BOTANY LETTERS, 2016
VOL. 163, NO. 4, 351–354
http://dx.doi.org/10.1080/23818107.2016.1236290

FOCUS EDITORIAL

Agroecology and conservation of weed diversity in agricultural lands

Sabrina Gaba[a], Xavier Reboud[a] and Guillaume Fried[b]

[a]Agroécologie, AgroSup Dijon, INRA, Université Bourgogne Franche-Comté, Dijon, France; [b]Laboratoire de la Santé des Végétaux, Anses, Unité entomologie et plantes invasives, CBGP, 755 avenue du campus Agropolis, Montferrier-sur-Lez cedex, France

This issue, entitled *Agroecology and conservation of weed diversity in agricultural lands*, gathers together several contributions on the functional role of weeds in two contrasting agricultural contexts, namely arable field and vineyard, and on the strategies for weed biodiversity conservation in farmlands.

Arable weeds are usually defined as all non-crop species found in a cultivated field. In regions considered as the birthplaces of agriculture, regular soil disturbances induced by agricultural practices have created suitable habitats for some well-adapted native plants (apophytic species). With the development of agriculture, this set of species strongly associated with arable lands have been diversely introduced to other regions of the world, where they progressively enriched the regional pool of arable weeds in addition to the local (apophytic) species. In France, about 1200 arable weed species have been identified (Jauzein 1995), among which 300 species can be frequently encountered (Fried et al. 2007). Ethnobotanical studies showed the great importance of arable weeds not only by considering weeding as a very early human activity but also by their different representations in dialects, and imaginary, symbolic and medicinal uses among rural societies until the twentieth century (Lieutaghi 1986). The threshold between the negative and positive perceptions of these species was probably fuzzier than today, even for farmers. For example, in traditional farming systems, weeds remaining after the harvest were used as a complementary resource for grazing of livestock. Nowadays, especially since the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005), the dual perception of weeds blends into the search for a trade-off between the antagonistic ecosystem services that they support. Indeed, weeds are now more widely recognized for their major contribution in supporting numerous ecosystem services (Marshall et al. 2003; Eraud et al. 2015; Requier et al. 2015; Rollin et al. 2016), among which several ecosystem services for crop production, such as not only pollination (Bretagnolle and Gaba 2015) and limitation of soil erosion but also auxiliaries in the vicinity of crops (Zandstra and Motooka 1978) (Figure 1). Consequently, the persistence of weed diversity in farmlands becomes mandatory for the provision of important ecosystem functions, but it also needs to be carefully managed so as to limit the impact of weeds on crop yields through the competition for major resources (i.e. water, light and nutrients) or even maintenance of pests (Reboud et al. 2016; DiTommaso et al. forthcoming). The search for a trade-off between the antagonistic weeds functions is emblematic of agroecology (Altieri 1995; Gliessman 1995), and requires determination of the optimal spatiotemporal distributions of weed species provisioning these functions at both the field and landscape scales. However, with the rise of modern agriculture after the 1950s, the loss of non-crop habitats, the simplification of landscapes and the intensive use of herbicides have led to a dramatic decline of weed diversity (Stoate et al. 2001) and particularly of rare arable weeds (Storkey et al. 2012). In the present section, Fried, Dessaint, and Reboud (2016) document the decline of arable weeds between the 1970s and the 2000s in a small region of Burgundy (France). Beyond the loss of rare arable weeds, this study also pinpoints a strong reduction of formerly common weed species. There was a 46% decrease in the average number of weed species found within a field, correlated to a 38% decrease in weed functional diversity. The trend was similar when focusing on response traits to management practices (e.g. plant height, seed mass, season of germination) or on effect traits that influence the timing and amount of resources available for pollinators (flowering phenology, pollination mode). The authors found a positive relationship between weed species richness and functional diversity, and highlighted that the current level of weed diversity is now often unable to cover the full range of functions that were provided by arable weed communities in the 1970s. Regarding traits such as production of pollen and nectar, changes in weed communities (with a higher proportion of wind-pollinated species today) reduce the availability of resources for honey bees, wild pollinators and pest natural enemies

CONTACT Sabrina Gaba sabrina.gaba@dijon.inra.fr

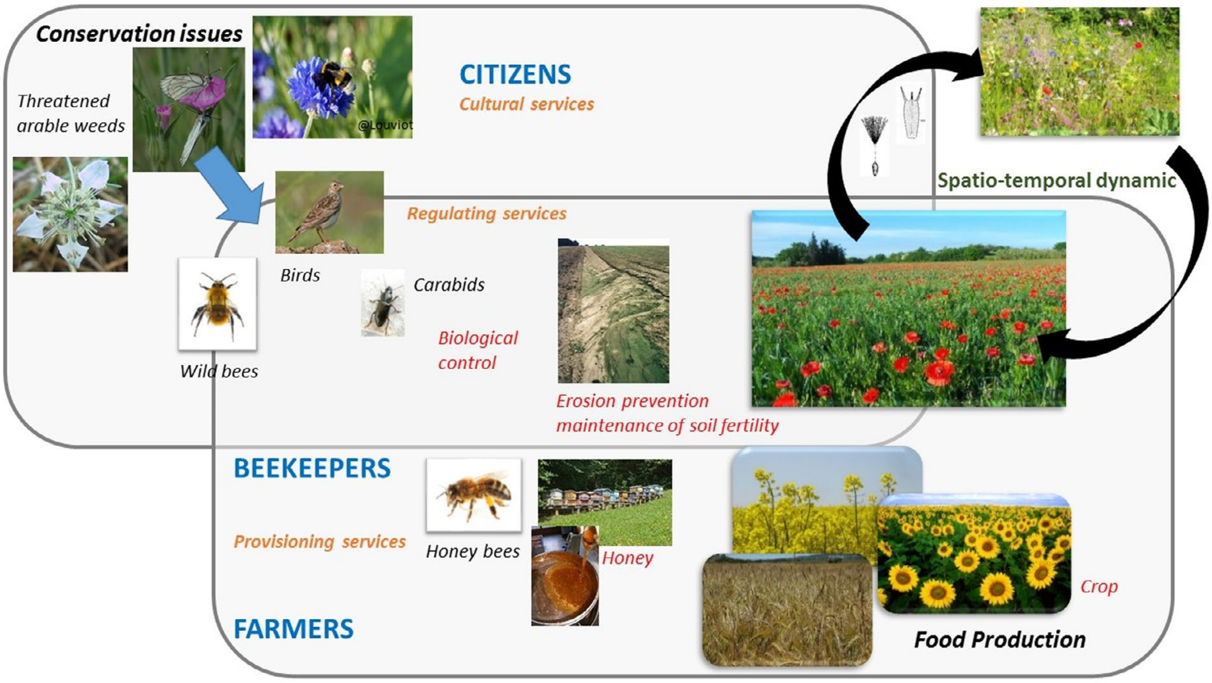

Figure 1. Schematic representation of the key role of weeds in agroecosystems with a focus on production and conservation, which are the focal issues of this special section. Weeds are directly and indirectly involved in food production (*provisioning service*). Weeds can reduce crop production by competing for resources with crop plants. However, weeds also provide food for honey bees during food scarcity (*regulating services*), hence ensuring honey production and also seed production of oilseed rape and sunflower (*provisioning services*). Weeds can also improve soil quality and provide food and shelter for insect pollinators, carabids and birds (*regulating services*). Some of these species supported by weeds may also act as biological control agents, and regulate crop pests. In addition, several of these organisms, including weeds, are flagship species that have a high cultural value for people such as botanists or ornithologists (*cultural services*). The multiple functions of weeds call for more holistic approaches to design weed management at both the field scale and the landscape scale.

(Tscharntke, Rand, and Bianchi 2005). Such diversity loss may also impact the abiotic properties of the fields. For example, in grape vine and orchards, weeds can be used as spontaneous cover to prevent soil erosion and renew soil fertility. After a transient phase where they may compete for water or other resources, with a resulting reduction of vine vigour, grape vines are able to adapt their root systems and so better buffer environmental variations. Such results have been explored in Mediterranean vineyards by Kazakou et al. (2016), who proposed, and used, a trait-based response-and-effect framework to assess the effect of soil management on the composition of wild plant communities with resulting implications for grape vine growth and performance. High weed biomass and diversity observed in vineyard plots with minimum management (spontaneous vegetation in inter-rows with just two mowing per year) did not lead to higher water stress in summer nor to lower vine grape yield when compared with more intensively managed plots (three superficial tillage in spring). The latter type of management led, however, to higher nitrogen in the vine must. A trade-off compromise between these two management approaches could be explored by positioning the control of vegetation during the key stage of nitrogen uptake of grape vine (i.e. at flowering). This would enable to both optimize weed functions related to soil properties and maintain a good quality of vine production.

These studies confirm the importance of weed diversity for agroecosystem functioning, and ask for the exploration and testing of alternative weed management strategies. Following agroecology principles, future research should test whether a decrease of chemical inputs (such as herbicides) could be compensated by biotic processes (e.g. soil fertility, pest control or pollination), and to what extent these alternative methods of management could result in higher economic and environmental benefits in the mid and long term. For instance, it has recently been proposed that the presence of weeds in winter cereals may lead to an increase of rape seed crop production in surrounding fields, by providing food for honey bees during food scarcity (Bretagnolle and Gaba 2015). The presence of weed species can also diversely affect crop yield through complex biotic interactions by not only hosting the crop pest but also by attracting auxiliaries, as recently shown by DiTommaso et al. (forthcoming). Weed conservation cannot, however, be restricted to species with functions related to crop production. Many weed species are flagship species with a cultural value (e.g. *Cyanus segetum* Hill, *Nigella arvensis* L.). Most of these declining rare weeds are poorly competitive with the crop (with some exceptions) and are shown as beneficial for supporting faunas (insects and invertebrates) (Storkey 2006). The challenge is therefore to design weed management strategies with high value for food production while conserving weed species with functions related to not only crop production but also weed species diversity per se. Albrecht et al. (2016) reviewed several strategies that have been developed in Europe to conserve rare arable weeds. In some strategies, such as organic farming or traditional low-intensity farming, the main objective remains the production of agricultural goods while conservation objectives, although important, stay subsidiary. However, management practices associated with these wildlife-friendly farming systems (Green et al. 2005) are usually compatible with a higher richness of rare arable weeds compared with conventional agriculture (Henckel et al. 2015). Other strategies are more specifically devoted to the conservation of threatened arable flora in conservation headlands, flower strips or set-asides. One benefit is that they tend to avoid potential conflicts between food production and conservation by segregating over space or time, production-focused and conservation-focused areas. The downside is that the approach is voluntary, based on financial incentives and not regionally coordinated, so that the sites are often poorly targeted, and include field borders that are not worthy of protection. These exploring systems mirror the general dichotomy between the policy options of land sparing or land sharing (Green et al. 2005; Fischer et al. 2014). Both policies may fail to conserve high levels of plant diversity, or very threatened species, for which a network of arable reserves may be necessary.

Altogether, the papers gathered in this theme issue provide new insights on the relationship between weed species and agroecosystem functioning in arable lands and vineyards. These researches highlight the need to reassess the role of weeds in the agroecosystem from small to large temporal and spatial scales. Further research should therefore explore weed population dynamic management options when intending to tightly combine economic benefits, social requirements and environmental issues.

Acknowledgements

The authors thank Elisabeth Dodinet for the opportunity of this special issue. We thank Bérenger Bourgeois for valuable comments on the manuscript. SG and XR are funded by INRA, and GF by ANSES. Some ideas developed here are part of the ANR AgroBioSE (ANR-13-AGRO-0001) and the FRB CESAB DISCO-WEED project.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Agence Nationale de la Recherche [grant number ANR-13-AGRO-0001]; Fondation pour la Recherche sur la Biodiversite [grant number Fondation pour la Recherche sur la Biodiversite]

Notes on contributors

Sabrina Gaba is an ecologist working at INRA, Dijon. She is studying weed community ecology in farmland in relation with their effect on crop production, and crop and wild plant species pollination and their role for the conservation of insect pollinators and seed predator birds. *Contribution*: contributed to the writing of the editorial and editing of the theme issue.

Xavier Reboud is an agroecologist with interest in plant health; he is currently deputy head of the Plant Health and Environment Division at INRA. Xavier's interests are on the diversity of organisms that derives from weeds' presence and plant community responses to agricultural changes. *Contribution*: contributed to the writing of the editorial and editing of the theme issue.

Guillaume Fried is a weed ecologist working at the Plant Health Laboratory of Anses (French Agency for Food, Environmental and Occupational Health & Safety), with interest in large-scale monitoring of arable weed communities and trait-based approaches. *Contribution*: contributed to the writing of the editorial and editing of the theme issue.

ORCiD

Sabrina Gaba http://orcid.org/0000-0002-7145-6713
Xavier Reboud http://orcid.org/0000-0001-6430-153X
Guillaume Fried http://orcid.org/0000-0002-3653-195X

References

Albrecht, H., J. Cambecèdes, M. Lang, and M. Wagner. 2016. "Management Options for the Conservation of Rare Arable Plants in Europe." *Botany Letters* 163 (4): 389–415.

Altieri, M. A. 1995. *Agroecology: The Science of Sustainable Agriculture*. 2nd ed. Boulder, CO: Westview Press.

Bretagnolle, V., and S. Gaba. 2015. "Weeds for Bees? A Review." *Agronomy for Sustainable Development* 35: 891–909.

DiTommaso, A., K. M. Averill, M. P. Hoffmann, J. Fuchsberg, and J. E. Losey. forthcoming. *Integrating Insect, Resistance, and Floral Resource Management in Weed Control Decision-Making*. Weed Science. doi: 10.1614/WS-D-16-00052.1.

Eraud, C., E. Cadet, T. Powolny, S. Gaba, F. Bretagnolle, and V. Bretagnolle. 2015. "Weed Seeds, Not Grain, Contribute to the Diet of Wintering Skylarks in Arable Farmlands of Western France." *European Journal of Wildlife Research* 61: 151–161.

Fischer, J., D. J. Abson, V. Butsic, M. J. Chappell, J. Ekroos, J. Hanspach, T. Kuemmerle, H. G. Smith, and H. von Wehrden. 2014. "Land Sparing versus Land Sharing: Moving Forward." *Conservation Letters* 7: 149–157.

Fried, G., X. Reboud, J. Gasquez, and M. Delos. 2007. "'Biovigilance Flore', a long-term French weed survey. 20eme Conférence du COLUMA." AFPP - Journées Internationales sur la Lutte contre les Mauvaises Herbes, Dijon, France, 11 et 12 décembre 2007.

Fried, G., F. Dessaint, and X. Reboud. 2016. "Local and Regional Changes in Taxonomic and Functional Diversity of Arable Weed Communities in Burgundy (France) between the 1970s and the 2000s." *Botany Letters* 163 (4): 359–371.

Gliessman, S. R. 1995. “Sustainable Agriculture: An Agroecological Perspective.” *Advances in Plant Pathology* 11: 45–57.

Green, R. E., S. J. Cornell, J. P. W. Scharlemann, and A. Balmford. 2005. “Farming and the Fate of Wild Nature.” *Science* 307: 550–555.

Henckel, L., L. Borger, H. Meiss, S. Gaba, and V. Bretagnolle. 2015. “Organic Fields Sustain Weed Metacommunity Dynamics in Farmland Landscapes.” *Proceedings of the Royal Society B: Biological Sciences* 282: 20150002. doi: 10.1098/rspb.2015.0002.

Jauzein, P. 1995. *Flore des champs cultives* [Flora of cultivated fields]. Paris: Sopra-INRA.

Kazakou, E., G. Fried, C. Violle, O. Gimenez, J. Richarte, and A. Metay. 2016. “A Plant Trait-Based Response-and-Effect Framework to Assess Vineyard Inter-Row Soil Management.” *Botany Letters* 163 (4): 373–388.

Lieutaghi, P. 1986. *L’herbe qui renouvelle : un aspect de la médecine traditionnelle en Haute-Provence* [The grass that renews: an aspect of the traditional medicine in Haute-Provence]. Paris: Les Éditions de la Maison des Sciences de l’Homme.

Marshall, E. J. P., V. K. Brown, N. D. Boatman, P. J. W. Lutman, G. R. Squire, and L. K. Ward. 2003. “The Role of Weeds in Supporting Biological Diversity within Crop Fields.” *Weed Research* 43: 77–89.

Millennium Ecosystem Assessment. 2005. *Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: Synthesis. A Report of the Millenium Ecosystem Assessment*. Washington DC: Island Press.

Reboud, X., N. Eychenne, M. Délos, and L. Folcher. 2016. “Withdrawal of Maize Protection by Herbicides and Insecticides Increases Mycotoxins Contamination near Maximum Thresholds.” *Agronomy for Sustainable Development* 36: 1–10.

Requier, F., J. F. Odoux, T. Tamic, N. Moreau, M. Henry, A. Decourtye, and V. Bretagnolle. 2015. “Honey Bee Diet in Intensive Farmland Habitats Reveals an Unexpectedly High Flower Richness and a Major Role of Weeds.” *Ecological Applications* 25: 881–890.

Rollin, O., G. Benelli, S. Benvenuti, A. Decourtye, S. D. Wratten, A. Canale, and N. Desneux. 2016. “Weed-Insect Pollinator Networks as Bio-Indicators of Ecological Sustainability in Agriculture. A Review.” *Agronomy for Sustainable Development* 36 (8): doi: 10.1007/s13593-015-0342-x.

Stoate, C., N. D. Boatman, R. J. Borralho, C. R. Carvalho, G. R. Snoo, and P. Eden. 2001. “Ecological Impacts of Arable Intensification in Europe.” *Journal of Environmental Management* 63: 337–365.

Storkey, J. 2006. “A Functional Group Approach to the Management of UK Arable Weeds to Support Biological Diversity.” *Weed Research* 46: 513–522.

Storkey, J., S. Meyer, K. S. Still, and C. Leuschner. 2012. “The Impact of Agricultural Intensification and Land-Use Change on the European Arable Flora.” *Proceedings of the Royal Society B: Biological Sciences* 279: 1421–1429.

Tscharntke, T., T. A. Rand, and F. Bianchi. 2005. “The Landscape Context of Trophic Interactions: Insect Spillover across the Crop-Noncrop Interface.” *Annales Zoologici Fennici* 42: 421–432.

Zandstra, B. H., and P. S. Motooka. 1978. “Beneficial Effects of Weeds in Pest Management – A Review.” *PANS* 24 (3): 333–338.