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Population Studies of *Hedysarum theinum* Krasnob. At the Ivanovsky Mountain Range of The Kazakh Altai Mountains.

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ABSTRACT

The current paper represents ecological, biological, and resource studies of *Hedysarum theinum* Krasnob. at the Ivanovsky Mountain Range of the Kazakh Altai Mountains. We have provided a phytocoenotic description of the species' habitat, and determined the ontogenesis, age composition of the coenopopulations, numbers, presence of pests and pathogenic organisms, as well as the seasonal rhythm of development of sweetvetch. We have found that *Hedysarum theinum* inhabits large territories of the Ivanovsky Mountain Range and undergoes excessive anthropogenic impact. The species does not form industrial reserves and may serve as a source of raw materials for the local pharmacy chain. Within the coenopopulations, the species acts as dominant or subdominant. The sweetvetch coenopopulations from different sites of the Ivanovsky Mountain Range have similar age composition with uniform age spectra: in all cases the absolute maxima account for mature reproductive individuals. The populations of this species have normal age distributions lacking certain stages, they are dominated by mature generative plants, the numbers of juvenile and premature individuals are low, whereas senile plants are completely absent. Seed productivity undergoes substantial fluctuations over the years, also depending on the altitude of the species' habitat and climatic conditions during the vegetative period, while almost all altitudinal belts are marked by relatively high seed productivity. The plants of the wild populations are affected by the pathogens, causing rust infection and various leaf spot diseases. The pest insects include the shaded broad-bar and *Eupithecia* larvae.

Keywords: *Hedysarum theinum* Krasnob., phytocoenosis, coenopopulation, ontogenesis, seasonal rhythm of development, pests and diseases

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INTRODUCTION

Hedysarum theinum is a rare high-altitude alpine species with a disjunctive distribution over Central Asia and Southern Siberia [1]. It can be observed in the high-altitude belt, in the adjacent territories of the forest belt at the alpine and subalpine meadows, at the rocky slopes, along the creeks, and at the forest meadows [2]. Sweetvetch is common in Western Altai within the territory of Eastern Kazakhstan, in the Tarbagatai Mountains, Dzungarian Alatau, and the mountain ranges of Western Mongolia [3].

The natural flora of Eastern Kazakhstan is one of promising regions of Kazakhstan in terms of the exploitation of the natural resources of medicinal plants due to rich and diverse flora of the Kazakh Altai Mountains [4].

Screening of natural flora has revealed 783 species of medicinal plants, belonging to 99 families, inhabiting this territory [5]. However, procurement of raw materials, including *Hedysarum theinum,* is mostly spontaneous, which has led to the deterioration of the species' populations in many mountainous areas, accessible for the pickers. In view of foregoing, comprehensive studies of the species' ecological and biological features and assessment of the resource characteristics define undeniable applicability of the selected research topic. The information on the ecological and biological features of maral root will promote the development of the cultivation technology for Eastern Kazakhstan.

Hedysarum theinum has been distinguished from *Hedysarum neglectum* on the basis of certain morphological and biological features*. Hedysarum theinum* has different structure and chemical composition of roots, short and thick multisided inflorescences, shorter peduncles, longer bracts, bractlets, reaching the top of the calyx teeth, botryoidal teeth of larger calyces, larger flowers, including keels with the rounded front-lower edges, and wide fruit wings [6]. Previous studies refer to *H. theinum* as *H. obscurum* L. and *H. austrosibiricum* [7].

H. theinum coenopopulation was studied by the Russian botanists in the high-mountain territories of Russian and Kazakh Altai Mountains at the altitude of 1600-2100 m a.s.l. [8]. Knyazev has studied the East European and certain Siberian populations [9]; Il'ina has examined the Middle Volga populations of sweetvetch [10]. The following researchers have made substantial contribution to the studies of cultivation, ecological and biological features, introduction and reintroduction, ontogenesis of sweetvetch: Syeva, Karnaukhova, Dorogina, Sviridova, Zinner, Zubairova [11-15].

The aerial parts of sweetvetch contain monosaccharides, disaccharides, tannins, vitamin C, carotene, xanthanoids mangiferin and isomangiferin [16]. Oligomeric catechins [17], isoflavonoids, butylphenols [18], alkaloids, tannins, flavonoids, saponins, coumarins, carbohydrates, vitamin C [19] have been found in the subterranean parts.

Sweetvetch exhibits a wide range of pharmacological properties: anti-inflammatory, anti-tumor, immunostimulatory, restorative effects, etc. [20-22]; its antibacterial influence is also well-known [23]. Red root tea has restorative and general tonic properties [24]. The plant roots are widely used in the Kazakh Altai traditional medicine for treatment of gastrointestinal diseases and gynecological disorders, as diuretic and anti-inflammatory agent. Procurement of sweetvetch root as a raw substance for tea brewing and adding to alcoholic beverages has particularly increased.

The objective of our study was to assess ecological and biological features of *Hedysarum theinum* in its natural habitats, to determine the coenotic structure, resource characteristics and thickets of the species, its diseases and pests, in order to lay the scientific foundation for preservation and sustainable exploitation of the species.

MATERIALS AND METHODS OF THE STUDY

Natural coenopopulations of *Hedysarum theinum* Krasnob. within the natural habitats at the Ivanovsky Mountain Range were chosen as the subject of study.

The Ivanovsky Mountain Range, where the population studies of *Hedysarum theinum* Krasnob. have been conducted, is a part of South-Western Altai Mountains. The highest eastern territory (approximately 2800 m a.s.l. (meters above sea level)) starts at the eastern border of Kazakhstan, near the sources of the White and the Black Uba Rivers, and continues to the west, to the valley of the Gromatukha River near the Ridder Mountain. In the south, it borders on the Ulba Mountain Range; on the northwest, it is separated from the Uba Mountain Range by the Gromatukha River. The altitudes range from 2000 to 2800 m a.s.l. [25].

The study of the coenopopulations was based on the route reconnaissance survey methodology [26]. Geobotanical methods with visual assessment of the number of individuals according to Drude scale [27] were used to describe the vegetative communities that included the subject of study. The structure of each specific coenopopulation was examined according to the guidelines of Rabotnyi [28] and Smirnova [29]. Methods described by Uranov [30] were implemented in the assessment of the life cycle. The guidelines developed by Golubev and Molchanov [31] were used as the basis for the examination of ecological and biological features of the species in the field. The size of the exploitable reserves and the volume of possible annual procurement, considering the recovery period of the examined species, were determined according to "Metodika opredeleniya zapasov lekarstvennykh rastenii" ["Methods of the assessment of the reserves of medicinal plants"] [32]. The statistical analysis of the data was performed according to the guidelines by Zaitsev [33].

RESULTS AND DISCUSSION

The habitats of sweetvetch are restricted to the north-western and north-eastern slopes of different steepness, which are protected from the dominant winds and have reasonably thick snow cover of 110-140 cm, occasionally reaching 200 cm during the winter period; sweetvetch also inhabits flattened areas of the mountain tops and vast watersheds within the belts of subalpine and, less often, alpine meadows, along the floors of the mountain river valleys. It can be less commonly observed at the overgrowing stone rivers, where soil accumulates between the rock fragments. The species rarely appears at the south-eastern and south-western slopes. It prefers more or less humid mountain meadow soils, rich in humus and moisture; it cannot tolerate waterlogging and meltwater accumulation. It freezes out at the sites, where snow is blown out by wind.

Within the territory of the Ivanovsky Mountain Range, we have spotted one of the largest populations of the species in the Kazakh Altai, up to 35 km^2, and have denoted it as "Ivanovskaya". The Ivanovskaya population is located along the upper reach of the Bol'shaya Poperechka River at the north-western slope. It has the following coordinates: 50º 19' 02" N, 83º 52' 32" E, 1860 m a.s.l. The population inhabits a sparsely covered old moraine with impoverished herbage in the form of separate unstructured groups. It can be subdivided into 6 coenopopulations that include sweetvetch: sweetvetch – saw-wort (*Saussurea latifolia* Ledeb., *Hedysarum theinum* Krasnob.), sweetvetch – columbine (*Aquilegia glandulosa* Fisch. ex Link., *Hedysarum theinum* Krasnob.), blueberry – sweetvetch – vernal grass (*Anthoxanthum odoratum* L., *Hedysarum theinum* Krasnob., *Vaccinium myrtillus* L.), sweetvetch – lousewort – columbine (*Pedicularis proboscidea* Stev., *Aquilegia glandulosa* Fisch. ex Link., *Hedysarum theinum* Krasnob.), *Doronicum* – sweetvetch (*Hedysarum theinum* Krasnob., *Doronicum altaicum* Pall.), sweetvetch (*Hedysarum theinum* Krasnob.) phytocoenoses. The ecological, phytocoenotic and resource description of these coenopopulations at the Ivanovsky Mountain Range, as the most common habitat of the species, is provided below.

The coenopopulation of the sweetvetch – saw-wort (*Saussurea latifolia* Ledeb., *Hedysarum theinum* Krasnob.) phytocoenosis with the total area of 1.3 hectares is located at the slightly steep slope. The relief is very complex, 70% of it are comprised of exposed fragments of ancient rocks. Poorly formed layer of soil is represented by leaf fall at the rate of 250 g/m^2. Organic material accumulates between the stone river debris and in depressions with favorable conditions for *Hedysarum theinum* Krasnob. growth.

Grass stand is well-developed, consists of three strata, and has poor diversity of species. The total projective cover does not exceed 40%.

The first layer is formed by *Hedysarum theinum* Krasnob. – cop_2; its share of the projective cover is approximately 25%. Separate groups or large single individuals of *Saussurea latifolia* Ledeb. can be observed (cop_3), its proportion of the projective cover is 25%. The list of accessory species includes *Rumex acetosella* L. –

sol, *Aquilegia glandulosa* Fisch. ex Link. – sol, *Sanguisorba alpina* Bunge – sol, *Geranium albiflorum* Ledeb. – sp, *Doronicum altaicum* Pall. – sol, *Phlomoides alpina* (Pall.) Adyl. – sol, *Poa pratensis* L. – sol.

The second layer is poorly developed, represented by *Carex aterrima* Hoppe– sol, *Festuca borissii* Reverd – sol, *Rhodiola rosea* L. – sp, *Ptarmica ledebourii* (Heimerl) Klok. – sp, *Lagotis globosa* (Kurz) Hook – sp, *Solidago virgaurea* L. – sp – sol, *Bistorta elliptica* (Willd. Ex Spreng.) Kom. – sol, *Festuka kryloviana* Reverd. – sol, *Taraxacum ceratophorum* (Ledeb.) DC. – sol.

The third layer is formed by *Oxytropis alpina* Bunge – sol, *Sibbaldia procumbens* L., *Cerastium pauciflorum* Stev. ex Ser. – sol, *Pachypleurum alpinum* Ledeb.– sol.

Hedysarum theinum Krasnob. plants are well-developed, constituting large monotypic groups. Abundance of the generative plants per 5 m^2 is 8.47±0.97 ind. (individuals)., V – 44%; the number of the vegetative plants per 5 m^2 – 4.01±0.62 ind., V – 60%; the number of the reproductive shoots per plant – 17.80±1.57, V – 34%; the height of the reproductive shoots – 75.73±1.52 cm, V – 8%.; the length of the inflorescences 28.73±1.39 cm, V – 18%; the length of the panicles 17.80±0.63 cm, V – 14%.

The coenopopulation of the sweetvetch – columbine (*Aquilegia glandulosa* Fisch. ex Link., *Hedysarum theinum* Krasnob.) phytocoenosis with the total area of 1.8 hectares is part of the alpine meadows on the left bank of the Bol'shaya Poperechka River, on the mild slope of an old moraine. It has the following coordinates: 50º 19' 05" N, 83º 52' 36" E, 1838 m a.s.l. The relief is smooth with occasional hummocky areas and vague ledges. The soil layer is well-developed, up to 40 cm thick. The soils are classified as mountain chernozems with insubstantial inclusions of fine pebbles. Ground cover is well-developed; it is formed by leaf fall and moss thicket. The leaf fall weight is 160 g/m^2. The total projective cover is 100%. Grass stand is well-developed, consists of three strata, and has poor diversity of species.

The first stratum, 80-100 cm high, is formed by *Hedysarum theinum* Krasnob. – cop_2, *Aquilegia glandulosa* Fisch. ex Link. – cop_1 with the share of phytocoenosis equal to 55%. The list of accessory species includes *Doronicum altaicum* Pall.– sol, *Phlomoides alpina* (Pall.) Adyl. – sol, *Rumex acetosella* L. – sol.

The second layer, 30-50 cm high, is represented by *Pedicularis proboscidea* Stev. – sp, *Geranium albiflorum* Ledeb. – sp, *Deschampsia cespitosa* (L.) P. Beauv. – sol, *Ptarmica ledebourii* (Heimerl) Klok. – sp, *Carex aterrima* Hoppe **–** sol, *Festuca kryloviana* Reverd. – sol, *Solidago virgaurea* L. – sp-sol, *Anthoxanthum alpinum* A. & D. Love – cop_2.

The third layer, 10-25 cm high, is formed by *Omalotheca sylvatica* (L.) Sch. Bip. & F. Schultz – sol, *Oxytropis alpina* Bunge – sp, *Swertia obtusa* Ledeb. – sol, *Sibbaldia procumbens* L. – sp, *Alchemilla acutiloba* Opiz – sol.

Hedysarum theinum Krasnob. is scattered over the area in small separate groups, consisting of 2-5 generative plants. The number of generative plants per 5 m^2 – 5.43±0.44 ind., V – 29%. The number of vegetative plants per 5 m^2 – 3.53±0.44 ind., V – 43%. The height of the generative shoots – 73.33±1.95 cm, V – 10%. The number of reproductive shoots per cluster – 16.73±0.42, V – 40%. The number of flowers per inflorescence 42.47±2.50, V – 10%. The length of the inflorescences – 27.00±1.35 cm, V – 20%. The length of the panicles – 13.40±0.55 cm, V – 40.

The coenopopulation of the blueberry – sweetvetch – vernal grass (*Anthoxanthum odoratum* L., *Hedysarum theinum* Krasnob., *Vaccinium myrtillus* L.) phytocoenosis with the total area of 5 hectares is part of the short-grass alpine meadows on the slope of a covered old moraine with the slope of 35-40°. It has the following coordinates – 50º 19' 13" N, 83º 52' 50" E, 1800 m a.s.l. The relief consists of fine hammocks with pronounced soil layer up to 30-40 cm thick. Ground cover is well-developed; it consists of leaf fall, mosses and lichens. The slope is well-illuminated, a considerable amount of snow can be observed during the winter period. The total projective cover is 100%.

The shrub stratum is not pronounced; young *Larix sibirica* Ledeb plants are occasionally observed.

Grass stand is polydominant, well-developed, has poor diversity of species, and consists of three distinct layers.

The first layer is formed by *Hedysarum theinum* Krasnob. – cop_2, its proportion of the projective cover is approximately 35%. The list of accessory species includes *Phlomoides alpina* (Pall.) Adyl. – sol, *Rumex acetosella* L. – sol, *Doronicum altaicum* Pall. – sol, *Phleum alpinum* L. – sp, *Hieracium virosum* Pall. – sol, *Aquilegia glandulosa* Fisch. ex Link. – sol.

The second layer is represented by the dominant *Anthoxanthum odoratum* L. species – cop_1, its share of the projective cover is 30%. The role of subdominant plants is played by *Solidago virgaurea* L. – sp – cop_1. The list of accessory species includes *Saussurea latifolia* Ledeb. – sp, *Rumex acetosella* L. – sol, *Aquilegia glandulosa* Fisch. ex Link. – sol, *Sanguisorba alpina* Bunge – sol, *Geranium albiflorum* Ledeb. – sp, *Phlomoides alpina* (Pall.) Adyl. – sol, *Poa pratensis* L. – sol, occasional clusters of *Doronicum altaicum* Pall. – sol.

The third layer is formed by *Vaccinium myrtillus* L. – cop_1, its proportion of the projective cover is 25%. The list of accessory species includes *Viola altaica* Ker. – Gawl. – sol, *Gentiana grandiflora* Laxm. – sol, *Llioydia serotina* (L.) Reichenb. – sol, *Bistorta elliptica* (Willd. ex Spreng.) Kom. – s, *Oxytropis alpina* Bunge – sol, *Gentiana uniflora* Georgi – s, *Pachypleurum alpinum* Ledeb. – sol, *Dracocephalum grandiflorum* L. – *sol, Sibbaldia procumbens* L. – sol, *Thalictrum alpinum* L.– sol.

The sweetvetch plants are scattered over the area as small clusters or large individual specimens. The number of generative plants per 5 m^2 – 4.67±0.36 ind., V – 29%; the number of vegetative shoots 8.07±1.05; V – 45%; the number of reproductive shoots per individual – 14.60±1.61, V – 42%; the height of the plants – 68.37±2.35 cm, V – 10%; the length of the inflorescences – 19.00±1.30 cm, V – 26%; the length of the panicles – 12.47±0.85 cm, V – 36%. We observed large numbers of vegetative plants of different age.

The coenopopulation of the sweetvetch – lousewort – columbine (*Pedicularis proboscidea* Stev., *Aquilegia glandulosa* Fisch. ex Link., *Hedysarum theinum* Krasnob.) phytocoenosis with the total area of 2.5 hectares is located at the alpine meadow in the upper reach of an old covered moraine, along the upper course of the Bol'shaya Poperechka River, at the slope of 45°. It has the following coordinates: 50º 19' 09" N, 83º 52' 51" E, 1862 m a.s.l. The relief is formed by fine hammocks, the soil layer is poorly developed, 15-20 cm thick, the underlying layer consists of the fragments of the moraine bedrock. The ground cover is poor, mostly represented by mosses. The total projective cover is 90%.

The vegetative cover has poor diversity of species, consists of three strata.

The first stratum, 50-70 cm high, is formed by *Hedysarum theinum* Krasnob. – cop_1 and *Aquilegia glandulosa* Fisch. ex Link – cop_1, with the proportion of the projective cover of 20-25%. The list of accessory species includes *Saussurea latifolia* Ledeb. – sol, *Rumex acetosella* L. – sol, *Aquilegia glandulosa* Fisch. ex Link. – cop_1, *Sanguisorba alpina* Bunge – sol, *Geranium albiflorum* Ledeb. – sp, *Phlomoides alpina* (Pall.) Adyl. – sol, *Poa pratensis* L. – sol, *Doronicum altaicum* Pall. – sol.

The second layer is dominated by *Pedicularis proboscidea* Stev. – cop_1; its share of the projective cover is 20%. The accessory species are *Ranunculus grandifolius* C.A. Mey. – cop_2, *Ptarmica ledebourii* (Heimerl) Klok.– sp, *Poa pratensis* L. – sol, *Tripleurospermum perforatum* (Merat) M. Lainz – s. *Deschampsia cespitosa* (L.) P. Beauv. – sol.

The third stratum is poorly developed. It includes *Swertia obtusa* Ledeb. – sol. *Sibbaldia procumbens* L. – sp., *Alchemilla acutiloba* Opiz – sol.

Hedysarum theinum Krasnob. plants are distributed over the area of the coenopopulation as narrow bands, perpendicular to the slope. The number of generative plants per 5 m^2 – 6.47±0.43 ind., V – 24%; the number of vegetative shoots per 1 m^2 – 5.2±0.42, V – 36%; the number of reproductive shoots per individual – 16.33±1.42, V – 33%; the height of the plants – 62.15±2.15 cm, V – 13%; the length of the inflorescences – 23.00±1.20 cm, V – 20%; the length of the panicles – 18.73±1.24 cm, V – 25%.

The coenopopulation of the *Doronicum* – sweetvetch (*Hedysarum theinum* Krasnob., *Doronicum altaicum* Pall.) phytocoenosis is located at a covered moraine in the subalpine belt, at the slope of 50°, occupying the area of 8.5 hectares. Its coordinates are 50º 19' 13" N, 83º 52' 53" E, 1812 m a.s.l. The relief is fine-stepped, the soil layer is well-developed, 30-35 cm thick, the underlying layer consists of the rock fragments. The ground cover is well-developed, formed by leaf fall and mosses.

Grass stand is well-developed, consists of three distinct layers. Total projective cover is 100%.

The first layer is formed by the dominant species: *Doronicum altaicum* Pall. – cop_3, its share of the projective cover is 45%, and *Hedysarum theinum* Krasnob. – cop_2, its proportion of the projective cover is 20%. The list of accessory species includes *Rumex acetosella* L. – sol, *Aquilegia glandulosa* Fisch. ex Link. – cop_1, *Sanguisorba alpina* Bunge – sol, *Geranium albiflorum* Ledeb. – sp, *Phlomoides alpina* (Pall.) Adyl. – sol, *Poa pratensis* L. – sol.

The second layer is formed by thick vegetative mass of *Doronicum altaicum* Pall. – soc, and vegetative mass of *Geranium albiflorum* Ledeb. – cop_1, *Anthoxanthum alpinum* A.&D.Love – sp, *Rhodiola rosea* L. – sp, *Ptarmica ledebourii* (Heimerl) Klok. – sp, *Lathyrus gmelini* Fritsch – sp, *Solidago virgaurea* L. – sp-sol, *Bistorta elliptica* (Willd. ex Spreng.) Kom. – sol, *Festuca kryloviana* Reverd. – sol, *Taraxacum ceratophorum* (Ledeb.) DC.– sol.

The third layer is well-pronounced, formed by *Viola biflora* L. – cop_1, *Vaccinium myrtillus* L.– sp, *Alchemilla acutiloba* Opiz – sol., *Gentiana grandiflora* Laxm. – sol, *Viola altaica* Ker.– Gawl. – sol.

The sweetvetch plants are scattered over the area as clusters or large individual specimens. The number of generative plants per 5 m^2 – 8.07±0.80 ind., V – 38%; the number of vegetative shoots per 1 m^2 – 7.4±0.32, V – 38%; the number of reproductive shoots per individual – 10.13±1.35, V – 47%; the height of the plants – 59.87±2.33 cm, V – 15%; the length of the inflorescences – 21.00±1.25 cm, V – 20%; the length of the panicles – 16.73±1.34 cm, V – 25%.

The coenopopulation of the sweetvetch (*Hedysarum theinum* Krasnob.) phytocoenosis is located along the upper course of the Bol'shaya Poperechka River, in a narrow ravine between two projections of an old moraine over the area of 1.8 hectares. The coordinates are 50º 19' 04" N, 83º 52' 51" E, 1878 m a.s.l. The complex relief is composed of small closed steps and various hollows. The soils are classified as mountain chernozems, formed by the products of plant decomposition, mixed with fine pebbles. Ground cover is poor.

The grass stand is poorly developed, includes a small variety of species. The total projective cover is 70%. The dominant species is *Hedysarum theinum* Krasnob – cop_2; its proportion of the projective cover is 35%. The grass stand consists of three strata.

The first layer is formed by *Hedysarum theinum* Krasnob – cop_2, the list of accessory species includes *Doronicum altaicum* Pall. – sol, *Phlomoides alpina* (Pall.) Adyl. – sol.

The second layer is sparse, formed by *Solidago virgaurea* L. – sp-sol, *Bistorta elliptica* (Willd. ex Spreng.) Kom. – sol, *Festuca kryloviana* Reverd. – sol, *Thalictrum alpinum* L. – *sol. Poa pratensis* L. – sol, *Tripleurospermum perforatum* (Merat) M. Lainz – s. *Deschampsia cespitosa* (L.) P. Beauv. – sol.

The third layer is formed by *Lathyrus gmelini* Fritsch – sol, *Oxytropis alpina* Bunge – sp, *Swertia obtusa* Ledeb. – sol, *Sibbaldia procumbens* L. – sp, *Alchemilla acutiloba* Opiz – sol.

Hedysarum theinum Krasnob. plants are scattered over the area as clusters or large individual specimens. The number of generative plants per 5 m^2 – 6.01±0.75 ind., V – 43%; the number of vegetative shoots per 1 m^2 – 11.07±1.30, V – 45%; the number of reproductive shoots per plant – 7.33±0.52, V – 27%; the height of the plants – 52.80±1.72 cm, V – 12%; the length of the inflorescences – 19.05±1.29 cm, V – 26%; the length of the panicles – 12.73±1.34 cm, V – 30%.

Table 1 shows the exploitable reserves of the sweetvetch air-dry raw materials within the coenopopulations and the volume of annual procurement.

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Table 1 – Reserves of the sweetvetch raw materials within the coenopopulations at the Ivanovsky Mountain Range

Procured parts	Name of the coenopopulation	Area, hectares	Yield of the air-dry raw materials, kg/hectare	Exploitable reserve of the air-dry raw materials, tons	Volume of possible annual procurement of the air-dry raw materials, tons
Whole plants	The coenopopulation of the sweetvetch – saw-wort phytocoenosis	1.3	3678	4.77	0.87
	The coenopopulation of the sweetvetch – columbine phytocoenosis	1.8	4930	8.85	0.93
	The coenopopulation of the blueberry – sweetvetch – vernal grass phytocoenosis	5	6728	33.6	3.32
	The coenopopulation of the sweetvetch – lousewort – columbine phytocoenosis	2.5	8186	20.46	1.9
	The coenopopulation of the *Doronicum* – sweetvetch phytocoenosis	8.5	6190	52.61	5.65
	The coenopopulation of the sweetvetch phytocoenosis	1.8	4211	7.47	1.29

The assessment of the ontogenetic structure of the studied sweetvetch coenopopulations has revealed 4 periods and 7 age stages.

The period of primary dormancy of the seed. It can last for 4-5 years. The seeds require natural stratification for 9-10 months. In autumn, the seeds shed, considerably swell and remain under the snow cover in this state. According to the experimental results, germinating capacity of the seeds increases by 10-15% after scarification (mild disruption of seed coat).

Pregenerative (virginile) period. It consists of the following age stages: seedlings, juvenile plants, premature plants, and virginile plants.

Seed germination is hypogeal. Massive germination of seeds is observed in spring, in May and the beginning of June, straight after the snow cover melting. The seedlings coexist for a single period of vegetation. They have two elliptical succulent cotyledons, slightly sinuate on the one side, 5 mm long and 3 mm wide, positioned on 5-7-mm long stalks, whose basal parts grow together and surround the primary bud. The bud is naked, the hypocotyl is 31 mm long, and the primary root is 41-52 mm long. The primary leaf is ternate; the second leaf of the same type develops in 12-20 days. The stem of a one-year seedling is 2-2.5 cm long. The stem ends in a covered bud. The hypocotyl is 0.5-0.7 cm long, incrassate; it further develops into a rootstalk. By the end of vegetation, the seedling has a root up to 7 cm long, developing up to 10 first-order lateral roots. By the end of vegetation, the primary root has 1-3 nitrogen nodules up to 1.5 mm long. The cotyledons wither away in August. By this time, well-developed buds are located at the bottom of the stem: one reserve bud and one dormant bud. By the end of the first vegetative period, the seedlings progress to the juvenile state (Figure 1, ***a; b; c; d***).

They usually stay in the juvenile state for 3-4 periods of vegetation. Juvenile plants are up to 12 cm high, having 3-4 ternate leaves. The rootstalk bulb is well-developed, has the diameter of up to 0.5 cm, 6-8

buds, it is covered in remnants of scales and stems of the previous years. The rootstalk has annual rings in the form of curly scars, where the dormant buds (6-8) are located. The incrassate part of the primary root is brownish, wrinkled, up to 4 mm in diameter. The major part of first-order and second-order roots develops at the lower part of the main root. The primary root grows down to 15 cm; the number of nodules is 3-4 (Figure 1, ***e; f; g***).

We observed the plants from 5-years to 7-8-years old among the individuals in the premature state. The most common age is 6-7 years. These plants usually have a single stem, 15-17 cm high, with 4-5 odd-pinnate leaves with two pairs of pinnae each; the blade of the bottom leaf is ternate. Rootstalk is well-developed and distinct from the incrassate part of the main root. There are 8-10 buds on the rootstalk. The main root grows down to 25 cm; its incrassate part is up to 4 cm long and 0.5 cm thick, fusiform, wrinkled at the upper part (Figure 1, ***h***).

The plants of the virginile state are 9-19 years old; this stage lasts for 10-11 years. The plants have 1-6 vegetative shoots, varying in height and developmental stage. The leaves are odd-pinnate, with 4-8 pairs of pinnae. Rootstalk is well-developed, up to 5 cm long and 2-2.5 cm wide: it is tightly covered by a muff of brown exfoliating crust. There 37-53 dormant buds, 2-7 vegetative buds, caudex is well-developed, up to 5 cm in diameter, certain branches of the caudex grow to 2 cm long. The main root grows down to 1 m, the incrassate part is up to 30 cm long, fusiform, covered by dark-brownish exfoliating and smooth glossy crust. The lower part of the main root extensively ramifies (Figure 1, ***i***).

There are three age stages within the generative period: young generative, mature generative, and old generative plants.

Young generative plants start blossoming at the age of 18-20 years, they have 1-2 reproductive shoots, less often 3-4, and 1-2 shortened vegetative shoots; the leaves are odd-pinnate, all of them have 2-7 pairs of pinnae; well-developed caudex is 8-10 cm in diameter, has many heads and branches that are up to 9 cm long. There are three types of buds: large ones, producing reproductive shoots; smaller ones, developing into vegetative shoots, and very small buds, which are dormant. The main root is very strong, the incrassate part is 28-32 cm long, fusiform, 3-5 cm in diameter, covered by dark-brownish exfoliating crust, the incrassate part gives off 25 first-order roots, which develop into thick roots, extensively branching in their lower parts. The root system goes down to 90-110 cm, with lateral extension up to 40-50 cm (Figure 1, ***j***).

Mature generative plants. This stage is typical for 55-80-years old plants. These specimens are very strong and have multiple stems, usually 8-37, 45-140 cm high, all leaves are odd-pinnated, with 3-7 pairs of pinnae. Rootstalk and root are very well developed, occasionally reaching the weight of 7 kg. Caudex is 23-40 cm wide, has multiple heads and 5-17 branches. The space between the branches is tightly packed with organic materials and mosses. The incrassate part of the root is up to 70 cm long, 8-12 cm in diameter in the upper part, covered by heavily exfoliating crust. In some individuals, the tissues of the central part of the main root start dying. The main root grows down to 150 cm. The major proportion of the first-order roots is directed upslope. The diameter of the root system in the lateral projection is 2.5 m (Figure 1, ***k***).

Old generative plants. The plants progress through this stage at the age of 80-95 years. They are marked by a small number of reproductive shoots (1-3) and large amounts of shortened vegetative shoots, as well as extensive destruction of the incrassate part of the main root. The root system easily breaks down into 2-5 parts. Caudex is tightly packed with organic matter and mosses. Fruit bearing capacity is small (Figure 1, ***l***).
Postgenerative (senile) period. The observed senile plants are older than 95-100 years. They do not have reproductive shoots and bear a large number of further shortened vegetative shoots. The hypogeal part is severely disrupted, particularly the main root and thick first-order roots, the number of latent buds is considerably smaller (Figure 1, ***m***).

It can be generally noted that the life cycle of the plants takes 95-120 years and, in some cases, longer.

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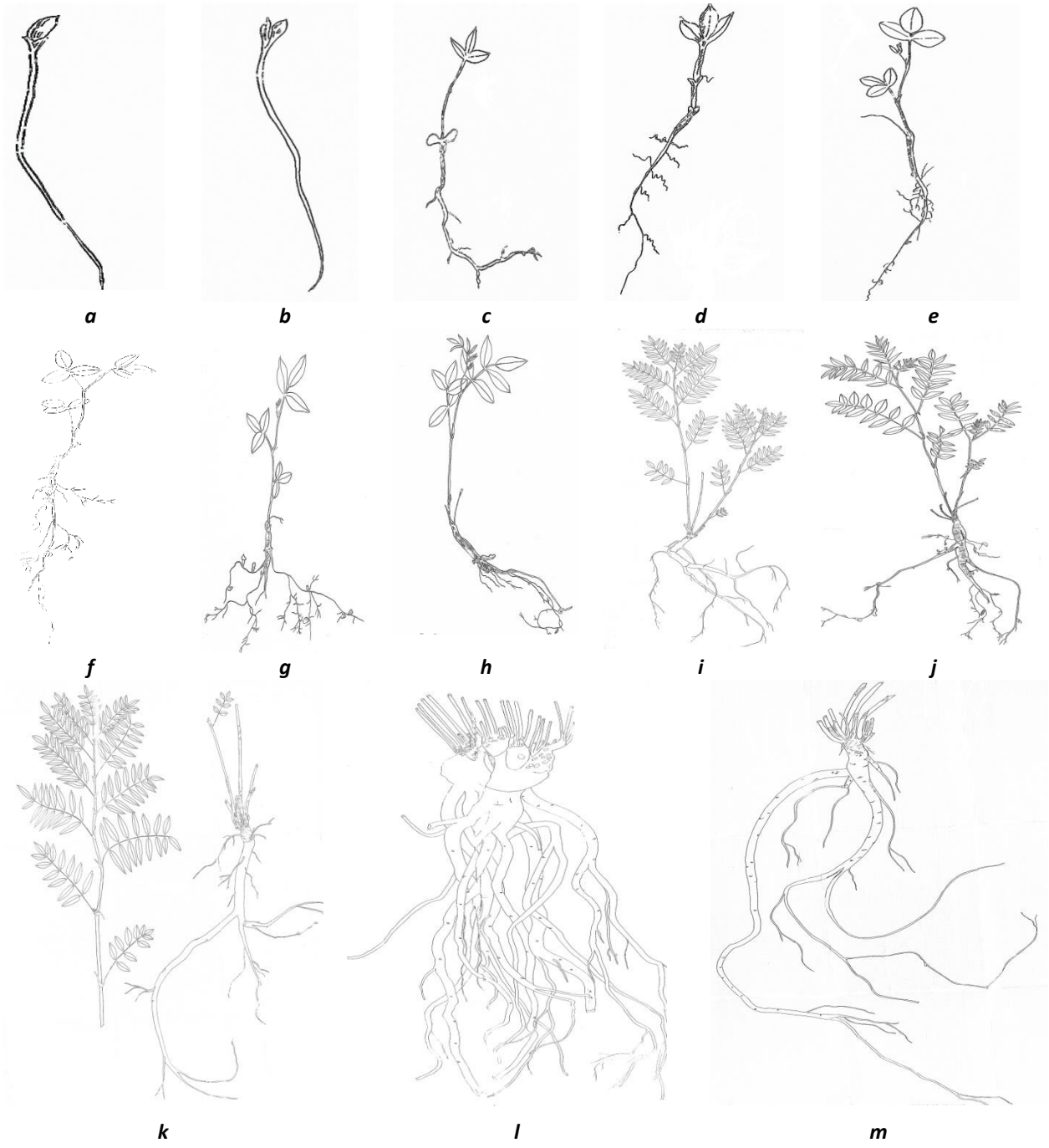

Figure 1 – Ontogenesis of the sweetvetch plants at the Ivanovsky Mountain Range (*a; b; c*; *d* – seedlings; *e; f; g* – juvenile plants; *h* – premature plants; *i* – virginile plants; *j* – young generative plants; *k* – mature generative plants; *l* – old generative plants; *m* – postgenerative plants (senile))

Sweetvetch is a long-vegetating plant. In spring, it begins to grow rather early, when the mean daily temperature is very low, 0+4 °C, immediately after the snow melts; it often starts vegetating under the snow cover. The period of vegetation lasts up to 130 days. The aerial parts of the plants are not damaged by spring frosts. Seasonal development of sweetvetch starts in May and ends in the middle of September. It is a summer-blooming plant, which starts to flower in the middle of June near the lower border of its geographical range (1700 m a.s.l.) and 20-30 days later at the upper border (2100 m a.s.l.). The fruits ripen from the end of July till the end of August, depending on the habitation altitude and weather conditions, which influence the duration of the phenological phases. Ripe fruits remain on the plants almost till the end of September, then fall to the ground. The leaves completely shed in the end of September, dry stems lodge under the weight of snow

and rot in 2-3 years. By the time the plants become covered by snow, they have well-developed buds, embedded into the ground to a depth of 1.5-2 cm.

The highest annual increase in the weight of the aerial parts – approximately 86.0-273.0 kg/hectare – was observed at the short-grass alpine meadows, where this species is often subdominant. At the alpine forb meadows with the grass stand height up to 110 cm and lower abundance of sweetvetch, the annual increase in the weight of the aerial parts is 96.0-145.6 kg/hectare on average. In the thinned cedar forests at the upper border of the species' range, the weight of the aerial parts is 35.4-98.0 kg/hectare. In the thinned cedar and fir forests at the lower border of the sweetvetch geographical range, the weight of the aerial parts is usually less than 16.0-78.0 kg/hectare. The proportion of foliage of the plants increases at higher habitation altitudes a.s.l. Near the lower border of the range, at the altitude of 1700 m a.s.l. it is 30% (per 1 kg of green mass), at the medium part of the range, in the cedar forests at the altitude of 1900 m a.s.l. – approximately 40%, at the upper territories, in the cedar and fir forests it is equal to 50%, whereas outside the forest belt it is approximately 55%. In the thinned cedar and fir forests with well-developed tall herbage (1700 m a.s.l.), the mean yield of the hypogeal mass is 87-517 kg/hectare; in the thinned cedar forests at 1900 m a.s.l. – 120-240 kg/hectare; at the alpine meadows – 230-570 kg/hectare.

Seed productivity considerably varies over the years, it also heavily depends on the habitation altitude and weather conditions during the period of vegetation; it is relatively high in almost every altitudinal belt (seed production coefficient is 37-51%). On average, each plant has 9 reproductive shoots, forming 1315-1560 seed buds, 17-35% of which develop into seeds. At the lower border of the species' range the seed stock is 1.2-2.3 kg/hectare; in the medium part, in the thinned cedar forests – 1.3-3.8 kg/hectare; at the upper border – 1.1-3.7 kg/hectare. We observed a relatively strong trend of seed production even under poor climate conditions, indicating substantial fitness of the species to the conditions of high-mountain regions.

The assessment of the natural sweetvetch populations at the Ivanovsky Mountain Range has revealed a range of pests and pathogenic organisms.

Among the diseases observed in the natural populations, one should note rust, manifesting in the second half of the vegetative period in the form of rusty or brownish spots on the leaves and stems. There are two pathogenic species causing rust in sweetvetch under the natural conditions: *Uromyces hydisaris* Lev., *Puccinia coronifera* Kleb. Crown rust (*Pucccinia coronifera*) progresses through the whole life cycle on the sweetvetch plants, including spring, summer and autumn spore formation.

Rust, caused by *Uromyces hydisarus*, produces spores on the sweetvetch plants only in summer and autumn. The intermediate host for the spring spore formation has yet to be discovered. Besides rust, the development of the pathogenic organisms, causing leaf spot diseases, – *Phyllostica sp*., *Ramularia sp*. infections – can be, to a small degree, observed in all studied coenopopulations.

Among the insects collected from the vegetative parts of sweetvetch in natural habitats, the following can be classified as pests, if more than 5-7 individuals are observed on the same mature plant: the larvae of *Ortholitha chenopodiata* L., *Eupithecia succenturiata* L., *Hypoxystis pluviaria* F., *Ortholitha moeniata* Scop., *Chrysomela graminis* L.

The sweetvetch seeds are damaged by the larvae of *Oxystoma* F genus. Its harmfulness correlates with the altitude of the generative sweetvetch plants' habitation a.s.l. At the upper border of the geographical range, at the altitude of 2100 m a.s.l., 1-3% of the seed yield are corrupted; at the altitude of 2000 m a.s.l., in the medium belt of the thinned cedar forests, – 19-25%, in the lower belt of the cedar forests, at the altitude of 1900 m a.s.l. 21-30%, whereas in the cedar and fir forests at the altitude of 1800 m a.s.l. the affected seeds comprise 37-40% of the samples.

The non-uniform nature of the *Oxystoma* F. reproduction can be explained by the special features of the sweetvetch seasonal development, leading to the later periods of blooming and fruiting of the generative plants in the high-mountain populations, which is apparently a limiting factor for massive reproduction of the pest.

Two bumblebee species (shrill carder bee and red-tailed bumblebee) are the sweetvetch pollinators in all natural populations.

The preservation of the species requires to include the part of the Ivanovskaya population fron the Razlivanka River to the Bol'shaya Poperechka River in the conservation zone of the West-Altai State Natural Reserve. It is desirable to establish control over the condition of the populations within all the habitats of the species, particularly along the upper course of the Belaya Uba River and the Bol'shoi Turgusun River. Furthermore, harvesting of the roots by the local population at the territories beyond the scope of the protective operations should be regulated.

CONCLUSION

Hedysarum theinum Krasnob. at the Ivanovsky Mountain Range is a long-vegetating plant with annual stages of blossoming and fruiting, the onset and duration of which depend on the habitation altitude and the weather conditions. The annual increase in the weight of the aerial parts and the proportion of the foliage of the plants rise at higher altitudes of the species' habitation above sea level. The ontogenetic spectrum of the studied sweetvetch coenopopulations, consisting of 4 periods and 7 age stages, can be considered a standard pattern for undisturbed coenoses, where the life cycle of the plants lasts for 95-120 years. One of the adverse factors for the sweetvetch growth and development in the Ivanovskaya population is the activity of pests and pathogenic organisms. In respect of phytocoenotic composition, the sweetvetch population at the Ivanovsky Mountain Range is polydominant, occupies a large territory, but the naturally growing plants of this species do not form commercially exploitable reserves; however, they can be used for procurement of raw materials for the local pharmacy chain.

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