Sektion 2: Populationsdynamik und Biodiversität

Section 2: Population dynamics and biodiversity

Arable weed flora in the Western Siberian grain belt

Segetalvegetation des Westsibirischen Getreidegürtels

Immo Kämpf[1,2*], Norbert Hölzel[2], Insa Kühling[1], Kathrin Kiehl[1]

[1]Faculty of Agricultural Sciences and Landscape Architecture, Osnabrück University of Applied Sciences, Oldenburger Landstr. 24, 49090 Osnabrück, Germany

[2]Institute of Landscape Ecology, University of Münster, Heisenbergstr. 2, 48149 Münster, Germany

[*]Corresponding author, immokaempf@uni-muenster.de

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Abstract

Between Ekaterinburg and Nowosibirsk, in the Western Siberian grain belt, spring wheat is grown on fertile Chernozem soils. Field and farm sizes are large but the land-use intensity per area is low compared to Central Europe. Fertilizers and pesticides are applied only in low to moderate quantities and yields range between 10 and 20 dt ha^{-1}. We studied the arable weed flora in the northern forest steppe zone of Tyumen region using a randomized sampling design. Surprisingly, the species richness was only moderate, on average 9.8 ± 3.8 species per 100 m^2. Compared to weed communities of Bashkiria (Southern Ural) and less intensively used arable land of Central Europe these numbers are rather low. Moreover, most of the recorded species were cosmopolitans or widely distributed throughout the temperate zone. We suggest that the land use intensity was high enough to reduce the density of a number of weed species in a way that they were not registered by our random sampling design. The limited conservational value of the weed vegetation of large grain fields in Tyumen leads to the conclusion that if intensification of land use is unavoidable, it should be directed to arable land and not to ex-arable land or ancient grassland, which is of higher conservation value.

Keywords: Cropland, land use, phytodiversity, segetal vegetation, summer wheat, Tyumen

Zusammenfassung

Die fruchtbaren Schwarzerden im Westsibirischen Getreidegürtel zwischen Jekaterinburg und Nowosibirsk werden großflächig mit Sommergetreide bestellt. Trotz des großen Anbaumaßstabes ist die Landnutzungsintensität pro Flächeneinheit gering, wenn man sie mit Mitteleuropa vergleicht. Der Einsatz von Düngemitteln und Pestiziden ist niedrig, und die Erträge liegen zwischen 10 und 20 dt ha^{-1}. Die Verteilung der Probenflächen erfolgte mittels eines randomisierten Samplingdesigns mit 99 Probenflächen à 100 m^2 im Tjumener Gebiet des Getreidegürtels. Überraschenderweise war der Artenreichtum mit einem Mittelwert von 9,8 ± 3,8 Arten niedriger, als bei der geringen Landnutzungsintensität zu erwarten wäre. Verglichen mit Ackergemeinschaften Baschkiriens (Südural) und extensiv bewirtschafteten Flächen in Mitteleuropa sind diese Artenzahlen gering. Außerdem waren die meisten erfassten Arten Kosmopoliten oder in großen Teilen der gemäßigten Zone verbreitete Arten. Aus unseren Ergebnissen schlussfolgern wir, dass die Landnutzungsintensität in Tjumen hoch genug ist, um die Dichten einer Reihe von Segetalarten so zu reduzieren, dass sie mit einem randomisierten Samplingdesign nicht mehr oder nur in geringen Stetigkeiten nachzuweisen sind. Die Unterschiede zum Artenreichtum Mitteleuropäischer Äcker ergeben sich auch aufgrund des geringen Anteils von Archäophyten in der Flora von Tjumen. Hieraus folgt, dass, wenn eine Steigerung der Landnutzungsintensität im Getreidegürtel Westsibiriens unvermeidbar ist, sie auf Ackerflächen stattfinden sollte und nicht auf Ackerbrachen oder Grünlandflächen, die einen höheren naturschutzfachlichen Wert besitzen.

Stichwörter: Acker, Landnutzung, Phytodiversität, Segetalvegetation, Sommerweizen, Tjumen

Introduction

Land-use intensification and the abandonment of marginal land have resulted in the dramatic decline of the biodiversity of agroecosystems in most highly industrialized regions of the world

(STOATE et al., 2001; PEREIRA et al., 2010). In Europe, the proportion of threatened arable plant species per country increases with national wheat yields, and the application of agrochemicals such as fertilizers and herbicides is the most important driver of biodiversity loss on arable land (STORKEY et al., 2012). Nevertheless, the intensification of land use is often considered as without alternative and there is an ongoing debate on how biodiversity conservation and food production can be combined (TSCHARNTKE et al., 2012).

In the Western Siberian grain belt, field and farm sizes are large but the land-use intensity per area is low compared to Central Europe. Fertilizers and pesticides are applied only in low to moderate quantities and yields range between 10 and 20 dt ha^{-1} (ROSSTAT, 2010). Spring wheat is grown on fertile Chernozem soils, but in the continental climate the agricultural production is constrained by a short growing season and generally poor drainage capacity of the Western Siberian lowland. Although 30% of Russia's arable land is found in the Western Siberian grain belt very little information on the arable weed vegetation is available. MIRKIN et al. (1985) have classified the segetal vegetation in the Bashkir Transural region, but no study exists on the phytodiversity of arable land the Western Siberian grain belt up to now.

The aim of our study is i) to describe the weed vegetation of the Tyumen region, which is located in a central part of the Western Siberian grain belt, and ii) to analyze the effect of land use on the phytodiversity of arable land in this region.

Materials and Methods

Study area

The study area is located in the southern part of the Tyumen region, within the temperate forest steppe zone in the Southwest of the Western Siberian lowland. All sampling was carried out within the SASCHA project (SASCHA, 2015) in three test areas of 20 km x 20 km in size, which are spaced about 150 km apart along a climatic gradient spanning northwest to southeast. The northern test area (*TA North*) is part of the hemi-boreal forest eco-region or *pre-taiga* as referred to in Russian literature (e.g. VOROBEV and BELOV, 1985; WALTER and BRECKLE, 1991). About 100 km south of Tyumen city the hemi-boreal zone is followed by the forest steppe zone. Here, the zonal vegetation consists of a macro-mosaic of birch forests and meadow steppe grasslands (SELEZNEVA, 1973). Within this eco-zone *TA Center* is situated around the small town of Omutinsk, and *TA South* is located 25 km south of the city of Ishim.

The climate is continental with a short vegetation period of 160 days (SELEZNEVA, 1973). The aridity increases from humid in TA *North* to sub-humid in TA *South* (TRABUCCO and ZOMMER, 2009) with mean annual precipitation and temperature of 476 mm and 1.8 °C in Tyumen city and 401 mm and 1.7 °C in Ishim, respectively (DEGEFIE et al., 2014). The parent material for soil development consists of calcareous loess-like sediments (FRANZ, 1973). Main soil types used for arable farming are Chernozems and Phaeozems (SHAHGEDANOVA, 2002). However, gleyic horizons are common in all soil types because of the poor drainage capacity of the Western Siberian plain and extreme seasonal groundwater-level changes (SHAHGEDANOVA, 2002). Due to its location in the fluvial terrace of the Tura river, TA *North* is less elevated (60 m a.s.l.) than TA C*enter* and TA S*outh* (120 m a.s.l.) and has a higher proportion of organic soils.

Tab. 1 Averaged land-use indicator values for arable land over three time steps from 1996 to 2013 for the three test areas of Tyumen region.

Tab. 1 *Mittelwerte des Landnutzungsindikators für Ackerland von 1996 bis 2013.*

Test Area	Rayon (district)	Land use indicator
TA *North*	Tyumenskiy	0,270
TA *Center*	Omutinskiy	0,138
TA *South*	Ishimskiy, Berdyuzhskiy, Kazanskiy Berdyuzhskiy	0,251

The land use intensity for arable land of the Tyumen districts (rayons) was calculated in means of an indicator by KÜHLING et al. (submitted) by using the fertilizer inputs, the proportion of cropland per province and the proportion of grain crops (Tab. 1). For TA *South* the indicator was calculated as average of the three districts' land use indicators that intersect in this test area, weighted by the area proportion.

Study design and statistical analyses

For the allocation of sampling sites to arable land within the three test areas we used a randomized sampling design. The minimum distance between plots was 500 m and the plots were at minimum 100 m away from the field margin. During the summers of 2012 and 2013, 99 plots 100 m² in size were sampled. Nomenclature of vascular plants follows the standard list for Russia and adjacent countries (CHEREPANOV, 1995). To analyze the completeness and diversity of the Tyumen weed communities we compared our relevés with relevés from the "Segetal communities of Bashkiria" (MIRKIN et al., 1985). Bashkiria = Bashkir Transural region is located at the same latitude as Tyumen region but directly west of the Ural Mountains. Similar to Tyumen region arable land is found in the forest-steppe and partly steppe ecozone. In our study, the effect of spraying was tested on an experimental site near to TA S*outh* by sampling spray windows that originated from spatial inaccurate application of the herbicide. The spray windows were identified by tracking the route of the sprayer with a GPS device. Sprayed plots were sampled adjacent to the spray window plots on the same field.

The status of origin for all registered species was obtained by analyzing areal diagnostics (MEUSEL and JÄGER, 1965, 1978, 1998), ecological species descriptions (KOMAROV et al., 2004) and distribution maps (HULTEN, 1971). The "Flora of Tyumen", an unpublished Flora by Igor KUZMIN (Tyumen) was used to determine if a species is part of the flora of Tyumen region.

Results

By using phytosociological methods following the classification from Bashkiria of MIRKIN et al. (1985), 86 of the 99 relevés could be assigned to the alliances *Galeopsion bifidae* (35 relevés), *Achillion millefolii* (20 relevés) and *Caucalidion lappulae* (21 relevés) (Tab. 2). Ten relevés contained a mixture of characteristic species from the *Galeopsion* and *Achillion*. However, many relevés seemed to be impoverished. Several relevés contained only one diagnostic species, many diagnostic species had low frequencies and the *Caucalidion* characteristic species *Stachys annua* was completely absent. Especially the *Caucalidion* was not well characterized. Moreover, 13 relevés could not be assigned to any plant community due to the lack of diagnostic species.

Species richness of vascular plants was 9.8 ± 3.8 species per 100 m² (mean ± 1 SD) and was neither affected by climatic differences nor by differences of land-use intensity between the three test areas (Fig. 1). The mean weed cover was highly variable with average values of 12% ± 11%. The comparison of the total species lists revealed that most of the weed species from Bashkiria also occur in Tyumen region. There was no annual arable weed species from the *Galeopsion bifidae* and the *Lactucion tataricae* of Bashkiria, which is not part of the Tyumen flora. Although some of these species were not found on the 99 randomized sampling plots, they were recorded by chance outside of the plots or in other habitat types: *Arenaria serpyllifolia*, *Buglossoides arvensis*, *Capsella bursa-pastoris*, *Galeopsis ladanum*, *Potentilla norvegica*, *Sinapis arvensis*, *Stachys annua* and *Trifolium arvense*, or were listed in the Tyumen flora: *Apera spica-venti*, *Brassica campestris*, *Consolida regalis*, *Galeopsis speciosa*, *Myosotis arvensis* and *Neslia paniculata* (this list includes only species with higher frequency than 2 occurrences in MIRKIN et al. (1985) relevés.

Tab. 2 Diagnostic species frequencies (%) of the weed vegetation of the Western Siberian grain belt sorted by the classification of MIRKIN et al. (1985). *Gal & Ach* = relevés with diagnostic species from the *Galeopsion bifidae* (Gal) and the *Achillion millefolii* (Ach). *Secalieta* and attendant species are not displayed.

***Tab. 2** Stetigkeiten (%) der diagnostischen Arten der Segetalvegetation des Westsibirischen Getreidegürtels, pflanzensoziologische Sortierung nach MIRKIN et al. (1985). Secalietea-Arten und Begleiter sind nicht dargestellt.*

	Galeopsion	***Gal & Ach***	***Achillion***	***Caucalidion***	***no diagnostic species***	**total**
mean no. of species	11	14	10	9	7	10
n	35	10	20	21	13	99
Galeopsion bifidae						
Galium aparine	67	60	15	24	0	32
Galeopsis bifida	61	50	0	5	0	23
Cannabis ruderalis	56	60	5	10	0	23
Viola arvensis	33	30	10	5	0	15
Fumaria officinalis	31	30	0	0	0	11
Camelina microcarpa	14	10	0	0	0	5
Spergula arvensis	3	10	0	0	0	1
Oberna behen	3	10	0	5	0	2
Stellaria media	3	0	0	0	0	1
Lycopsis arvensis	0	0	5	5	0	2
Achillion millefolii*						
Tripleurospermum perforatum	0	0	35	5	0	8
Taraxacum officinale	31	50	85	24	0	33
Linaria vulgaris	17	40	35	10	0	15
Nonea pulla	8	10	25	10	0	10
Elytrigia repens	11	30	20	0	0	8
Plantago major	11	20	10	0	0	6
Polygonum aviculare	6	20	5	0	0	3
Artemisia vulgaris	3	10	5	0	0	2
Crepis tectorum	3	10	0	5	0	2
Berteroa incana	3	10	0	0	0	1
Melilotus officinalis	3	10	0	0	0	1
Pastinaca sativa	0	0	5	0	0	1
Dracocephalum thymiflorum	0	0	5	0	0	1
Lepidium ruderale	3	0	0	0	0	1
Caucalidion lappulae						
Lathyrus tuberosus	11	20	20	57	0	20
Panicum miliaceum	3	0	5	29	0	8
Lactuca tatarica	0	0	0	10	0	2
Centaurea cyanus	3	10	0	10	0	3

*This group also contains species from other ruderal plant communities, i.e. *Plantaginetalia majoris* and *Artemisietea vulgaris*

The analysis of spray windows showed that herbicide application had a negative effect on plant species richness (Fig. 2). Analyses of distribution maps, areal diagnostics and ecological species descriptions revealed the floristic status for the weed species of all relevés (Tab. 3). The majority of the species originated from natural habitats. Most of the native species were cosmopolitans or were distributed throughout the whole temperate zone of Eurasia. Only 26% of the species were archaeophytes or anecophytes, most of them with a Mediterranean origin. The two detected Neophytes *Amaranthus retroflexus* and *Conyza canadensis* originated from America. Only 10 species had their main areal in Asia or Eastern Europe, namely *Camelina microcarpa*, *Cannabis ruderalis*, *Dracocephalum thymiflorum*, *Fagopyrum tataricum*, *Lactuca tatarica*, *Lappula squarrosa*, *Lathyrus tuberosus*, *Malva pussila*, *Nonea pulla* and *Thlaspi arvense*.

Tab. 3 Status of origin for the species from 99 relevés on arable land in the Western Siberian grain belt (n = 87)

Tab. 3 *Herkunft der Arten der Segetalvegetation des Westsibirischen Getreidegürtels (n = 87).*

Floristic status	no. of species
native species	55
archaeophytes or anecophytes	23
crop species	7
neophytes	2

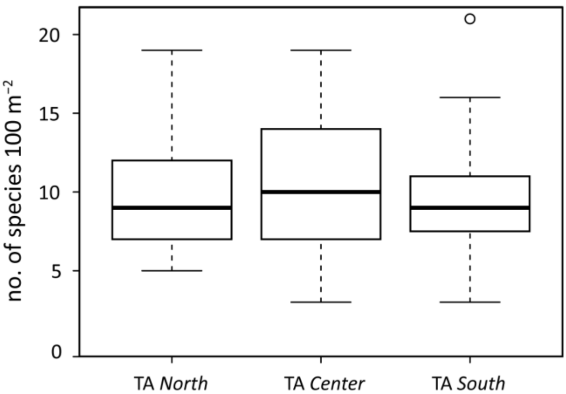

Fig. 1 Floral species richness in arable land of the Western Siberian grain belt along a climatic gradient from N to S (sample sizes: TA N*orth*=29, TA *Center*=30, TA *South*=40).

Abb. 1 *Artenreichtum der Äcker des Westsibirischen Getreidegürtels entlang eines klimatischen Gradients von N nach S (Stichprobenumfang: TA North=29, TA Center=30, TA South=40).*

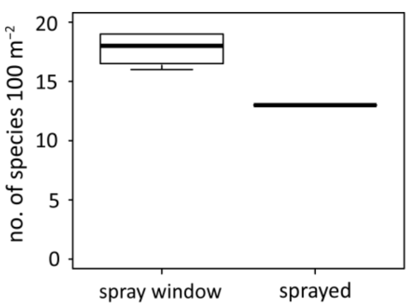

Fig. 2 The effect of herbicide application on the floral species richness of weeds in the Western Siberian grain belt (n = 4 in each of the two variants).

Abb. 2 *Einfluss von Herbizidanwendung auf den floristischen Artenreichtum von Unkrautgemeinschaften im Westsibirischen Getreidegürtel (n = 4 in jeder der beiden Varianten).*

Discussion

The analysis of weed vegetation of the Tyumen region revealed no effects of land-use intensity and climate on species richness. However, the registered species richness was rather low compared to the *Caucalidion* and *Galeopsion* communities in Bashkiria, where MIRKIN et al. (1985) with few exceptions found in general 10 to 20 and partly even 20 to 30 vascular plant species on 100 m^2 plots. Although Bashkiria is about 800 km west of Tyumen region the comparison is reasonable because the relevés were from the same ecozone and the set of species in the relevés from Bashkiria is very similar to the species set which we recorded in Tyumen region. Although our records from Tyumen could partly be assigned to phytosociological units described for Bashkiria, the weed communities of our study region seems to be impoverished, as many diagnostic species had only low frequencies. Since the entire weed species found in Bashkiria are part of the Tyumen flora we conclude that on a larger scale all weed species probably would be present on arable fields. The density of some of the species, however, was strongly reduced by the agricultural management, which results in lower species numbers on plot scale. That species richness of weed vegetation is negatively affected by an agricultural management that is of low intensity when compared with Central Europe was also shown by MIRKIN et al. (2007). They analysed the effect of post-soviet reduction of arable land-use intensity in Bashkir Transural region by comparing relevés from 1985 and 2002 and found an increase of average species numbers from 16 to 21 in the *Galeopsion bifidae* and 9 to 14 in the *Lactucion tataricae*. The increase of species numbers was accompanied by an increase of perennial weeds and grassland species.

In general, the most important management limitations for weed species are high crop densities, efficient seed cleaning and high application rates of fertilizer and herbicides (STORKEY et al., 2012). In Tyumen region crop densities are usually low and fertilizers are applied in low quantities (ROSSTAT, 2010). Therefore, we suggest that herbicide application possibly is one of the main responsible factors for reduced weed densities in Tyumen region (Fig. 2). However, the smaller species richness of Tyumen weed communities compared to Bashkiria can also be a result of methodological differences. In contrast to our randomized sampling design, which avoided for example possibly more species-rich field margins, MIRKIN et al. (1985) used a subjective, targeted sampling design probably choosing only well-developed weed stands. It remains unclear to what extent the differences in species richness are caused by these methodological differences.

The field interior of intensively managed fields in Europe is almost free of weeds, and weeds are restricted to the field margin, for instance with an average of 24 species on 100 m^2 stripes of field margin (SIMMERING et al., 2013). SEIFERT et al. (2014) recorded on average only roughly 4 species in the field interior and about 10 species at the field margin. In contrast, in Tyumen weeds were present in moderate and occasionally high densities all over the fields. On the other hand arable weed species richness in Central Europe is much higher than in Western Siberia when compared with fields managed according to agro-environmental schemes: about 20 species on average in the field interior (SEIFERT et al., 2014) or when compared with sampling sites, which are chosen in well-developed stands: 30 to 40 species in the segetal vegetation of the Czech Republic (KROPAC, 2006).

The generally low species richness in Tyumen weed vegetation may also be explained by the scarcity of archaeophytes in the Tyumen flora. Archaeophytes are an important part of the Central European weed flora, especially the *Caucalidion* is build up by many thermophilous archeophytic species (KROPAC, 2006). Most of these species originate from the Mediterranean or Southwest Asia which is why many of them reach their eastern distribution limit already west of the Ural Mountains. Due to the extreme continental climate, especially the winter in Tyumen is probably not warm enough for many archaeophytes, which are often winter annuals. Evidence for the negative effect of harsh climate on archaeophytes was also given by LOSOSOVA et al. (2004), who found decreasing numbers of archaeophytes with increasing altitude. Correspondingly, in Yakutia (Eastern Siberia) – where the climate is extremely cold and arid – weed vegetation has a low cover, is species poor and monotonous: 10–13 species in the southern and 5–10 species in the northern part (MIRKIN et al., 1988).

Conclusion

Despite the low land-use intensity the plant species richness of the Tyumen weed vegetation was low and contained only very few species specific for the region. Results of the SASCHA project show that on the contrary ancient grassland vegetation and also ex-arable land that was left to succession had a significant higher conservation value. We conclude that if an intensification of land use in Tyumen region is unavoidable, it should concentrate on arable land and avoid the (re-) cultivation of ex-arable land and ancient grassland.

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