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Source / Izvornik: **Archives of Biological Sciences, 2020, 72, 403 - 411**

Journal article, Published version
Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

https://doi.org/10.2298/ABS200605034S

Permanent link / Trajna poveznica: https://urn.nsk.hr/urn:nbn:hr:112:338598

Impact of weeds from field margins on adjacent agriculture land

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Received: June 5, 2020; **Revised**: July 31, 2020; **Accepted**: July 31, 2020; **Published online**: August 25, 2020

Abstract: A vegetation survey in northeastern Croatia explored the influence of intensive arable farming on the weed community in relation to the crop edge and adjacent field margin. A total of 141 vascular plants were recorded, and significant differences among the species appear in the field margins (134) as compared to the crop edges (109) and middle of the fields (49). Native plants predominated (83.7%), but among non-natives, the most abundant were *Ambrosia artemisiifolia* L., *Abutilon theoprasti* Med. and *Veronica persica* Poir., with the highest cover values inside the cropped areas, particularly during spring sowing of row crops. The most diverse (having significantly higher Evenness and Shannon's diversity index) was the community from the field margin, followed by the weed community that developed on the crop edges. Three distribution patterns were observed: weeds typically limited to the crop area, weeds limited to the non-crop area and weeds with some ability to spread from the field margins. Major variations in species composition were identified according to sowing season and crop type. Wind dispersal annuals with light- and nitrogen-demands were associated with disturbed, tilled habitats, while perennials with higher requirements for moisture and other than a wind mode of dispersal, were associated with the field margins.

Keywords: field margins; weed communities; plant diversity; agricultural land use intensity; environmental gradient

INTRODUCTION

Field margins have an important agricultural, environmental and ecological role in rural landscapes. These boundaries, such as hedgerows, road verges, ditch verges and forest edges, represent a strip of semi-natural vegetation that borders arable fields and separate them from the next landscape element [1,2]. As such, a very diverse set of plants inhabit field margins and contain a variety of plant communities in different structures. They can range from aquatic elements to ruderal and even woodland communities. Nowadays, it is widely recognized that field margins and crop edges play an important role in the conservation of biodiversity and provide a habitat for several animal and insect species that depend on them for food, shelter, reproduction, overwintering and dispersal [3,4]. Moreover, they are a buffer against run-off of chemicals from the field, and can reduce soil erosion, floods and pesticide drift [5].

However, due to changes in agricultural land-use intensity during the past decades, field margins have become areas of regular and extensive disturbance by anthropogenic factors, which has resulted in a decrease in the number and the lengths of field margins, particularly hedges [6], in western European countries [7], but not yet in central and eastern Europe [8].

Several studies have established that simplification of cropping system complexity and intensification of certain agricultural practices are responsible for a significant decrease in floristic diversity in the arable landscape [9,10]. Flora from field margins also depends on specific management practices associated with

How to cite this article: Štefanić E, Antunović S, Kovačević V, Turalija A, Zima D.Impact of weeds from field margins on adjacent agriculture land. Arch Biol Sci. 2020;72(3):403-11.

agriculture, such as mowing, grazing, fertilizer and pesticide application and crop rotations [11].

The physical structure of margins (type and width of the boundary between the fields and its adjacent land cover, the presence of ditches, etc.) influences margin flora, and is also related to global land management at the local scale, as well as public policies and land planning by local communities [12]. Therefore, it is relevant for researchers, farmers and legislators to know if a relationship exists between boundary structures and weed abundance and their frequency in boundaries and adjacent fields [13].

The flora of field margins can have both direct and indirect influences on adjacent agriculture, and a variety of interactions exist between fields and their margins. Some margin flora may spread into crops, becoming field weeds, but more often, the weed flora of arable crops is unrelated to the flora in the margin [14,15].

The objective of this study was to analyze the floristic composition and diversity of field margins and adjacent cultivated lands on a large-scale landscape level in the northeastern part of Croatia. More specifically, the goal of this research was to examine which agronomic and environmental variables best explain the weed communities of field margins and nearby cultivated fields.

MATERIALS AND METHODS

The study area

A two-year-long phytocoenological survey was conducted in the Osijek-Baranja county located in the northeastern part of the Republic of Croatia (DMS: 45° 38' 13.2" N, 18° 37'4.8" E; Supplementary Fig. S1A). This is the most fertile agricultural area in Croatia where farming is characterized by capital-intensive and market-oriented production, with maize, wheat, sugar beet, soybeans, sunflower, oilseed rape and barley as the main crops. The region experiences a warm and moderate to dry lowland climate from the west to the eastern part of the region, respectively. The average yearly temperature is 11.4°C, and the average yearly precipitation is 699 mm, with the highest spring rainfall regime in June.

Sampling procedure

A total of 32 randomly selected sites were surveyed during the 2017 and 2018 vegetation seasons. At each site, one phytocoenological relevé at a standard size of 100 m^2 (2 m x 50 m) was recorded in the central parts of the monitored field (Table 1), followed by one relevé (2 m x 50 m) that was chosen at the crop edge, and one (2 m x 50 m) on an adjacent undisturbed field margin strip (Supplementary Fig S1B), with a total of 96 phytocoenological relevés. Field boundaries analyzed in this survey were flat or bank structures <3 m or >3m, with no trees nearby.

Table 1. Summary of floristic data and community diversity metrics for vegetation within the field margins, crop edges and the middle of the fields in northeastern Croatia

	Field margins	Crop edges	Middle of the fields
Floristic summary data			
Total species richness	134^{a}	109^{b}	49^{c}
Adventive species richness	15^{a}	9^{b}	5^{b}
Species richness (per relevé)	23.36^{a}	16.4^{b}	9.1^{c}
Community diversity metrics			
Evenness (E)	0.69^{a}	0.60^{ab}	0.42^{b}
Shannon diversity index (H')	3.05^{a}	2.37^{b}	1.69^{c}
Simpson's dominance index (D)	0.19^{b}	0.26^{b}	0.39^{a}

Different letters among the field margins, crop edges and the middle of the fields indicate significant differences by a Dwass-Steel-Critchlow-Fligner multiple comparison test (with a significance of $P<0.01$).

The cover abundance value of each species was estimated using the Braun-Blanquet cover abundance scale [16], which considers the percentage of ground cover with the following scale intervals: 0-1, 1-5, 5-10, 10-25, 25-50, 50-75, 75-100%. The mean of each interval was transformed to an ordinal scale and was used as the absolute species cover [17].

Sites were visited during the fully developed stage for cereals in May, and for wide-row crops in June and August. Plant nomenclature was unified in accordance with the Flora Croatica Database (https://hirc.botanic.hr/fcd/).

Explanatory variables and data analysis

As a first step, the community-level indices were used to evaluate the floristic structure of weed communities of field margins, crop edges and the middle of the fields. They were calculated as follows: total species richness = total number of species in a sample area; adventive species richness = total number of non-native (exotic) species in a sample area; species richness = number of plant species in each relevé; Evenness (E) = H'/ln(richness) [18]; Shannon-Wiener diversity index (H') = $-\Sigma[p_i \ln(p_i)]$, where p_i is the proportion of the total number of species made up of i^{th} species [19]; Simpson index of dominance (D) = Σp^2_i [19], where p_i is the proportion of each taxon in the sample area (relevé).

To compare and contrast each index, the means were analyzed by the Kruskal-Wallis nonparametric test since the data were not normally distributed. Statistical testing was performed with SAS using the PROC NPAR1WAY procedure after testing for normality with the Shapiro-Wilk normality test [20]. Post-hoc comparison was done using the Dwass-Steel-Critchlow-Fligner multiple comparison procedure.

Five agronomic and five environmental variables were chosen for further analysis. In the agronomic category, the variable "Location in the field" (1) distinguished between relevés taken from the field margins, crop edges and the middle of the field; the variable "Crop" (2) included sites where maize (*Zea mays* L.), sunflower (*Helianthus annuus* L.), soybean (*Glycine max* (L.) Merr.), oilseed rape (*Brassica napus* L.), sugar beet *(Beta vulgaris* L.), winter wheat (*Triticum aestivum* L.) and winter barley (*Hordeum vulgare* L.) were grown; the variable "Sowing arrangement" (3) distinguished between winter sown crops (wheat, barley and oilseed rape) and spring sown crops (maize, sunflower, soybean and sugar beet); the variable "Crop row distance" (4) distinguished between ≤50 cm (wheat, barley and soybean) and >50 cm (soybean, maize, sunflower, sugar beet and oilseed rape) row spacing and "Crop height" (5) distinguished between crops as <100 cm (sugar beet, wheat, barley, soybean) and >100 cm (soybean, oilseed rape, maize and sunflower).

Environmental variables included: the variable "Life forms" (i), annuals and perennials; the variable "Dispersal mode" (ii) incorporated the following mechanisms of dispersal: animals, wind, and other; variable (iii) included Ellenberg indicator values for light (EIV – L); variable (iv) included Ellenberg indicator values for moisture (EIV – H); variable (v) included Ellenberg indicator values for nitrogen (EIV – N) [21].

For classification and ordination of floristic, agronomic and environmental data, multivariate analysis was applied using CANOCO 5 [22]. First, detrended correspondence analysis (DCA) was done in order to obtain a graphical representation of the ecological structure of the vegetation projected along to its position on the fields (field margins, field edges, the middle of the field). Prior to ordination analysis, species with a constancy less than 5% were excluded from the analysis due to the sensitivity of the DCA to rare species [23].

Next, the importance of five agronomic and five environmental descriptors were checked using two redundancy analyses (RDA). The significance of explanatory agronomic and environmental characteristics of both RDAs was tested using a Monte Carlo permutation test (999 permutations). The permutation test was also used to test the significance of the explanatory variables in the forwarded selection procedure to determine the statistical significance of each descriptor singly (marginal effect), and in the order of additionally explained variance (conditional effects).

RESULTS

Floristic structure of the weed community

A total of 141 species of vascular plants belonging to 113 genera and 38 families were found during the study period**.** From the total recorded species, 134 and 109 plants appeared in the field margins and crop edges, respectively, while 49 weeds were present inside the fields. Significant differences (Kruskal-Wallis test: H=12.46, *P*=0.001) in total species richness were noted between these three different habitats (Table 1). Crop edges and the middle of the fields shared 28 species, while only 19 were found to be common to field margins and the middle of the fields. There were 24 species common to the field margins and crop edges and only 44 species common to all habitats and locations (Fig. 1).

Native plants (118 species, 83.7%) predominated, and only 23 adventive species (16.3%) were identified during the study. The number of alien species differed between the field crops (middle of the fields and the peripheral zone) and the field margins (Kruskal-Wallis test: H=9.22, *P*=0.0022). However, the floristically richest weed community in the field margins contained 11.2% of adventive flora (15 out of 134) of the total species recorded. There were 8.3% alien plants in the crop edges, while the middle of the fields consisted of 10.2% of non-native flora.

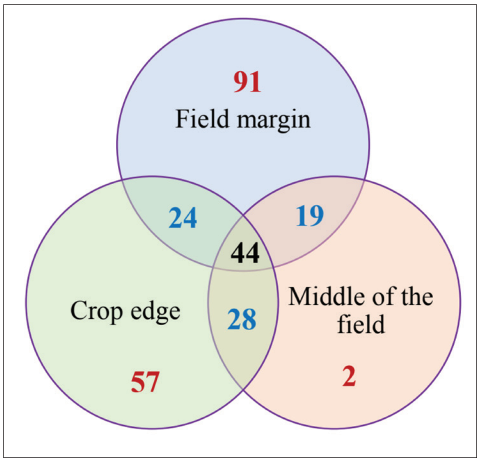

Fig. 1. Floristic structure of the weed community. Venn diagram showing the total number of weed species found within the field margins, crop edges and in the middle of the fields during the study period (2017-2018).

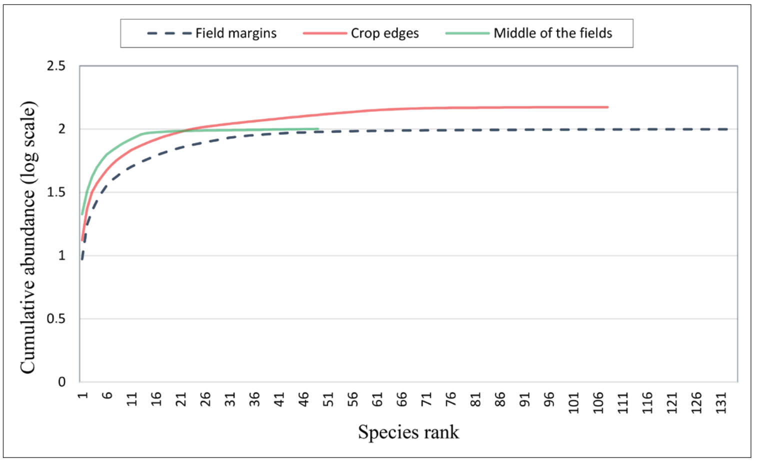

Fig. 2. Species richness and diversity. Species abundance distribution within the field margins, crop edges and in the middle of the fields during the study period (2017-2018).

Although a significantly higher number of alien species was identified outside of the cultivated fields, the most abundant among the non-native plants were *Ambrosia artemisiifolia*, *Abutilon theoprasti* and *Veronica persica*, having the highest cover values in cultivated fields, particularly in spring sowing, row crops. However, the less abundant invasive *Amorpha fruticosa*, *Solidago gigantea* and *Asclepias syriaca* preferred field margins and were rarely found in crop edges, and never inside the crops.

Species richness and diversity

The average weed species richness per relevé significantly decreased (Kruskal-Wallis test: H=10.98, *P*=0.0156) from the field margins (23.36±8.96) to the crop edge (16.4±6.68) and the middle of the fields (9.1±3.82) (Table 2). The same pattern was observed with the mean values of Shannon's diversity index (H'). This measure of species diversity, which takes into account both the abundance and evenness, separates (Kruskal-Wallis test: H=12.59, *P*=0.0162) more diverse and equally distributed plant communities in field margins (H'=3.05) from less diverse communities on crop edges (H'=2.23) and the middle of the field (H'=1.69). Also, the Evenness indices (E) for the boundary areas (E=0.69 and 0.60 for the field margins and crop edges, respectively) were significantly higher (Kruskal-Wallis test: H=11.234, *P*=0.0044), indicating the development of more even and equal communities on less disturbed habitats when compared to those from the middle of the fields (E=0.42).

The distribution of species abundance within an investigated area indicates that most of the species found in all habitats are relatively rare, with only a few being common. The most diverse (the curve lies completely below other curves) was the field margin community, followed by the weed community that developed on the crop edges (Fig. 2).

Although all three communities were characterized by the presence of a few dominant species, the remaining species were with low abundance, and a significantly higher Simpson dominance index (D) was present in the weed community in the tilled, crop area (Kruskal-Wallis test: H=10.99, *P*=0.0036).

Relationship between weed species composition and agronomic and environmental factors

Variations in the composition of weed communities across the whole data set were detected using DCA. Results confirmed that habitat type explained most of the variations in species composition (Fig. 3). Weed communities from the cultivated area (middle of the fields) significantly differed from those at the field margins and crop edges. The first axis explained 49.8% of variation (F-ratio=8.56, *P*=0.009) and corresponded

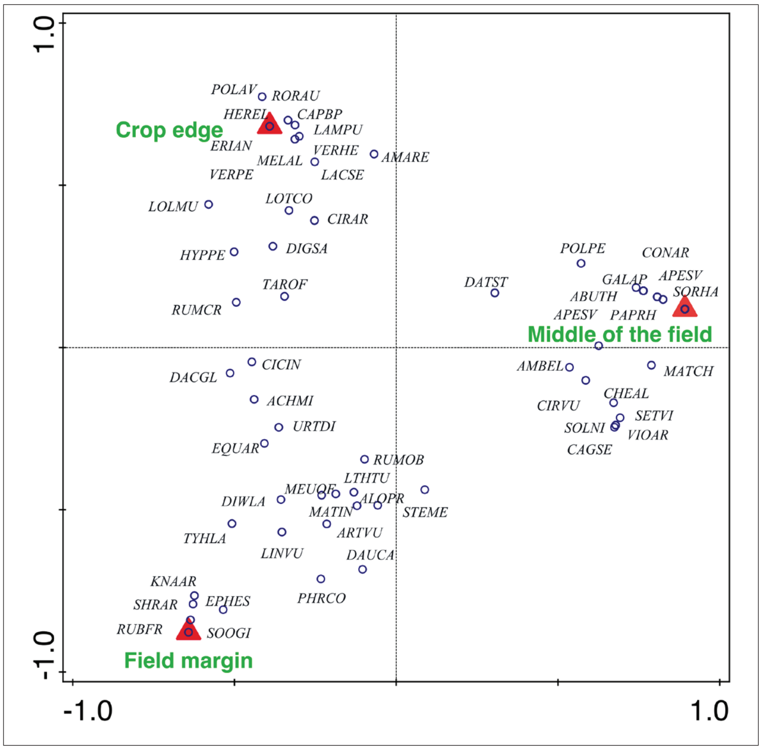

Fig. 3. Relationship between weed species composition and agronomic and environmental factors. DCA ordination of weed species along axes 1 and 2. BAYER code of Latin names for weeds in ordination diagram: POLAV (*Polygonum aviculare* L.), RORAU *(Rorippa austriaca* (Crantz) Besser), HEREL (*Heracleum sphondylium* L.), CAPBP (*Capsella bursa-pastoris* (L.) Medik.), LAMPU (*Lamium purpureum* L.), ERIAN (*Erigeron annuus* (L.) Pers), VERPE (*Veronica persica* Poir), MELAL (*Melandrium album* (Mill) Garcke), VERHE (*Veronica hederifolia* L.), AMARE (*Amaranthus retroflexus* L.), LACSE (*Lactuca seriola* L.), LOTCO (*Lotus corniculatus* L.), CIRAR (*Cirsium arvense* (L.) Scop), LOLMU (*Lolium multiflorum* Lam.), HYPPE (*Hypericum perforatum* L.), DIGSA (Digitaria sanquinalis (L.) Scop.), TAROF (*Taraxacum officinale* F.H. Wigg.), RUMCR (*Rumex crispus* L.), CININ (*Cichorium intybus* L.), DACGL (*Dactylis glomerata* L.), ACHMI (*Achillea millefolium* L.), URTDI (*Urtica dioica* L.), EQUAR (*Equisetum arvense* L.), RUMOB (*Rumex obtusifolius* L.), LTHTU (*Lathyrus tuberosus* L.), MEUOF (*Melilotus officinalis* (L.) Lam.), DIWLA (*Dipsacus laciniatus* L.), MATIN (*Matricaria inodora* L.), ALOPR (*Alopecurus pratensis* L.), STEME (*Stellaria media* (L.) Vill), ARTVU (*Artemisia vulgaris* L.), TYHLA (*Typha latifolia* L.), LINVU (*Linaria vulgaris* Mill), DAUCA (*Daucus carota* L.), PHRCO (*Phragmites communis* Trin.), SHRAR (*Sherardia arvensis* L.), KNAAR (*Knautia arvensis* (L.) Coult.), RUBFR (*Rubus fruticosus* L.), EPHES (*Euphorbia esula* L.), SOOGI (*Solidago gigantea* Aiton), POLPE (*Polygonum persicaria* L.), CONAR (*Convolvulus arvensis* L.), SETVI (Setaria viridis (L.) P. Beauv.), GALAP (*Galium aparine* L.), APESV (*Apera spica-venti* (L.) Beauv.), SORHA (*Sorghum halepense* (L.) Pers.), ABUTH (*Abutilon theophrasti* Medik.), PAPRH (*Papaver rhoeas* L.), AMBEL (*Ambrosia artemisiifolia* L.), MATCH (*Matricaria chamomilla* L.), CHEAL (Chenopodium album L.), CIRVU (Cirsium vulgare (Savi) Ten.), DATST (Datura stramonium L.), SOLNI (*Solanum nigrum* L.), VIOAR (*Viola arvensis* Murray), CAGSE (*Calystegia sepium* L.). Centroids for habitat type were also projected.

to differences between weeds associated with the middle of the fields as compared to weed communities that developed at the crop edges and field margins. The species typically associated with the tilled area (middle of the fields) were as follows: *Abutilon theoprasti*, *Apera spica-venti*, *Ambrosia artemisiifolia*, *Chenopodium album*, *Cirsium vulgare*, *Convolvulus arvensis, Datura stramonium* and *Sorghum halepense.* Field margins and crop edges were occupied mostly by non-arable plants such as *Solidago gigantea*, *Euphorbia esula*, *Sherardia arvensis, Rubus fruticosus* (associated with field margins) and *Polygonum aviculare*, *Rorippa austriaca*, *Capsella bursa-pastoris*, *Lamium purpureum* (associated with crop edges).

The second axis with 13.9% of total variation, distinguished between perennial species that had the highest densities in the non-crop areas and did not spread from the field margins, as mentioned above. The opposite side of axis 2 was occupied by weeds with some ability to spread from the field margins and acted as a filter for exchanges between the field margins and the fields. They were, aside from those mentioned above, *Cirsium arvense*, *Taraxacum officinale*, *Rumex crispus* and *Cichorium intybus.*

RDA between management practices and environmental gradients are presented in Fig. 4A and B, respectively. As shown in Fig. 4A and Tables 2 and 3, agronomic practices that appeared as significant explanatory variables for species composition were the sowing season and crop type, and they mainly influenced tilled areas (cultivated fields) but not the field margins. In the Monte Carlo test, the significance of the first axis was *P*=0.046 (F=3.005) and for all axes it was *P*=0.001 (F=3.643).

Regarding environmental gradients (Fig. 4B, Tables 2 and 3), the first axis correlated best with light- and nitrogen-

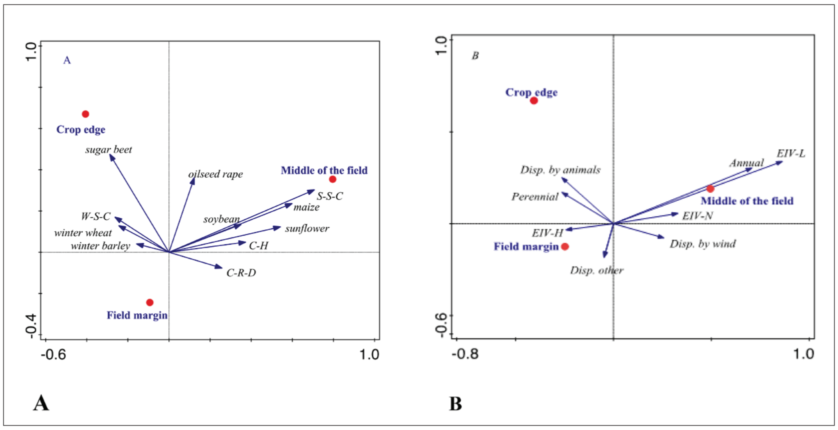

Fig. 4. Results of the first two axes of RDA analysis: coefficients for agronomic (**A**) and environmental variables (**B**). Codes for the variables are given in Table 2. Centroids for habitat type were also projected.

Table 2. Agronomic and environmental variables, units, basic statistics and their coordinates on the first and second ordination axes.

Variables	Mean (Min-Max) or counts	Axis 1	Axis 2
Agronomic variables			
Location in the field			
field margin	n=32	-0.086	-0.244
crop edge	n=32	-0.402	-0.669
middle of the field	n=32	0.792	0.392
Crop			
maize	n=6	0.607	0.232
sunflower	n=5	0.467	0.135
soybean	n=5	0.379	0.117
oilseed rape	n=2	0.129	0.388
sugar beet	n=3	-0.227	0.462
winter wheat	n=9	-0.217	0.139
winter barley	n=2	-0.189	0.151
Sowing arrangement			
winter sown crops	n=13	-0.232	0.189
spring sown crops	n=19	0.737	0.304
Crop row distance (cm)	≥50	0.246	-0.094
Crop height (cm)	≥100	0.712	0.331
Environmental variables			
Life form			
Annual	n=59	0.726	0.298
Perennial	n=82	-0.299	0.176
Dispersal mode			
By animals	n=77	-0.281	0.300
By wind	n=45	0.325	-0.079
Other	n=19	-0.041	-0.219
Ellenberg indicator value for light (EIV-L)	7.43 (4-9)	0.819	0.342
Ellenberg indicator value for moisture (EIV-H)	4.26 (1-7)	-0.226	-0.021
Ellenberg indicator value for nitrogen (EIV-N)	6.72 (1-9)	0.422	0.199

demanding (Ellenberg-L and -N) and wind-dispersal annuals, associated with the middle of the fields (F-ratio=3.783, *P*=0.001). Perennials with high requirements for moisture (Ellenberg-H) and with other vectors of dispersal were associated with negative loadings.

DISCUSSION

A weed community that occurred in field margins, crop edges and the middle of the fields consisted of typical flora of this region, but with different species' composition, density and relative abundance. Due to the rapid changes in farming practice in recent decades, the intensification of agriculture has led to declines in species diversity and abundance [26]. The increase in inputs of fertilizers, herbicides and other chemicals that are effective in seed-cleaning processes and the sowing of highly competitive crops, have significantly reduced species richness in the fields, while crop edges and field margins remain three or more times floristically richer communities and serve as particularly important habitats for wildlife conservation in some cropland surroundings [5]. Studies performed in the Mediterranean region [27], Poland [28] and Finland [29] also revealed field margins as a hotspot of richness and diversity of regional flora.

The dramatic decline in arable flora observed during this study confirmed the research findings from other similar surveys at regional and field levels [30-32]. However, field boundaries and even crop edges had a significantly higher species richness, Evenness (E) and Shannon diversity index (H') than was

Table 3. Summary of the global permutation test (999 Monte Carlo permutations) and the results of forward selection of agronomic and environmental descriptors.

Variable	Marginal effects	Conditional effects	F	P
Agronomic variables				
Location in the field	0.54	0.54	11.78	0.001
Crop	0.40	0.19	3.95	0.006
Sowing arrangement	0.46	0.24	4.89	0.001
Crop row distance	0.38	0.12	3.26	0.067
Crop height	0.36	0.07	2.14	0.212
Environmental variables				
Life form	0.51	0.26	7.97	0.001
Dispersal mode	0.35	0.05	1.77	0.168
Ellenberg indicator value for light	0.51	0.37	9.21	0.001
Ellenberg indicator value for moisture	0.33	0.12	3.98	0.306
Ellenberg indicator value for nitrogen	0.32	0.02	0.86	0.587

recorded in the middle of the fields. These buffer zones are therefore capable of accepting greater plant-species diversity by supporting increased heterogeneity of vegetation [33], although, plant diversity in field boundaries has also slightly changed in recent decades [34] because of agricultural intensification at both field and landscape levels.

Crop edges in this survey appeared to be more heterogenous and diverse than the centers of the fields, since crop management at peripheral parts of fields slightly differed here than in the main field areas [35,36]. These findings confirmed the thesis that arable field edges not only support higher levels of species richness than field centers [37], but they represent a unique habitat since they are subjected to spatial mass effects or spillover of species from neighboring habitats [38], and are biotically linked more to the neighboring field margins than to crop areas [39,40].

Conversely, Simpson's dominance index (D) appeared to be significantly higher in the cropping area, where species such as *Ambrosia artemisiifolia*, *Convolvulus arvensis* and *Sorghum halepense* dominated in the fields. These weeds are found to be noxious, and the particularly invasive *A. artemisiifolia* is highly abundant in row crops [41-43]. From the results presented herein it could be concluded that field margins represent a minor habitat for the distribution and dispersion of non-native plants, while cultivated fields are a more important reservoir, particularly due to their alteration by human activities. Similar findings were obtained for field margins and fields in southwestern Poland [44]; moreover, it was suggested that the relationships between alien and native species in these habitats are not completely understood.

As expected, the habitat type resulted in significant differences in species composition and formed two separate groups: (i) in the tilled area (middle of the fields) and (ii) at crop edges and field margins. Hence, three distribution patterns can be observed: (1) weeds typically limited to the crop area, (2) weeds limited to the non-crop area, and (3) weeds with some ability to spread from the field margins.

Species possessing the ability to spread from field margins are referred to as transient species [45], which rely on regular recolonization from neighboring habitats and are characterized by a more competitive ecological strategy.

The weed community of the boundary regions was not affected to the same extent by the management regime as the weed community inside the crop areas, probably due a lack of regular weed-control measures [6]. Weed control in non-crop areas has economic and environmental costs, and farmers use such control only when it is effective in reducing weed populations within adjacent fields [46]. Therefore, the potential benefits associated with managing weeds are missing.

Agronomic practice indicated that major variations in species composition were identified according to sowing season and crop type, and mainly influenced cultivated fields and to a lesser extent crop edges, but not field margins. It is likely that changes in plant communities in response to management are usually slow [47], and no visible relationship between plant communities of the field margin and arable weed flora was found. Moreover, field margin weeds contributed little to the weed community composition in the fields, suggesting that weed management of field margins may often be of little value. It was suggested [46] that two conditions need to be fulfilled for field margin weeds to affect weed population dynamics within the field: the presence of an unoccupied weed area and high dispersal rates of field margin weeds relative to the field weeds.

Based on the environmental gradient in ordination analysis, perennial, shade-tolerant species with a high requirement for soil moisture (Ellenberg-H) were preferentially associated with non-arable land and crop edges, while annuals, drought-tolerant and light-demanding (Ellenberg-L) species were associated with arable crop habitats [48].

Although wind-dispersal annuals can serve to recolonize and invade fields from the field margins, their actual effect is usually limited to the edge of the fields. This study confirms findings from other research [49,50] showing that weed dispersal from the field margins is important where their density dependence is strong or where local extinction is common.

In summary, weed community composition showed clear spatial patterns from the field margin to the field center, displaying a significantly higher species richness value, Evenness and Shannon's diversity index in field margins with regard to crop edges and the middle of the fields. However, the weed community in the tilled crop area had a significantly higher Simpson dominance index due to the presence of several highly abundant and predominant weeds. Three distribution patterns were observed during the study: weeds typically limited to the crop area, weeds limited to the non-crop area, and weeds with some ability to spread from the field margins. Agronomic practice indicated that major variations in species composition were identified according to the sowing season and crop type, and mainly influenced crop edges and cultivated fields but not field margins. As regards the environmental gradient, the floristic composition of wind-dispersal annuals with light- and nitrogen-demands was associated with disturbed, tilled habitats, while perennials with higher requirements for moisture and other types of dispersal were associated with field margins.

Funding: All funding was provided by authors.

Author contributions: EŠ, SA, VK, AT and DZ participated in collecting data in the field. EŠ performed the data analysis and wrote the manuscript. The interpretation of the results was done and approved by all authors. SA, VK, AT and DZ contributed to the draft of the manuscript.

Conflict of interest disclosure: The authors declare no conflict of interest.

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Supplementary Material

The Supplementary Material is available at: http://serbiosoc.org.rs/NewUploads/Uploads/Stefanic%20et%20al_5443_Supplementary%20Material.pdf