The influence of farming on weed flora in the Gäu region of Southwestern Germany with an emphasis on rare arable weed species

Einfluss der Bewirtschaftung auf die Unkrautflora und insbesondere seltene Ackerunkräuter der Gäu-Region von Baden-Württemberg

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Abstract

Highly developed weed control strategies manage to suppress weeds and therefore contribute to a shift in weed community composition as well as a decline in rare weed occurrence. To counteract this decline fields containing rare weed species are taken under contract for preservation purposes, however only time limited. We mapped the weed flora in cereals of conventional (K) and organic (O) fields as well as current (V) and former (E) rare species conservation fields in the Gäu region of Southwestern Germany in 2016. We found similar weed species numbers in O (24 - 38 species) and V (36 - 43 species) and in C (7 - 17 species) and E (13 - 15 species). Weed community composition varied considerably between fields. By performing a CCA (Canonical Correspondence Analysis) we were able to explain 23% of the weed community composition by the parameters seeding rate and nitrogen fertilization. Nevertheless species such as *Alopecurus myosuroides*, *Geranium dissectum*, *Papaver rhoeas*, *Poa trivialis* and *Veronica persica* showed a high consistency in all observations. Rare and endangered weed species like *Papaver argemone*, *Consolida regalis*, *Ranunculus arvensis* and *Galium tricornutum* were only present in V and occasionally E and O. This indicates a rapid decline of weed species diversity after contracts expire, which slowly leads to a similar floral composition as in conventional fields. Therefore new concepts for constant protection of rare weed species should be put into action to ensure conservation success.

Keywords: Arable weed species, farming, species conservation, weed community

Zusammenfassung

Durch hoch entwickelte Unkrautbekämpfungsmaßnahmen werden Unkräuter effektiv unterdrückt, was im gleichen Zuge zu einer Veränderung der Zusammensetzung der Unkrautflora sowie dem Rückgang von selteneren Arten führt. Um dieser Entwicklung entgegenzuwirken und Arten zu schützen, werden Flächen mit seltenen Arten unter Naturschutz-Vertrag genommen, jedoch meist nur zeitlich begrenzt. Wir kartierten 2016 in der Gäu-Region Baden-Württembergs die Unkrautflora konventioneller (K) und ökologischer (O) Getreideflächen sowie früherer (E) und aktueller (V) Schutzäcker. Die Unkrautartenzahlen waren zwischen O (24 – 38 Arten) und V (26 – 43 Arten) sowie zwischen C (7 – 17 Arten) und E (13 – 15 Arten) sehr ähnlich. Die Zusammensetzung der Unkrautflora variierte beträchtlich zwischen den untersuchten Flächen. Mithilfe einer Kanonischen Korrespondenzanalyse (CCA) war es möglich, 23 % dieser Variation durch die Parameter Aussaatstärke und Stickstoffdüngung zu erklären. Trotzdem zeigten einige Arten wie *Alopecurus myosuroides*, *Geranium dissectum*, *Papaver rhoeas*, *Poa trivialis* und *Veronica persica* eine hohe Stetigkeit in allen untersuchten Flächen. Seltene und gefährdete Unkrautarten wie *Papaver argemone*, *Consolida regalis*, *Ranunculus arvensis* und *Galium tricornutum* waren nur in aktuellen Vertragsflächen vorhanden und traten gelegentlich in E oder O auf. Dies weist auf einen Rückgang der Artenvielfalt hin, sobald die Verträge für diese Äcker auslaufen. Die Unkrautflora nähert sich dann kontinuierlich der Florenzusammensetzung von konventionellen Flächen an. Um einen dauerhaften Erhalt der seltenen Arten zu garantieren, sollten deshalb neue Entwürfe zum Artenschutz entwickelt und umgesetzt werden.

Stichwörter: Ackerwildkräuter, Artenspektrum, Artenschutz, Bewirtschaftung

Introduction

After the invention of herbicides in the early 1950s, agriculture was the main driver of weed species losses. In addition to herbicides also improvements in soil tillage, increased fertilizer application and the Green Revolution led to a steep decline in weed species numbers from then on (Albrecht and Mattheis, 1998; Meyer et al., 2013; Hyvönen and Salonen, 2002). Not only the number of weed species but also weed coverage in general decreased over the years (Meyer et al., 2015). A lot of the weed species that were not able to cope with the intensification of agriculture are nowadays highly endangered or even extinct (MEYER et al., 2013). Instead of a rich weed flora on the fields, a community dominated by few weed species evolved, which were able to survive intensive farming (HILTBRUNNER et al., 2008). More and more of these weed species also demonstrate resistance to current herbicides (HEAP et al., 2013).

To counteract this species loss, conservation concepts were developed to protect the remaining rare arable weeds, such as conservation fields, field margin strips and extensification of farming. These concepts often involve a contract between the government and the farmer, which states explicitly the permitted farming operations and the compensatory payments in return. Contracts are normally effective to protect these species, but are time limited.

We surveyed the weed flora of conventional and organic fields as well as current and former weed conservation fields to determine (i) if rare weed species are still present in former contract fields, (ii) if the weed community composition differs between the farming types and (iii) which farming operations affect the weed community in particular.

Materials and Methods

Experimental region

Observations were performed in the region “Gäu” in Baden-Württemberg (Southwestern Germany). This region is located between the Black Forest and the Swabian Alps. The parent rock material is Muschelkalk and in some locations Unterer Keuper (clay or sandstone). Soil types in this region range from sandy clay to heavy clay soils.

Experimental setup

Experimental fields were got from the District Office for Nature Conservation. The obtained cereal fields were either currently under contract (V) due to the occurrence of rare arable weed species or have been in the past (E). In addition conventionally (K) and organically (O) farmed cereal fields with the same site characteristics were mapped in the vicinity of these contract fields. In total the survey comprised 4 K, 4 O, 3 V and 3 E fields.

Fields were mapped according to the method of VAN ELSEN (1989). The extended BRAUN-BLANQUET scale (WILMANNS, 1998) was used to record weeds on a 2m by 50m strip on the field margin and a second strip in the middle of the crop stand.

Furthermore, a survey among the farmers was performed to obtain information about farming strategies such as crop choice, fertilization, weed control and crop rotation.

Statistical Analysis

Constancy of species among the observed fields was calculated using R (version 3.1.1). Species numbers were analysed with the standard analysis of variance (ANOVA) and means compared with a Tukey-HSD test ($p \leq 0.05$).

The 29 most constant weed species together with the farming data were subjected to a canonical correspondence analysis (CCA).

Results

Weed species numbers tended to be higher at the field margins compared to the middle of the fields. Furthermore organically farmed fields and contract fields showed a similar weed species diversity, while conventionally farmed fields and former contract fields had a much lower diversity.

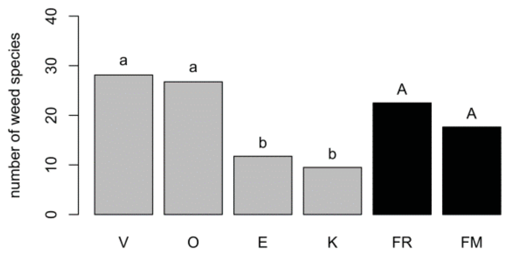

Fig. 1 Weed species numbers in conventional (K) and organic (O) fields as well as former (E) and current (V) conservation fields in the field margins (FR) or the field centre (FM). Bars represent mean values; significant differences (p≤0.05) are indicated by different letters.

Abb. 1 *Mittlere Unkrautartenzahlen in konventionell (K) und ökologisch (O) bewirtschafteten Äckern sowie ehemaligen (E) und aktuellen (V) Vertragsnaturschutz-Äckern am Feldrand (FR) und in der Feldmitte (FM). Signifikante Unterschiede (p≤0,05) sind mit unterschiedlichen Buchstaben gekennzeichnet.*

In winter wheat, 57 weed species were recorded of which 9 were constant throughout all the fields. These were namely: *Alopecurus myosuroides*, *Geranium dissectum*, *Myosotis stricta*, *Galium tricornutum*, *Papaver rhoeas*, *Poa trivialis*, *Taraxacum officinale*, *Veronica persica* and *Vicia villosa* ssp. *villosa*. Rare species like *Papaver argemone*, *Consolida regalis*, *Ranunculus arvensis* and *Galium tricornutum* had medium to low constancy and were mainly present in V, E and sometimes O fields.

Tab. 1 Weed spectrum and respective coverage (%) in winter wheat fields of conventionally (K) and organically (O) farmed fields as well as former (E) and current (V) conservation fields in condensed form. Underlined species are endangered in Baden-Württemberg.

Tab. 1 *Auszug des Ackerwildkrautspektrums und der jeweiligen Deckungsgrade (%) in konventionell (K) und ökologisch (O) bewirtschafteten Winterweizenfeldern sowie ehemaligen (E) und aktuellen (V) Vertragsnaturschutz-Äckern mit Winterweizen. Hervorgehobene Arten sind in Baden-Württemberg gefährdet.*

Scientific names	**Field margin**				**Field centre**			
	V	**E**	**K**	**O**	**V**	**E**	**K**	**O**
Alopecurus myosuroides	2	3	0	0.5	0	1	0	6
<u>*Consolida regalis*</u>	0.1	0	0	0	0.1	0	0	0
Convolvulus arvensis	12	17	1	25	0	5	0	35
<u>*Galium tricornutum*</u>	0.5	1	0	5	30	13	0	20
Geranium dissectum	8	2	0	0.1	0	0.1	0	5
Matricaria recutita	0	35	0	0	0	0.5	0	0
<u>*Myosotis stricta*</u>	10	18	0	15	0	2	0	12
<u>*Papaver argemone*</u>	0.5	0	0	0	0	0	0	0
Papaver rhoeas	15	1	0	9	0	0.1	0	0.5
Poa trivialis	1	1	0	8	0	0	0	1
<u>*Ranunculus arvensis*</u>	0	27	0	0.5	0	1	0	2
Secale cereale	0	0.5	3	0	0	1	0.5	0
Taraxacum officinale	7	1	0	25	0	0	0	30
Veronica persica	1	0.1	0	0.5	0	3	0	0

Due to incomplete farming data from the farmers, only nitrogen fertilization and seeding rates were quantified and used in the CCA. *Alopecurus myosuroides*, *Fumaria officinalis* and *Lamium purpureum* were associated with a high nitrogen rate. Low nitrogen fertilization and low seeding rates were associated with species such as *Anagallis arvensis*, *Cirsium arvense* and *Sherardia arvensis*, while *Myosotis arvensis* occurred under medium seeding rates. In toto, seeding rate and nitrogen fertilization were able to explain 23% of the weed community composition.

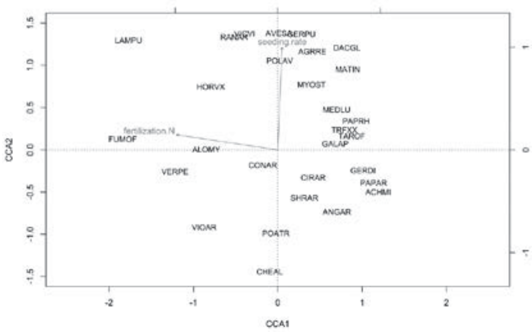

Fig. 2 Influence of farming operations on the composition of the weed flora: ordination graph of the Canonical Correspondence Analysis (CCA) with parameters seeding rate (seeding.rate) and nitrogen fertilization (fertilization.N). Total inertia was 2.7290, constrained inertia was 0.6371 with eigenvalues of 0.4388 (CCA1) and 0.01983 (CCA2) of the axes. Scientific plant names were substituted by their respective EPPO codes.

***Abb. 2** Einfluss der pflanzenbaulichen Maßnahmen Aussaatstärke und Stickstoffdüngung auf die Zusammensetzung der Ackerwildkrautflora: Ordinationsdiagramm der Kanonischen Korrespondenz Analyse (CCA) mit den Parametern Aussaatstärke (seeding.rate) und Stickstoffdüngung (fertilization.N). Die Gesamtvariabilität beträgt 2,7290, Variabilität der verwendeten Achsen ist 0,6371, die Eigenwerte der Achsen sind 0,4388 (CCA1) und 0,01983 (CCA2). Wissenschaftliche Pflanzennamen wurden mit EPPO-Codes abgekürzt.*

Discussion

Rare arable weed species that were present in the experimental region and considered to be endangered in Germany or Baden-Württemberg were: *Consolida regalis*, *Ranunculus arvensis*, *Galium tricornutum*, *Myosotis stricta*, *Papaver argemone* and *Valerianella rimosa*. Especially for the first two species Baden-Württemberg has a high responsibility, as they are not endangered in the experimental region yet, but extinct or highly endangered in most other parts of Germany (BREUNIG and DEMUTH, 1999).

Fields under contract, as well as organically farmed fields, seem to be most suitable for the conservation of weed biodiversity and especially rare species (CHAMORRO et al., 2014; ARMENGOT et al., 2012; VAN ELSEN, 2000). However, due to the limited spectrum of weed control options these rare species are threatened by highly competitive species such as *Cirsium arvense*, *Convolvulus arvensis* and *Elymus repens* (ARMENGOT et al., 2017).

It is therefore of paramount importance to conserve the present rare weed species (ROTCHÉS-RIBALTA et al., 2015a) by adequate farming operations (ROTCHÉS-RIBALTA et al., 2015b) without time limitations. Otherwise the weed community will inevitably change according to the implemented modern farming operations (RYAN et al., 2010).

The survival time of rare weed seeds in the soil is often quite short. As a consequence these species are lost rapidly. It is therefore of utmost importance to continue contracts of fields with existing populations to prevent this. The matter is even more exacerbated as climate change effects might further negatively affect rare species (RÜHL et al., 2015). To counteract this trend towards short term conservation a system similar to the „100 Fields for Diversity" project (MEYER et al., 2014) should be started, which established a dense network of protection fields all over Germany. This was realized by a close coordination between universities, farmers and nature conservation authorities with sufficient monetary and advisory support for the farmer. Especially the latter is highly important for long term collaboration.

In terms of weed community composition especially nitrogen fertilization favoured ordinary or even problematic weed species. The data regarding herbicide use of the farmers was unfortunately unavailable, but would have illuminated the process of weed community shifts (RYAN et al., 2010).

Occurring problematic weed species do not only threaten rare weed species but also the crop yield. To ensure crop safety and quality, integrated weed control strategies need to be put into action, but for the focus of diversity and nature conservation extensive methods are more suitable.

References

ALBRECHT, H. and A. MATTHEIS, 1998: The effects of organic and integrated farming on rare arable weeds on the Forschungsverbund Agrarökosysteme München (FAM) research station in southern Bavaria. Biological Conservation **86**, 347–356.

ARMENGOT, L., L. JOSÉ-MARÍA, L. CHAMORRO and F.X. SANS, 2017: *Avena sterilis* and *Lolium rigidum* infestations hamper the recovery of diverse arable weed communities. Weed Research **57**, 278–286.

ARMENGOT, L., F.X. SANS, C. FISCHER, A. FLOHRE, L. JOSÉ-MARÍA, T. TSCHARNTKE and C. THIES, 2012: The β-diversity of arable weed communities on organic and conventional cereal farms in two contrasting regions. Applied Vegetation Science **15**, 571–579.

BREUNIG, T. and S. DEMUTH, 1999: Rote Liste der Farn- und Samenpflanzen Baden-Württemberg. Landesanstalt für Umweltschutz Baden-Württemberg. Landesanstalt für Umweltschutz, Karlsruhe. 246 S.

CHAMORRO, L., L. ARMENGOT, L. JOSÉ-MARÍA and F.X. SANS, 2014: Organic farming enhances the recovery of ancient crops and segetal weeds in Catalonia (NE of Spain). Building Organic Bridges **3**, 979–982.

HEAP, I., 2013: Herbicide resistant weeds. Integrated Pest Management **3**, 281-301.

HILTBRUNNER, J., C. SCHERRER, B. STREIT, P. JEANNERET, U. ZIHLMANN and R. TSCHACHTLI, 2008: Long-term weed community dynamics in Swiss organic and integrated farming systems. Weed Research **48**, 360–369.

HYVÖNEN, T. and J. SALONEN, 2002: Weed species diversity and community composition in cropping practices at two intensity levels - a six-year experiment. Plant Ecology **154**, 73–81.

MEYER, S., C. LEUSCHNER, B. BLÜMLEIN and H. ALBRECHT– DEUTSCHE BUNDESSTIFTUNG UMWELT, DEUTSCHER VERBAND FÜR LANDSCHAFTSPFLEGE, 2015: 100 Äcker für die Vielfalt: Initiativen zur Förderung der Ackerwildkrautflora in Deutschland. Universitätsverlag, Göttingen. 351 S.

MEYER, S., K. WESCHE, B. KRAUSE and C. LEUSCHNER, 2013: Dramatic losses of specialist arable plants in Central Germany since the 1950s/60s - a cross-regional analysis. Diversity and Distributions **19**, 1175–1187.

MEYER, S., T. VAN ELSEN, B. BLÜMLEIN, M. KAERLEIN, J. METZGER, F. GOTTWALD, S. WEHKE, M. DIETERICH, W. WAHMHOFF, R. STOCK and C. LEUSCHNER, 2014: Conserving agrobiodiversity through arable field sanctuaries. Natur und Landschaft **9**, 434–41.

ROTCHÉS-RIBALTA, R., J.M. BLANCO-MORENO, L. ARMENGOT, L. CHAMORRO and F.X. SANS, 2015a: Both farming practices and landscape characteristics determine the diversity of characteristic and rare arable weeds in organically managed fields. Applied Vegetation Science **18**, 423–431.

ROTCHÉS-RIBALTA, R., J.M. BLANCO-MORENO, L. ARMENGOT, L. JOSÉ-MARÍA and F.X. SANS, 2015b: Which conditions determine the presence of rare weeds in arable fields? Agriculture, Ecosystems & Environment **203**, 55–61.

RÜHL, A.T., R.L. ECKSTEIN, A. OTTE and T.W. DONATH, 2015: Future challenge for endangered arable weed species facing global warming: Low temperature optima and narrow moisture requirements. Biological Conservation **182**, 262–269.

RYAN, M. R., R. G. SMITH, S. B. MIRSKY, D. A. MORTENSEN and R. SEIDEL, 2010: Management Filters and Species Traits: Weed Community Assembly in Long-Term Organic and Conventional Systems. Weed Science **58**, 265–277.

VAN ELSEN, T., 2000: Species diversity as a task for organic agriculture in Europe. Agriculture, Ecosystems & Environment **77**, 101–109.

VAN ELSEN, T., 1989: Ackerwildkraut-Gesellschaften herbizidfreier Ackerränder und des herbzidbehandelten Bestandesinneren im Vergleich. Tuexenia **9**, 75-105.

WILMANNS, O., 1998: Ökologische Pflanzensoziologie: eine Einführung in die Vegetation Mitteleuropas. 6. Auflage, Quelle & Meyer, Wiesbaden.

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