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DISTRIBUTION PATTERNS OF SEGETAL WEEDS OF CEREAL CROPS IN TAJIKISTAN

ARKADIUSZ NOWAK[1,2*], SYLWIA NOWAK[1], MARCIN NOBIS[3,4] AND AGNIESZKA NOBIS[3]

[1]*Department of Biosystematics, Laboratory of Geobotany & Plant Conservation, Opole University, Oleska 22, 45-052 Opole, Poland*
[2]*Department of Biology and Ecology, University of Ostrava, 710 00 Ostrava, Czech Republic*
[3]*Department of Plant Taxonomy, Phytogeography and Herbarium, Institute of Botany, Jagiellonian University, Kopernika 27, 31-501 Kraków, Poland*
[4]*Laboratory of Biodiversity and Ecology, Institute of Biology, Tomsk State University, 36 Lenin Prospekt, Tomsk, 634050, Russia*
**Corresponding author's e-mail: anowak@uni.opole.pl*

Abstract

Using the literature data and field research conducted in 2009-2013 the distribution patterns, habitat conditions, phytogeographical characterisation and endangerment of weeds occurring in cereal crops in Tajikistan were analysed. We found out that Tajik weed flora of cereal crops counts 686 taxa. The most species rich families include Asteraceae, Poaceae and Fabaceae. The highest number of cereal weeds were noted in large river valleys of Syr-Daria, Amu-Daria and their tributaries in south-western and northern Tajikistan. This subregions have the warmest climate conditions and extensive arable lands. The greatest weed species richness was observed in submontane and montane elevations between approx. 700 and 1,900 m a.s.l. Cereal weeds occur frequently outside segetal communities in Tajikistan. They were noted usually in screes, wastelands, xerothermophilous grasslands, river gravel beds and in steppes habitats. The assessment of threat status reveals that ca. 33% of total cereal weed flora in Tajikistan are disappearing or occur very rarely. According to the chorological data we find that in the cereals of Tajikistan, 35 endemic and 14 subendemic species occur. The most numerous chorological elements of threatened weed flora of Tajikistan are Irano-Turanian (55%), pluriregional (16%), cosmopolitan (14,5%), Mediterranean (9%) and Eurosiberian (5%) species. Further research is suggested to explore the distribution patterns of all weed species in Tajikistan as it should be useful for economy and effectiveness of crop production as well as conservation of most valuable species.

Key words: Chorology, Agroecosystems, Biodiversity, Middle Asia, Altitudinal amplitude.

Introduction

As a central country within the Middle Asian hotspot of biodiversity (Mittermeier *et al.*, 2006), Tajikistan is among the most diverse and richest regions in terms of plant species. According to recent studies, more than ca. 4,550 vascular plant species occur within the country, with several having been described in the past few years (*e.g.* Nobis *et al.*, 2010; Nobis, 2011, 2013; Nobis & Nowak, 2011; Nobis *et al.*, 2013, 2014). Tajikistan, as one of the Middle Asian countries, is also known as a crucial and focal area in terms of weed origin and segetal species diversity (as weeds we consider the plant species spontaneously occurring in agrocoenoses; Vavilov, 1951). Up to 900 vascular plant species are known to occur in agrocoenoses as weeds. Astonishingly, also endemic species contribute to field phytocoenoses; however, many of them are red-listed (Nowak *et al.*, 2014a). Generally, in Tajikistan approximately 30% of vascular plants are defined as endemics of the country (Rasulova, 1991; Nowak A. *et al.*, 2011).

Middle Asia (Tajikistan, Kyrgyzstan, Uzbekistan, Turkmenistan and part of Afghanistan) as well as Central Asia (Kazakhstan, Mongolia, north-west China), include extensive lands undergoing agricultural cultivation (Statistical Committee, 2006). Despite that, to date, in certain countries of Middle Asia, research on segetal plant communities is very scarce in terms of syntaxonomical, ecological or even floristic data. Recently, it is only in Tajikistan and Kyrgyzstan that a few works on syntaxonomical diversity of cereal, root and rice field crops have been made available (Nowak *et al.*, 2013a, b, c; Nowak & Nowak, 2013), notwithstanding other work contributing to more complete knowledge of Middle Asian vegetation (Nobis *et al.*, 2013; Nowak & Nobis, 2012, 2013; Nowak *et al.*, 2014b, c, d, e). In the immediate vicinity of Tajikistan, investigation focused on field habitats have been undertaken only for a few regions, *e.g.* Pakistan (Saeed & Hussain, 1986; Malik & Hussain, 1990; Hussain & Ali, 2006), Bashkortostan and Mongolia in Central Asia (Hilbig & Bumžaa, 1985; Yamalov *et al.*, 2007).

Weeds have contributed significantly to the floristic diversity. As it was shown for Europe traditional farming before the industrial revolution promoted species diversity (Kornaś, 1983). Weeds, especially archaeophytes, including species created by speciation due to human impact (*archaeophyta anthropogena*; Zając, 1988), have evolved over the long period of crop cultivation and throughout the history of agriculture. In present times new aliens (neophytes) also considerably change the vegetation of agrocoenoses. Still it is of great importance from economical and conservation point of view to have current knowledge regarding the distributional patterns and population size of weeds.

After thorough bibliographical query and on the basis of our own floristic and ecological studies, we find it important to answer for the following questions: (1) How are Tajiks segetal plants distributed along the altitudinal gradient, (2) what are the habitats from which the facultative segetal weeds originated, (3) what is the biogeographical affiliation of the segetal species and (4) what is the weeds distribution across the geobotanical subregions in Tajikistan.

Material and Methods

Study area: Tajikistan covers 143,500 km^2 and is located in Middle Asia between 36°40′–41°05′ E and 67°31′–75°14′ N (Fig. 1). As more than a half of the country surface is elevated above 3,000 m, Tajikistan should be recognized as typically mountainous country. The south-western outskirts of the country is influenced by a hot mediterranean climate. The northern areas are characterised by the temperate climate (Vladimirova, 1968). Generally, the area of Tajikistan has high insolation rate, high annual temperatures amplitude, high rate of aridity and small precipitation amount. In southern regions of the country, mean June temperatures are over 30°C. In the temperate zone and in the the higher mountains, the climate conditions are much harsher, with average summer temperatures approx. 9.7°C to 13.5°C. The mean annual precipitation ranges here from ca 70 mm (Eastern Pamir) to ca 600 mm (Hissar southern slopes). The limits of perpetual snow cover are generally at an altitude of 3,500-3,600 m a.s.l. in Zeravshan, Hissar and Turkestan Ranges and 5,800 m a.s.l. in the Pamir Plateau and Peter the 1st Range (Latipova, 1968; Narzikulov & Stanjukovich, 1968).

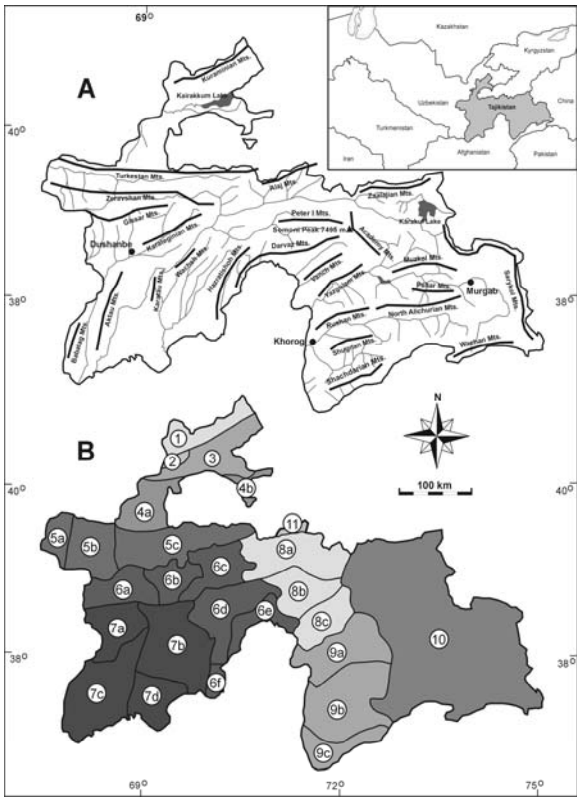

Fig. 1. A: The area of Tajikistan with main cities, mountain ridges, rivers and lakes. B: The geobotanical division of Tajikistan: 1 - Kuraminian; 2 – Mogoltausian; 3 - Prisyrdarian; 4a - Turkestanian A, 4b - Turkestanian B; 5a - Zeravshanian A, 5b - Zeravshanian B, 5c - Zeravshanian C; 6a - Hissaro-Darvasian A, 6b - Hissaro-Darvasian B, 6c - Hissaro-Darvasian C, 6d - Hissaro-Darvasian D, 6e - Hissaro-Darvasian E, 6f - Hissaro-Darvasian F; 7a - South Tajikistanian A, 7b - South Tajikistanian B, 7c - South Tajikistanian C, 7d - South Tajikistanian D; 8a - East Tajikistanian A, 8b - East Tajikistanian B, 8c - East Tajikistanian C; 9a - West Pamirian A, 9b - West Pamirian B, 9c - West Pamirian C; 10 - East Pamirian; 11 - Alajian.

Due to extensive mountainous wastelands share in Tajikistan, the arable ecosystems are not dominating in the landscape of the country (approx. 28% of the state territory). Nevertheless, the rural areas concentrate more than 70% of the Tajiks population and employ ca. 60% of the total labor force. During the Soviet times, agriculture was based on a a dual system. It consists of large-scale collective and state farms and small, private land owners which use subsidiary household plots. After the Soviet Union collapse, the third type of farming was implemented - the so called '*dehkan* peasant farms' which use the mid-sized plots. According to the 2006 statistical data, ca. 25,000 peasant farms own 60% of arable grounds. In Tajikistan cotton and wheat plantations predominate in agrarian structure. Both plants are cultivated on nearly 70% of the total crop area. Other common crops are: barley (12%), rye (5%), oats (3%), maize (3%), rice (2%) and sorghum (1%). Almost 70% of Tajik crops are main-season, primarily wheat and barley. Late-planted spring crops occupy ca. 12% of agricultural land (Statistical Committee, 2006). The cereal crop fields in Tajikistan are almost all irrigated, albeit generally without any support from technical measures. This is the reason some plots host a significant share of species typical for wet habitats (*e.g. Mentha asiatica*, *Plantago major*, *Rorippa palustris* and others). The method of cultivation is extensive and based on traditional management. Many fields are neither weeded nor fertilized. Manual work and hoeing are the most common methods of weed control. The growing year starts at the beginning of April when the crop is sown, also often without any technical support. The harvest period begins in June in the outlying areas to the south of the country and is prolonged until late September in the mountains.

The study was conducted over the entire area of Tajikistan in cereal crop fields. The most suitable lands for agriculture in Tajikistan are located within the wide river valleys of Syr-Daria, Amu-Daria, Pyandzh, Veshan, Vakhsh, Zeravshan, Kofirnighon, Khanaka and Surkhandaria Rivers. These areas belong to the Zeravshanian, Hissaro-Darvasian, East Tajikistanian, West Pamirian and South Tajikistanian geobotanical regions with the most suitable conditions for agriculture (Goncharov, 1937; Fig. 1).

Data and analyses: To find the distributional patterns of segetal weeds in Tajikistan, an extensive survey of the available literature sources (Vasilchenko, 1953; Ovchinnikov, 1957, 1963, 1968, 1978; Ovchinnikov & Kochkareva, 1975; Ovchinnikov & Kinzikaeva, 1981; Chukavina, 1984; Kochkareva, 1986; Kinzikaeva, 1988; Rasulova, 1991) and field studies in all geobotanical regions of Tajikistan was done in 2009-13. Also, a checklist of weeds inhabiting the cereal crop was prepared prior to analysing the chorological status of all taxa. Several taxa had to be excluded due to taxonomical revisions. For example, *Cuscuta brevistyla* A. Br. ex A. Rich. has been divided into *C. palaestina* and *C. planiflora*, with no information as to which one occurs in Tajikistan. The threat categorization was given according to Nowak *et al.* (2014a).

To support the literature query, an exhaustive bibliographical survey was carried out and the herbarium specimens deposited in St. Petersburg (LED; ca. 2000 specimens), Tashkent (TASH; ca. 200 specimens) and Dushanbe (TAD; ca. 1300 specimens) were checked.

In the course of the field research, 332 samples were taken from segetal vegetation plots with well-developed weed phytocoenoses in the years 2009-2013. The plot size used to sample segetal flora was 50 m^2. Sampling was arranged as to reflect the proportion of arable lands in distinct geobotanical subregion and altitudinal zone (lowlands, montane and alpine zones) (Table 1). The phytogeographical classification of species was done according to the division of Takhtajan (1986) and Grubov (2008). If a given species occurred within two or three biogeographical provinces, it was categorized as pluriregional. If in more then it was considered as cosmopolitan species. Fully developed phytocoenoses were investigated regards to their phenological aspects. For cereals the sampling period was from May to July in lowlands and in montane zone, and in July-September in alpine zones of Tajik mountains.

We designated as endemic species all taxa with spontaneous range comprised within the borders of Tajikistan. These is in line with a definition of 'national endemics' (*e.g.* Jarris & Robertson, 1999; Müller *et al.*, 2003) and corresponds with the widely accepted definitions of endemism (*e.g.* Gaston, 1994).

The status of the weed species, in terms of abundance and habitat preferences (obligatory versus facultative weeds), was based on Vasilchenko (1953) and the authors' field observations. For each species we analyse altitudinal distribution, life form, ecology and habitat preferences as well as taxonomic affiliation. To show the horiznontal distribution patterns we use the geobotanical division proposed by Goncharov (1937; Fig. 1). To discover the similarities between this 26 geobotanical subregions the floristic data were analysed by two-way unweighted arithmetic average (UPGMA) cluster analysis using the euclidean distance (Anon., 2004).

The nomenclature of the species is given according to Czerepanov (1995).

Results

As one of the richest floristic regions in the world, Tajikistan also has a considerable number of weed species contributing to the segetal communities of cereal crops. In result of the study, it was determined that Tajik all segetal weed flora consists of 686 taxa. This total equals about 15% of the country flora. The most weed-abundant families include Asteraceae (122 plant species), Poaceae and Fabaceae (both 72 species), Brassicaceae (58), Boraginaceae (37), Chenopodiaceae (34), Apiaceae (32), Lamiaceae, Scrophulariaceae and Polygonaceae (each family 25 species), Caryophyllaceae (23), Ranunculaceae (16), Rosaceae (15), Malvaceae and Rubiaceae (both 11 species). In total representants of 50 families were noted. The richest regions of the country as weeds are concerned are the south-western areas, i.e. the south Tajikistanian region, where almost 500 weeds were noted. The Zeravshanian, Hissaro-Darvasian and Prisyrdarian regions, where approximately 250-350 weed species occur, are also abundant in segetal species (Fig. 2).

Analysis of dissimilarity of species composition of the various segetal weed groups indicate that the differences correspond to the geobotanical subdivision implemented in Tajikistan (Fig. 3).

Table 1. Sampling design in relation to geobotanical division and altitudinal zonation of Tajikistan.

Geobotanical subregion	Plot number	Altitudinal zone [m a.s.l.]		
	Cereals	300-800	800-2000	>2000
Kuraminian	9	2	7	0
Mogoltausian	8	6	2	0
Prisyrdarian	10	9	1	0
Turkestanian A	16	3	10	3
Turkestanian B	7	0	5	2
Zeravshanian A	17	7	7	3
Zeravshanian B	19	0	13	6
Zeravshanian C	18	0	13	5
Hissaro-Darvasian A	16	2	11	3
Hissaro-Darvasian B	17	0	13	4
Hissaro-Darvasian C	19	0	14	5
Hissaro-Darvasian D	16	1	12	3
Hissaro-Darvasian E	12	0	10	2
Hissaro-Darvasian F	2	0	2	0
South Tajikistanian A	12	7	5	0
South Tajikistanian B	17	9	7	1
South Tajikistanian C	10	10	0	0
South Tajikistanian D	12	12	0	0
East Tajikistanian A	18	0	12	6
East Tajikistanian B	16	0	10	5
East Tajikistanian C	14	0	10	4
West Pamirian A	17	0	10	7
West Pamirian B	15	0	11	4
West Pamirian C	12	0	7	5
East Pamirian	3	0	0	3
All	332	68	192	71

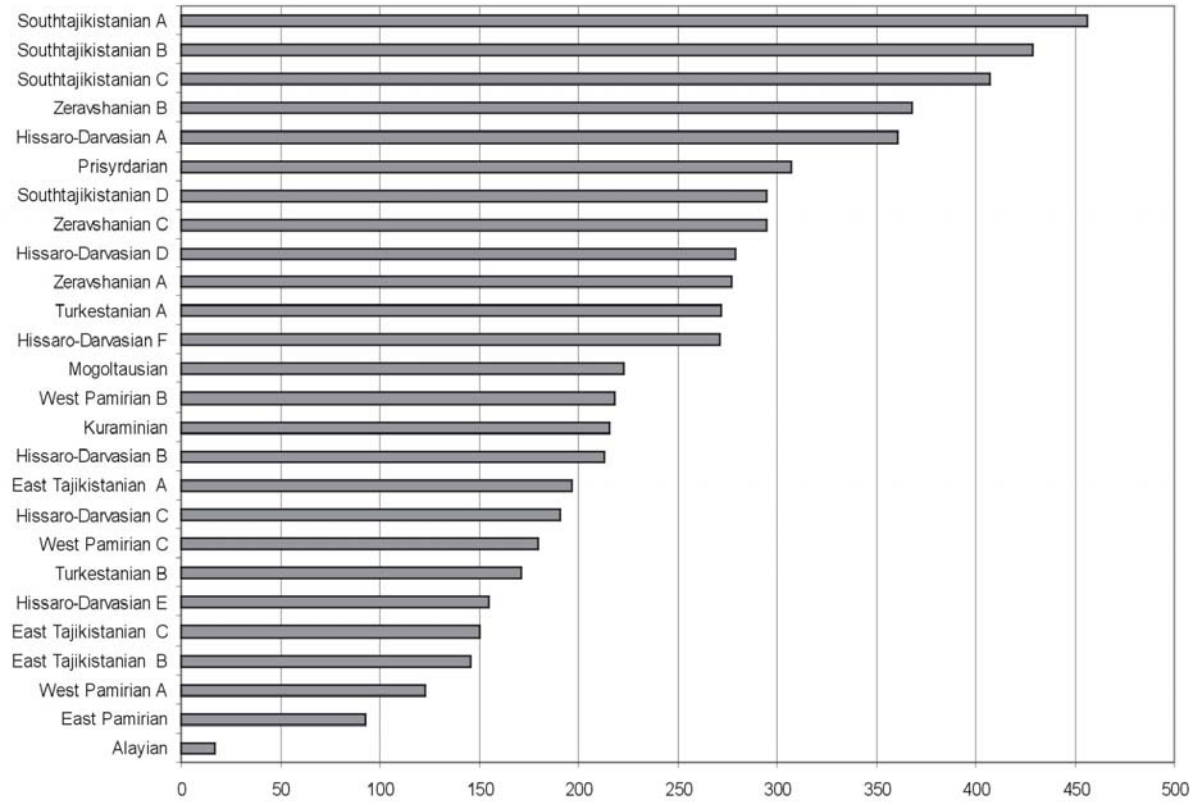

Fig. 2. Distribution of ceral weed taxa in geobotanical regions. Names of geobotanical subregions according to Fig. 1.

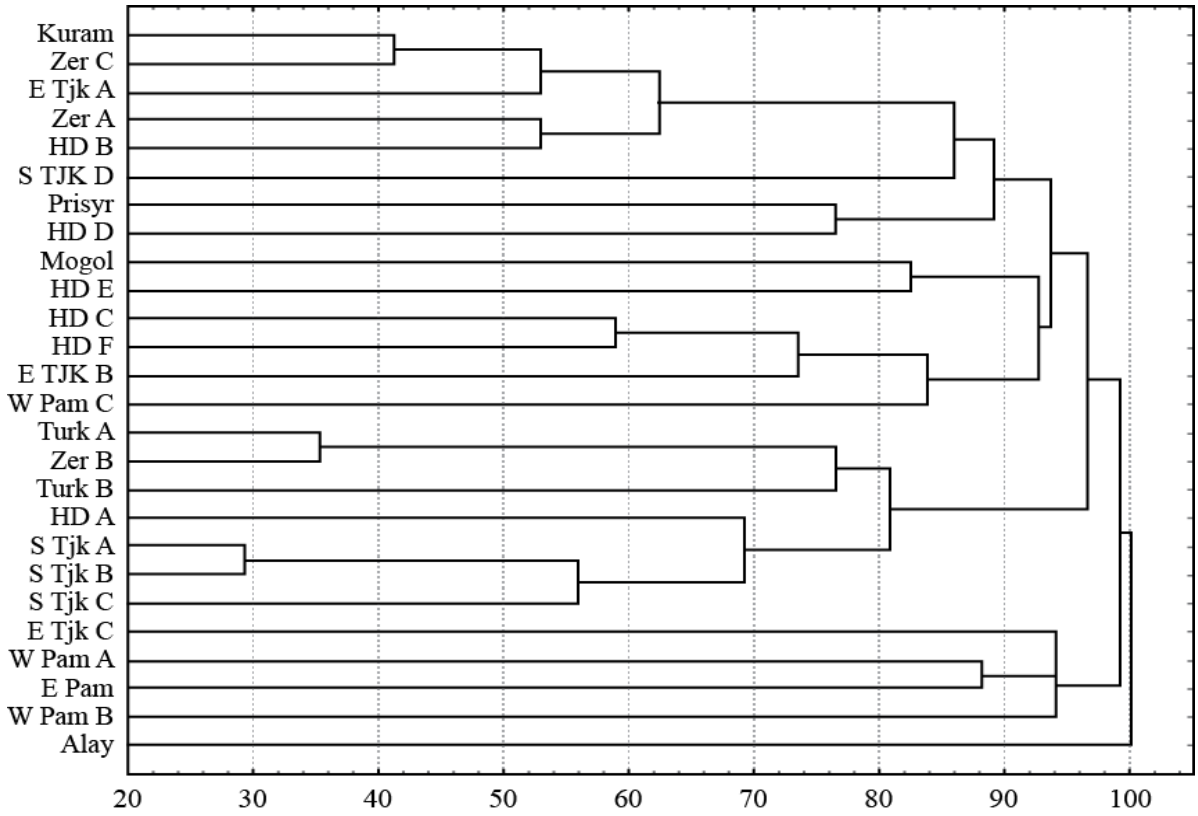

Fig. 3. Dendrogram based on UPGMA clustering of 26 geobotanical subregions using cereal taxa composition.

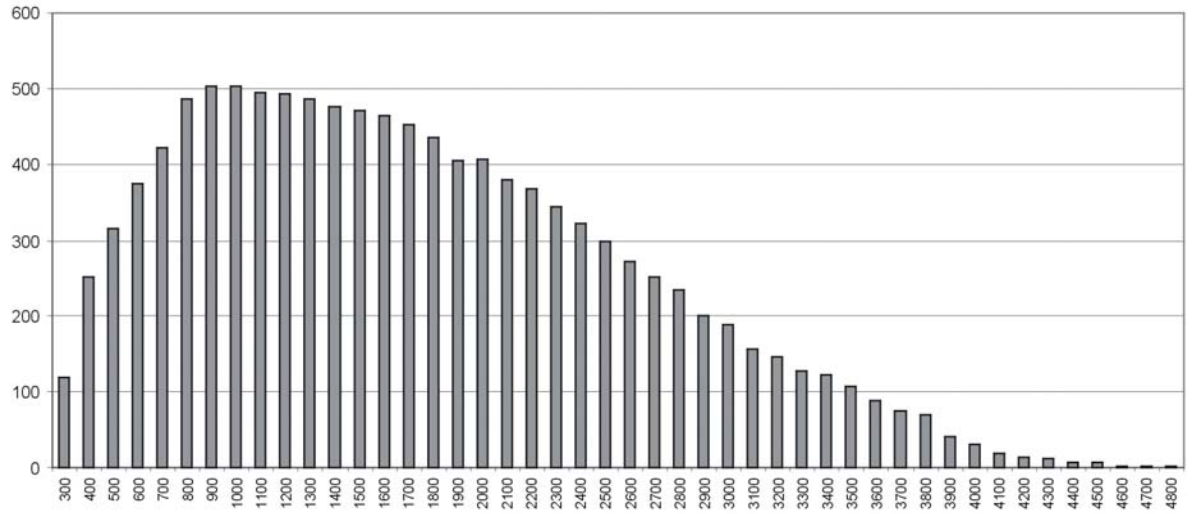

Fig. 4. Altitudinal distribution of cereal weeds shown as a number of endemics occurring in 100 m altitudinal belt.

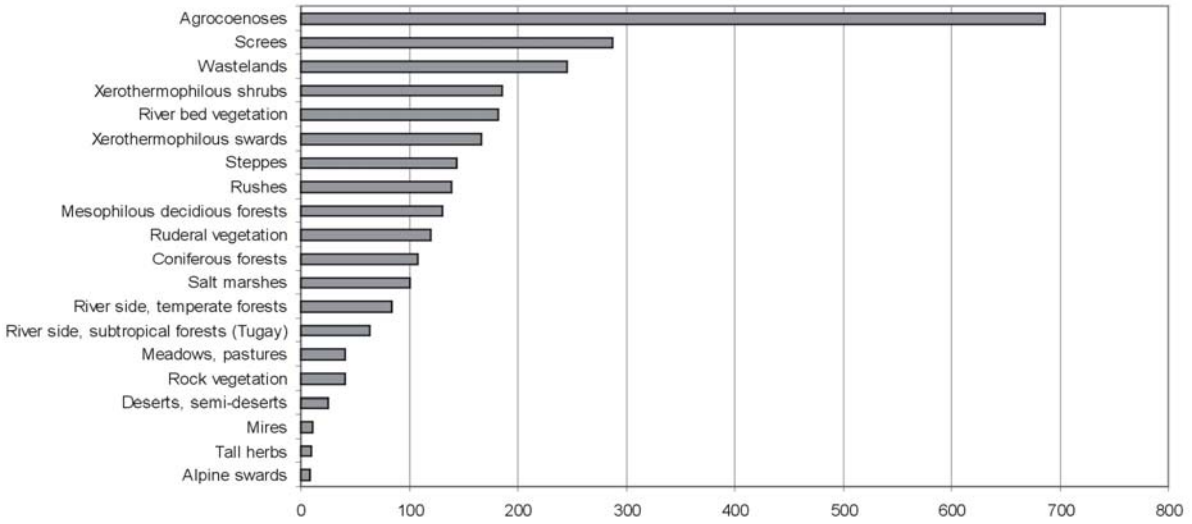

Fig. 5. Richness of cereal crop weeds in different types of Tajik vegetation.

The most important dissimilarities occur within Eastern Tajikistanian region which has very scattered subregions due to different weed composition. Also Hissaro-Darvasian subregion "A" seems to be closely related to south Tajikistanian region. The Western Pamirian "C" subregion is quite similar to some of eastern Hissaro-Darvasian subregions or eastern Tajikistanian region.

Along the altitudinal gradient, the highest segetal plant richness was found between 700 and 2,000 m a.s.l. (Fig. 4). Due to habitat similarities as well as the extensive acreage of wastelands and fallow lands in Tajikistan, weeds commonly occur outside agrocoenoses. However this holds true generally to common and expansive species. Cereal weeds were frequently noted in screes, wastelands, xerothermophilous grasslands, river gravel beds and in steppes communities (Fig. 5).

The assessment of threat status reveals that 232 weed taxa (approximately 33% of total weed flora in Tajikistan) are disappearing or occur very rarely. Thirty three species have to be regarded as critically endangered, 36 as endangered, 36 as vulnerable, 34 as near threatened, 43 as in the 'least concern' category. For 50 species, due to data scarcity and deficiency, it was not possible to precisely determine the endangerment level (Nowak *et al*., 2014a). This is in line with the frequencies of weed species in cereals. The most numerous group are very rare species (378), followed by rare (100), frequent (54), very frequent (79) and common (29). According to the chorological data we find that in the arable cereals of Tajikistan, 35 endemic and 14 subendemic species occur. As shown in figure 6, the most numerous chorological elements of threatened weed flora of Tajikistan are Irano-Turanian (55%), Pluriregional (16%), Cosmopolitan (14,5%), Mediterranean (9%) and Eurosiberian (5%) species.

Among life forms, clearly the therophytes (65%) and hemicryptophytes (24%) predominate. Geophytes also make up a considerable share (approximately 4%). Hydrophytes and chamaephytes maintain a negligible presence.

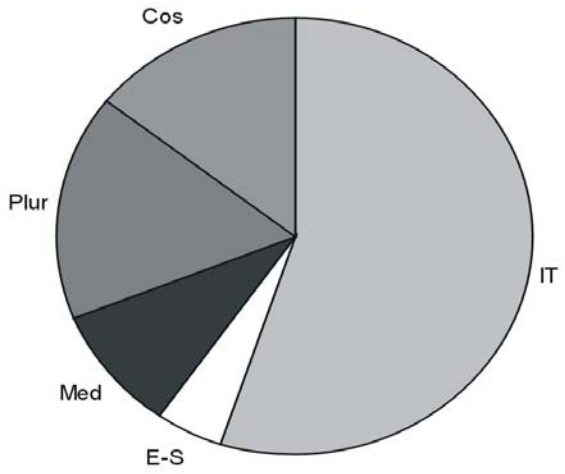

Fig. 6. Phytogeographical characterisation of cereal weeds occurring in Tajikistan. Explanations: IT - Irano-Turanian, Med - Mediterranean, Plur - Pluriregional, Cos - Cosmopolitan, E-S - Eurosiberian

Discussion

Compared to other countries, the number of cereal weed species in Tajikistan is considerably high (*e.g.* Saeed & Hussain, 1986; Malik & Hussain, 1990; Preston *et al*., 2004; Eliáš *et al*., 2005; Hulina, 2005; Türe & Böcük, 2008). Our research has enlarge the list of the species by ca. 20% (Vasilchenko, 1953). This is mainly due to still low intensity of agriculture in mountainous areas of the country and in consequence encroachment of native species from neighbouring habitats into the cereal crops. The richness of segetal weed flora in cereal plantations is also a result of general high species richness of Tajikistan and very long history of agriculture here. As it is commonly accepted, the Middle Asia is one of the world cradles of agriculture and segetal species speciation and origin (Vavilov, 1951; Vasilchenko, 1953; Zając, 1988). It is also important that during the last glaciations (Quaternary), ice cover did not enter Middle Asia, and allows the warm river valley to play a role of Tertiary refuge for many plant species including numerous weeds (Safarov, 2003). Additionaly very diverse field habitats contribute considerably to segetal weeds richness. As we frequently observe in Tajikistan there are plenty of fields on steep slopes of different expositions and at different elevations with no possibility of implementation of any technical support. Some acreages are close to mountainous screes or even glaciers, exposed to land slides and other extreme phenomena that could influence the weed composition. Due to the similarity, in terms of habitat parameters, of extensively used fields to the adjacent habitats of xerothermic grasslands, screes, riverside gravel areas and other open habitats, segetal flora is formed by many species originating from these biotopes.

The altitudinal pattern in the concentration of cereal weeds is partially an effect of the different field acreage at different zones. The higher elevation the lowest surface of agricultural lands. Also the varied total flora richness at different altitudes contribute to weed diversity as we consider the overcoming by native species from outside to agrocoenoses. The highest richness of cereal weeds is observed in Tajiks submontane and montane zones with warm to moderately warm microclimate which could be classified as Mediterranean (Vladimirova, 1968; Latipova, 1968). This pattern is also reflected in horizontal inequality of segetal weeds distribution. The geobotanical subregions with warmest climate and largest agricultural lands have the richest weed flora. The south Tajikistanian and Prisyrdarian regions located alongside the large river valleys (Syr-Daria, Amu-Daria, Vahsh, Pyandzh) have over 350 cereal weed species. The opposite situation is in eastern Pamir and highly elevated subregions of eastern Tajikistan and western Pamir. Here, the harsh, alpine climatic conditions, the scarcity of suitable lands for cultivation determine the very low number of segetal weeds.

The extensive farming allows the frequent encroachment of Tajiks native species into agroecosystems. Despite the conservation issues (*e.g.* endemic species in crops), this could also be important in terms of weed flora origin explorations and analogue habitat comparisons. As we shown on Fig. 5, the most important biotopes which play a donator role are screes, wastelands, xerothermophilous swards and shrubs, and river bed vegetation. Excluding the wastelands (ruderal vegetation) as a secondary habitat, the other seems to be similar in terms of pH value, humidity, thermicity and insolation in comparison to agrocoenoses. It is in line with the conclusions regarding the origin of segetal weeds in Europe (Zając, 1979).

The most significant chorological elements within the cereal weed flora in Tajikistan are Irano-Turanian (55%), pluriregional (16%), cosmopolitan (14,5%) and Mediterranean (9%) species. It is worth noting that among Irano-Turanian species, approximately 50% are restricted to the Middle Asia area (Kyrgyzstan, Tajikistan, northern Afghanistan, Turkmenistan and Uzbekistan). This is completely different proportion as we compare it to the European segetal floras. In Europe the field vegetation consists mainly of alien species (so called archaeophytes and kenophytes) which could have share of 50-70% (*e.g.* Nowak, 2007; Anioł-Kwiatkowska, 1990). From one point of view this may have a consequence in higher number of well adapted and nuisant weed occurrence in Tajik agrocoenoses. But from another, the share of native and even endemic species in anthropogenic habitat of cultivated field has to change the attitude to conservation of some weeds and their habitats. The fact that also several dozens of unique species of very restricted range (endemics and subendemics) were spotted in cereal crops needs consideration while weeding and raising the effectiveness of crop production. This situation is significant for the protection of field habitats and their floristic diversity, since it turns out that anthropogenic habitats may constitute ephemeral or even permanent habitats for unique endemic species, which constitute one of the most important plant groups in conservation biology (*e.g.* Pinke *et al*., 2011). As the analysis of endangerment level of Tajik weed flora shows, despite the low intensity of agriculture and poor farming techniques, a numerous group of taxa has retreating tendency and was classified as threatened. Intensification of farming, crop rotation, reduced soil tillage, effective seed cleaning, intensive use of fertilizers, modern harvesting and

threshing technologies, landscape simplification, the abandonment of low productive sites, and weed control could caused significant changes in weed flora of Tajikistan and severe decline of many plants typical not only for agrocoenoses. Nowadays there are still many extensively farmed fields under very poor agricultural management with conditions suitable for the existence of rare weeds. Among them are taxa originating on rocky slopes and screes (*e.g. Arabidopsis korshinskyi*, *Cousinia hastifolia* or *Silene gasimailikensis*), semi-deserts (*e.g. Cousinia ambigens*, *C. dichromata* or *Onopordum seravshanicum*), steppes (*e.g. Astragalus acormosus*, *Cousinia integrifolia* or *Silene gasimailikensis*) or xerothermophilous swards (*e.g. Nigella bucharica* or *Prangos fedtschenkoi*). Most of them have the only currently existing populations only in the secondary habitats of agrocoenoses. Endemic species enter segetal communities for various reasons, the main one being the great extensiveness of crops, especially in mountain valleys and basins at high altitudes, where fields frequently lie fallow. Under these conditions, the permanent existence of perennials (such as *Salvia komarovii*, *Astragalus acormosus* or *Euphorbia sogdiana*) in farmlands is possible. Other reasons include frequently occurring landslides and screes, which encroach on fields and change the soil seed bank by carrying species from neighbouring phytocoenoses into segetal communities. Primitive farming, including infrequent sowing, enables the coexistence of several taxa from beyond field habitats. Although they are somewhat unique, a considerable share of endemic species in segetal communities have been observed in other countries with a Mediterranean or warm temperate climate, such as Turkey or Hungary (*e.g.* Türe & Böcük, 2008; Pinke *et al.*, 2011).

Conducting the analysis of weed occurrence in Tajikistan it is also important to mention, that unlike many other regions of the world, the share of invasive aliens is still negligible in field phytocoenosis of that country. Even species known for their invasive potential, such as *Galinsoga parviflora* or *G. ciliata*, make up a very small share or occur on the peripheries of field phytocenoses (Nowak *et al.*, 2013b, c).

Due to sensibility of arid regions to climate change, there is still a need to conduct conservation analyses and research in crop plantations of Tajikistan and Middle Asia (Shakoor *et al.*, 2011). As well, basic chorological analyses and distributional pattern evaluations will be of great importance for the recognition of weed species origin as well as for the optimisation of weed control (Hussain & Ali, 2006). Bearing in mind the possible changes in agricultural intensity in Tajikistan aimed at increasing crop production, the implementation of a special campaign to stop the disappearance of rare field species in one of the world's cradles of weeds (Vavilov, 1951) must be also considered.

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