 361 centners (ha^{-1}). On average, over four years of research, the yield of the aboveground phytomass of *P. polygamum* was 321 centners (ha^{-1}) (r = 0.39-0.91). The correlation coefficient indicates a positive correlation between the yield of the green mass of *P. polygamum* and the metrological conditions of the year.

Indicators of seed productivity of individuals are determined, on the one hand, by their hereditary characteristics, on the other, by the conditions of their cultivation. Seed productivity reflects the stability of cenopopulations and species, as well as the degree of their ecological plasticity under specific environmental conditions. In our experiments, in individuals of *P. polygamum*, on average, 3-4 capitate inflorescences are formed on one shoot, each consisting of 25-31 flowers (Table 2).

Table 2. Seed productivity of *P. polygamum* in culture

Indicators	Years of research		
	2011	2012	in the average
Number of generative shoots, pcs / m^2	796.9±3.1	890.9±4.7	843.9
Number of heads per shoot, pcs.	3.3±0.1	4.1±0.2	3.7
Number of seeds in 1 head, pcs.	10.2±0.02	10.0±0.03	10.1
Seed weight from 1 shoot, g	0.9±0.01	1.1±0.01	1.0
Weight of 1000 seeds, g	8.0±0.02	9.2±0.02	8.6
Seed yield, kg / ha	773.3±4.2	947.8±5.0	862.6

By the end of the growing season, up to 10 pieces are formed in each head. seeds. Fruits are set no more than 10.2-13.7%. The average weight of 1000 seeds was 8.6 g.

On average, over the years of research, the seed productivity of P. *polygamum* ranged from 773.3 to 947.8 pcs. per 1 m^2. At the same time, the coefficient of seed productivity varied from 19.5 to 40.9%. Such stable productivity allows individuals of *P. polygamum* in natural conditions to withstand competition with other plants, and in culture makes the species promising for cultivation as a fodder crop.

4. Conclusion

As a result of the studies carried out, it was found that in culture under the conditions of North Ossetia-Alania, the species *P. polygamum*, which is promising for forage production in many regions of the country, has a high bioresource potential: stable indicators characterizing the process of photosynthesis, a high rate of formation of aboveground phytomass, an average and stable level of seed productivity. This in culture can ensure the maintenance of the stability of *P. polygamum* cenopopulations over a long period of cultivation.

References

[1] Cherniavskih V I, Dumacheva E V, Gorbacheva A A , Vorobyova O V and Ermakova L R 2018 The Use of Morphobiological Characteristics in the Selection of Phacelia Tanacetifolia Benth International Journal of Green Pharmacy vol 12 (2) pp 433 – 436

[2] Chernyavskikh V I, Dumacheva E V, Sidelnikov N I, Lisetsky F N and Gagieva L Ch 2019 Use of Hissopus officinalis L culture for phytoamelioration of carbonate outcrops of anthropogenic origin the south of European Russia Indian Journal of Ecology vol 46 (2) pp 221 – 226

[3] Cherniavskih V I, Sidelnikov N I, Dumacheva E V, Borodaeva Z A, Glubsheva T N, Gorbacheva A A, Vorobyova O V and Korolkova S 2019 Biological resources of natural forage grassland of the cretaceous south of the European Russia EurAsian Journal of BioSciences 13 (2) pp 845 – 849

[4] Dumacheva E V, Cherniavskih V I, Tokhtar V K, Tokhtar L A, Pogrebnyak T A, Horolskaya E N, Gorbacheva A A, Vorobyova O V, Glubsheva T N, Markova E I and Filatov S V 2017 Biological resources of the Hyssopus L on the south of European Russia and prospects of itsintroduction International Journal of Green Pharmacy vol 11 (3) pp 476 – 480

[5] Dumacheva E V, Cherniavskih V I, Prisniy A V, Vorobyova O V, Gorbacheva A A, Glubsheva T N and Grigorenko S E 2018 Studies of biological resources of Urtica dioica L as initial material for breeding Journal of International Pharmaceutical Research vol 45 pp 473 – 476.

[6] Dumacheva E V, Cherniavskih V I, Gorbacheva A A, Vorobyova O V, Borodaeva Z A, Bespalova E N, Ermakova L R 2018 Biological resources of the Fabaceae family in the cretaceous south of Russia as a source of starting material for drought-resistance selection International Journal of Green Pharmacy vol 12 (2) pp 354 – 358

[7] Cherniavskih V I, Dumacheva E V, Lisetsky F N, Batlutskaya I V and Tsugkieva V B 2019 Impact

of endemic calciphilous flora of the central Russian upland on the nitrogen regime of carbonate soils and sub-soils. Bioscience Biotechnology Research Communications. 12 (3) pp 548–554
[8] Kotlyarova E G, Cherniavskih V I and Dumacheva E V 2013 Ecologically safe architecture of agrolandscape is basis for sustainable development Sustainable Agriculture Research vol 2 (2) pp 11 – 23
[9] Cherniavskih V I, Dumacheva E V, Lisetskii F N, Tsugkieva V B and Gagieva L Ch 2020 Productivity of Galega (Galega orientalis) in single-species and binary crops with Sainfoin (Onobrychis arenaria): a case study of forest-steppe of European Russia Bioscience Biotechnology Research Communications vol 13 (1) pp 15 – 22
[10] Cherniavskih V I, Dumacheva E V, Borodaeva Z A, Gorbacheva A A, Horolskaya E N, Kotsareva N V, Korolkova S V and Gagieva L C 2019 Features EurAsian Journal of BioSciences vol 13 (2) P 733 – 737.1
[11] Vasin V G, Vasin A V, Kozhaeva A A and Karlova I V 2018 Productivity of grass-legumes mixtures with Poterium polygamum applying growth stimulators Agriculture for the next 100 years (Proceedings of the 26th NJF Congress) 164 – 169
[12] Kshnikatkina A N and Yudin I Yu 2019 Productivity of Poterium Polygamum depending on a cover crop Volga Region Farmland vol 3 (3) pp 76 – 81
[13] Gasiev V, Khokhoeva N and Mamiev D 2019 T. Biological features of formation of Perennial binary grass crops Agronomy Research vol 17 (5) pp 1891 – 1897
[14] Vasin V G, Karlova I V, Narushev V B, Vasin A V and Kozhaeva A A 2018 Productivity of the herbage mixtures with Bromus inermis leyss and poterium polygamum waldst et kit. Treated with growth stimulators Journal of Pharmaceutical Sciences and Research vol 10 (10) pp 2612 – 2615
[15] Alenin P G, Kshnikatkin S A and Voronova I A 2017 The production process of seed agrophytocenoses of milk thistle and blackhead polygamous in the forest-steppe conditions of the Middle Volga region Niva Povolzh'ya vol 1 (42) pp 2 – 9
[16] Lapenko N G and Lebedeva N S 2020 Creation of new types of productive agrocoenosis – the basis of a sustainable feed base Proceedings of Gorsky State Agrarian University vol 57 (3) pp 103 – 109
[17] Kravtsov V V and Kravtsov V A 2017 Chernogolovnik polygamous cultivar Stimulus for pastures and hayfields Byulleten' Stavropol'skogo nauchno-issledovatel'skogo instituta sel'skogo khozyaystva vol 9 pp 167 – 170
[18] Voronova I A and Savitskaya A A 2015 Seed productivity of burnet Poterium Poiygamum Wildest depending on methods of cultivation Niva Povolzhya vol 3 (36) pp 40 – 46
[19] Kshnikatkina A N and Orlov A A 2019 Methods of cultivation of Androgynous burnet (Poterium polygamum) in the conditions of the forest-steppe of the Middle Volga Region Volga Region Farmland vol 3 (3) pp 70 – 75
[20] Dospekhov B A 2012 Field experience methodology (with the basics of statistical processing of research results) (Moscow: Kniga po Trebovaniyu) p 352
[21] Nichiporovich A A 1970. The most important problems of photosynthesis in crop production (Moscow: Kolos) p 320
[22] Vajnagij I V 1974 On the method of studying the seed productivity of plants Bot. zhurn vol 59 (6) pp 826–831
[23] Gagiyeva L Ch 2009. Polygamous blackhead is a promising fodder plant Zemledeliye vol 1 p 37