

Floral variety of *Fabaceae* Lindl. family in gully ecosystems in the south-west of the Central Russian Upland

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ABSTRACT

The multi-year geobotanical studies have shown that in the south-west of the Central Russian Upland the floristic composition of gully ecosystems includes 274 genera, which are combined into 65 families. The species from 3 families: *Asteraceae* Dumort., *Fabaceae* Lindl. and *Poaceae* Barnh. take the lead in the taxon hierarchy. The value of the generic coefficient, which is calculated by the number of species per genus, is quite significant and is equal to 1.81. It has been established that *Fabaceae* Lindl. species have extensive presentation (it comes second place in the first triad of families). Among *Fabaceae* species, a particular importance is given to wild related cultural species, which have high biological, and resource value by a mix of morphological and qualitative characteristics and which are potential selection sources for improvement of various economically useful features. The most striking example include species of the *Medicago*: *Medicago sativa* L. genus and the *Medicago* var Mart. hybrid genus. The *M. sativa* L. and *M. varia* Mart. coenopopulations in gully mouths are the most complete and they often have continuity of species distribution by age groups. It has been found that any forms, which act as carriers of multidimensionality recessive mutation, i.e. mf-mutation, have a

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high degree of occurrence in local populations. With seed renewal, the proportion of species with mf-mutation is from 5 to 55% in families (the offspring of the first plant). The *M. sativa* L. and *M. varia* Mart. forms, which have been identified by us in the natural habitats of gully geocomplexes, have a number of valuable selection crop-related characteristics: high seed production, good leaf coverage and high protein content.

KEY WORDS: FLORISTIC COMPOSITION OF PHYTOCENOSES, MEDICAGO SATIVA L., MEDICAGO VARIA MART., MF-MUTATION, MULTIPLICITY

INTRODUCTION

Due to some, ecological and climatic changes which have been observed in the last decades we have to make a new assessment of flora changes in the regions with ecotones, for example, a forest-steppe zone. Some plant species can actively adapt to any environmental changes thanks to the fact that they are ready to be divided into separate populations, which are tolerant to the conditions of new ecological niches. Even small changes in natural heterogeneous populations cause new systematic taxon's and ecotypes. Their use is of great importance for the creation of a new source material for breeding and the formation of new biological resources (Givnish, 2002).

The form-building process is most active on the territories with complex geological history and a variety of ecological-climatic and soil conditions, in mountainous or foothill areas and in ancient agricultural centres (Takhtajan, 1986, Vavilov, 1992, Goncharov, 2007). The south-west part of the Central Russian Upland largely corresponds to the above-mentioned historical, geographical, ecological and anthropogenic conditions. It is important that the Dneprovskoe and Valdaiskoe glaciation did not affect a significant part of the south-west of the Central Russian Upland. The unique features of the Central Russian Upland landscapes are based on a wide spread of typical karst and cretaceous landscape complexes with involvement of exposed and shallow chalk rocks, which make the region similar to foothills. Therefore, the study region has all the conditions, which accompany primary microevolution processes at the level of microgeocenter (Zhukovsky, 1971, Diamond, 2002, Dumacheva *et al.*, 2015). The recent decline in the share of arable land due to more stringent environmental requirements has created space for the formation of autogenous successions (Lisetskii *et al.*, 2016a) which include both new relationships among plants in communities (Degtyar' and Chernyavskikh, 2006, Gusev, 2016 a, b) and spontaneous changes in plant habitats, including soil reproduction (Lisetskii, 2012, Prikhodko and Manakhov, 2014, Lisetskii *et al.*, 2016b and Terekhin and Chendev, 2018).

The ecological and biological characteristics of the species growing in difficult conditions of gully complexes may be of particular interest as a potential biore-source used to select plants, to obtain starting materials

of herbal origin and to improve ecosystems stability. The present paper was aimed to study the floristic composition of natural communities of gully complexes with carbonate outcrops towards the south-west of the Central Russian Upland (on the example of the east of the Belgorod region). We estimated the species composition of the *Fabaceae* Lindl. family as a possible starting material for selection.

MATERIALS AND METHODS

Study area: Research was conducted in the Belgorod region in 2002-2016. The climate of the study area is temperate continental. Its main particular features as follows: large annual temperature range, relatively mild winters with frequent thaws and snowfalls, sunny and long summers, moderate and not quite stable moisture with summer precipitation being prevailed (Table 1).

Table 1. Average long-term weather conditions at the site where the studies were conducted according to the nearest weather stations

Indicators	Weather station	
	Valuyki	Alekseevka
Rainfall, mm	568	545
Average summer temperature, °C	+20.0	+20.0
Average winter temperature, °C	-7.0	-7.5
Duration of the frost-free period, days	155	155
The sum of the air t for the period with stable t > 10 °C	2750	2700
The average depth of soil freezing in winter, cm	60	60

Methods: Natural communities were studied in the course of route studies using the method of intermittent transects and geobotanical descriptions in accordance with the field geobotany procedures (Lavrenko and Korchagin, 1972).

Transects of 400 m² (2×200 m) in size were established diagonally to the direction of the gully under study. Four hundreds transects were established in total. P.F. Mayevsky (Mayevsky, 2006) determined the species composition of the plants. Throughout any transect we additionally set up permanent fixed plots with an

area of 100 m² (only 400 sites) for geobotanical descriptions, these plots were also used for further geobotanical descriptions of the communities with *M. sativa* L. and *M. varia* Mart. Each species is linked to a certain life form according to the system Raunkiaer (Raunkiaer, 1937). The florocoenotypes of the *Fabaceae* Lindl. family and their life forms have been classified of in relation to water (Kolchanov *et al.*, 2012). The species have been distributed with respect to calcium substrate according to V.I. Malyshev (Malyshev, 1965). The occurrence of a species has been defined as a percentage of related geobotanical descriptions. The species names are given in S.K. Szerepanov (Szerepanov, 1981).

RESULTS AND DISCUSSION

The conducted analysis has shown that the floristic composition of phytocenoses of gully complexes consists of 65 families, which include 274 genera. The species from three families: *Asteraceae* Dumort., *Fabaceae* Lindl. and *Poaceae* Barnh. take the lead in the taxon hierarchy. They account for 161 species (32.8%) in the floral spectrum, ten leading families include 329 species or 67.0% of their total number (495 species) (Table 2). The number of families represented by one species is 22, those of two species – 13 and those of three species – 4. Each of six families contains four species, two families – five species each and 2 another families – seven species each. One family has nine, ten, eleven and twelve species, and two families contain thirteen species each. As for the number of genera, the leading triad of families include *Asteraceae* Dumort., *Brassicaceae* Burnett. and *Poaceae* Barnh. – they account for 77 genera (28.1%) (Table 2).

A study of ecological features, coenotic and geographical relations has shown that the examined bean species belong to five groups according to geographical

confinement. There is a predominance of 20 plant species (44.4%) of Palearctic areal and 16 species (35.5%) of steppe area. The European-Caucasian, European and adventive types of geographical areas account for four (8.8%), three (6.6%) and two (4.4%) species respectively.

The generic coefficient (the number of species that per genera) is quite high and it is equal to 1.81, which reflects the diversity of the floristic composition of the communities of the studied gully complexes.

It has been found that the *Fabaceae* Lindl. species are quite numerous (they come second in the first triad of families). The *F.* Lindl. family is a valuable source of food and feed protein; it also produces soil symbiotic nitrogen. These species are distinguished by longevity, an exceptional ability to grow in a variety of natural conditions, multipurpose use, soil fertility recovery through atmospheric nitrogen fixation, and a number of other useful economic and biological features. The wild relatives of cultural species become of particular importance as sources for improvement of various economically useful features (Dzyubenko, 2015).

As follows from the analysis of the species composition of the bean component of the phytocenosis of gully complexes 45 species have been detected, i.e. about 58% of the diversity of the regional flora families (Table 3).

A study of general habit and life cycle duration has shown that taproot redevise tend to prevail among leguminous grasses. There is maximum 13.2% of annual and biennial plants and 17.6% of shrubs, sub-shrubs and dwarf sub-shrubs in gully complexes. A variety of ecological conditions, which have formed bean family species in gully complexes, is quite sufficiently shown by the spectrum of life forms. We have revealed that the majority of species (84.5%) belongs to hemicryptophytes – perennial herbaceous plants with aboveground sprouts being died away by wintertime. Their reproduc-

Table 2. Spectrum of the leading families of natural communities of ravine complexes (2002-2013)

Family	Family rank	Number of genera	Number of species	
			pieces	%
<i>Asteraceae</i> Dumort.	1	38	72	14.6
<i>Fabaceae</i> Lindl.	2	17	45	9.1
<i>Poaceae</i> Barnh.	3	22	44	9.0
<i>Lamiaceae</i> Lindl.	4	21	37	7.5
<i>Brassicaceae</i> Burnett	5	23	34	6.9
<i>Rosaceae</i> Juss.	6	17	25	5.1
<i>Scrophulariaceae</i> Juss.	7	8	22	4.5
<i>Caryophyllaceae</i> Juss.	8	11	19	3.9
<i>Ranunculaceae</i> Juss.	9	10	18	3.7
<i>Boraginaceae</i> Juss.	10	9	13	2.6
Total	65	274	495	100

Table 3. Species composition of the family Fabaceae in gully complexes with chalk outcrops (2002-2013)

No	Latin species name	Life form ^a	florocenotic ^b	Environmental group ^c
1	<i>Anthyllis vulneraria</i> L.	HC	MD	MX
2	<i>Astragalus albicaulis</i> DC.	HC	ST	X
3	<i>Astragalus austriacus</i> Jacq.	HC	ST	MX
4	<i>Astragalus cicer</i> L.	HC	MD	MX
5	<i>Astragalus danicus</i> Retz.	HC	ST	MX
6	<i>Astragalus dasyanthus</i> Pall.	HC	ST	MX
7	<i>Astragalus glycyphyllos</i> L.	HC	GB	M
8	<i>Astragalus onobrychis</i> L.	HC	ST	X
9	<i>Astragalus pubiflorus</i> DC.	HC	ST	X
10	<i>Astragalus sulcatus</i> L.	HC	MD	X
11	<i>Astragalus ucrainicus</i> M. Pop. et Klok.	HC	MO	X
12	<i>Astragalus varius</i> S.G. Gmel.	HC	SAN	MX
13	<i>Caragana frutex</i> (L.) C. Koch	PH	MD	X
14	<i>Chamaecytisus austriacus</i> (L.) Link	PH	CH	MX
15	<i>Chamaecytisus ruthenicus</i> (Fisch. ex Woloszcz.) Klaskova	PH	SAN	MX
16	<i>Coronilla varia</i> L.	HC	ST	M
17	<i>Genista tanaitica</i> P. Smirn.	HC	CH	M
18	<i>Genista tinctoria</i> L.	PH	MD	MX
19	<i>Hedysarum grandiflorum</i> Pall.	HC	CH	MX
20	<i>Lathyrus pannonicus</i> (Jacq.) Garcke	HC	ST	MX
21	<i>Lathyrus pallescens</i> (Bieb.) C. Koch	HC	ST	MX
22	<i>Lathyrus pratensis</i> L.	HC	MD	M
23	<i>Lathyrus tuberosus</i> L.	HC	SYN	MX
24	<i>Lotus corniculatus</i> L.	HC	MD	M
25	<i>Medicago falcata</i> L. subsp. <i>romanica</i> (Prodan) Schwarz et Klinkovski	HC	ST	MX
26	<i>Medicago lupulina</i> L.	HC	SAN	M
27	<i>Medicago varia</i> Mart.	HC	SYN	MX
28	<i>Melilotus albus</i> Medik.	HC	ST	MX
29	<i>Melilotus officinalis</i> (L.) Pall.	HC	ST	MX
30	<i>Onobrychis arenaria</i> (Kit.) DC.	HC	ST	MX
31	<i>Ononis arvensis</i> L.	HC	MD	M
32	<i>Oxytropis pilosa</i> (L.) DC.	HC	ST	X
33	<i>Robinia pseudoacacia</i> L.	PH	SYN	MX
34	<i>Trifolium alpestre</i> L.	HC	MD	MX
35	<i>Trifolium arvense</i> L.	T	MD	MX
36	<i>Trifolium fragiferum</i> L.	HC	MD	MH
37	<i>Trifolium hybridum</i> L.	HC	MD	MH
38	<i>Trifolium medium</i> L.	HC	MD	M
39	<i>Trifolium montanum</i> L.	HC	MD	MX
40	<i>Trifolium pratense</i> L.	HC	MD	M
41	<i>Trifolium repens</i> L.	HC	MD	M
42	<i>Trifolium aureum</i> Poll.	HC	MD	MX
43	<i>Vicia cassubica</i> L.	HC	FR	M
44	<i>Vicia cracca</i> L.	HC	MD	MX
45	<i>Vicia villosa</i> Roth.	T	MD	MX

Note: a Life form: HC – hemikryptophytes (hemikriptofyte), T – therophytes (terofyte), PH – phanerophytes (fanerofyte), b florocenotic: ST– steppe, SYN – synanthropic, MD – meadow, FR – forest, GB – types of fields and shrubs, SAN – sandy habitat species, CH – types of chalk downs. c Environmental group: M – mesophyte, MX – mesoxerophyte, MH – mesogigrophyte, X – xerophyte

Table 4. Distribution of Fabaceae species in gully complexes depending on relief elements (2008–2013)

Sampling point	mesophyte	mesoxerophyte	mesogigrophyte	xerophyte
Slopes of beams with steppe phytocenosis	1	7	-	3
Slopes of beams with lime-loving association	-	4	-	4
Ravine mouths with alluvial cone	4	8	-	-
Alluvial cone acting ravines	6	7	2	-
Total	11	25	2	7

ing buds are located on the soil surface and protected by leaf litter. Phanerophytes and Therophytes are generally represented by 15.5% of species in the regional gully complexes. The bean species distribution in gully complexes is largely determined by soil moisture. An analysis of species-to-moisture factor ecological spectrum has shown that the species (55.5%) predominantly belong to mesoxerophytes, i.e. plants, which are able to tolerate a short-term drought. As for the number of species mesophytes, xerophytes and mesohygrophytes take the second, third and fourth places, respectively.

Various manifestations of calciphilia, which is related with calcium excess and substrate carbonate content have made it possible to distribute bean species by plant confinement to calcium substrate according to the classification by V.I. Malyshev (Malyshev, 1965). The bean gully complexes (73.3%) are prevailed by facultative calciphile plants, which are quite common on carbonate soils but can also grow outside. A group of calcium-indifferent bean plants (17.8%) include the species which are either unobviously confined to carbonate substrates or fail to be calciphobes. We have found 8.9% of obligatory calciphile plant, which grow almost exclusively on the calcium substrate. Under severe environmental conditions a combination of resources in a particular ecotope point is of critical importance for coenopopulations. The gully complexes have a well-defined micro-relief, which has impact on spatial distribution of species. 60.0% of mesophytic bean species are concentrated on the rank soils in ravine mouths and existing gully cone deltas, i.e. in more humid living environment. On gully slopes with steppe plant formations there are 20.0% of xerophytic and mesoxerophytic species whereas slopes with calciphilous communities have 15.5% of them (Table 4).

In general, in the conditions of gully complexes the ecological features of bean plants are characterized by the predominance of mesoxerophytes and facultative calciphile plants as regards ecotope conditions and steppe florocenotype hemicyptophytes by life form.

The landscape conditions of the gully complex ecotopes with cretaceous outcrops tend to create conditions for the introduction of new synanthropic species and their active formation. Many species may be of high bio-resource value. The most striking example include species of the *Medicago* genus: *M. sativa* L. and hybrid

M. varia Mart. species. The history of wide distribution of these species, which are mainly of Central Asian and Mediterranean origin in the conditions of the Central Russian Upland, goes back about one hundred years. It is noteworthy that there is not a single record of blue-flowered and variegated-flowered *M. sativa* L. and *M. varia* Mart. species ("native" type alfalfa) in the detailed geobotanical descriptions of gully complexes with cretaceous outcrops which were made > 100 years ago V.I. Taliev (1904a) (Taliev, 1904b, Juan *et al.*, 1993).

Currently the *M. sativa* L. and *M. varia* Mart. species make an essential and integral component of natural herbaceous phytocenoses. The studies conducted in 2008–2013 and repeated in 2014–2016 showed that an average increase in the occurrence of these species had made up to from 3.2 to 4.5% for all geobotanical descriptions, with the most significant increase being demonstrated by the plant communities located on the Cretaceous outcrops (Table 5). In 2008–2013, the steppe areas and meadows were characterized by discrete (incomplete) local populations, which are mainly represented by old-aged blueing and non-blueing individual plants. However, in 2014–2016 some even-aged young plants were also reported to appear for seed regeneration.

In vegetation communities of chalk, outcrops the *M. sativa* L. and *M. varia* Mart. coenopopulations are subject to habitual areas, which have been earlier connected with human economic activities: locations of former farms, marginal plots on fields used for farm and soil conservation crop rotations. A more detailed study of the occurrence of blue-flowered alfalfa in gully complexes

Table 5. Occurrence of *M. sativa* L. and *M. varia* Mart. in natural association, %

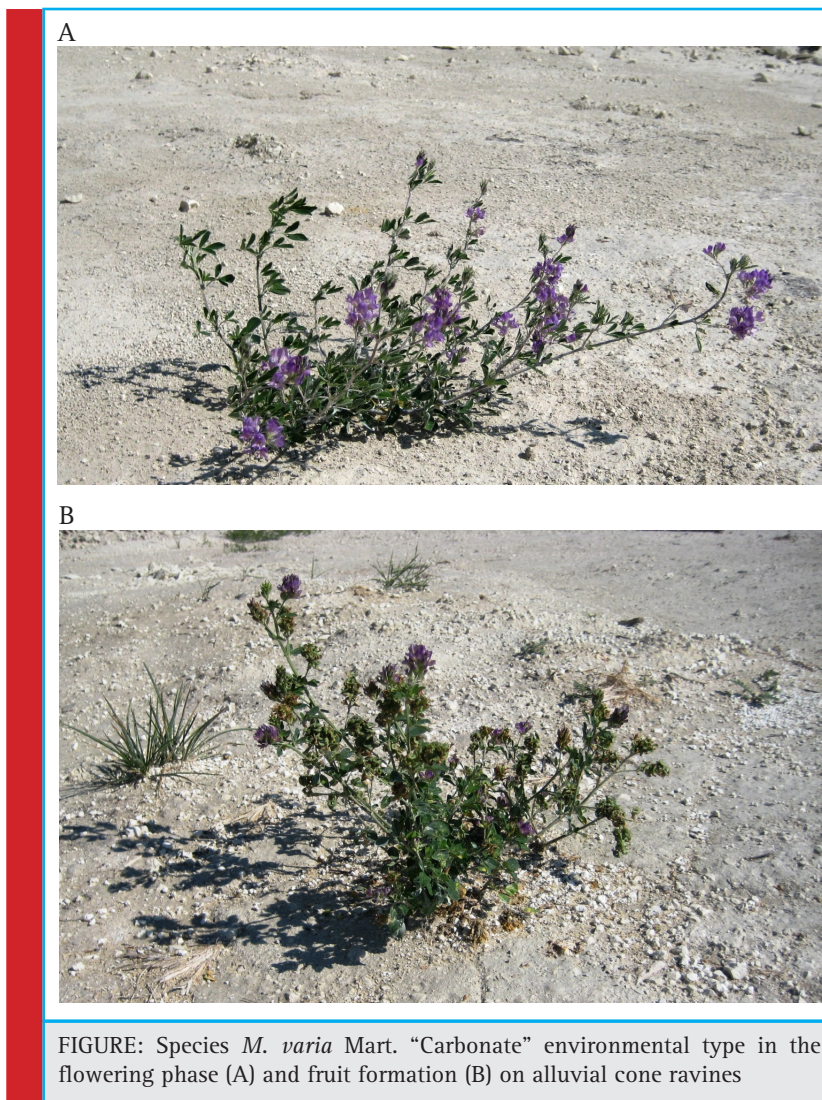
Association	Years of research	
	2008–2013	2014–2016
Meadow steppes	2.0	3.6
Real steppes	3.0	3.5
Calciphilous steppes	4.0	6.2
Chalk outcrops	5.0	7.1
Meadows	2.0	2.0
Average	3.2	4.5

Table 6. Occurrence of <i>M. sativa</i> L. and <i>M. varia</i> Mart. in ecotopes of ravine complexes, %		
Ecotopes	Study years	
	2008–2013	2014–2016
Slopes of beams with steppe association	0.0	0.2
Slopes of beams with lime-loving association	3.0	2.5
Ravine mouths with alluvial cone	8.0	11.2
Alluvial cone acting ravines	7.0	9.1
Average	4.5	5.6

and its dynamics has made it possible to identify the ecotopes with the most favourable conditions for the development of *M. sativa* L. and *M. varia* Mart. and for the formation of their stable populations (Table 6).

The occurrence of blue-flowered alfalfa is higher in lower gullies (in the existing gully cone deltas and in the ravine mouths with cone deltas) for a number of possible reasons. Firstly, due to the transfer of seeds through ecotonic corridors being gully slopes. Secondly, due to the particular features of the soil substrate (chalk residues), which forms high-degree crushing, low projective cover and, therefore, low distribution of cereals and lower inter-species competition. Thirdly, due to the influence of natural selection of sustainable forms in the hybrid populations which have formed in the ravine mouths with the varieties of *M. sativa* L. and *M. varia* Mart. and local forms of *M. falcata* L. which were previously cultivated on the arable land.

Local coenopopulations of *M. sativa* L. and *M. varia* Mart. are most complete in ravine mouths and they often have species distributed by age groups on a continuous basis. We have found a wide variation of all



main morphometric parameters, which proves alfalfa's intrapopulation heterogeneity and ecological plasticity. Hence, these two species provide material for the selection of competitive forms. Adaptive transformations are oriented towards the preservation of individual plants accompanied by a specific increase in leaf coverage, a reduction of generative organs with increased numbers of stemmed beans, bean curls and their dissemination. There has been observed the formation of *M. sativa* L. and *M. varia* Mart. coenopopulations with individual plants of "carbonate" ecotype, which is close to cultural forms by a number of morphological features but has a pronounced stress-tolerant type of adaptive strategy (Figure). The upper slope seeds (these are usually fields of crop rotations) used to be transferred by water flow to the bottom of the gullies where they fell on rubble chalk eluvium. A vegetation cover with low projective coating was formed in the cone deltas. There alfalfa found favourable conditions for its growth and development in conditions of low competition with cereals. Against the background of negative influence produced by carbonate substrate, primarily, due to iron deficiency, the population have quite promptly eliminated unstable forms and generated *M. sativa* L. and *M. varia* Mart. coenopopulations with high level of preservation of individual plants having a complete spectrum of adaptive changes. They have become the basis for microevolution transformations under extreme ecotope conditions. The local populations were reported to have high occurrence of forms carrying multifoliolate recessive mutation (mf-mutations). Externally, it is expressed by the formation of complex leaves with 4-7 leaflets in individuals instead of three. These forms are positioned as sources of high-quality material for the selection of high-quality cultural alfalfa (Juan, 1993, Petkova, 2010, Odorizzi *et al.*, 2015).

The researchers consider the emerging multi-leafness in leguminous grasses as a throwback, i.e. atavism, which is most strongly manifested in the conditions of disturbed habitual areas when they grow outside the phytocenosis, on poor rocky soils, rock outcrops and in the areas being far from the optimal conditions (Plennik, 2002). An estimation of the populations by the method of transfer into favourable conditions have shown that the share of mf-mutant forms is from 3.3 to 53.3% in different populations. With seed renewal, the proportion of species with mf-mutation (the offspring of the first plant) is from 5 to 55% in families.

It is important that the *M. sativa* L. and *M. varia* Mart. forms, which have been found in the habitual areas of gully complexes, have a number of valuable crop selection features: good leaf coverage, high protein content and high seed production and others.

CONCLUSION

We have found a high variety of plant species with high biological potential in the gully complexes in the southern-west part of the Central Russian Upland. It is possible to have accumulations of stable viable recessive forms of individual species, which can be used to generate initial selection material. The example of *M. sativa* L. and *M. varia* Mart. was used to establish the formation process for coenopopulations of certain sustainable ecotype, which is close to cultural forms, by a number of morphological and qualitative characteristics. The populations studied are characterized by high occurrence of mutant forms (recessive mf-mutation). This phenomenon becomes obvious in the course of development of natural local populations along the boundaries of species distribution areas.

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