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Weed cover, frequency and diversity in field plots and edges in the soybean central region of Argentina

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ABSTRACT

A comparative survey of the weed species present in field plots and edges was performed in fields at Zavalla (Santa Fe) Argentina in the soybean central region of the country in order to determine changes in cover, frequency and diversity of the weed communities. Five to twelve soybean fields were surveyed in 2006, 2007, and 2009. Weed surveys were carried out in the soybean fallow in winter and after soybean planting in spring. In edges, species richness was higher than in field plots in spring-summer but diversity showed an erratic response. The weed community cover showed a shift in weed vegetation composition relative to the field plot. Our results indicate that the community in crop edges relative to field plots differs in structure and abundance and that many weed species are only present either in crop edges or in field plots.

Keywords: Weed Community; Richness; Glyphosate

1. INTRODUCTION

Agricultural practices have caused major changes in the composition and species richness of weed communities in the field [1,2]. Arable weed species play an important role in supporting biological diversity in agroecosystems [3,4].

Weed species that thrive in the field edges and may colonize cropped plots include *Avena sterilis* and *Galium aparine* [5], *Conyza canadensis* [6] and *Senecio vulgaris* [7]. In other studies, plant populations in field edges have not resulted in weed infestations in the adjacent crop in many studies [8].

There is evidence that herbicide efficacy, increased crop competition and changes in cropping patterns have resulted in a gradual decline in weed abundance and diversity over recent decades [9-11]. Herbicide use is a widespread practice detrimental to weeds [12] and continued use of a single herbicide often results in weed composition shifts from highly susceptible species to those having greater tolerance to the herbicide [13]. The most used herbicide in arable crops in Argentina is glyphosate which provides application flexibility, lacks of rotational restrictions and controls a broad spectrum of weeds [14]. However, as a result of repeated use, species difficult to control with glyphosate have become more common in many countries [15-17] and in Argentina as well [18].

Weed diversity may be concentrated in the crop edges, especially in the weed communities of conventional cereal fields [19,20]. In Argentina, crop edges are narrow areas that are taken out from agriculture. In crop edges, insecticides, fungicides are not used and occasionaly, herbicides are applied. In the field plot, the most used herbicide is glyphosate-alone or in combination with residual herbicides [21]. The objective of this study was to analyze weed abundance and diversity as well as the frequency of weeds tolerant or resistant to glyphosate in field plots and edges in the soybean central region of Argentina.

2. MATERIALS AND METHODS

A weed survey set up in Zavalla (Santa Fe, Argentina) (Lat. 33˚01'S) was designed to measure the weed community in field plots and edges. The survey was carried out across 5 to 12 fields chosen to represent the diversity of cultural practices and environmental conditions present in arable fields in the region. The survey was done each year approximately 30 days after soybean planting in late spring (December 2006 and 2007) and in winter in fallows between summer crops (June 2007 and 2009). These two sampling dates made it possible to account for seasonal variations in weed populations (*i.e.* weeds associated with both autumn-winter and spring-summer cropping patterns). Surveys were generally made after herbicide treatments.

In each arable field plot, in the field plot, an area of approximately 20 ha subjected to normal field management practices was surveyed, positioned at least 20 m from field edge to avoid field border effects. The border of each arable field consisted of narrow areas taken out from agriculture as no herbicides, insecticides, fungicides or fertilizers were applied and no crop was planted.

The same fields were sampled in the successive samplings. In each field, both, field plot and edges surveys were performed by two or more trained persons walking across the survey area sampling randomly all species in 50 records each 20 m in a semicircle 1 m in diameter (3.14 m^2). The method takes into account the cover in percentage of each species in each semicircle. A few plant records determined only at the genus level were discarded from the analysis.

For each species, % frequency of occurrence was calculated using **Eq.1**.

% frequency of occurrence = (number of fields species was detected/total fields sampled) × 100.

Also, each species average cover was calculated using **Eq.2**.

Average cover = Σ (cover from each field where species was present)/number of fields species was detected.

Multi response permutation procedure (MRPP) was used to analyze differences between weed cover in the edge and field plot communities. MRPP was conducted using PCORD [22] software. Euclidean distance was used as the distance measure. MRPP is a nonparametric procedure that does not depend on assumptions such as normally distributed data or homogeneous variances, but rather depends on the internal variability of the data [23]. MRPP evaluates the uniqueness of a priori defined groups relative to all other possible permutations among groups of objects within the sample that have the same size of the proposed classification [24].

Multivariate analysis of data was carried out to partition the respective importance of field plots and edges on weed species composition. Data were classified with the minimal variance method [25], using a resemblance matrix of standarized Euclidean distances [26] and were ordered with PCA (Principal Component Analysis) [27] using a species covariance matrix. Analyses were done using PC-ORD programs [22]. Biplots of samples and species dispersion diagram were made on the plane of the first two axes. In field plots and edges in each date, richness, Shannon's and Simpson's diversity indexes were analyzed using a t-test.

3. RESULTS

3.1. Richness and Diversity

The total number of species recorded was 76 in spring-summer and 66 in winter. Richness and diversity indexes in spring-summer were generally higher in edges relative to field plots and in winter the opposite trend was observed (**Table 1**).

In field plots the percentage of annuals was higher than perennials. Perennials showed higher percentage in edges compared with the field plots (**Table 2**). Of the plant species recorded in the survey, only 8 were grasses in spring summer and 5 in winter.

3.2. Cover

Species composition in crop edges is often different relative to the cropped plot [2,19]. In our study, MRPP showed significant differences between weed cover in field plots and edges. In spring-summer: 2006 ($p < 0.00003$), 2007 ($p < 0.00007$), in winter 2007 ($p < 0.01$), 2009 ($p < 0.007$).

In both, spring-summer and winter surveys when the overall analysis of community compositional differences using PCA was conducted, weed cover in communities under field plots was distinctly separated from edges along the first canonical variable. In spring-summer in 2006 the first axis explained 54.1% of the variation and corresponded to differences between field plots and crop edges (**Figure 1**).

Bromus catharticus, *Sorghum halepense* and *Cynodon*

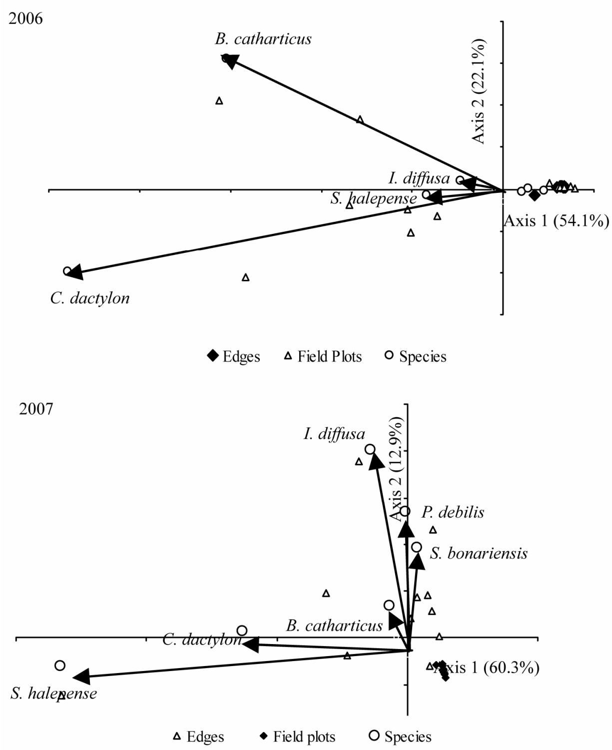

Figure 1. Overall analysis of community weed cover compositional differences using PCA of weed cover in communities under field plots and edges in spring-summer (2006-2007).

Table 1. Richness (S), Shannon's (H), and Simpson's diversity indexes (D).

		S			H			D		
December 2006	Plot	9.8	(6.02)	*	1.9	(0.56)	NS	0.80	(0.11)	NS
	Edge	15.8	(5.26)		1.9	(0.43)		0.75	(0.10)	
December 2007	Plot	10.4	(2.84)	*	2.1	(0.27)	NS	0.86	(0.04)	NS
	Edge	21.4	(4.45)		2.4	(0.32)		0.84	(0.06)	
June 2007	Plot	15.0	(2.1)	*	2.1	(0.41)	*	0.78	(0.14)	*
	Edge	10.0	(2.4)		1.5	(0.54)		0.62	(0.20	
June 2009	Plot	10.4	(5.5)	NS	1.9	(0.79)	NS	0.80	(0.18)	NS
	Edge	11.0	(6.6)		1.8	(0.39)		0.77	(0.11)	

For each column and date * indicates significant differences using a t tet (p = 0.05).

Table 2. Percentage of annual and perennial weed species in field plots and edges.

Summer	2006		2007	
	Field plot	Edge	Field plot	Edge
		(%)		
Annuals	63.6	57.9	72.2	61.8
Perennials	36.4	42.1	27.8	38.2
Winter	2007		2009	
	Field plot	Edge	Field plot	Edge
		(%)		
Annuals	68.1	64.5	57.6	46.4
Perennials	31.9	35.5	42.4	53.6

dactylon were only present in edges. *Iresine diffusa* showed much higher cover in edges and the species most associated with crop field was *Eleusine indica*. The second axis explained 22.1% of total variation. In 2007 the first axis explained 60.3% of the variation and corresponded to differences between field plots and crop edges. Results were similar to 2006 but some other species showed relative high weed cover. *Sphaeralcea bonariensis* was only present in edges and *Parietaria debilis* in both treatments but more associated to edges. The second axis explained 12.9 % of total variation.

In winter in 2007 the first axis explained 59.8% (**Figure 2**). The same the species were found both in the field plots and edges. *Bowlesia incana* was more associated to crop edges while *Poa annua* showed more cover in field plots. The second axis explained 17.3% of total variation. In 2009 the first axis esplained 62.7 and the second axis 36.2% of total variation. *B. catharticus* was only present in edges and *P. debilis* was more associated to edges but also present in the field plot.

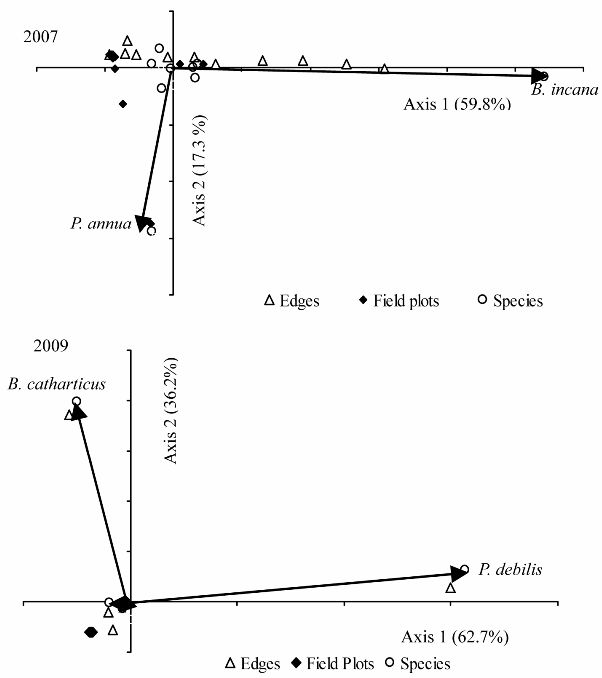

Figure 2. Overall analysis of community weed cover compositional differences using PCA of weed cover in communities under field plots and edges in winter (2007-2009).

3.3. Frequency

In spring-summer, the most frequently encountered species in both treatments and both years were *Anoda cristata* and *Portulaca oleracea* were observed in greater than 50% of the fields. *C. dactylon*, *I. diffusa*, *P. debilis*, *S. halepense*, *Carduus acanthoides*, *Verbena litoralis* occurred only in edges. *Euphorbia hirta* was the only species present with frequency higher than 50% only in the field plot (**Table 3**). Within the annual grassy weeds, *Digitaria sanguinalis*, *Echinochloa colona* and *Eleusine indica* showed the highest frequency.

In winter, *P. debilis* was the only species present with

Table 3. Mean maximum frequencies of the most common field plot and edge species in spring-summer in 2006 and 2007.

	2006		2007	
	F. Plot	Edge	F. Plot	Edge
Althernanthera philoxeroides (Mart.) Griseb.	-	15	-	9
Amaranthus quitensis Kunth	31	38	45	6
Ammi majus L.	-	23	-	9
Anoda cristata (L.) Schltdl	54	54	64	64
Artemisia annua L.	-	15	-	9
Baccharis salicifolia (Ruiz & Pav.) Pers.	-	-	-	18
Bidens subalternans DC.	-	23	-	18
Brassica rapa L.	-	23	-	-
Bromus catharticus Vahl.	-	53	-	100
Capsella bursa-pastoris (L.) Medik.	31	0.01	36	18
Carduus acanthoides L.	16	54	0.01	82
Centaurium pulchellum (Sw.) Druce	-	7	-	9
Chenopodium album L.	30	8	0.01	18
Chenopodium pumilio R. Br.	-	15	-	9
Cirsium vulgare (Savi) Ten.	0.01	31	9	9
Commelina erecta L.	10	77	0.01	10
Convolvulus arvensis L.	7	31	-	0.01
Conyza bonariensis (L.) Cronquist	15	85	81	27
Coronopus didymus (L.) Sm.	23	8	9	9
Cynodon dactylon (L.) Pers	15	62	0.01	100
Cyperus esculentus L.	47	46	0.01	47
Cyperus rotundus L.	-	-	-	36
Cyclospermum leptophyllum (pers.) Sprague	8	24	0.01	19
Datura ferox L.	15	8	-	-
*Dichondra microcalyx (*Hallier f.) Fabris	15	8	27	18
Digitaria sanguinalis (L.) Scop.	77	35	54	100
Echinochloa colona (L.) Link	77	38	63	55
Eleusine indica (L.) Gaertn.	69	54	35	55
Eleusine tristachya Lam.	8	-	54	-
Eryngium eburneum Decae.	-	15.4	-	9
Euphorbia hirta L.	61	31	72	36
Euphorbia serpens Kunth	0.01	31	72	27
Gamochaeta subfalcata (Cabrera)	0.00	8	90	-
Iresine difusa L.	15	69	0.01	100
Ipomoea nil (L.) Roth.	0.01	8	9	9

Continued

Ipomoea purpurea (L.) Roth.	-	-	-	27
Ipomoea rubriflora O Donell	-	23	-	18
Jaborosa runcinata Lam.	15	8	-	-
Lamium amplexicaule L.	15	-	18	-
Lolium multiflorum L.	-	23	-	36.
Modiolastrum gillesii (Steud.) Krapov.	-	-	-	36
Nicotiana longiflora Cav.	-	23	-	-
Oenothera indecora Cambess.	0.01	8	27	-
Parietaria debilis G. Forst.	0.01	51	27	91
Physalis viscosa L.	23	46	45	10
Portulaca oleracea L.	77	54	72	51
Polygonum aviculare L.	8	-	-	-
Rapistrum rugosum (L.) All.	-	15	-	45
Rumex crispus L.	0.01	8	9	36
Senecio grisebachii Baker	-	15	-	27
Solanum diflorum Vell.	-	15	-	36
Sonchus oleraceus L.E.	61	31	54	64
Sorghum halepense (L.) Pers.	-	61	-	63
Sphaeralcea bonariensis (Cav.) Griseb.	-	30	-	45
Trifolium repens L.	15	15	36	36
Urochloa platyphylla (Nash) R.D. Webster	15	8	18	-
Verbena litoralis Kunth	15	51	0.01	100
Verónica persica Poiret.	15	-	-	-

Especies with frequency lower than 10% in both years *Amaranthus viridis* L.; *Ambrosia tenuifolia* Spreng; *Ammi visnaga* (L.) Lam.; *Chloris canterae* Arechav.; *Festuca arundinacea* Schreb.; *Geranium dissectum* L.; *Ipomoea grandifolia* (Dammer) O Donell; *Linaria canadensis* (L.) Dum.Cours; *Nothoscordum gracile* (Dryand. Ex Aiton) Stearn; *Oxalis micrantha* Bert. ex Colla; *Plantago lanceolata* L.; *Setaria viridis* (L.) P. Beauv.; *Sida spinosa* L.; *Solanum sisymbriifolium* Lam.; *Taraxacum officinale* Weber; *Urtica urens* L.; *Verbena bonariensis* L.; *Wedelia glauca* (Ortega) Hoffman.

frequency higher than 50% only in edges. *B. incana*, *C. bursa-pastoris*, *C. didymus* and *S. oleraceus* were observed in greater than 50% of the fields (**Table 4**). *Rapistrum rugosum* ocurred only in edges. The only annual grassy weeds were *B. catharticus* and *Poa annua.*

4. DISCUSSION

Overall, MRPP indicated variations in species composition between edges and field crops. Two weed communities were identified according to season: Spring-summer (soybean crop) and winter (fallow). Variations in weed species composition between seasons were also observed in another study [28].

The higher richness and diversity in spring-summer observed for edges relative to field plots concurs with other studies [8,19,20,29,30] which may be due to the absence of chemical control in edges as ocurred in another study [11]. Crop fields are characterised by considerable herbicide applications which may partially explain why their weedy vegetation is different from edges not subjected to these inputs [31]. However, in our study in winter, the opposite trend was observed as higher or similar diversity values were determined for field plots relative to edges. The effect of herbicides on weed diversity has also been erratic in other studies where herbicides applied over more than one year either reduced [32] or maintained [33] diversity. In both spring-summer and winter surveys and in both years between 52% and 67% of the observed species were annuals which concurs with another study in arable fields [34].

In arable fields, the generalized adoption of glyphosate-

Table 4. Mean maximum frequencies of the most common field plot and edge species in winter in 2007 and 2009.

	2007		2007	
	F. Plot	Edge	F. Plot	Edge
Althernanthera philoxeroides (Mart.) Griseb.	54	9	-	-
Ammi majus L.	0.01	9	20	-
Amaranthus quitensis Kunth	-	-	60	20
Artemisia annua L.	0.01	9	20	-
Baccharis salicifolia (Ruiz & Pav.) Pers.	-	18	-	20
Bowlesia incana Ruiz & Pav.	82	91	55	61
Brassica rapa L.	18	36	-	-
Bromus catharticus Vahl.	9	40	-	60
Capsella bursa-pastoris (L.) Medik.	82	45	60	-
Carduus acanthoides L.	18	36	60	60
Cirsium vulgare (Savi) Ten.	82	45	0.01	20
Conyza bonariensis (L.) Croquist	100	63	20	40
Coronopus didymus (L.) Sm.	91	55	80	20
Convolvulus arvensis L.	-	-	20	20
Cotula australis (Sieber ex Spreng.) HooK. F.	64	36	-	-
Cynodon dactylon (L.) Pers.	-	-	20	60
Cyperus esculentus L.	36	27	80	-
Cyclospermum leptophyllum (Pers.) Sprague	9	36	-	-
Dichondra microcalyx Meisn.	27	9	20	-
Eryngium eburneum Decne.	9	36	-	-
Eryngium horridum Malme	-	-	20	40
Fumaria capreolata L.	9	9	0.01	40
Gamochaeta subfalcata (Cabrera) Cabrera	91	91	40	20
Geranium dissectum L.	-	27	-	-
Geranium molle L.	-	-	-	20
Hypochoeris brasiliensis (Less.) Benth. et Hook.	-	-	-	20
Hybanthus parviflorus (Mutis ex L.f.) Baill.	-	-	-	20
Jaborosa runcinata Lam.	28	27	-	-
Lamium amplexicaule L.	100	27	20	-
Linaria canadensis (L.) Dum. Cours.	-	-	20	-
Lolium multiflorum L.	-	9	-	-
Medicago lupulina L.	-	-	40	-
Modiolastrum gilliessi (Steud.)	-	-	20	-
Modiola caroliniana (L.) G. Don	9	27	-	-
Nicotiana longiflora Cav.	-	18	-	-

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Oenothera indecora Cambess.	9	27	20	-
Oxalis articulata Savigny	-	-	-	20
Oxalis cordobensis Knuth.	45	-	-	-
Parietaria debilis G. Forst.	36	55	10	100
Physalis viscosa L.	0.01	9	20	-
Plantago lanceolata L.	9	18	-	-
Poa annua L.	73	27	40	-
Rapistrum rugosum (L.) All.	-	18	-	40
Rorippa bonariensis Poir. Macloskie	27	-	-	-
Rumex crispus L.	9	-	-	40
Senecio grisebachii Baker	64	-	40	60
Senecio vulgaris L.	55	-	-	-
Side rhombifolia L.	-	-	-	40
Solanum diflorum Vell.	-	-	-	20
Sonchus oleraceus L.	100	-	80	80
Sorghum halepense (L.) Pers.	-	-	40	-
Stellaria media (L.) Villars	82		-	-
*Taraxacum officinal*e Weber	18	-	0.01	20
Trifolium repens L.	18	-	20	-
Urtica urens L.	36	-	20	40
Verbena litoralis Kunth	27	-	0.01	20
Veronica persica Poiret	73	-	-	-
Veronica peregrina L.	9	-	20	-

Species with frequency lower than 10%: *Anagallis arvensis* L.; *Anthemis cotula* L.; *Centaurium pulchelum* (Sw.) Druce; *Datura ferox* L.; *Gnaphalium gaudichaudianum* DC.; *Mollugo verticilada* L.; *Polygonum aviculare* L.; *Raphanus sativus* L.

resistant soybean resulted in a less dense and variable weed community in many other studies [14,21,35-38]. Glyphosate shows very effective control of a wide range of species including non-target species and changes in weed populations in response to the adoption of glyphosate-resistant soybean has been reported elsewhere [39,40]. Although there is no evidence to suggest that herbicides such as glyphosate lead to the elimination of species at the field scale [41], in the present study, weed cover in average in the field plot was always low. The absence of glyphosate application in edges may favour potentially rare arable, broad-leaved weeds.

The crop planted at high density and the use of herbicides and fertilizers favour crop production, and increase the growth of the crop relative to the weed species [42] which can account for the low weed cover in the field.

In our study the species composition differed between years. Some of the most common species in spring-summer were *A. cristata* and *P. oleracea* which are also quoted as important weed species in other studies [43,44]. In our study, the most comon grassy perennial weeds were *S. halepense*, *C. dactylon* and *B. catharticus*. Those grassy perennials species usually form a dense canpy which exerts high competitive pressure for many other weeds. *S. halepense* and *C. dactylon* aerial biomass is killed by frosts but the dead canopy remains during winter. *B. catharticus* is a short-lived perennial densely-tufted and robust. Its aerial biomass is not killed by frosts and consequently its green canopy is present during the whole year. Some species common in crop edges are adapted to grow under the canopy of perennial species [28]. Among these especies, *P. debilis* is a broad-leaved annual species which showed higher cover in edges relative to the field crop. The canopy of the grassy preenial weeds can accout for this different behaviour as edges protect *P. debilis* from freezing, allowing plants to achieve more biomass accumulation than in the field plots [45]. Another annual broad-leaved species common in winter was *B. incana*, present in both the crop field and edges. This species is also mentioned as an important winter weed in the region in another study [37].

The most frequent annual grassy annuals were *D. sanguinalis*, *E. colona* and *E. indica*. In the last years, grassy annuals are more abundant due to the adoption of no-tillage systems [21]. Increases in summer grassy annual density when tillage is eliminated has been shown in previous research [46].

In our study, the only species found with high frequency that is tolerant to glyphosate was *A. cristata*. No resistant weeds were detected. In edges, several species tolerant to glyphosate in high frequency were observed: *C. erecta*, *C. dactylon* and *P. debilis*.

Our results indicate that the community in crop edges relative to field plots differs in structure and abundance and many weed species are only present either in crop edges or in field plots.

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