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Assessment of the Biological Resource Potential of Species of *Symphytum L.* in the Flora of the Kabardino-Balkarian Republic

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Abstract

The paper investigates ecological and biological features, chemical composition and nutritional value of the aboveground phytomass of *Symphytum asperum* Lepech. and *Symphytum caucasicum* M. Bieb. within the primary range through the example of phytocenoses of the Kabardino-Balkarian Republic. The range of *S. asperum* covers the foothill and middle mountain zones up to a height of 2400 m a.s.l., and *S. caucasicum* covers the flat and foothill zones up to 750 m a.s.l. The limiting factors for the species of *Symphytum L.* are moisture, nitrogen availability and acidity of the soil. In the studied ecotopes, the realized ecological niche of *S. asperum* and *S. caucasicum* is within the limits of the fundamental one. The relationship has been established between the content of nitrogen, phosphorus and potassium in the aboveground phytomass of comfrey plants and the content of humus, mobile phosphorus and exchangeable potassium in the soil of the species habitat. The accumulation of vitamin C in the aboveground phytomass depends on the height above sea level, the average temperature and the amount of precipitation during the growing season. The nutritional and energy value of phytomass, high yield and good regrow capacity of plants indicate the possibility of using *S. asperum* and *S. caucasicum* in fodder production. Since comfrey plants grow sparsely and in places difficult for farm animals to access, it is advisable to create plantations of *S. asperum* and *S. caucasicum* in the territory of Kabardino-Balkaria for multiple purposes (fodder, melliferous and medicinal).

Keywords: Symphytum asperum, Symphytum caucasicum, *phytocenosis, cenopopulation, ecological valence, habitat, nutritional and energy value, yield*.

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1. Introduction

The *Boraginaceae* family of the flora of the Kabardino-Balkarian Republic is represented by 20 genera and 41 species [1]. The genus *Symphytum* L. is one of the smallest genera. The natural phytocenoses of Kabardino-Balkaria include prickly comfrey (*Symphytum asperum* Lepech) and Caucasian comfrey (*Symphytum caucasicum* M. Bieb.), which are of interest as types of multi-purpose economic use.

S. asperum is a relict Caucasian species and an edificator of high-mountain meadows [2]. The species range in the North Caucasus is quite wide -- from lowland to the upper mountain belt. In other regions of Russia, the prickly comfrey is known as an adventive species due to its ability to grow in disturbed habitats, to penetrate into semi-natural and natural communities [3, 4]. *S. caucasicum* is endemic to the Caucasus [5] and grows sparsely in lowlands and in the lower mountain belt in light forests, forest glades, along forest edges and ruderal ecotopes [6]. In central Russia and Siberia, Caucasian comfrey has acquired invasive status and is listed in the Black Book [4, 7].

Due to high content of biologically active substances (pyrrolizidine alkaloids, allantoin, vitamins, phenylcarboxylic acids, flavonoids, tannins, polysaccharides, triterpenes), *S. asperum* and *S. caucasicum* are used in official and traditional medicine [8--13]. Prickly comfrey is used in fodder production due to high productivity of the aboveground phytomass, cultural longevity, early vegetation, resistance to low temperatures, good regrow capacity, high content of protein, vitamins and ash elements in phytomass. *S. asperum* and *S. caucasicum* are recommended for cultivation in hay, haylage and silage culture [14]. These are good honey plants with nectar productivity of 160--360 kg/ha [15].

S. asperum and *S. caucasicum* were mostly studied during introduction, therefore, the study aimed to assess the bioresource potential (ecological and biological features, chemical composition and nutritional value of phytomass) of the comfrey through the example of phytocenoses of the Kabardino-Balkarian Republic.

2. Methods and Materials

The studies were conducted in May--June 2016--2018 in the territory of the Kabardino-Balkarian Republic. The projective cover and abundance of *S. asperum* and *S. caucasicum* were determined in the discount areas. The edaphic conditions of the discount areas were assessed by the scales of moisture (Hd), salt conditions (Tr), acidity (Rc) and nitrogen fertility (Nt) [16]. For comfrey cenopopulations, the potential (PEV) and realized (REV) ecological valences, the index of tolerance (It) and the coefficient of ecological efficiency (Kec) were calculated [17]. For each edaphic factor, the valence group was determined: stenovalent (SV) -- It≤0.33; hemistenovalent (HSV) -- It=0.34--0.45; mezovalent (MV) -- It=0.46--0.56; hemieryvalent (HEV) -- It=0.57--0.66; evrivalent (EV) -- It≥0.67 [18].

Agrochemical analysis of the soil in the study areas included determination of humus, pH_{KCl}, mobile phosphorus, exchangeable potassium, and calcium. Chemical composition of the phytomass of *S. asperum* and *S. caucasicum* was studied at the budding-flowering stage within cenopopulations from the periphery of Nalchik (CP 1), the vicinity of Dzhenal (CP 2), a subalpine meadow of the Kabardino-Balkarsky State High-Mountain Nature Reserve (CP 3), spoil heap in the stanitsa Aleksandrovskaya (CP 4), the vicinity of the settlements Lechinkai (CP 5), Yantarnoye (CP 6), Zavodskoye (CP 7) and Zhemtala (CP 8). The phytomass was analyzed to determine the content of nitrogen, potassium, phosphorus, calcium and vitamin C. The nutritional value of the phytomass was estimated by the content of crude protein, crude fat and crude fiber. The content of nitrogen-free extractable matter (NFEM), the available energy in the silage for cattle (AE) and feed units were determined by the calculation method [19].

The fresh yield of *S. asperum* and *S. caucasicum* was determined for different soil types. The plants were cut at a height of 4--5 cm from the soil surface, the air-dry weight of the crop was determined for 2 crops per 1 m^2 (the first crop was at the budding-flowering stage, the second crop was 2 months later) and the leaf area index (LAI).

3. Results

The botanical studies indentified cenopopulations of *S. asperum* in the foothill and middle mountain zones of the Kabardino-Balkarian Republic up to a height of 2400 m a.s.l. The cenopopulations of *S. caucasicum* are found in the steppe and foothill zones of the republic up to a height of 750 m a.s.l. In the majority of phytocenoses, *S. asperum* and *S. caucasicum* are components of semi-ruderal and ruderal communities. Single specimens of *S. asperum* are found at altitudes above 2600 m a.s.l. (Kabardino-Balkarsky State High-Mountain Nature Reserve, vicinity of the Mt. Elbrus). *S. asperum* shows the largest projective cover and abundance (up to 8 %) in grassy phytocenoses of broadleaf forests and mesophilic high-grass subalpine meadows in the lower part of the subalpine belt in low reliefs with moist soil. Moderate abundance (up to 2.5 %) is found for the phytocenoses of post-forest steppes. The cenopopulations of S. caucasicum are characteristic of the flat zone of the republic in the valleys of the rivers Malka (CP 6), Chernaya Rechka (CP 7), Terek (CP 4), Chegem (CP 5), Psygansu (CP 8). The greatest projective cover and abundance (4.5--8 %) of *S. caucasicum* can be observed in areas with moist friable soils.

Analysis of potential ecological valence showed that *S. asperum* is stenovalent on the scale of soil moisture, hemistenovalent on the scale of soil acidity, hemiverivalent on

the scale of nitrogen fertility, and euryvalent on the scale of salt conditions. *S. asperum* most fully uses the potential niche on the scale of acidity (57.4 %) and moisture (43.3 %) of the soil. The realized ecological niche of the studied *S. asperum* cenopopulations is within the limits of the fundamental ecological niche. At the same time, the realized ecological valence of *S. asperum* is lower than the potential for all ecological factors. The effectiveness of the development of ecological space with respect to edaphic factors (average Kec.eff.) was 32.77 %. The index of tolerance of a species to edaphic factors is 0.54, which makes it possible to assign *S. asperum* to mesobiont species (It=0.46--0.56) with a sufficiently high adaptive potential for various edaphic habitat conditions (Table 1).

S. caucasicum makes full use of the potential niche on the scale of soil moisture. The realized ecological valence is lower for all ecological factors, and for moisture it is similar to the potential one. The effectiveness of the development of the ecological space relative to edaphic factors (average Kec.eff.) was 50.40 %.

The limiting factors for *S. asperum* and *S. caucasicum* are moisture and acidity of the soil. Soil moistening in the habitat of *S. asperum* ranges from dry-meadow to marsh-meadow, and soil acidity varies from poor (pH 5.0--5.5) to highly alkaline (pH 8.4--9.1). The maximum projective abundance of the species can be observed on fairly rich soils with a pH of 6.0--7.5 and wet-meadow moistening. Rich soils with a pH of 6.0--7.5 and marsh-meadow moistening are optimum for *S. caucasicum*. It should be noted that *S. caucasicum* does not self-seed in the conditions of introduction (secondary range of the species) and spreads by root sprouts only [20]. According to our observations, seed specimens of *S. caucasicum* grow on wet, loose and water-permeable soils, which indicate favorable conditions not only for vegetative, but also for seed reproduction of the species within the primary range.

In the aboveground phytomass of *S. asperum*, the average nitrogen content is 2.76 %, calcium content is 16.84, phosphorus content is 4.73, potassium content is 4.84 g/100 g; the nitrogen content in *S. caucasicum* amounts to 1.96 %; 14.50, 3.13 and 5.88 g/100 g, respectively (Table 2).

Comparison of the obtained results with the agrochemical indicators of soil in the cenopopulation habitat shows a moderate relationship between the nitrogen content in phytomass and the humus content in soil (r=0.48); a strong relationship between the content of phosphorus/potassium in the phytomass and mobile phosphorus/exchangeable potassium in the soil (r=0.78/0.84); a weak relationship between the calcium content in the phytomass and in the soil (r=0.19).

The content of vitamin C in the phytomass varies from 1160 to 1582 mg % and averages 1456 mg % in *S. asperum* and 1253 mg % in *S. caucasicum* (Table 3). Analysis of the results indicates a strong relationship between the accumulation of vitamin C and the height above sea level (r=0.94), and a moderate relationship between the content of vitamin C, the average temperature (r=--0.46) and the total amount of precipitations from April to August (r=0.69).

The average fresh yield of *S. asperum* in two crops is 1.6 kg/m^2 of the air-dry weight, which is 4.0 fold higher than that of *S. caucasicum*. The yield of the second crop of *S. asperum* and *S. caucasicum* is 54 and 30 % of the first crop, respectively (Table 4). The fresh yield of *S. asperum* in two crops harvested on gray forest soil (CP 1) 1.43 fold exceeds the yield on alluvial meadow soil (CP 2). The leaf area index ranges from 4.05 to 4.11 m^2/m^2. For *S. caucasicum*, higher yields and LAI are observed on carbonate chernozem soil (CP 4). In *S. asperum* cenopopulation, the average fresh yield and LAI are 3.96 and 1.18 times higher, respectively (Table 4). *S. asperum* can yield 5--6 crops, whereas *S. caucasicum* yields no more than two crops. Due to the fact that comfrey plants are demanding on soil fertility and cultivation conditions, high yields can be harvested on fertile, well-fertilized, permeable and non-acidic soils [14].

TABLE 1: Ecological characteristics of *S. asperum* (Sa) and *S. caucasicum* (Sc).

Scale range	Ecological niche of species	PEV	Realized ecological niche		REV		Kec, %	
			Sa	Sc	Sa	Sc	Sa	Sc
Hd (1--23)	10--16	0.30 (SV)	11--14	10--16	0.13 (SV)	0.30 (SV)	43.33	100.00
Tr (1--19)	3--15	0.68 (EV)	7--9	9--13	0.11 (SV)	0.21 (SV)	16.28	30.88
Nt (1--11)	4--10	0.64 (HEV)	6--7	4--6	0.09 (SV)	0.18 (SV)	14.06	28.12
Rc (1--13)	5--11	0.54 (HSV)	7--11	7--10	0.31 (SV)	0.23 (SV)	57.41	42.59

The average content of crude protein in the aboveground phytomass of *S. asperum* and *S. caucasicum* is 13.5 and 11.9 %, respectively, crude fiber content is 14.4 and 15.9 %, crude fat content is 2.9 and 3.1 %, crude ash content is 14.4 and 17.6 %, and NFE content is 54.7 and 51.4 %; the calculated content of the available energy in the silage for cattle is 0.95 and 0.88 MJ, respectively, which corresponds to 0.15--0.16 feed units (Table 5).

Table 2: Chemical composition of the aboveground phytomass of *S. asperum* and *S. caucasicum* at the budding--flowering stage depending on agrochemical indicators of soil in the species habitat.

Species	Habitat	N, % (humus, %)*	Ca, g/100 g (Ca, %)*	P, g/100 g (P_2O_5, mg/100 g)*	K, g/100 g (K_2O, mg/100 g)*
S. asperum	CP 1	2.55 (2.80)	16.13 (0.73)	5.50 (60.50)	4.70 (241.20)
	CP 2	2.95 (6.40)	17.15 (1.14)	4.37 (26.80)	5.23 (358.10)
	CP 3	2.78 (3.00)	17.26 (0.65)	4.32 (26.40)	4.58 (250.00)
S. caucasicum	CP 4	1.80 (2.90)	16.58 (0.79)	2.65 (28.00)	5.50 (270.10)
	CP 5	2.14 (4.20)	12.93 (0.92)	2.46 (20.50)	6.62 (459.50)
	CP 6	1.92 (3.30)	16.68 (0.83)	2.52 (22.80)	5.48 (270.00)
	CP 7	1.96 (3.50)	12.74 (0.74)	3.41 (36.10)	6.35 (385.90)
	CP 8	1.98 (3.70)	13.56 (0.65)	4.63 (50.10)	5.47 (265.10)

*Agrochemical indicators of soil in the species habitat are provided in parentheses

Table 3: content of vitamin C in the aboveground phytomass of *S. asperum* and *S. caucasicum* depending on the species habitat.

Species	Habitat	Vitamin C, mg%	a.s.l., m	Average temperature in April--August, °C	Total amount of precipitations in April--August, mm
S. asperum	CP 1	1320	518	+17.2	401
	CP 2	1465	875	+13.6	360
	CP 3	1582	1860	+13.0	443
S. *caucasicum*	CP 4	1184	253	+14.9	360
	CP 5	1330	755	+13.1	410
	CP 6	1160	236	+14.6	305
	CP 7	1210	275	+14.4	362
	CP 8	1380	760	+12.7	447

Table 4: fresh yield (air-dry weight) of *S. asperum* and *S. caucasicum* in phytocenosis.

Species	Habitat	Yield of crop I, kg/m^2	Yield of crop II, kg/m^2	Yield of two crops, kg/m^2	LAI, m^2/m^2
S. asperum	CP 1	1.210	0.659	1.869	4.11
	CP 2	0.845	0.459	1.304	4.05
	average	1.027	0.559	1.586	4.08
S. caucasicum	CP 4	0.272	0.082	0.354	3.24
	CP 5	0.344	0.103	0.447	3.68
	average	0.308	0.092	0.400	3.46

Table 5: nutritional and energy value of *S. asperum* and *S. caucasicum* at the budding--flowering stage.

Показатель	Unit of measurement	*S. asperum*		*S. caucasicum*	
		CP1	CP 2	CP 4	CP 5
Dry matter (DM)	%	9.84	10.75	13.27	13.45
Crude protein	g/100 g DM	11.30	15.90	11.20	12.60
Crude fiber	g/100 g DM	14.22	14.53	15.65	16.24
Crude fat	g/100 g DM	3.00	2.86	3.12	3.15
Crude ash	g/100 g DM	13.38	15.50	17.40	17.9
NFE	g/100 g DM	58.10	51.31	52.63	50.11
Feed units	--	0.16	0.16	0,15	0.15
AE	MJ	0.93	0.96	0.88	0.88

4. Conclusion

In the territory of the Kabardino-Balkarian Republic, the range of *S. asperum* covers the foothill and mid-mountain zones up to 2400 m a.s.l., and *S. caucasicum* grows in the flat and foothill zones up to 750 m a.s.l. The limiting factors for *S. asperum* and *S. caucasicum* are moisture, nitrogen supply and acidity of soil. In the studied ecotopes, the realized ecological niche of *S. asperum* and *S. caucasicum* cenopopulations is within the limits of the fundamental one. The relationship between the content of nitrogen, phosphorus and potassium in the aboveground phytomass of comfrey plants and the content of humus, mobile phosphorus and exchangeable potassium in the soil of the species habitat is established. The accumulation of vitamin C in the aboveground phytomass depends on the height above sea level, the average temperature, and the amount of precipitation in the growing period. The nutritional and energy value of the phytomass and sufficiently high yields indicate the possibility of using *S. asperum* and *S. caucasicum* in fodder production. Due to the fact that in the territory of Kabardino-Balkaria comfrey plants grow sparsely and in places difficult for farm animals to access, it is rational to create plantations of *S. asperum* and *S. caucasicum* for fodder, melliferous and medicinal purposes.

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