THE FUNCTION OF SMALL FARMS IN SUPPORTING BIOLOGICAL DIVERSITY OF AGRICULTURAL ECOSYSTEMS[1]

Denise F. Dostatny

Plant Breeding and Acclimatization Institute – National Research Institute in Radzików, Poland
Head of Department: prof. dr hab. Wacław Orczyk

Key words: small farms, diversity, weeds, preservation, agroecosystems
Słowa kluczowe: małe gospodarstwa, różnorodność, chwasty, zachowanie, agroekosystemy

A b s t r a c t. Biodiversity is formed, among other things, by the extensive use of arable land and therefore Poland has one of the most species abundant agricultural landscapes in Europe. Small ecological farms, especially in southern and south-eastern Poland, still host rare plant species named in the red lists of many European states. The diversity of animal and plant species in these areas is significantly higher than in the remaining parts of Poland. Consequently, the balance of agroecosystems is far more stable. The presence of rare plant species in the fields does not mean lower yields but contributes to maintaining the considerable diversity of insects and birds. Preserving the mosaic structure of crop fields and the traditional rural landscape is only possible on small farms and hence the importance of their continued existence.

INTRODUCTION

In the past people knew how to use natural resources skilfully. However, over time, they learnt to employ new technologies and unthinkingly ignore the laws of nature and to consider the extinction of a few species of living organisms to be unimportant, given the high diversity and the rapid progress. Shifting from hunting and gathering to farming caused replacement of the mosaic system of habitats by a growing number of single species cultivations. By simplifying the complex ecosystems and eliminating the 'unwanted' species, human beings made their diet poorer and changed the habitats of wild flora and fauna completely. By the end of the 20th century there were 4.5 billion people and as little as 180 species of plants used for consumed of which 6 species provided more or less 90% of the food of plant origin [*The state*... 1996]. In Polish registers there are 140 varieties of cultivated plants of several dozens of species [COBORU 2011].

Modern agriculture should put considerable emphasis on maintaining biological diversity. The purpose of original and modern agriculture is to produce food. The difference is that primitive farming used mainly the work of men and animals and simple tools while modern farming is based on advanced technology of cultivation, which is characterised by a very intense nature, and the entire production is dedicated for sale. There is no place

[1] Paper was presented at the 19th Congress of the International Farm Management Association (IFMA), Warsaw (Poland), 21-26 July 2013.

to maintain diversity in agricultural ecosystems. Large scale monocultures, excessive agrochemical applications and heavy machinery have destroyed the balance of agroecosystems. The genetic impoverishment of crop plants has occurred; also accompanying plants species as well as microorganisms and animals directly related to them are disappearing. The survival of small farm agriculture is the only method of maintaining diversity and balance in agricultural ecosystems and preserving rare species of plants and the animals that depend upon them.

Weeds provide many positive impacts in agroecosystems. They protect the surface of the soil from crusting, drying and erosion. Furthermore, after ploughing weeds decay in the soil replacing composting and organic fertilisation. They also stimulate the growth of crop plants through their allelopathic activity – the so called positive allelopathy consists in improved growth of a given species in the vicinity of others, caused by emitting complexes of different chemical compounds. They can be used as a 'biological weapon'. Weeds may reflect actual habitat conditions and therefore can be used as bioindicators. They are food or ingredients of fodder mixtures for animals. They are also widely used in phytotherapy and the cosmetic industry.

MATERIAL AND METHODS

The research area is situated in the Nadnidziański natural landscape park and is partly within the 'Natura 2000' network (Ponidzie area). This area has been settled for a very long time. The oldest traces of settlement date back to neolith times. The Ponidzie was examined in detail, thanks to funding among others by the State Committee for Scientific Research of a supervisory research grant 'Diversity of field weeds of the Nadnidziański Natural Landscape Park, its determinants and preservation' [Dostatny 2000] and by a grant of the Ekofundusz Foundation as well as the Plant Breeding and Acclimatization Institute (2007-2009). A detailed survey of weed species was performed that enabled the comparison of changes occurring in plant communities and further monitoring thereof. The location of vanishing weed species, in particular among cereal crops cultivated on small farms of the region, were identified. Research was carried out in close cooperation with local farmers that were very helpful in providing information on traditional cultivations of the area. A favourable inclination towards the idea of maintaining of biodiversity and relevant activities was observed amongst these farmers.

Since 2004 missions to collect plants have been held that cover the area under study. Such missions have been organized annually by the National Centre for Plant Genetic Resources and their purpose was to collect ancient and local crop plants and their accompanying species, i.e. weeds. Also during the expeditions data were gathered and observations were made concerning genetic impoverishment of a given area.

In the years 2008, 2010, and 2012 phytosociological records were made using the Braun-Blanquet method [1964]. Each year 2 records were made from an area of 100 sq. m (within an area of 0.3 ha) in the crops at each farm during the growing season. In this paper only results referring to the share of coverage by crop plants and weeds in a given area (100 sq. m), calculated following a phytosociological record, will be used. Within the area of 0.3 ha farmers did not use any chemicals and the sowing rate for crop plants (cereal) was 30% lower than that recommended.

The occurrence of weed species in the cultivations of 10 farmers was monitored. The number of weed species in the material harvested directly by the farmer was identified. Marking of weed seeds was made according to Kulpa [1974]. For that purpose 0.5 kg of material was taken directly from the harvester on the aforesaid fields between 2008 and 2012. A list of weed species in the entire material was prepared based on the indices of frequency and abundance of occurrence [Kulpa and Tabisz 1963]. It must be mentioned that farmers who took part in the research have small farms (usually up to 10 ha) and despite crop rotation the fields were more or less in the same location year on year. Thus, the material could be compared.

RESULTS

Following the analysis of all phytosociological records that were made in individual years, it may be stated that the general weed coverage in fields used for this study did not increase, notwithstanding the fact that rare weed species occurred and the coverage of crop plant declined slightly. In 2012, the weed coverage was between 25-45% and the coverage of crop plants between 80 and 90% in all fields. However, in 2008 the weed coverage was between 25-40 % and the coverage of crop plants between 80 and 95% (Tab. 1).

Table 1. Comparison of percentage coverage of a crop plant and weeds in the ten researched smallholders

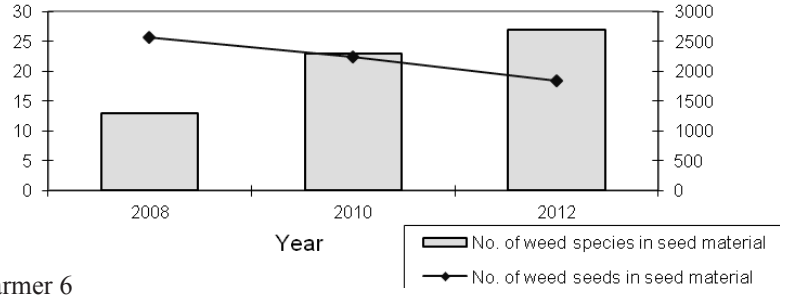
Farmer	Farmer field size [ha]	Year					
		% coverage of the crop plant/ % coverage of the weeds					
		2008		2010		2012	
1	10	85	35	85	30	80	25
2	10	90	25	90	35	90	30
3	10	90	25	90	25	85	35
4	9	80	45	90	30	90	30
5	10	95	35	90	35	90	30
6	10	80	40	90	35	85	35
7	7	90	35	90	30	80	45
8	10	85	40	85	40	90	35
9	10	85	40	85	35	90	30
10	5	85	40	85	40	85	35

*Area under study = 0.3 ha
Source: own study.

In the first years of the research, in most of fields studied, the average number of species was low, but their coverage was high, because two or three weed species were dominant. In the case of dominance of one weed species other species that are rare and characteristic for a given community do not occur; this leads to impoverishment of the floral composition of field weed communities. In consecutive years more weed species occurred in the fields and despite that fact the average weed coverage was the same or lower than in the first year of the study – no dominance of any of the weed species had ever been observed; they were usually quite evenly spread in the field (Tab. 1. and Fig. 1.).

a. Farmer 4

b. Farmer 5



c. Farmer 6

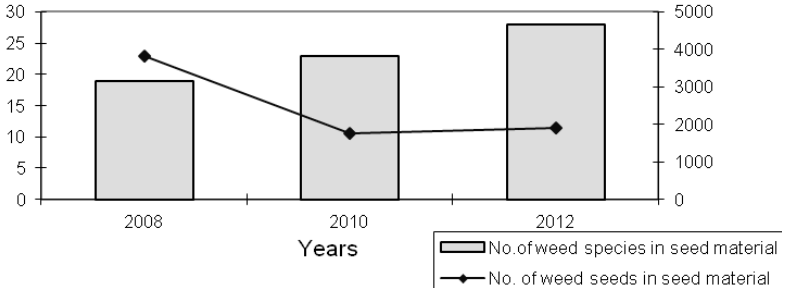


Figure 1. Number of weed seeds in the seed material of the selected smallholders
Source: own study.

In the analysed material (from 10 farms), after harvest in the initial years of monitoring in Niecka Nidziańska area, a small number of weed species was observed (from 65 to 67 species, between 2008-2010) with high numbers of the more common species such as: *Elymus repens, Avena fatua, Convolvulus arvensis, Galium aparine*, *Polygonum convolvulus*, that were present in almost every one of the 10 samples, with a high abundance index. In the following years, the number of weeds in the material collected from farmers increased gradually. In the last year the differences in abundance between common and rare weeds were not so evident (from 71 to 91 species in 0.5 kg of collected material, in all 10 samples). The abundance of common species declined, which was caused by the occurrence of other, less common, species, such as: *Adonis aestivalis, Aethusa cynapium, Agrosthemma githago, Bupleurum rotundifolium, Camelina microcarpa, Lithospermum*

arvense, Neslia paniculata, Valerianella dentata, among others. Specimens of these species probably came from the soil seed bank. After two years of research an observation was made that some rare species of weeds were occurring in cultivations, despite the fact that seeds of these weeds were not present in the collected seed material. In 2010 a few specimens of *Caucalis daucoides* were noted, while in 2012 the following species were recorded: *Ranuculus arvensis, Stachys annua* and *Bupleurum rotundiflorum* (it was increasing its coverage in the fields). After years of cultivation without the use of herbicides one may expect that weed species that had vanished, though still present in the soil seed bank, would germinate and create a full composition of the different, vanished weed complexes. A greater number of higher plants in crop fields means an increased abundance of other species such as: microorganisms, insects, birds, etc., that are necessary to keep agroecosystems in balance.

During the collection missions organised by the National Centre for Plant Genetic Resources in the last 10 years, we observed that the South and Southeastern part of Poland is still abundant in local, old varieties of annual vegetable plants, leguminous plants, medicinal plants and rare species of weeds, as well as old varieties of fruit trees. Rare species of weeds are only present in the fields in small farms in a few villages in Poland, where the mosaic structure of crop fields is preserved, as in the research area.

DISCUSSION

Very interesting weeds of crop fields occur in Niecka Nidziańska, on rendzina soils, which make up 1% of Polish soils. Most of them are very rare plants in Poland [Dostatny 2004]. An example would be *Adonis flammea* which is endangered due to intensified farming systems. There are several factors causing the extinction of the species as well as others of the *Caucalido-Scandicetum* communities. The main ones include intensification and modernisation of contemporary agriculture: introduction of prolific cereal varieties, improved cleaning of seeding material, long-term usage of herbicides. Equally significant are changes of habitat conditions, particularly strong and continuing acidification of limestone soils [Anioł-Kwiatkowska, Popiela 2011]. Also urbanisation and changing arable land into non-arable as well as abandoning farming of difficult land (e.g. high slopes) are of great importance. These factors have had a strong influence on the extinction of *Adonis flammea* and other species of the complex (*calciphile archaeophytes* related to traditional methods of cultivation, of Mediterranean reach).

Very often higher plants compete with one another, not only with the crop plant, which means that a greater number of weeds, with low coverage, only slightly decreases the yield of the crop plant. This phenomenon may be explained by the fact that the more species (partners) to share the resources of an ecological niche, which is a field, the more often growth of one of them limits the growth and development of the others which results in an absence of dominance. A reverse case occurs when one or several weed species predominate in fields treated with herbicides. Some of the species have become resistant to herbicides causing increasing numbers of them in the field (so-called compensation), consequently resulting in a drop of crop plant yield.

The layering architecture of the cornfield determines the inclusion of the weed seeds in the material collected (crop). Research made in Kurpie confirms this phenomenon [Dostatny, Małuszyńska 2007]. Most of the seeds came from the medium layer, some from the higher,

and only a few from the lower. Therefore, we do not have to be afraid of weeds from the lowest layer of cornfield getting into the harvested crop. Their presence is advantageous as they protect soils from crusting [Dostatny, Małuszyńska 2007]. This means that growing biodiversity in agricultural ecosystems does not equal a loss or deterioration of the quality of the harvest. Whereas a loss in biodiversity of rural areas caused by intensified farming, is inseparably connected with degradation of the agricultural ecosystems' functions.

Further existence of populations of rare, annual weed species is connected with turning of the soil surface during cultivation. This agrotechnical treatment prevents the invasion by biotopes of different grasses or perennials with higher competitive potential. We may hereby state that the seed resources in the soil are of crucial significance for the preservation and dynamics of populations of higher plants [Czarnecka, Czarnecka 2006].

Species that accompany cultivations have the ability to adapt to the life cycles of crop plants [Kornaś 1977]. A given complex of weeds with a whole spectrum of species reflects a specific type of cultivation. If the cultivation is abandoned, then the accompanying species slowly recede. The same happens with bird and insect species that were dependent upon these plants. For example for the last 300 years approximately 150 species of mammals (another 240 are endangered) and 100 bird species have become extinct; of which around 70% species died out due to the elimination of their habitats. In the second half of the 20th century world agricultural production became 2.6 times higher and mineral fertilisation 8 times more intense. At the same time 6 million hectares of arable land per year is reduced to desert owing to excessively extensive agricultural use.

The national strategy of preservation and moderate use of biological diversity (2003) emphasises that all that has not been previously appreciated or even intentionally destroyed, e.g. 'pests and weeds', should be preserved. Therefore, from the point of view of the convention and nature there are no 'pests' or 'weeds'. The strategy has been prepared at the request of the Polish Ministry of Environment and drawn up in accordance with the 'Convention on Biological Diversity' announced during the Earth Summit in Rio de Janeiro held in 1992. To maintain balance and increase diversity in agricultural ecosystems, a 'model refuge of agrobiodiversity' has been formed in Niecka Nidziańska, southern Poland. The model refuge has been created thanks to the funds of Ekofundusz Foundation and the Plant Breeding and Acclimatization Institute. Its aims is to preserve and maintain biodiversity in farming ecosystems and to protect field plant species that are threaten by extinction by maintaining typical weed species of the region in the fields. It would be possible in small farms. Individual small farmers often cultivate several varieties of crops. According to Boyce [2004] large farms, in contrast, are more likely to sow a single variety over a wide area. This inverse relationship between farm size and varietal diversity has several explanations. First, high diversity farming is generally more labour-intensive than low diversity farming. It takes more time and effort to cultivate varieties with different sowing dates, harvest times, and other requirements than to practice varietal monoculture. Second, high diversity agriculture depends on the farmers' knowledge of different crop varieties and their relationships to microhabitat variations and third, small farms often predominate in the marginal agricultural environments where the spread of modern varieties has been held in check by unfavourable growing conditions.

As has already been mentioned, weeds provide many positive impacts in agricultural systems and therefore they should be covered by protection or preservation schemes (reserves and refuges are not sufficient). The basis for an efficient plan of weed management is the ecological knowledge of this plant group and its relations with other organisms.

Research carried out in Great Britain [Marshall et al. 2003] show that many higher plant species influence the maintenance of a high diversity of insects. A drop in the number of food plants, i.e. weeds, may have an impact on the reduction of insect populations as well as other animal species, such as birds. Weeds play an important ecological role by giving shelter to spiders and insects on which birds feed (e.g. larks). Poland has 26% percent of the entire bird population that depends on arable land [*Birds in Europe…* 2004]. In order to keep this abundance of bird species, the current diversity of the agricultural landscape must be preserved [Wuczyński et al. 2011], this refers among others to buffer zones planted with grass and papilionaceous plants [Dajdok, Wuczyński 2008].

Transformation of the natural environment and the production of food through the widespread use of chemicals have a negative impact on human life. A reaction to the situation was, among others, Directive 2078/92 of 1992 of the UE Parliament introducing the term of agri-environmental plans, i.e. valuing such types of agricultural production that guarantee the preservation of the natural environment as well as enabling satisfactory economic results being the basis of agricultural production. Farmers who join the agri-environmental plans produce food and maintain diversity in agroecosystems and their activities are subsidised. In Poland, the national agri-environmental plan was established within the Rural Areas Development Plan aimed at satisfying objections, priorities and principles, based upon which activities towards a sustainable development are supported. The plan was drawn up by the Ministry of Agriculture and Rural Development and approved by the European Commission. The Sixth Package (second stage: 2007-2013) – Preservation of endangered genetic plant resources in agriculture is directly connected to the improvement of diversity in rural areas. Option 6.3 of the package – Seed production requested by gene bank, is addressed at small farms. Sub-option C provides for preservation of rare flora accompanying cultivations. Participation in this option allows farmers from Niecka Nidziańska (also from the rest of the country) to continue activities undertaken as part of the aforesaid project and enables other interested farmers from the entire country to join the plan which, with no doubt, contributes to the improvement of diversity and the maintenance of a balance of agroecosystems. In the third stage (2014-2020) this option will probably be moved into another package – buffer zones.

Rare species of weeds are only present in the fields of small farms in a few villages in Poland, where the mosaic structure of crop fields is preserved, like in the study area. According to Boyce [2004] and other authors [Altieri 2009], small farms are the 'keystones species' in agricultural ecosystems, because they sustain the crop genetic diversity that underpins humankind's long term food security. Unfortunately such places are becoming rare in Poland. The collection missions organised by the National Centre for Plant Genetic Resources in the last 10 years, showed that the South and Southeastern part of Poland is still abundant in local, ancient varieties of annual vegetable plants, leguminous plants, medicinal plants and rare species of weeds, as well as ancient varieties of fruit trees. Fortunately during the collection missions, many samples of the above groups of plants were collected. Those samples are stored in a "gene bank" (National Centre for Plant Genetic Resources) in *ex-situ* collection, but they do not represent an adequate substitute for *in situ* diversity for several reasons: the gene banks are not completely secure, they cannot adequately replace *in situ* diversity and because there is a big difference between "having" a seed in the bank and "knowing" what you have – since many genetic attributes can be observed only by growing plants in the microhabitats from which they come [Boyce 2004].

CONCLUSIONS

Constant presence of rare weed species in crop fields does not mean a "worse crop", as a significant part of these species belong to the lowest layer of the cornfield that will never be collected by a harvester. Additionally, after a longer period of ecological or extensive farming the ecosystems regains balance. Different species coexist, supplement and compete with one another, which does not end in the expansion of any of them. This is, with no doubt, more favourable to nature than uniform landscapes with vast areas of one crop plant, where only a few species of the most common weeds, resistant to herbicides, prevail, creating a simple system of agricultural ecosystems. The mosaic structure of crop fields of small farms ensures living conditions for many animals and plants already rare across Europe and may help us to save some species that could have a crucial importance for the generations to come. According to Boyce [2004], a productive and resilient world agriculture requires a diverse mix of crop varieties, agricultural techniques, and farming systems. In this mix, there is a future for small farms.

BIBLIOGRAPHY

Altieri M.A. 2009: *Agroecology, Small Farms, and Food Sovereignty,* monthlyreview.org.

Anioł-Kwiatkowska J., Popiela A. 2011: *Adonis flammea* (*Ranunculaceae*) *wymarły archeofit Dolnego Śląska,* [in] *Zagrożony archeofity Dolnego Śląska,* J. Anioł-Kwiatkowka, E. Szcześniak (red.), „Acta Bot. Siles.", Supl., 1, 32-34.

Boyce J.K. 2004: *A Future for Small Farms? Biodiversity and Sustainable Agriculture*. Political Econ. Res. Inst. Working papers series, no. 86, 1-24.

Birds in Europe: Population Estimates, trends and Conservation Status. 2004: BirdLife International, Cambridge.

Braun-Blanquet J. 1964: *Pflanzensoziologie Grundzüge der Vegetationskunde,* Wien, New York, "Springer Verl.", 1-185.

COBORU. 2011: Centralny Ośrodek Badań Odmian Roślin Uprawnyc, Słupia Wielka.

Czarnecka J., Czarnecka B. 2006: *Glebowy bank nasion rzadkich gatunków murawowych i segetalnych: solidne zabezpieczenia czy zawiedzione nadzieje?* Ogólnopolska konferencja i warsztaty: *Rzadkie, ginące i reliktowe gatunki roślin i grzybów. Problemy zagrożenia i ochrony różnorodności flory,* Kraków.

Dajdok Z., Wuczyński A. 2008: *Alien plants in field margins and fields of southwestern Poland*, "Biodiv. Res. Conserv.", 9-1, 19-33.

Dostatny D. 2000: *Różnorodność gatunkowa chwastów polnych Nadnidziańskiego Parku Krajobrazowego, jej uwarunkowania i ochrona,* Grant promotorski nr 6 P04F 029 15.

Dostatny D.F. 2004: *Preservation of weeds diversity in protected areas,"*Bulletin of Botanical Gardens", 13, 79-83.

Dostatny D.F., Małuszyńska E. 2007: *Skład gatunkowy chwastów podczas wegetacji i w materiale ze zbioru w uprawach ekologicznych i konwencjonalnych,"*Pam. Puł.", 145, 1-17.

Kornaś J. 1977: *Zespoły synantropijne,* [w] *Szata roślinna Polski,* W. Szafer, K. Zarzycki (red.), wyd. III, Warszawa, 442- 462.

FAO. 1996: *The state of food and agriculture,* Roma.

Kulpa W. 1974: *Nasionoznawstwo chwastów, w*yd. II, PWRiL, Warszawa.

Kulpa W., Tabisz H. 1963: *Zanieczyszczenie nasion koniczyny czerwonej w województwie lubelskim, „*Biul. IHAR", 52(1), 149-156.

Marshall E.J.P., Brown V.K., Boatman N.D., Lutman P.J. W., Squire G.R., Ward L.K. 2003: *The role of weeds in supporting biological diversity within crop fields,* "Weed Res.", 43, 77-89.

Wuczyński A., Kujawa K., Dajdok Z., Grzesiak W. 2011: *Species richness and composition of bird communities in various filed margins of Poland,* "Agric. Ecos. Env.", 141, 202-209.

Denise F. Dostatny

ROLA MAŁYCH GOSPODARSTW W PODTRZYMYWANIU RÓŻNORODNOŚCI BIOLOGICZNEJ W EKOSYSTEMACH ROLNYCH

Streszczenie

W małych gospodarstwach ekologicznych, szczególnie w południowej i południowej-wschodniej części Polski można spotkać rzadkie gatunki chwastów, znajdujące się na czerwonych listach różnych państw Europy. Różnorodność gatunkowa zarówno roślin, jak i zwierząt na tych obszarach jest większa niż w pozostałych częściach Polski. W konsekwencji równowaga w agroekosystemach jest stabilniejsza. Obecność rzadkich gatunków chwastów na polach nie równa się obniżeniu plonów, a przyczynia się do podtrzymanie dużej różnorodności owadów i ptaków. Utrzymanie mozaikowej struktury pól uprawnych oraz tradycyjnego krajobrazu rolniczego jest możliwe tylko w małych gospodarstwach rolnych, dlatego jest tak ważne ich dalsze istnienie.

Coresspondence address:
Senior scientist (adjunct) Denise F. Dostatny
Plant Breeding and Acclimatization Institute – National Research Institute
National Centre for Plant Genetic Resources Radzików
05-870 Błonie, Poland
e-mail: d.dostatny@ihar.edu.pl