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The role of weeds from field margins in supporting pollinators

Značaj korova s rubova polja za oprašivače

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ABSTRACT

Field margins are pollinator-friendly habitats and important refuges for many pollinators. As a valuable food resource throughout the vegetation season, not just when crop species are in flower, field margins need to be protect or restore in areas of intensive farming. This paper examines the floristic and functional structure of weed communities on field margins in the northeastern part of the Republic of Croatia. A phytocoenological survey was conducted during the summer period of 2017 and 2018. A total of 32 field margins was analyzed for species richness, abundance and their role for entomofauna. Floristically rich field margins consist of 72,6% plant species beneficial to pollinators. Foraging period can be stretching throughout the year, but stabile and high flowering period is from May to end of September. Among highest ranked honeybee plants, several invasive species with significant relative abundance are: *Solidago gigantea*, *Asclepias syriaca* and *Amorpha fruticosa* who pose a serious threat to plant biodiversity. Positive role of vegetation from field margins was not valuable for pollinators only, but they also serve as supply the substrates that provide a shelter and nesting sites.

Keywords: biodiversity, boundary strip, food resource, nectar resource, pollinators, weeds

SAŽETAK

Rubovi polja su pogodna staništa za brojne oprašivače. S obzirom da su vrijedan izvor hrane korisnoj entomofauni tijekom cijele vegetacijske sezone, a ne samo u vrijeme cvatnje usjeva, potrebno ih je sačuvati ili obnoviti, osobito na prostorima intenzivne poljoprivredne proizvodnje. U ovom radu ispitana je floristička i funkcionalna struktura korovne zajednice na rubovima polja u sjeveroistočnom dijelu Republike Hrvatske. Fitocenološka istraživanja su provedena tijekom ljetnog razdoblja 2017. i 2018. godine. Bogatstvo vrsta, abundacija i njihova uloga za entomofaunu analizirani su na ukupno 32 poljska ruba. Florom bogati rubovi polja sadrže ukupno 72,6% biljnih svojti korisnih za oprašivače. Razdoblje paše može trajati tijekom cijele godine, ali najjači intenzitet je u vrijeme pune cvatnje od svibnja do kraja mjeseca rujna. Među najviše rangiranim medonosnim biljkama sa značajnom relativnom abundacijom nalaze se i invazivne vrste *Solidago gigantea*, *Asclepias syriaca* i *Amorpha fruticosa* koje predstavljaju ozbiljnu prijetnju biološkoj raznolikosti. Pozitivna uloga vegetacije rubova polja ne pogoduje samo oprašivačima, nego služi i kao podloga koja osigurava sklonište i prostor za formiranje gnijezda.

Ključne riječi: bioraznolikost, izvor hrane, izvor nektara, korovi, oprasivači, rubovi polja

INTRODUCTION

Intensive agricultural production poses significant threats to biological diversity. Many previously common species of flora and fauna associated with farmlands have shown marked reduction in range and population size due to improved crop management techniques, changes in land uses, intensive pesticide application and loss and fragmentation of habitat (Marshall, 2001; Stoate at al., 2001). This radical changes in farmlands caused by the intensification of agriculture, led also to huge degradation in wild and domestic pollinators (Klein et al., 2006). Since the production of diverse and affordable crops depends on pollination service, agriculture relies heavily on these beneficial insects. It is estimated that thirty-five percent of global production from crops, including at least 800 cultivated plants depend on animal pollination (Gallai et al., 2009; Nicholls and Altieri, 2013).

Several groups of insect species are involved in pollination, including honeybees, wild bees, bumblebees, hoverflies and butterflies, etc. They rely on floral resources for their diet. Mass flowering crops are available through reduced time of their pollination, but weeds, which provide less flowers than crops, are spatially and temporarily more available as a constant food source. However, the response of weeds to agricultural intensification has been associated with decrease of abundance of many species, dominance of small number of species and a decline in the functional biodiversity for agro-ecosystems (Schumacher et al., 2018).

In agricultural landscape, field margins represent important refugia for flora and fauna (Marshall, 2001; Marshall et al., 2006). These semi-natural, manmade habitats contain a variety of communities with different structures. The principal components of field margins are boundary, and they often consist of mosaic of different ruderal habitats, such as field tracks and railroad beds, hedge, grass bank or ditch, nature conservation or others strip and the crop edge (Marshall and Moonen, 2002). A pioneer study by van Emden (1965) reports the ecological link between plant resources and insect biology, and positive role of weeds in enhancing beneficial insect survivorship in crop ecosystems. Many other research studies also confirmed that field margins a worthwhile for maintenance and enhancement of farmland biodiversity (Marshall et al., 2003; Weibull et al., 2003), and to support crop pollinators (Backman and Tiainen, 2002; Russo et al., 2013). Although field margins provide habitat for a range of beneficial insects, some pest species also occur (Booij and Noorlander, 1992).

The objective of this paper is to explore the relationship between plant diversity of field margins in intensively used agricultural region of northeastern Croatia in order to evaluate their contribution to providing a range of resources for associated insect fauna, particularly for supporting crop pollinators.

MATERIALS AND METHODS

The vegetation survey was conducted during 2017 and 2018 in northeastern part of the Republic of Croatia, mainly in Osijek-Baranja and Vukovar-Srijem counties (Figure 1). This is an important agricultural region with a warm and moderate to dry lowland continental climate (from the west to east part of the region, respectively). The average annual temperature is 11.4 °C, and average annual rainfall of 699 mm having the highest spring rainfall regime in June.

Figure 1. Surveyed area (in circle) displayed on the Map of the Republic of Croatia

The vegetation records were obtained from 32 field margins during the summer months when the vegetation was fully developed. For this purpose, a 2 m by 50 m area along the field margins were selected according to van Elsen (1989). All occurring plant species were evaluated using a seven-degree Braun-Blanquet cover- abundance scale (Braun-Blanquet, 1964). The values from each species recorded in relevés were afterwards transformed to an ordinal scale (van der Maarel, 1979) for further analysis of weed composition, community characteristics and their beneficial role to pollinators.

Plants nomenclature was unified in accordance with Nikolić (2019), while weed species beneficial to the pollinators were collected from published records and pollination networks. Several databases were used to select the majority of floral criteria – eFLORAsys (Plantureux and Amiaud, 2010), BiolFlor (2004) and FloreAlpes (2005) - freely available on Internet. Vegetation structure was analyzed in terms of species and functional group composition.

Data were first subjected to calculate the proportion of field margins in which a given species was found (species constancy), and alpha, beta and gamma diversity (Whittaker, 1975; Magurran, 1988). Alpha diversity, or species richness, represents the number of species in a survey. Beta diversity [(gamma diversity/average alpha diversity)-1] is the rate of change of species richness across survey. Gamma (regional diversity) is the total number of species occurring in a system.

An ANOVA was performed on plants functional groups and values to pollinators. Prior to ANOVA, all data were subjected to Shapiro-Wilk test for homogeneity of error variances. Means were compared using a Fisher's Protected LSD test at 5% probability level. The above statistical analysis was done with PROC ANOVA in SAS (SAS Institute 1996).

Second step was to calculate a mean relative abundance of each species found throughout the study. For this purpose, the three measures were combined into a single value in order to summarize abundance of a species as the final quantitative measure (Derksen et al., 1993). Relative cover was calculated as cover of individuals from a given species within all relevés, divided by the total cover of all species in survey. Relative frequency was calculated as the proportion of relevés in which species was present divided by the total frequency of all species. Subsequently, relative abundance value was calculated for each weed species as follows: (relative cover + relative frequency)/2. Relative abundance was used to rank the plants beneficial to insects in the survey. In the scatter plot (frequency vs mean cover) of the top ranked species five groups were detected: I – very abundant, II – abundant, III – locally abundant, IV – moderate abundant and V – common according to a method used by Thomas and Ivany (1990).

Finally, data were subjected to multivariate, canonical correspondence analysis (CCA) to determine the association between the species composition on field margins and range of resources for associated fauna using CANOCO 5.0 package (ter Braak and Smilauer, 2012). The statistical significance was tested using Monte Carlo permutation test with 1000 iterations. CCA ordination diagram was constructed with species showing the highest weight (the species weight is equal to the sum of abundances of the species taken overall the relevés).

RESULTS

A total of 129 species (gamma diversity) was found in the 32 surveys over two years' period. Species richness per relevé or alpha diversity was 28 ± 0,82 and beta diversity was 5,89 ± 0,74.

The share of dicotyledonous species (Table 1) was significantly greater (77%) compared to monocotyledons (22%) and cryptogam (1%). Asteraceae (19 spp.) and Poaceae (12 spp.) were the most numerous families from dicotyledons and monocotyledons, respectively. Most of the species identified are characteristic for segetal habitats.

No significant differences were observed between amount of annuals and perennials, but biennials had the lowest relative abundance. There were more native species (62%) than cosmopolitan (26%) and exotic (12%).

Table 1. Relative abundance of weeds in fields of north-eastern Croatia during 2017 and 2018

Functional groups		Relative abundance (%)
Morphotype	Dicotyledons	77 a
	Monocotyledons	22 b
	Cryptogam	1 c
Life cycle	Annuals	43 a
	Perennials	49 a
	Biennials	8 b
Origin	Native	62 a
	Cosmopolitan	26 b
	Exotic	12 c
Values to the pollinators	Honeybees	58,7 a
	Bumblebees	40,2 a
	Wild bees	47,5 a
	Butterflies	45,0 a

Means followed by different letters significantly differ (P ≤ 0.05) within each main functional group (morphotype, life cycle, origin) and values to the pollinators (honeybees, bumblebees, wild bees, butterflies)

Out of total number of species found in field margins in study area, 72.6% are beneficial to insect pollinators. Among them proportion of floral resources (nectar and pollen) does not significantly differ for pollinator species (honeybees, bumblebees, wild bees and butterflies).

Blooming period of plants beneficial for pollinators (Figure 2) indicates that weeds from field margins significantly contribute as a food source, particularly those flowering from May to September. Summer months June, July and August are the main foraging period, when the more than 70% of honeybee plants are in blooming. Moreover, September, with the insignificantly less percent (66%) of flowering plants, provides an excellent late-season resources for pollinators.

The ranking of weeds beneficial for pollinators according to their frequency and mean relative cover demonstrate that vegetation from field edges can provide an alternative food resources (pollen and nectar) before, during and after the bloom of the crops (Figure 3).

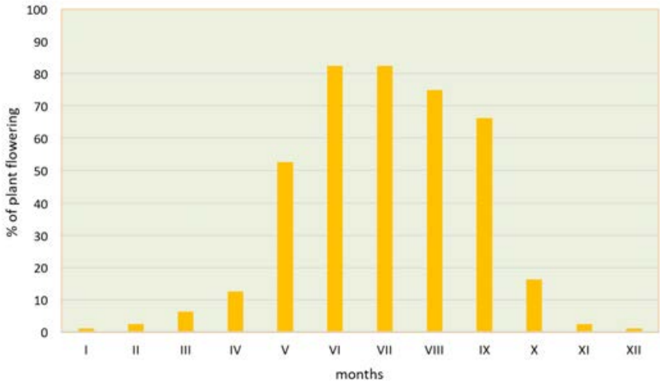
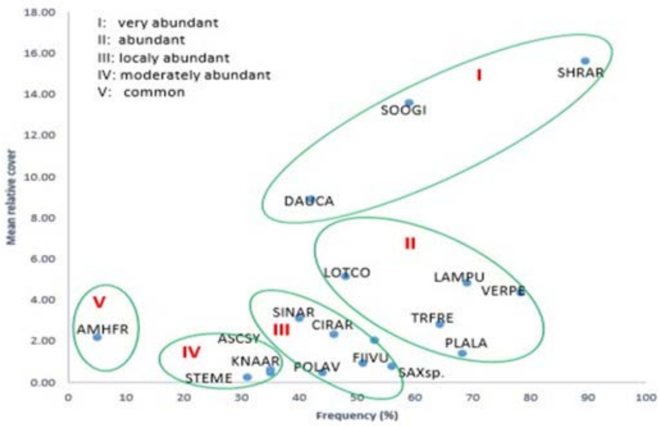


Figure 2. Blooming period of plants beneficial for pollinators found in field margins of investigated region



BAYER code of latin names for weeds with a highest frequency and mean relative cover beneficial for crop pollinators: **group I**: SHAR (*Sherardia arvensis* L.), SOOGI (*Solidago gigantea* Aiton), DAUCA (*Daucus carota* L.); **group II**: VERPE (*Veronica persica* Poir.), LAMPU (*Lamium purpureum* L.), TRFRE (*Trifolium repens* L.), PLALA (*Plantago lanceolata* L.), LOTCO (*Lotus corniculatus* L.); **group III**: SAXsp (*Salix* sp.), FIIVU (*Filipendula vulgaris* Moench), CIRAR (*Cirsium arvense* (L.) Scop.), POLAV (*Polygonum aviculare* L.), SINAR (*Sinapis arvensis* L.); **group IV**: KNAAR (*Knautia arvensis* (L.) Coult), ASCSY (*Asclepias syriaca* L.), STEME (*Stellaria media* (L.) Vill.); **group V**: AMHFR (*Amorpha fruticosa* L.)

Figure 3. Five group of crop pollinator beneficial species based on frequency and mean relative cover occurring in field margins in northeastern Croatia

Seventeen plants with higher frequency and/or significant cover dominated in the field edges bloom from May to end of September. However, among them four non-natives, invasive species were recorded: *Solidago gigantea*, *Veronica persica*, *Asclepias syriaca* and *Amorpha fruticosa*.

The relationship of floristic composition from field margins and floral resources for entomofauna diet were analyzed using CCA (Figure 4). Only species with the highest weight are displayed. The first ordination axis explained 21.13% of variation and corresponded to

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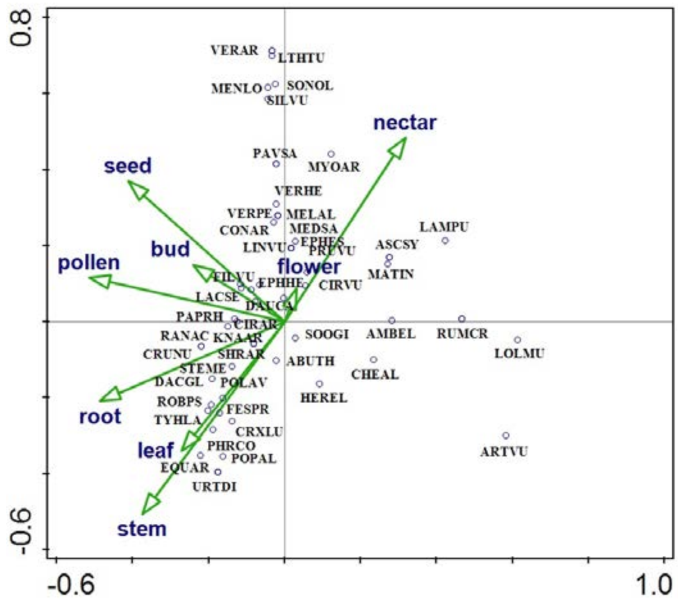

BAYER code of latin names for weeds in ordination diagram: VERAR (*Veronica arvensis* L.), LTHTU (*Lathyrus tuberosus* L.), MENLO (*Mentha longifolia* (L.) Huds.), SONOL (*Sonchus oleraceus* L.), SILVU (*Silene vulgaris* (Moench) Garcke), PAVSA (*Pastinaca sativa* L.), MYOAR (*Myosotis arvensis* (L.) Hill), VERHE (*Veronica hederifolia* L.), VERPE (*Veronica persica* Poir.), MELAL (*Melandrium album* (Mill.) Garcke), CONAR (*Convolvulus arvensis* L.), MEDSA (*Medicago sativa* L.), LINVU (*Linaria vulgaris* Mill.), EPHES (*Euphorbia esula* L.), PRUVU (*Prunella vulgaris* L.), LAMPU (*Lamium purpureum* L.), ASCSY (*Asclepias syriaca* L.), MATIN (*Matricaria inodora* L.), CIRVU (*Cirsium vulgare* L.), DAUCA (*Daucus carota* L.), LACSE (*Lactuca seriola* L.), PAPRH (*Papaver rhoeas* L.), CIRAR (*Cirsium arvense* (L.) Scop.), RANAC (*Ranunculus acris* L.), KNAAR (*Knautia arvensis* (L.) Coult.), CRUNU (*Carduus nutans* L.), SHRAR (*Sherardia arvensis* L.), STEME (*Stellaria media* (L.) Vill.), DACGL (*Dactylis glomerata* L.), POLAV (*Polygonum aviculare* L.), ROBPS (*Robinia pseudoaccacia* L.), FESPR (*Festuca pratensis* Huds.), TYHLA (*Typha latifolia* L.), CRXHI (*Carex hirta* L.), PHRCO (*Phragmites australis* (Cav.) Trin. ex Steud.), POPAL (*Populus alba* L.), EQUAR (*Equisetum arvense* L.), URTDI (*Urtica dioica* L.), SOOGI (*Solidago gigantea* Aiton), AMBEL (*Ambrosia artemisiifolia* L.), RUMCR (*Rumex crispus* L.), LOLMU (*Lolium multiflorum* Lam.), ABUTH (*Abutilon theophrasti* Medik.), CHEAL (*Chenopodium album* L.), HEREL (*Heracleum sphondylium* L.), ARTVU (*Artemisia vulgaris* L.)

Figure 4. Ordination of plant species from the field margins beneficial to local entomofauna

differences between the plants more attractive as a nectar sources from others. For example, *Lamium purpureum*, *Asclepias syriaca*, *Veronica hederifolia*, *Myosotis arvensis*, *Lathyrus tuberosus* are visited by pollinators more for nectar, than other food source. The second axis explained 17.8% of total variation and contrasts species mainly served as a food for leaf-, stem- or root- eating insects, from those using nectar and pollen or consuming seeds or flowers. Plants associated with insect food preference to vegetative parts are mainly perennial wind pollinated species as: *Equisetum arvense*, *Urtica dioica*, *Typha latifolia*, *Phragmites australis* and *Carex hirta*.

DISCUSSION

In the Republic of Croatia weed flora in arable lands have changed over past several decades (Radojčić et al., 2018; Štefanić et al., 2019). Some species are declining in their abundance, whereas others have increased (Štefanić et al.,2018). Agricultural intensification in this region has led to more homogenous landscapes, contrasted by large crop fields and less uncultivated areas. This makes farms poor habitat for wild bees and other pollinators, since they rely on floral resources for their diet (Kremen et al., 2002).

In intensive farmland landscapes, mass-flowering crops provide a valuable source of food during a short period of time. However, the blooming period of oilseed crops (rapeseed and sunflower) are short and separated by a gap of about 2 months, while surrounding areas with legumes and orchards are in lesser extent. Pollinators have to rely on other resources, weeds, which are not usually as abundant and dense as the crops (Russo et al., 2013) and one of the challenge that bees have in agricultural environment is a lack of season-long food source (Bohart, 1971).

Many studies have shown that peripheral areas around fields contains a variety of wildflower species, and have positive effect on the pollinators (Denisow and Wrzesien, 2015, Rands and Whitney, 2011). This research demonstrated that vegetation on the field margins in the northeastern Croatian fields is floristically diverse and flower-rich habitat around intensively farmed landscapes. Pollen and nectar resources are available through whole season, particularly from May to the end of September.

Neophytes made up 12% of the total flora recorded during the study, and was less than Dajdok and Wuczinsky (2008) found in field margins of southwestern Poland. Among the top ranked species that provide pollen and nectar for pollinator communities in investigated area, four alien species were recorded. The most frequent one, but with the low relative cover is *Veronica persica* (group II: abundant). This weed is characteristic for segetal habitats, and is most commonly found in the cultivated fields than in field margins (Dajdok and Wuczinsky, 2008), suggesting that direction in which this species disperse is from crops to field margins. However, very abundant (group I) *Solidago gigantea*, pose a serious threat to the field margin communities. Together with moderate abundant (group IV) *Asclepias syriaca*, and common (group V) *Amorpha fruticosa* can readily form xenospontaneous communities, and jeopardize plant biodiversity. However, above mentioned species are valuable food sources for the pollinators, and beekeeping in the region (Stefanic et al., 2003; Stefanic et al., 2005).

Positive role of vegetation from field margins was not valuable for pollinators only, but also serve as supply the substrates that provide a shelter and nesting sites for many other insects.

Different plant parts may provide a range of resources for associated fauna. Leaves and stems may be browsed, whereas pollen and nectar provide resources for pollinating insects. Interestingly, many plant species were not clear separated by either between or closeness to their relationship to phytophagous diet preferences, such as *Stellaria media*, *Cirsium arvense*, *Papaver rhoeas*, *Polygonum aviculare*, *Sonchus arvensis*. Similar host plant relationship to phytophagous insects was reported by Marshall et al. (2002).

CONCLUSIONS

Field margins have important role in the biological diversity of farmlands since pollinators require floral resources (pollen and nectar) throughout their active season. Weed communities on field margins in northeastern Croatia can be a stable and functional additional provider of flower resources for crop pollinators, particularly when crop species are not in flower. Honey bees and other pollinators can forage throughout the year, but main period is from May to end of September. However, an attention should be pay on several invasive, but for pollinators very attractive species that were found abundant on crop margins. They are: *Solidago gigantea*, *Asclepias syriaca* and *Amorpha fruticosa*.

Positive role of vegetation from field margins was not valuable for pollinators only, but they also serve as supply the substrates that provide a shelter, nesting sites and various foods for many other entomofauna.

REFERENCES

Backman, J. P. C., Tiainen, J. (2002) Habitat quality of field margins in a Finnish farmland area for bumblebees (Hymenoptera: *Bombus* and *Psithyrus*). Agriculture, Ecosystem and Environment, 89, 53-68. DOI: https://doi.org/10.1016/S0167-8809(01)00318-8

BiolFlor (2004) Database BiolFlor. Helmholtz Centre for Environmental Research. [Online] Available at: http://www2.ufz.de/biolflor/index.jsp [Accessed 18 May 2019]

Bohart, G. E. (1971) Management of Habitats for Wild Bees. In: Proceedings Tall Timbers Conference on Ecological Animal Control by Habitat Management no. 3, Tallahassee, February 25-27, 253-266.

Booij, C. J. H., Noorlander, J. (1992) Farming systems and insect predators. Agriculture, Ecosystem and Environment, 40, 125-135. DOI: https://doi.org/10.1016/0167-8809(92)90088-S

Braun-Blanquet, J. (1964) Pflanzensoziologie. Wien, New York: Springer, 865 pp.

Dajdok, Z., Wuczynski, A. (2008) Alien plants in field margins and fields of southwestern Poland. Biodiversity Research and Conservation, 9-10, 19-34.

Denisow, B., Wrzesien, M. (2015) The Importance of Field-Margin Location for Maintenance of Food Niches for Pollinators. Journal of Apicultural Science, 59 (1), 27-36. DOI: https://doi.org/10.1515/jas-2015-0002

Derksen, D. A., Lafond, G. P., Thomas, A. G., Loeppky, H. A., Swanton, C. J. (1993) Impact of Agronomic Practices on Weed Communities: Tillage Systems. Weed Science, 41, 409-417. DOI: https://doi.org/10.1017/S0043174500052127

FloreAlpes (2005) [Online]. Available at: (http://www.florealpes.com/) . [Accessed 26 May 2019].

Gallai, N., Salles, J.-M., Settele, J., Vaissiere, B. E. (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics, 68, 810-821. DOI: https://doi.org/10.1016/j.ecolecon.2008.06.01

Klein, A. M., Vaissiere, B. E., Cane, J. H., Stefan-Dewenter, I., Cunningham, S. A., Kremen, C., Tscharntke T. (2006) Importance of pollinators in changing landscapes for world crops. In: Proceedings of the Royal Society B: Biological Sciences 274 (1608), 303-313. DOI: https://doi.org/10.1098/rspb.2006.3721

Kremen, C., Williams, N. M., Thorp, R. W. (2002) Crop pollination from native bees as risk from agricultural intensification. In: Proceedings of the National Academy of Science, 99, 16812-16816.

Magurran, A. E. (1988) Ecological Diversity and Its Measurement. Princeton University Press, Princeton, 179 pp.

Marshall, E. J. P. (2001) Biodiversity, herbicides and non-target plants. In: Proceedings 2001 Brighton Crop Protection Conference – Weeds, Brighton, UK, 855-862.

Marshall, E. J. P., Moonen, A. C. (2002) Field margins in northern Europe: their functions and interactions with agriculture. Agriculture, Ecosystems and Environment, 89, 5-21. DOI: https://doi.org/10.1016/S0167-8809(01)00315-2

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 Research, 43, 77-89. DOI: https://doi.org/10.1046/j.1365.3180.2003.00326x

Marshall, E. J. P., West, T. M., Klejin, D. (2006) Impacts of an agri-environment field margin prescription on the flora and fauna of arable farmland in different landscapes. Agriculture, Ecosystems and Environment, 113 (1-4), 36-44.
DOI: https://doi.org/10.1016/j.agee.2005.08.036

Nicholls, C. I., Altieri, M. A. (2013) Plant biodiversity enhances bees and other insect pollinators in agroecosystems. A review. Agronomy for Sustainable Development, 33,257-274.
DOI: https://doi.org/101007/s13593-012-0092-y

Nikolić, T, ed. (2019) Flora Croatica Database [Online] Available at: http://hirc.botanic.hr/fcd. Prirodoslovno-matematički fakultet, Sveučilište u Zagrebu [Accessed 16 May 2019]

Plantureux, S., Amiaud, B. (2010) e-FLORA-sys, a website tool to evaluate the agronomical and environmental value of grasslands. [Online] Available at: http://eflorasys.inpl- nancy.fr/. In: 23th General Meeting of the European Grassland Federation, Kiel (Allemagne). [Accessed 28 May 2019].

Radojčić, N., Štefanić, E., Antunović, S., Zima, D., Dimić, D., Štefanić, I. (2018) Weed Species Changes over Long-term Period in Sugar Beet Production. Listy Cukrovarnicke a Reparske 134, (6-7), 242-246.

Rands, S.A., Whitney, H.M. (2011) Field Margins, Foraging Distances and Their Impacts on Nesting Pollinator Success. PLoS One, 6 (10), e25971. DOI: https://doi.org/10.1371/journal.pone.0025971

Russo, L., DeBarros, N., Yang, S., Shea, K., Mortensen, D. (2013) Supporting crop pollinators with floral resources: network-based phenological matching. Ecology and Evolution, Sep;3(9):3125-40.
DOI: https://doi.org/10.1002/ece3.703

SAS Institute (2019) The SAS system for Windows (Release 9.4) [Software]. Cary, NC: SAS Institute.

Schumacher, M., Ohnmacht, S., Rosenstein, R., Gerhards, R. (2018) How Management Factors Influence Weed Communities of Cereals, Their Diversity and Endangered Weed Species in Central Europe. Agriculture, 8 (11)
DOI: https://doi.org/10.3390/agriculture8110172

Stefanic, E., Puskadija, Z., Stefanic, I., Bubalo, D. (2003) Goldenrod: a valuable plant for beekeeping in northeastern Croatia. Bee World, 84 (2), 88-92.
DOI: https://doi.org/10.1080/0005772X.2003.11099581

Stefanic, E., Stefanic, I., Solic, M. E. (2005) Common indigobush and its significance for beekeeping in the Republic of Croatia. Bee World, 86 (2), 42-44.
DOI: https://doi.org/10.1080/0005772X.2005.11099652

Stefanic, E., Kovacevic, V., Antunovic, S. (2018) Decline of arable flora diversity in Istria (from the year 2005 to the year 2017). Zbornik Veleucilista u Rijeci, 6, 385-398.
DOI: https://doi.org/10.31784/zvr.61.25

Štefanić, E., Kovačević, V., Antunović, S., Japundzić-Palenkić, B., Zima, D., Turalija, A., Nestorović, N. (2019) Floristic Biodiversity of Weed Communities in Arable Lands of Istria Peninsula (from 2005 to 2017). Ekologia (Bratislava), 38, 166-177.
DOI: https://doi.org/10.2478/eko-2019-0013

Stoate, C., Boatman, N. D., Borralho, R. J., Carvalho, C. R., De Snoo, G. R., Eden, P. (2001) Ecological impacts of arable intensification in Europe. Journal of Environmental Management, 63, 337-365.
DOI: https://doi.org/10.1006/jema.2001.0473

ter Braak, C. J. F., Smilauer, P. (2012) Canoco Reference Manual and User's Guide.

Software for Ordination (version 5.0). Biometris, Wageningen and Česke Budejovice, 496 pp.

Thomas, A. G., Ivany, J. A. (1990) The weed flora of Prince Edward Island cereal fields. Weed Science, 38, 119-124.
DOI: https://doi.org/10.1017/S0043174500056241

Van Elsen, T. (1989) Ackerwildkraut-Gesellschaften herbizidfreier Ackerränder und des herbzidbehandelten Bestandesinneren im Vergleich. Tuexenia, 9: 75– 105.

Van Emden, H. F. (1965) The role of uncultivated land in the biology of crop pests and beneficial insects. Scientia Horticulturae, 17, 121-136.

Van der Maarel E. (1979) Transformation of cover-abundance values in phytosociology and its effect on community similarity. Vegetatio, 39, 97–114.

Weibull, A. C., Ostman, O. (2003) Species composition in agroecosystems: The effect of landscape, habitat, and farm management. Basic and Applied Ecology, 4, 349-361.
DOI: https://doi.org/10.1078/1439-1791-00173

Whittaker, R. H. (1975) Communities and Ecosystems. Mac Millan, New York. 162 pp.