

Weeds and endangered herbs have unforeseen dispersal helpers in the agri-environment: gastropods and earthworms

Manfred Türke^{1,*}, Tamara Blattmann², Eva Knop², Anne Kindermann¹, Julia Prestele^{3,4}, Leonardo Marquez⁵, Nico Eisenhauer^{1,6} and Christina Fischer⁷

¹Research Department Ecology and Ecosystem Management, Terrestrial Ecology, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, D-85354 Freising-Weihenstephan, Germany.

²Institute of Ecology and Evolution, University of Bern, Baltzerstrasse 6, CH-3012 Bern, Switzerland.

³Bavarian State Research Center for Agriculture (LfL), Institute for Agro-Ecology, Organic Farming and Soil Protection, Lange Point 12, D-85354 Freising-Weihenstephan, Germany.

⁴Research Department Ecology and Ecosystem Management, Restoration Ecology, Technische Universität München, Emil-Ramann-Strasse 6, D-85354 Freising-Weihenstephan, Germany.

⁵Crop Protection Division, Philippine Rice Research Institute, Maligaya, Science City of Muñoz, PH-3119 Nueva Ecija, Philippines.

⁶Present address: Institute of Ecology, Friedrich-Schiller-University Jena, Dornburger Straße 159, D-07743 Jena, Germany.

⁷Research Department Ecology and Ecosystem Management, Landscape Ecology, Technische Universität München, Emil-Ramann-Strasse 6, D-85354 Freising-Weihenstephan, Germany.

*Corresponding author: manfred.tuerke@gmx.net

Accepted 11 December 2012

From the Field

Abstract

Agri-environmental schemes involving organic farming or set-aside management aim at promoting biodiversity and restoring ecosystem functioning in agrarian landscapes. Application of pesticides in these crop fields is strongly regulated facilitating the spread of weeds but also allowing for the establishment of endangered herbs and a variety of animals. Recent studies found gastropods and earthworms to be legitimate dispersers of seeds of wild plants. We assumed that both groups also play a significant role in the spread and establishment of wild plants within crop fields. Therefore, we are conducting a series of experiments in three different study systems on (1) the role of earthworms and gastropods as dispersers of rare herbs and weeds in an organic rye field in Germany, (2) the seed feeding behavior of gastropods of plants sown in fallow ground in Switzerland, and (3) weed dispersal in irrigated rice fields by golden apple snails in the Philippines.

Key words: seed dispersal, slugs, snails, crop field, feeding trial

Introduction

In the course of agricultural intensification, farmland biodiversity has declined due to the decrease of semi-natural habitats in agrarian landscapes and the increased application of pesticides and fertilizers, impairing a variety of ecosystem functions and services¹. Different approaches of agri-environmental management have been found to successfully restore biodiversity². Plant diversity that provides habitat and food for animals can be established at the border of crop fields by set-aside

management, e.g. wildflower strips, or within crop fields. Common weeds and rare arable herbs both profit from non-intensive or organic farming. While rare herbs are sown intentionally to strengthen their populations, weeds will colonize fields reducing crop yield³. Seed dispersal is essential for the viability and competitiveness of arable plant populations⁴. Most arable plant species, however, lack obvious adaptations for dispersal and rely on gravity when shedding their seeds⁴, which permits very limited dispersal distances unless seeds are transported by man³. Recent research highlights the importance of so far

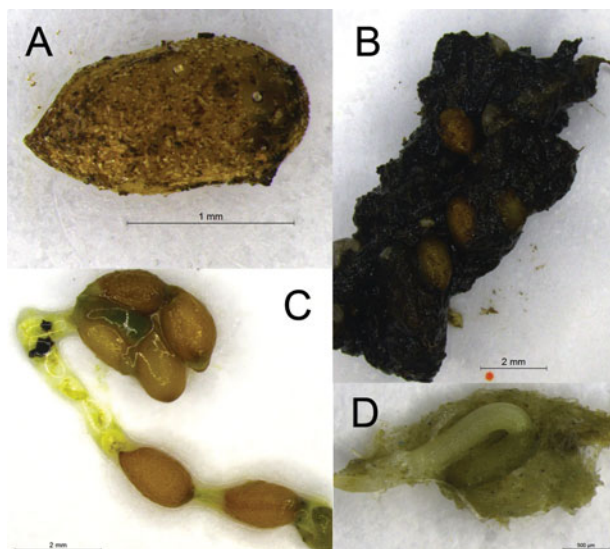


Figure 1. Seeds of field pansy (*Viola arvensis*) in (A, B) earthworm casts (*Lumbricus terrestris*) and in (C) slug feces (*Arion lusitanicus*), and (D) a seed of German chamomile (*Matricaria recutita*) germinating from slug feces.

underappreciated invertebrate taxa, in particular, gastropods⁵ and earthworms⁶ in the dispersal of seeds of herbs. Also in crop fields or adjacent wild flower strips, gastropods were responsible for the removal of a fair proportion of weed or herb seeds^{7,8}. We are conducting experiments within three projects to test the potential of gastropods, and partly also earthworms, to disperse seeds and also to predate on seeds of agricultural weeds and rare arable plants by the ingestion of seeds. In the following, we briefly present the three projects, their aims and first findings.

The Projects

Weeds and rare herbs in an organic rye field (Germany)

We established an organically managed rye field in Germany to assess the effects of management and animals on the establishment of rare arable wild herbs. A number of weeds are growing naturally in the field. We conducted seed removal experiments with five weeds and three rare herbs (Appendix 1) with one treatment accessible to all animals and one treatment protected against rodents. In addition, we used video cameras to identify all seed-feeding animals. In accompanying laboratory experiments, we offered seeds to two slug and two earthworm species of up to 15 plant species (animal species-dependent), including 12 common weeds and three rare herbs (Appendix 1), followed by germination experiments. Slugs and earthworms readily swallowed seeds of different species and defecated them mostly apparently intact (Fig. 1). Seeds of several species germinated after

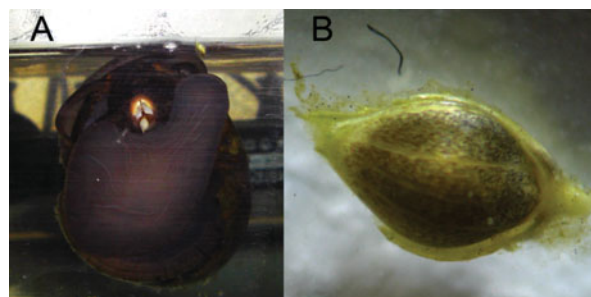


Figure 2. Seeds of common barnyard grass (*Echinochloa crus-galli*) (A) eaten by a golden apple snail (*Pomacea canaliculata*) and (B) collected from its feces.

being defecated. By screening the first videos, we observed rodents, carabids, earthworms and slugs visiting seed depots in the field, supporting the significance of interactions between seeds and the latter two invertebrate groups.

Herbs sown in fallow ground (Switzerland)

In a lab experiment, we fed four different gastropod species (*Arion lusitanicus*, *Arion rufus*, *Cepaea nemoralis* and *Helix pomatia*) with five different herb species often sown in fallow ground in Switzerland (Appendix 1). Consumption and damage of seeds after gut passage were assessed; defecated seeds were collected and put on soil to evaluate germination rates. We found high consumption rates in all mollusc species and for all five plant species. Furthermore, the seeds that had previously been defecated showed high germination rates, similar to those without gut passage. Our results therefore support our hypothesis that molluscs act as efficient and important seed dispersers of a wide range of plant species in agricultural landscapes.

Weeds in irrigated rice fields (Philippines)

Rice farmers in South-East Asia make a great effort to fight weeds. Exotic golden apple snails (*Pomacea canaliculata*) were introduced to control weeds in rice fields, amongst other things⁹. In most cases, however, the snails were a major pest, consuming rice plants⁹. We suggested that this invasive snail might also be spreading weeds in rice fields. Within the LEGATO project on land-use intensity and ecological engineering in irrigated rice (<http://www.legato-project.net/>), we collected seeds of 12 common weeds in the Philippines (Appendix 1), which currently are being offered to snails in feeding experiments. First observations in the laboratory showed that the snails readily consumed seeds of the troublesome barnyard grass *Echinochloa crus-galli* and defecated them apparently intact (Fig. 2). We will further conduct seed removal experiments and observations in rice fields in the Philippines.

Outlook

Our complementary experiments in multiple settings will help us to understand whether gastropods and earthworms are important for weed movement and the establishment of sown plants in the agri-environment. Based on our findings, it is possible that invertebrates such as slugs that dwell in planted wild flower strips might affect crop yields negatively if they transport weeds into the fields, even if they do not feed on the crop. Thus, it might be valuable to establish structured habitats at crop margins which do not promote these invertebrates but their predators. In environments where seed dispersal is beneficial, such as in ecological restoration, knowing which seed traits encourage dispersal, and which animals are important in dispersal, would be beneficial. In consideration of our preliminary results, we suggest that future research on weed ecology, dispersal and predation should take these invertebrate groups into account.

References

- 1 Tschardtke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., and Thies, C. 2005. Landscape perspectives on agricultural intensification and biodiversity—ecosystem service management. *Ecology Letters* 8:857–874.
- 2 Batary, P., Andras, B., Kleijn, D., and Tschardtke, T. 2011. Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. *Proceedings of the Royal Society B-Biological Sciences* 278:1894–1902.
- 3 Liebman, M., Mohler, C.L., and Staver, C.P. 2001. *Ecological Management of Agricultural Weeds*. Cambridge University Press, Cambridge, UK.
- 4 Benvenuti, S. 2007. Weed seed movement and dispersal strategies in the agricultural environment. *Weed Biology and Management* 7:141–157.
- 5 Türke, M., Andreas, K., Gossner, M.M., Kowalski, E., Lange, M., Boch, S., Socher, S.A., Müller, J., Prati, D., Fischer, M., Meyhöfer, R., and Weisser, W.W. 2012. Are gastropods, rather than ants, important dispersers of seeds of myrmecochorous forest herbs? *American Naturalist* 179:124–131.
- 6 Forey, E., Barot, S., Decaens, T., Langlois, E., Laossi, K.-R., Margerie, P., Scheu, S., and Eisenhauer, N. 2011. Importance of earthworm–seed interactions for the composition and structure of plant communities: a review. *Acta Oecologica–International Journal of Ecology* 37:594–603.
- 7 Fischer, C., Thies, C., and Tschardtke, T. 2011. Mixed effects of landscape complexity and farming practice on weed seed removal. *Perspectives in Plant Ecology Evolution and Systematics* 13:297–303.
- 8 Kollmann, J. and Bassin, S. 2001. Effects of management on seed predation in wildflower strips in northern Switzerland. *Agriculture, Ecosystems and Environment* 83:285–296.
- 9 Joshi, R.C. and Sebastian, L.S. (eds). 2006. *Global Advances in Ecology and Management of Golden Apple Snails*. Philippine Rice Research Institute, Munoz, Philippines.

Appendix 1. Plant species of which seeds were/will be offered in field seed removal experiments (=Field) or to gastropods and earthworms in laboratory feeding trials (=Laboratory).

Project	Plant species		Common name	Family	Laboratory ¹	Field ¹	
Germany	<i>Alopecurus myosuroides</i>	Huds.	Slender meadow foxtail	Poaceae	AL, LT, DV		
	<i>Apera spica-venti</i>	(L.) P. Beauv.	Silky bent grass	Poaceae	AL, LT, DV		
	<i>Capsella bursa-pastoris</i>	(L.) Medik.	Shepherd's purse	Brassicaceae	AL, LT, DV		
	<i>Cirsium arvense</i>	(L.) Scop.	Creeping thistle	Asteraceae	AL, DR, LT, DV	Yes	
	<i>Consolida regalis</i>	S.F. Gray	Forking larkspur	Ranunculaceae	AL, LT, DV	Yes	
	<i>Elymus repens</i>	(L.) Gould s. str.	Cough grass	Poaceae	AL, LT, DV		
	<i>Galium aparine</i>	L.	Cleavers	Rubiaceae	AL, LT, DV	Yes	
	<i>Legousia speculum-veneris</i>	(L.) Chaix	Venus' looking glass	Campanulaceae	AL, DR, LT, DV	Yes	
	<i>Lithospermum arvense</i>	(L.) I. M. Johnst.	Field gromwell	Boraginaceae	AL, LT, DV	Yes	
	<i>Matricaria recutita</i>	L.	German chamomile	Asteraceae	AL, LT, DV		
	<i>Poa trivialis</i>	L.	Rough bluegrass	Poaceae	AL, LT, DV		
	<i>Stellaria media</i>	(L.) Vill.	Common chickweed	Caryophyllaceae	AL, DR, LT, DV	Yes	
	<i>Thlaspi arvense</i>	L.	Field penny-cress	Brassicaceae	AL, DR, LT, DV	Yes	
	<i>Tripleurospermum perforatum</i>	(Mérat) Lainz	Scentless chamomile	Asteraceae	AL, LT, DV		
	<i>Viola arvensis</i>	Murray	Field pansy	Violaceae	AL, DR, LT, DV	Yes	
	Switzerland	<i>Valerianella locusta</i>	L.	Corn salad	Valerianaceae	AL, AR, CN, HP	
		<i>Melilotus albus</i>	(L.) Medik.	Honey clover	Fabaceae	AL, AR, CN, HP	
		<i>Brassica napus</i>	L.	Rapeseed	Brassicaceae	AL, AR, CN, HP	
		<i>Agrostemma githago</i>	L.	Common corncockle	Caryophyllaceae	AL, AR, CN, HP	
<i>Camelina sativa</i>		L. Crantz	False flax	Brassicaceae	AL, AR, CN, HP		
Philippines	<i>Chloris barbata</i>	Steud.	Swollen finger grass	Poaceae	(PC)	(?)	
	<i>Cyperus iria</i>	L.	Rice flat sedge	Cyperaceae	(PC)	(?)	
	<i>Digitaria ciliaris</i>	(Retz.) Koel.	Crab grass	Poaceae	(PC)	(?)	
	<i>Echinochloa crus-galli</i>	(L.) P. Beauv.	Barnyard grass	Poaceae	PC	(Yes)	
	<i>Echinochloa glabrescens</i>	Munro ex Hook. f.	Barnyard grass	Poaceae	(PC)	(?)	
	<i>Eleusine indica</i>	(L.) Gaertn.	Goose grass	Poaceae	(PC)	(?)	
	<i>Heliotropium indicum</i>	L.	Indian heliotrope	Boraginaceae	(PC)	(?)	
	<i>Ischaemum rugosum</i>	Salisb.	Wrinkled grass	Poaceae	(PC)	(?)	
	<i>Leptochloa chinesis</i>	(L.) Nees	Chinese sprangletop	Poaceae	(PC)	(?)	
	<i>Ludwigia octovalvis</i>	(Jacq.) Raven	Longfruited primrose-willow	Onagraceae	(PC)	(?)	
	<i>Paspalidium flavidum</i>	(Retz.) A. Camus	Yellow watercrown grass	Poaceae	(PC)	(?)	
	<i>Sphenoclea zeylanica</i>	Gaertn.	Gooseweed	Campanulaceae	(PC)	(?)	

Gastropods: AL = Spanish slug (*Arion lusitanicus* Mabille; syn.: *Arion vulgaris* Moquin-Tandon), DR = Grey field slug (*Deroceras reticulatum* O.F. Müller), AR = Red slug (*Arion rufus* L.), CN = Grove snail (*Cepaea nemoralis* L.), HP = Roman snail (*Helix pomatia* L.), PC = Golden apple snail (*Pomacea canaliculata* Lamarck). Earthworms: LT = common earthworm (*Lumbricus terrestris* L.), DV = European nightcrawler (*Dendrobaena veneta* Rosa; syn.: *Eisenia hortensis* Michaelsen).

¹ Parentheses indicate that experiments are planned.