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The study was conducted on the amplitude of inter- and intrapopulation variability of the main features of the vegetative and generative organs of the four endemic Ural species of the *Astragalus* in dependence on environmental conditions.

The flora of the mountain steppes and rocky outcroppings of the Urals comprises a number of endemic species (Gorchakovskii, 1969), including among them several representatives of the family *Astragalus* L. The Ural endemic astragaluses are insufficiently studied, and their previously published diagnoses (Goncharov, 1946; Borisova, 1950; Belkovskaya, 1978) are very short and do not reflect the amplitude of variations of individual features. These species are encountered infrequently in the form of small isolated populations; therefore, they can serve as convenient objects for the study of inter- and intrapopulation variability.

The aim of the present investigations is to clarify the morphological characteristics of endemic Ural astragaluses, tracing the variability of principal features of vegetative and generative organs and taking account of their geographical diversity, and to show the taxonomic significance of individual morphological features.

Four species were selected as the object of the study: *Astragalus karelinianus* M. Pop., *A. helmi* Fisch s.l., *A. clerceanus* Iljin et Krasch, and *A. kungurensis* Boriss. Data concerning their ecological characteristic features and distribution are presented in the paper by Gorchakovskii (1969). All the studied species are dwarf semishrubs growing on a rocky and stony substrate. *Astragalus karelinianus* and *A. helmi* are associated principally with the stony steppes, but in the northern part of their range they are found on limestone outcrops. *Astragalus clerceanus* is connected preferentially with granite outcrops, and *A. kungurensis*, which is a narrowly local endemic form, is known from only a single location on the gypsum outcrops by the river Sylva.

The basic material was gathered in natural habitats within the Ural mountainous country in three botanical-geographical zones: boreal-forest (taiga), forest-steppe, and steppe. To study the variability of astragaluses at their endemic locations, 11 experimental plots; were set up, each 100 m² in dimension. From each experimental plot, annual shoots were selected from individual plants of the studied species of average age; on these, measurements of 12 features of the leaf, 14 of the flower, and 11 of the fruits and seeds were conducted. The specimens of annual shoots for the studies were taken during the flowering and fruit-bearing period. The results of measurements were processed by applying the method of statistical variance analysis.

To reveal and display the differences between populations, the graphical method was used (Jentys-Szaferowa, 1959; Mizianthy, 1978). On the graphs, the straight vertical line, designated by the numeral 1, served as the comparative unit of measurement. This is the arithmetical mean magnitude of the feature obtained as a result of measurements on the entire set of samples. The numerals on the horizontal line denote tenth parts of that unit of measurements: on the left, 0.7, 0.8, 0.9, on the right, 1.1, 1.2, 1.3, etc. The points which characterize the meaning of the features of the given population are connected by straight lines. The relation of the obtained curves indicates the relation of the characteristics of the given population to the average values of the corresponding features calculated for the entire set of populations. On the cyclograms are shown the differences of populations with regard to the eight most important and variable features. For construction of the cyclogram, the values of individual features were plotted on the radial lines divided

Institute of Plant and Animal Ecology, Ural Scientific Center, Academy of Sciences of the USSR. Translated from *Ékologiya*, No. 4, pp. 20-27, July-August, 1982. Original article submitted April 21, 1982.

TABLE 1. Intrapopulation Variability of Morphological Features* of the Leaf of Astragaluses (ranges of variance coefficients C_v in various populations), Percent

Feature	A. karelinianus	A. helmii	A. clerceanus	A. kungurensis
l of leaf	12—29	16—21	11—28	16
l of blade	14—26	22—26	14—28	22
l of petiole	26—33	13—23	8—50	18
l of blade	29—35	20—32	47—66	30
l of petiole	10—30	14—28	6—36	15
b of petiole	13—18	17—24	11—19	16
n of pairs of leaflets	14—27	23—34	14—21	12
l of leaflets	8—32	19—26	11—28	10
b of leaflets	12—34	17—30	16—54	10
l of leaflets	7—30	22—35	12—43	—
b of leaflets	—	11—37	—	—
l of stipule	—	15—41	—	—
l of hair	—	—	—	—
n of hairs	—	—	—	—

*In Tables 1-3, l is length, b is width, c is thickness, and n is number.

TABLE 2. Intrapopulation Variability of Morphological Features of the Flower of Astragaluses (ranges of C_v in various populations), Percent

Feature	A. karelinianus	A. helmii	A. clerceanus	A. kungurensis
Standard				
l of blade	11—12	5—16	9—13	5
l of claw	11—15	11—23	10—17	17
l total	7—9	3—9	8—10	5
l of blade	13—42	16—38	15—24	53
l of claw				
Wing				
l of blade	5—11	7—23	5—11	8
l of claw	4—10	5—16	15—35	7
l total	4—9	4—13	5—17	4
l of blade	7—14	11—30	8—15	11
l of claw				
Carina				
l of blade	3—9	5—13	9—12	8
l of claw	7—14	5—11	5—17	11
l total	5—7	2—6	2—7	8
l of blade	7—16	5—28	13—20	11
l of claw				
Calyx				
l total	6—12	5—13	7—11	6
l of tubule	2—12	5—12	8—10	8

into sections corresponding to the values of the feature in increasing order from the center to the periphery. Real values of the features are plotted as points which are connected by straight lines.

The levels of variability are estimated from the magnitude of the variance coefficient in accordance with the following scale: < 7%, very low; 8-15%, low; 16-25%, average; 26-35%, increased; 36-50%, high; > 50%, very high (Mamaev, 1978).

Samples for biometric studies were collected at the following points: *A. karelinianus* sample on the Vishnevy mountains (Eremikha hill, Karavai mountain) and on the Egoze mountain on the Chelyabinsk district near the village Verkhnee Bikkuzino in the Bashkir ASSR; *A. helmii*, at the Govorlivyi Kemen' on the river Vishera, at Dyrovatyi Kamen' on the river Chusovaya in the Perm district, on the Kush-Tau hill near the town Sterlitamak in the Bashkir ASSR, and on the Poperechnaya hill in Guberlinski mountains in the Orenburg district; *A. clerceanus*, in the vicinity of the town Sverdlovsk near the station Severka on the Medvezhka hill, on the rocks Chertovo Gorodishche, and on the Palkinsk stony stands; *A. kungurensis* in the only one known location of that species, on the Podkamennaya hill on the river Sylva in the vicinity of the town Kungur in the Perm district. In addition, for some of the species, for

TABLE 3. Intrapopulation Variability of Morphological Features of the Fruit of Astragaluses (range of C_v in various populations), Percent

Feature	<i>A. karelinianus</i>	<i>A. helmii</i>	<i>A. clerceanus</i>	<i>A. kungurensis</i>
l of fruit	9—16	10—17	13—16	12
b of fruit	8—14	14—22	5—12	17
l of rostellum	22—27	15—28	16—32	17
n of seed	13—49	43—56	29—44	32
n of ovules	12—31	13—38	11—20	20
c of fruit	10—15	14—19	3—17	11
l of hair	—	13—25	—	—
n of hairs	—	18—40	—	—
l of seed	7—12	8—15	5—42	6
b of seed	5—9	2—12	2—9	2
c of seed	13—15	15—22	2—30	12

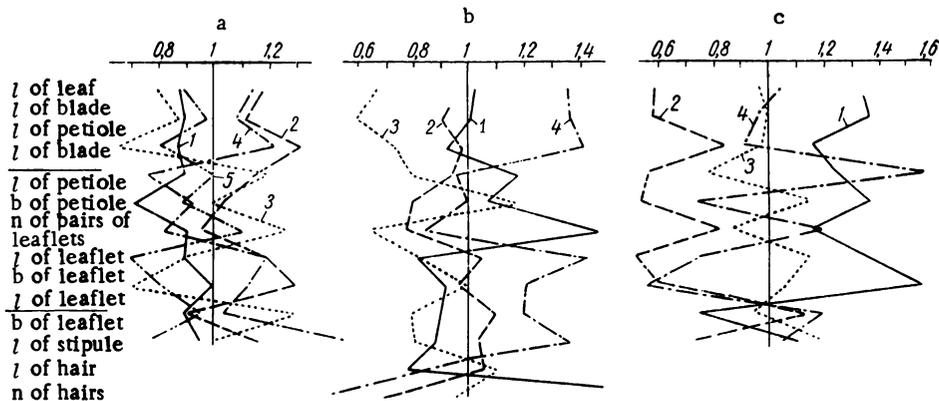


Fig. 1. Interpopulation variability of the features of the leaf in endemic astragaluses: l), length; b) width; n) number. Species and cenopopulations: a) *A. karelinianus* (1, Karavai; 2, Eremikha; 3, Bikkuzino; 4, Egoza; 5, Botanical Garden); b) *A. helmii* (1, Sterlitamak; 2, Govorlivyi Kamen'; 3, Guberlya; 4, Dyrovatyi Kamen'); c) *A. clerceanus* (1, Chertovo Gorodishche; 2, Palkino; 3, Severka; 4, Botanical Garden).

comparison, plants grown in the Botanical Garden of the Ural Scientific Center of the Academy of Sciences of the USSR in Sverdlovsk were studied.

Intrapopulation variability of the four studied species (Tables 1, 2, and 3) in the features of the leaf is characterized principally by their average and increased level; in the features of the flower, by low, less often average level; in the features of the fruit, by low, average, increased, and less often high level. Variability of the flower is lower than the variability of the leaf and fruit, which is explained, apparently, by the connection between the basic parameters of the flower and the dimensions of the body of insect pollinators. The range of variability of relative features is in the majority of cases larger than the range of absolute features. The most stable are the following morphological features: in the leaf — overall length of the leaf, length of the blade, number of pairs of leaflets, length and width of the blade; in the flower — overall length of the standard, wing, and carina; in the fruit — length and width of the fruit, width of the seed.

Interpopulation variability of morphological features of the studied species is characterized by Fig. 1-6. As can be seen, interpopulation differences in all the species are greater with respect to the features of the leaf and fruit than to the features of the flower. Comparison of the data obtained in individual species of the astragaluses indicates that the interpopulation differences in the features of the leaf are smaller in *A. karelinianus*, but greater in *A. helmii* and *A. clerceanus*.

Relative features have in some cases a smaller range of variability than the absolute features, and in other cases, they have a larger range. Quantitative indexes (number of seeds, number of ovules, number of hairs per 1 mm²) are subject to larger variations than the linear features (length, width of fruit, etc.).

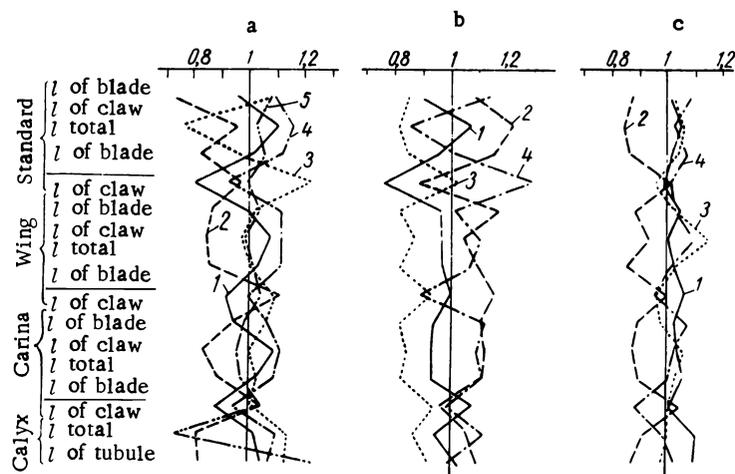


Fig. 2. Interpopulation variability of the features of the flower of endemic astragaluses. Designations the same as in Fig. 1.

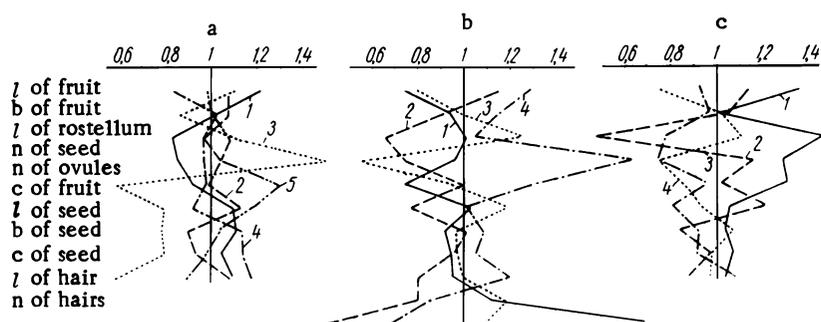


Fig. 3. Interpopulation variability of the features of the fruit of endemic astragaluses (c, thickness; remaining designations as in Fig. 1).

In all *Astragalus* species the following features are most stable: ratio of the length of the leaflet to its width, total length of the standard, total length of the wing, ratio of the length of the wing's blade to the length of its claw, total length of the carina, and ratio of the length of the carina's blade to the length of its claw.

In *A. karelinianus* the populations from "Eremukha" and "Egoza," which are at a distance of 30 km from each other, are fairly similar and are distinguished by greater length of leaves and leaflets and by larger width of leaflets. The same features show considerable similarity between the populations "Karavai" and "Bikkuzino" separated by a distance of the order of 420 km. The given features constitute substantial differences between the territorially very close populations "Karavai" and "Eremikha" (distance between them 8 km). These differences are explained by the fact that the "Karavai" population is submitted to quite considerable anthropogenic stresses, while the "Eremikha" population has lately experienced almost no anthropogenic stresses. The smaller sizes of leaves, flowers, and fruits of cultivated *A. karelinianus* is apparently explained by the fact that local soil conditions of its growing site in the Botanical Garden were unfavorable.

Differences between individual populations of *A. helmi* with respect to basic morphological features of vegetative and generative organs appear particularly clearly on the cyclogram (Fig. 5). Two groups of population are distinguished: on the one hand, south Ural ("Guberlya", and "Kush-Tau"), on the other, the populations from Mid and North Ural ("Dyrovatyi Kamen'" and "Govorlivyi Kamen'"). The northern populations clearly differ from the south Ural by the entire complex of features: by larger length of leaflets, smaller pubescence of leaves and fruits, larger length of the standard, wing, carina, and calyx, and by larger fruits.

In the middle of the last century, K. Meyer described a separate species of the permian astragalus (*Astragalus permianensis* C. A. Mey ex Rupr.) from the collections made by the ex-

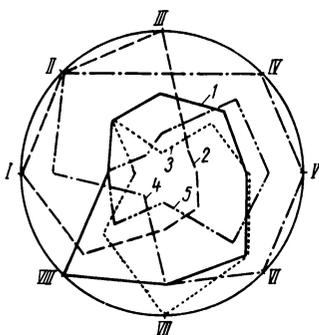


Fig. 4

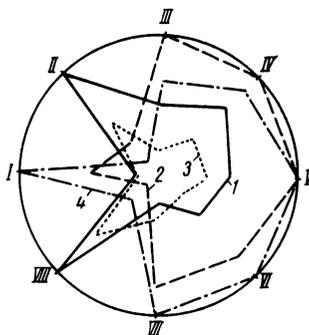


Fig. 5

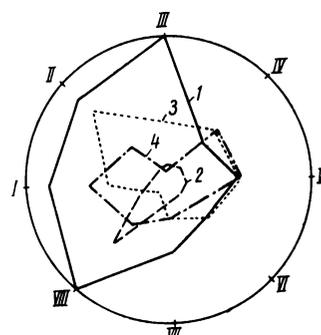


Fig. 6

Fig. 4. Main morphological differences in the cenopopulation of *A. karelinianus*. I) \bar{l} of leaf; II) \bar{l} of leaflet; III) b of leaflet; IV) \bar{l} of standard; V) \bar{l} of wing; VI) \bar{l} of carina; VII) \bar{l} of calyx; VIII) \bar{l} of fruit. 1-5) Cenopopulations: 1) Karavai; 2) Eremikha; 3) Bikkuzino; 4) Egoza; 5) Botanical Garden.

Fig. 5. Main morphological differences in cenopopulations of *A. helmi*. I) \bar{l} of leaflet; II) \bar{l} of leaf; III) \bar{l} of standard; IV) \bar{l} of wing; V) \bar{l} of carina; VI) \bar{l} of calyx; VII) \bar{l} of fruit; VIII) pubescence of fruit (number of hairs). 1-4) Cenopopulations: 1) Kush-Tau; 2) Govorlivyi Kamen'; 3) Guberlya; 4) Dyrovaty Kamen'.

Fig. 6. Main morphological differences in the cenopopulation of *A. clerceanus*. I) \bar{l} of leaf; II) \bar{l} of leaflet; III) b of leaflet; IV) \bar{l} of standard; V) \bar{l} of wing; VI) \bar{l} of carina; VII) \bar{l} of calyx; VIII) \bar{l} of fruit. 1-4) Cenopopulations: 1) Chertovo Gorodishche; 2) Severka; 3) Palkino; 4) Botanical Garden.

pedition of E. K. Hofmann on the river Vishera. The diagnosis of that species was published in the work of Ruprecht (1856). Korshinsky (1898) ascribed the plants from the river Vishera to the variety of *A. helmi* [var. *permiensis* (C. A. Mey) Korsh.]. In analyzing the genus *permiensis* for "Flora of the USSR," N. F. Goncharov did not admit the existence either of an independent species of *A. permiensis*, nor a var. *permiensis* of *A. helmi*. Our studies, however, have revealed clear differences between the populations from the river Vishera and Chusovaya on the one hand, and the populations from the Southern Ural, on the other.

Karyological studies carried out by N. B. Vernigor indicated that individuals of *Astragalus helmi* s.l. from Southern Ural are characterized by the chromosome number $2n = 16$, while individuals from the river Vishera and Chusovaya are represented by tetraploid plants ($2n = 64$). All this, concurrently with morphological differences, indicate that populations from the rivers Vishera and Chusovaya have been properly ascribed to the separate species *A. permiensis* C. A. Mey.

In *A. clerceanus* substantial differences are observed between the populations "Severka" and "Chertovo Gorodishche." The plants of the former populations have shorter leaves, smaller leaflets, and thinner petiole, while in the latter population the length and width of the leaves and of leaflets are larger, the petiole is thicker, and the calyx and fruit longer. The Palkino population occupies an intermediate position between these two, on account of the complex of leaf features. With regard to some of the features, the individuals from the Botanical Garden are close to individuals from the population "Chertovo Gorodishche," and in some other features they resemble individuals from the population "Severka," but still other features place them in an intermediate position.

The study conducted made it possible to obtain for the Ural endemic astragaluses a considerably more comprehensive idea about the real parameters and the variability of their morphological features than previously quoted in the literature sources.

CONCLUSIONS

1. In all studies astragaluses the level of variability of the leaf features considerably exceeds the variabilities of linear parameters of the fruits. Quantitative indexes are characterized by larger variability than linear indexes.

2. The range of variability in leaf features is considerably larger in species which occupy heterogeneous habitats with diverse conditions of illumination and humidity (for instance larger in *Astragalus clerceanus* than in species associated with comparatively homogeneous habitats (for instance *A. karelinianus*). The populations occupying drier habitats with stronger illumination and more warmth are characterized by smaller leaves and leaflets, while the cenopopulations associated with shady, cooler, and more moist habitats are distinguished by large size of leaves and leaflets.

3. The following more stable morphological features have greater taxonomic importance: in *A. karelinianus* the length of leaf blade, total length of the standard, ratio of the length of wing's blade to the length of its claw, length of carina's blade; in *A. Helmi*, the width of the leaflet, ratio of the length of leaflet's blade to the length of petiole, total length of standard and wing, ratio of the length of carina's blade to the length of its claw; in *A. clerceanus*, the number of leaflets pairs, total length of standard, ratio of the length of wing to the length of its claw, ratio of the length of the carina's blade to the length of its claw; in *A. kungurensis*, the width of the leaflet, total length of standard and wing, and the length of the carina's blade.

4. Anthropogenic influences exert a substantial effect on the morphological features of endemic astragaluses. In the case where the populations are to a varying degree submitted to anthropogenic influences, the differences between them caused by the factor can exceed the differences stipulated by the geographic position of the populations and resulting from heterogeneity of ecological factors.

5. Northern and southern populations of *Astragalus helmi* s.l. differ considerably from one another. For the northern populations (from the rivers Vishera and Chusovaya in the Perm district) the characteristic are: smaller pubescence of fruits and leaves, larger width of leaflets, larger length of standard, wing, and carina, and greater length of fruit than found in the southern populations (from the Bashkir ASSR and from Orneburg district). All this together with karyological data gives grounds for ascribing the northern populations to the independent taxon in the rank of a species (*A. permiensis* C. A. Mey).

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