Crop rotation effects on weed communities of soybean (*Glycine max* L. Merr.) agricultural fields of the Flat Inland Pampa

Emilio H. Satorre [1,5#], Elba B. de la Fuente [2], M. Teresa Mas [3], Susana A. Suárez [4], Betina C. Kruk [a], Antonio C. Guglielmini [a], Antoni M. C. Verdú [c]

[1] Universidad de Buenos Aires. Facultad de Agronomía. Departamento de Producción Vegetal. Cátedra de Cerealicultura. Buenos Aires, Argentina.

[2] Universidad de Buenos Aires. Facultad de Agronomía. Departamento de Producción Vegetal. Cátedra de Cultivos Industriales. Buenos Aires, Argentina.

[3] Escola Superior d'Agricultura de Barcelona, Departament d'Enginyeria Agroalimentària i Biotecnologia-Universitat Politècnica de Catalunya, Castelldefels, Barcelona, Spain.

[4] Universidad Nacional de Río Cuarto. Facultad de Exactas Físico-Químicas y Naturales. Departamento de Ciencias Naturales. Río Cuarto, Argentina.

[5] CONICET- Universidad de Buenos Aires. Instituto de Investigaciones Fisiológicas y Ecológicas Vinculadas a la Agricultura (IFEVA). Buenos Aires, Argentina.

*Corresponding author
Name: Emilio Horacio Satorre
Email: satorre@agro.uba.ar
Address: Universidad de Buenos Aires. Facultad de Agronomía. Departamento de Producción Vegetal. Cátedra de Cerealicultura. Avenida San Martín 4453, (C1417DSE) Ciudad Autónoma de Buenos Aires, Argentina.
Tel: (54+11) 4524 8039; 4524 8053
Fax: (54+11) 4514 8737; 4514 8739

Abstract

Extensive grain crop production systems in the flat inland Pampas mainly include soybean, double crop wheat-soybean and maize in rotation. Due to difficult-to-control weed problems farmers are tending to intensify the rotations in their fields by increasing the number of double crops or by including cover crops before the main crop. Land use intensification may be characterized using the intensification sequence index (ISI), which is the number of crops *per* year considering all crops sown in a particular period; *i.e.* the average number of crops sown in a time unit. To determine how agricultural intensification and crop sequences may modify weed communities, 31 soybean fields of commercial farms located in the Flat Pampa of Argentina were surveyed. Frequency of individual weeds within the fields was determined and various statistical methods were used to evaluate changes in weed community composition or function due to intensification (ISI level). A total of fifty-three species, mostly therophytes (28 species), were recorded in soybean crop fields at harvest. Three weed communities were identified, which were related to the ISI level of the fields and to the number of years continuously sown with grain crops (*i.e.* number of years since the last pasture). Weed community under intensified fields was characterized by low species richness ($p<0.05$); i.e. the number of weed species was reduced when more crops were sown per year. However, total weed frequency (weed abundance) and weed functional groups were not significantly reduced by field intensification. Since weed problems in grain crops of the Pampas are increasing, mainly due to herbicide resistant weeds, the use of ISI as part of an integrated weed management strategy is discussed.

Keywords

Crop rotations, intensified crop sequences; soybean; weed shift; integrated weed management

1. Introduction

The Flat Pampa is one of the five highly productive Pampa ecological zones (Hall et al, 1992). It has experienced over the past 50 years huge agricultural changes mainly driven by the expansion of soybean (*Glycine max* L. Merr.) crops. Soybean was introduced as grain crop in the 1970s and became the most important summer crop since the 1990s (Satorre, 2001; 2005; 2011). At present, transgenic soybean is sown in almost 60% of flat Pampas with a narrow package of agricultural practices such as no-till cropping, glyphosate resistant varieties, and sowing dates as single-crop or double-crop soybean. The soybean centered crop system has influenced arable weed species shifting. In fact, Pampa´s weed community composition was modified and weed abundance was reduced during the early stages of the expansion process of soybean (Vitta et al., 2004; Puricelli and Tuesca, 2005; de la Fuente et al., 2006; Mas et al., 2010). However, recently herbicide resistant weeds have progressed from only one reference in the early 90´s to more than 27 different biotypes comprising 14 species mostly appearing during the past 10 years (REM AAPRESID, http://www.aapresid.org.ar/rem/). Herbicide tolerant and herbicide resistant weeds became the main agriculture problem (Satorre, 2016) and the simplification and repetitive disturbances of the crop production system has been pointed as the main cause (Martínez-Ghersa et al., 2000; Scursoni and Satorre, 2010; de la Fuente and Satorre, 2016). In response to this, the number of herbicide applications and their rate was increased while moment and type of herbicide applications (i.e from systemic foliar absorbed herbicides to residual soil applied herbicides) were simultaneously changed. These have raised concerns, mainly from the associated risks on production (due to cost and phytotoxicity increases), environment and human health. To reduce the negative influence of such weed management changes, land use intensified crops such as double-crops and cover crops have been proposed. Land use intensification is here referred as the number of crops *per* year considering all crops sown in a particular rotation period which is usually quantified by the intensification sequence index (ISI).

Weed communities may be greatly affected by crop rotation since various, sometimes different, herbicides are applied and some crops may strongly compete for resources (Leroux et al., 1996; Bàrberi et al., 1997; Doucet et al., 1999; Gulden et al., 2010). Moreover, intensified crop rotations (i.e. a rotation with high ISI) may not only reduce growth and fecundity but also weed establishment. The reduction of the fallow period or its absence may reduce weed establishment by regulating dormancy release factors (Satorre and Ghersa, 1987; Benech Arnold et al., 2000; Poggio, 2005; Poggio and Ghersa, 2011; Andrade et al, 2017). However, the extent to what can be expected as community changes from intensifying crop rotations, have not been documented in real on farm crops.

In the Flat Pampas soybean still is the main crop; although in the last campaign the area under soybean was slightly reduced and that under maize was increased. Few other summer crop species such as sunflower and sorghum are sporadically sown (Ministerio de Agroindustria, 2019; https://datos.agroindustria.gob.ar/dataset/estimaciones-agricolas). Despite the prevalence of a reduced number of winter (wheat and barley) and summer crop species (soybean and maize), individual fields experienced various crop sequences and levels of intensification including almost single soybean monocultures to more intensified complex rotations. In this region long time changes in the structure and functioning of weed communities following the expansion of agriculture from mixed beef cattle-grain crop to permanent grain crop production systems have been reported (Ghersa and León, 1999; de la Fuente et al., 1999, 2006, 2010; Mas et.al., 2010; Poggio et al., 2010, 2013;). However, little attention has been paid to short term forces of change. Increases in intensification levels (i.e. the set of rotations with greater ISI levels) could rapidly affect the weed communities in the region. A recent experimental approach with two different land intensification levels in the Pampa showed that the frequency of highly common weeds was negatively associated with the number of days with high crop cover (Andrade et al., 2017b). In this paper, the hypothesis that floristic composition and richness of weed communities is changed and that the frequency of predominant weed species is reduced by agricultural intensification levels on farm fields under various crop sequences were tested. For this purpose, commercial fields under a wide range of ISI management levels were evaluated to detect short term weed community shifts on species composition, richness and on species frequency in soybean fields of the Flat Pampas of Argentina.

2. Materials and methods

Weed surveys were performed in commercial fields within selected farms located in the main grain crop producing area of the Flat Pampas in the northwest of Buenos Aires province, Argentina (34° 59´ to 35° 06´ South, 60° 23´ to 60° 37´ West, approximately; Fig 1 inset). Surveys were performed in soybean fields during the summer of 2012, 2013 and 2014. In the region, climate is temperate, mild and humid with hot summers, historic annual precipitation average is 993 mm and historic average temperature is 16 ^{o}C. Total summer rainfall was 545.3 mm in 2012, 391.03 mm in 2013 and 496 mm in 2014. Fields were chosen after analyzing a historical data base of two groups of farmers (Bragado and Alberdi, Buenos Aires, Argentina) that belong to AACREA organization (https://www.crea.org.ar/) Fields represented the variability of actual rotations and crop management of nearly 5,000 km^2. Average field size was 70 ha to ensure that almost all spontaneous species of the Flat Pampa crop system may be included in the surveys (Mueller-Dombois & Ellenberg, 1974). Surveyed soybean crops were grown under direct drilled rainfed conditions on typic and entic Hapludoll soils which were similarly managed. Weed control was the usual in the region and glyphosate tolerant varieties were used in all fields. During the fallow and after crop emergence, weed control included grass and broadleaf herbicides.

Sampled areas within the fields fulfilled the following requirements (Mueller-Dombois and Ellenberg, 1974): (i) they were large enough to contain all species belonging to the plant community), (ii) the habitat was uniform within the field area, and (iii) plant cover was homogeneous. Field margins and low areas were avoided, because they may represent different habitats (e.g. different management and soil conditions). A total of thirty one fields were surveyed to assess weed species frequencies and weed community composition at soybean seed-maturing growth stage R7 (Table 1; Fehr et al., 1971). Surveys were made between 15 March and 15 April. This time interval was chosen based on two criteria: (i) spring-summer and autumn-winter weed communities were present; and (ii) the last weed chemical control during the soybean crop cycle had already been applied, in average 70 days before.

Table 1

Year	Farm name	Farm geographic coordinates	Number of fields
2012	San José	34° 52’ 26’’ S / 60° 39’ 28’’W	2
	Los Montes	34° 27’ 33’’ S / 61° 47’ 33’’ W	1
	La Suerte	34° 28’ 04’’ S / 61° 42’ 51’’ W	3
	La Larga	34° 59’ 25’’ S / 60° 37’ 32’’ W	4
	La Manchada	35° 05’ 55’’ S / 60° 24’ 00’’ W	4
2013	La Manchada	35° 05’ 55’’ S / 60° 24’ 00’’ W	1
	San Felipe	34° 27’ 36’’ S / 61° 47’ 34’’ W	4
	La Colorada	35° 04’ 13’’ S/ 60° 23’ 56’’ W	1
2014	La Colorada	35° 04’ 13’’ S/ 60° 23’ 56’’ W	3
	San Felipe	34° 27’ 36’’ S / 61° 47’ 34’’ W	2
	La Larga	34° 59’ 25’’ S / 60° 37’ 32’’ W	3
	La Manchada	35° 05’ 55’’ S / 60° 24’ 00’’ W	3

Table 1 caption: Farm name, geographic coordinates and number of fields surveyed at each one of the three years study.

Within each field a group of trained persons surveyed weed species presence or absence in 1 m^2 sample quadrats. Surveys were performed along four radial transects each 30 m long oriented at North, East, South and West. Along each transect quadrats were placed every 2 m and all weeds present were recorded. Therefore, in each field, 60 quadrats were sampled to determine the frequency of each species (proportion of quadrats per field containing a given species) and the species richness (number of species per field) and to estimate weed constancy (percentage of fields containing a given species).

Arrangement of weed species in functional groups was used to give a better understanding of how weed communities were assembled (Ghersa and León, 1999; Booth and Swanton, 2002). Functional attributes were determined for each weed species considering (i) Raunkiaer life forms into therophytes, geophytes, hemicryptophytes, chamaephytes, phanerophytes; (ii) origin, into native and exotic and; and (iii) growth habit (annual or perennial). Few taxa were only identified at the level of genus and in this case their functional groups were not considered.

At survey time, fields had various preceding crops, agriculture history length and land use intensification levels (ISI) during the last seven-year cropping period. The number of years under continuous agriculture (YCA) since the last pasture and number of crops after the last maize sown (CALM) were used to characterize the field history and crop sequence. Three categories of ISI were considered for the analysis; *i.e.* ISI-A (from 0.571 to 1.143, 6 fields), ISI-B (from 1.250 to 1.286, 16 fields), and ISI-C (from 1.429 to 1.714, 9 fields). Statistical differences among categories were tested and resulted significantly different (p<0.001) with a Tukey-Kramer least square means multiple comparison test performed with the GLM procedure of SAS (SAS® University Edition; SAS Institute Inc. 2015, Cary, N.C., USA).

Weed species composition in the different ISI categories was tested by using the Multi-Response Permutation Procedure (MRPP; Mielke, 1984) using PC-ORD Multivariate Analysis of Ecological Data Version 5.0 with squared Euclidean distances (McCune and Mefford, 1999). Pair-wise comparisons between categories were also performed (Zimmerman et al., 1985). Linear associations among weed assemblages and ISI and YCA as explanatory variables were obtained by mean of canonical correspondence analysis (CCA; ter Braak, 1987). Axis scores were centered and standardized to unit variance, and were scaled for representation of species and surveys. A biplot from CCA was obtained by overlaying a vector diagram based on coefficients from the canonical functions describing each axis.

The GENMOD procedure of SAS was used to perform generalized linear models and least-square means comparisons. Number of species *per* quadrat was analyzed using a generalized linear model with Poisson distribution. Year, ISI and CALM were considered as sources of variation in the model. The CALM (number of crops after the last maize crop) was categorized for this analysis into two levels, (i) two crops or less (12 fields) and (ii) more than two crops after the last maize grown (19 fields); while the three categories previously defined were considered for ISI.

The analyses of the proportion of quadrats with presence of weeds (frequency) were performed using a generalized linear model with a binomial distribution and logit link function considering the same sources of variation as previously described. Due to over-dispersion, all statistical parameters were adjusted by the deviance divided by their degrees of freedom. Leastsquares means were computed and used to compare mean values of each source of variation using probability values from the chi-square distribution.

3. Results

Fifty-three species were recorded from all 31 soybean fields. There were more therophytes (28 species) than any of the other functional groups. There were also 10 hemicryptophytes species, 8 geophytes, 4 chamaephytes and only one phanerophyte species (Table 2). Weeds were mainly annuals (28 species). However, 18 species were perennials and one was annual–biennial and one biennial–perennial. According to species origin almost the same quantities were natives and exotics (26 and 21, respectively; Table 2).

Table 2

Floristic group	Species name	Species code	Plant life form	Status	Growth habit	Species constancy (%)			
						ISI-A	ISI-B	ISI-C	Total
I	*Digitaria sanquinalis* (L.) Scop.	digsa	Therophytes	Exotic	Annual	100	53	75	68
	Stellaria media (L.) Cirillo	steme	Therophytes	Exotic	Annual	83	53	63	61
	Lamium amplexicaule L.	lamam	Therophytes	Exotic	Annual	50	53	63	55
	Cyperus sp.	cypsp	Geophytes		Perennial	67	41	50	48
	Chenopodium album L.	cheal	Therophytes	Exotic	Annual	50	53	25	45
	Conyza bonariensis (L.) Cronquist.	conbo	Therophytes	Native	Annual	50	47	38	45
	Portulaca oleracea L.	porol	Therophytes	Exotic	Annual	50	41	50	45
	Triticum aestivum L.	triae	Therophytes	Exotic	Annual	50	35	63	45
	Anoda cristata (L.) Schltdl.	anocr	Chamaephytes	Native	Perennial	50	47	25	42
	Oxalis conorrhiza Jacq.	oxaco	Hemicryptophytes	Native	Perennial	67	35	38	42
	Amaranthus hybridus L.	amahy	Therophytes	Exotic	Annual	83	24	13	32
	Euphorbia lasiocarpa Klotzsch	eupla	Hemicryptophytes	Native	Perennial	17	29	38	29
	Euphorbia dentata Michx.	eupde	Therophytes	Native	Annual	17	18	38	23
	Cirsium vulgare (Savi) Ten	cirvu	Therophytes	Exotic	Annual	17	18	25	19
	Tagetes minuta L.	tagmi	Therophytes	Native	Annual	17	24	13	19
	Commelina erecta L.	comer	Geophytes	Native	Perennial	17	12	13	13
	Sida rhombifolia L.	sidrh	Chamaephytes	Native	Perennial	33	6	13	13
	Datura ferox L.	datfe	Therophytes	Native	Annual	17	6	13	10

	Senecio pampeanus Cabrera	senpa	Chamaephytes	Native	Perennial	17	6	13	10
	Xanthium strumarium L.	xanst	Therophytes	Native	Annual	17	6	13	10
II	*Eleusine indica* (L.) Gaertn.	elein	Therophytes	Exotic	Annual	67	35		32
	Lepidium didymum L.	lepdi	Hemicryptophytes	Native	Annual-Biannual	33	12		13
	Bidens subalternans DC.	bidsu	Therophytes	Native	Annual	33	6		10
	Bowlesia incana Ruiz et. Pav.	bowin	Therophytes	Native	Annual	17	12		10
	Dichondra microcalyx (Hallier f.) Fabris	dicmi	Geophytes	Native	Perennial	33	6		10
	Gleditsia triacanthos L.	gletr	Phanerophytes	Exotic	Perennial	17	12		10
	Urtica urens L.	urtur	Therophytes	Exotic	Annual	17	6		6
	Sorghum halepense (L.) Pers.	sorha	Geophytes	Exotic	Perennial	17	6		6
	Senecio vulgaris L.	senvu	Therophytes	Exotic	Annual	17	6		6
	Setaria parviflora (Poir.) Kerguélen	setpa	Geophytes	Native	Perennial	17	6		6
	Gamochaeta sp.	gamsp	Hemicryptophytes			17	6		6
III	*Solanum* sp.	solsp				17		13	6
	Jaborosa integrifolia Lam.	jabin	Geophytes	Native	Perennial	17		13	6
	Juncus sp.	junsp				17		13	6
IV	*Zea mays* L.	zeama	Therophytes	Native	Annual	17			3
	Panicum bergii Arechav.	panbe	Hemicryptophytes	Native	Perennial	17			3
	Physalis viscosa L.	phyvi	Geophytes	Native	Perennial	33			6
	Poa annua L.	poaan	Therophytes	Exotic	Annual	17			3
	Eragrostis sp.	erasp	Hemicryptophytes			17			3
V	*Amaranthus viridis* L.	amavi	Hemicryptophytes	Native	Perennial		12		6
	Chaptalia nutans (L.) Po.	chanu	Hemicryptophytes	Native	Perennial		6		3
	Chloris sp.	chlsp	Hemicryptophytes				12		6
	Sonchus oleraceus L.	sonol	Therophytes	Exotic	Annual		12		6
	Lolium multiflorum Lam.	lolmu	Therophytes	Exotic	Annual		6		3
	Echinochloa colona (L.) Link	echco	Therophytes	Exotic	Annual		6		3
	Convolvulus arvensis L.	conar	Geophytes	Exotic	Perennial		6		3
	Bromus catharticus Vahl	broca	Hemicryptophytes	Native	Biannual-Perennial		6		3
	Carduus acanthoides L.	carac	Therophytes	Exotic	Annual		6		3
	Cenchrus spinifex Cav.	censp	Therophytes	Native	Annual		6		3
VI	*Hordeum vulgare* L.	horvu	Therophytes	Exotic	Annual			13	3
	Iresine diffusa Humb. & Bonpl. ex Willd.	iredi	Chamaephytes	Native	Perennial			13	3
	Bidens pilosa L.	bidpi	Therophytes	Native	Annual			25	6
	Anagallis arvensis L.	anaar	Therophytes	Exotic	Annual		12	13	10
Total number of species						39	42	27	53

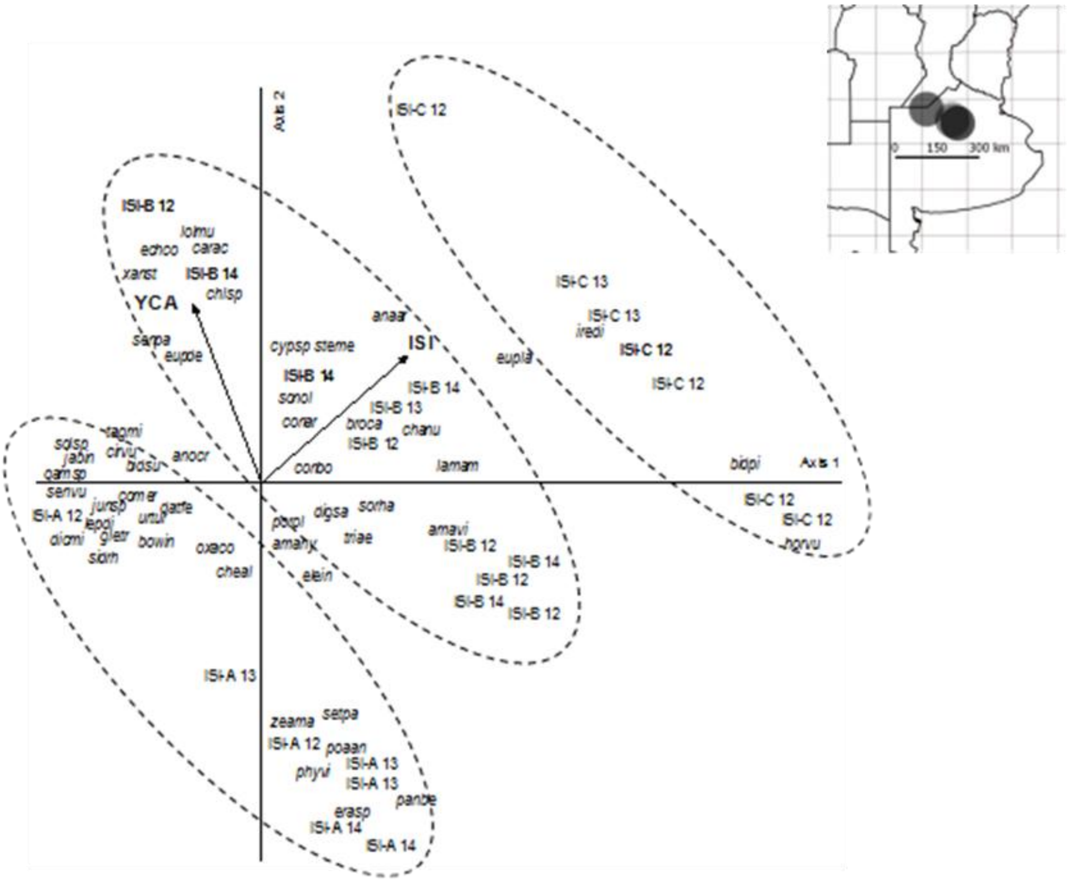
(*) The code is formed with the three first letters of the genus and two of the specific epithet.

Table 2 caption: Floristic groups, species list, code (*), function (plant life form, status, growth habit) and constancy according to levels of ISI (ISI-A, ISI-B and ISI-C) registered in the fields surveyed.

Level of intensification (ISI) determined three different weed communities, one for each ISI category (see material and methods), which varied in the arrangement of floristic groups. Six floristic groups were recognized according to the species composition and constancy. Floristic group I was represented by species present with high constancy values in all the ISI ranges. Floristic group II was present in ISI-A and B while floristic group III was present in ISI-A and C. Floristic groups IV, V and VI were only present in ISI-A, ISI-B and ISI-C, respectively (Table 2). The richness of ISI A, B and C weed communities was 39, 41 and 26 respectively ($p<0.05$); i.e. species richness decreases as intensification increases. Floristic composition differed statistically according to MRPP only between weed communities related to extreme ISI (ISI-A and ISI-C, $p<0.05$) but functional composition was similar among weed communities ($p>0.10$, Table 2).

The CCA arranged weed species in both axis regarding to the years under continuous agriculture (YCA) and the intensification sequence index (ISI). Axis 1 explained 30 % of the total variance and was mostly related to the ISI values of fields; therefore it strongly separate floristic group VI from floristic groups II and III (Fig. 1). Floristic group V was between the previously mentioned floristic groups and it was associated to ISI-B fields. Within each ISI group the distance in axis 2 explained 20 % of the total variance, and it was mostly related to the number of years under continuous agriculture of fields (YCA; Fig. 1). All ISI categories and floristic groups were represented by fields surveyed in different years and with long and short agricultural history.

Fig. 1.



Caption Fig. 1: Ordination diagram of weeds (code: three-first letters, genus; two last letters, specific epithet, see Table 2) in the two principal axes of the CCA. The relative lengths of the arrows indicate the importance of a variable. The distribution of data points in the analysis is represented by the ISI level (ISI-A, B, and C) followed by the last two numbers of the year of the survey (12, 13, and 14). Inset indicates the position and area where the surveys were performed.

The probability of finding together different species in the same quadrat was overall low (1.03 species m^{-2} on average from all fields, Table 3). However, there were significant differences among ISI categories (0.75 for ISI-C and 1.12 for ISI-A, Table 3). The frequency of some species from floristic group I was analyzed separately (Table 3). Some species were negatively ($p<0.05$) affected by crop sequence intensification of the fields while others were promoted or remained unaffected. The frequency of *Digitaria sanguinalis* and *Oxalis conorrhiza* diminished as the ISI increased but in the case of *Euphorbia dentata* the frequency increased as the ISI also increased. All the other species explored (*Amaranthus hybridus*, *Conyza bonariensis*, *Cyperus* sp. and *Portulaca oleracea*) remained statistically unaffected by ISI (Table 3). Weed frequency, as a measure of the weed infested area of the fields, was relatively high (62 %; Table 3) and it was not significantly affected by ISI, *i.e.* weed infested areas were similar in fields with different ISI levels.

Among the variables considered to characterize the structure of the crop sequence of the fields, CALM (the number of crops after the last maize sown) significantly affected some of the weed populations. The frequency of *A. hybridus* was higher and that of *E. dentata* was lower when maize crops were grown less than two years before the surveyed soybean crop (CALM<2 years, $p<0.05$, Table 3).

Table 3

	Effects					
	Intensification (ISI)		CALM			
Variable	*p*>chi-square	Lsmeans (*)	*p*>chi-square	Lsmeans (*)	Overall mean	deviance/ df
Richness	<0.0001	ISI-A 1.12 a ISI-B 1.08 a ISI-C 0.75 b	<0.0001	L- 1.12 a H- 0.84 b	1.03	1.19
Total frequency of weed species	0.7324	ISI-A 0.71 a ISI-B 0.64 a ISI-C 0.57 a	0.5717	L- 0.68 a H- 0.60 a	0.62	24.6
Frequency of:						
Digitaria sanguinalis	0.0363	ISI-A 0.40 a ISI-B 0.07 b ISI-C 0.15 ab	0.0614	L- 0.31 a H- 0.09 a	0.22	26.1

Cyperus sp.	0.4905	ISI-A 0.01 a ISI-B 0.05 a ISI-C 0.04 a	0.5457	L- 0.02 a H- 0.04 a	0.04	7.3
Conyza bonariensis	0.3273	ISI-A 0.02 a ISI-B 0.03 a ISI-C 0.06 a	0.5916	L- 0.03 a H- 0.04 a	0.04	4.2
Portulaca oleracea	0.5687	ISI-A 0.02 a ISI-B 0.03 a ISI-C 0.01 a	0.1275	L- 0.03 a H- 0.01 a	0.02	3.6
Oxalis conorrhiza	0.0053	ISI-A 0.046 a ISI-B 0.012 b ISI-C 0.005 b	0.1143	L- 0.022 a H- 0.009 a	0.02	2.2
Amaranthus hybridus	0.3144	ISI-A 0.017 a ISI-B 0.035 a ISI-C 0.006 a	0.0007	L- 0.051 a H- 0.005 b	0.03	4.4
Euphorbia dentata	0.0313	ISI-A 0.0011 a ISI-B 0.0044 a ISI-C 0.0154 b	<.0001	L- 0.0006 a H- 0.0284 b	0.03	2.3

(*) Least-square means of the same effect with different letters are different at $p<0.05$.

Table 3 caption: Effects of ISI and CALM on (i) richness, as average number of weed species per square meter, (ii) total frequency of weed species, and (iii) the frequency of some abundant summer-crop weed species. If effects are significant ($p<0.05$) different letters are presented to identify different means. Categories of ISI were ISI-A, 0.57 to 1.14, ISI-B, from 1.25 to 1.29, and ISI-C, from 1.43 to 1.71. Levels of CALM considered were equal or less than two crops (L) and more than two crops (H). Overall least-square mean values and deviance are also presented for each effect and level.

4. Discussion

Agricultural intensification reduced floristic richness of weed communities in agricultural fields of the Flat Pampa (Table 2, Fig. 1). Various authors indicated that intensified agriculture may reduce plant biodiversity (Vandermeer et al., 1998; Yeates and Bongers 1999; Chapin et al., 2000; Norris et al., 2003; Butler et al., 2007). In addition, there are evidences that land use intensification greatly modify the habitat, resource availability or soil properties which may be responsible of changes in plant biodiversity and weed community composition (Lacher et al., 1999; Tscharntke, 2002; Benton et al.,. 2003; Foley et al., 2005; Andrade et al., 2015, 2017a) independently from the herbicides used as weed control strategies. Large canopy gaps due to fallow periods, which are usually more frequent in single than double crops were signaled to reduce crop competition and to promote greater weed richness in low intensified fields (Poggio et al., 2005). Although weed richness was reduced, it appeared that overall weed infestation was not significantly reduced by ISI (Table 3). As it was expected, some weed populations may persist and grow under intensified rotations while others may not (Kruk, 2015). Weeds differed in their performance when ISI was modified (Fig. 1, Table 2 and 3). Various mechanisms could take part in the persistence and growth of some weed populations and the failure of others under the studied conditions. For example, it may be hypothesized that *Eleusine indica* establishment has been affected by the higher amount of plant residues on top soil under direct drilled more intensified fields since plant residues reduce alternating temperatures which are necessary for germination of *E. indica* (Ismail et al., 2002; Chauhan and Johnson, 2008). Other species, such as *Bidens subalternans*, *Sonchus oleraceus*, *Carduus acanthoides* and *Physalis viscosa* are very sensitive to soil degradation (de la Fuente et al., 1999) which may occurred in fields under continuous soybean which was frequent in poorly intensified (ISI-A) conditions. On the contrary, *Iresine diffusa*, from floristic group VI present in intensified fields (ISI-C), is a perennial species, less dependent on dormancy terminating factors and tolerant to glyphosate (Puricelli and Faccini, 2009). To recognize and consider the various weed responses involved is important if ISI is going to be part of an integrated weed management strategy.

Some important soybean weeds were not reduced under high ISI fields. Most of these species were characterized within floristic group I (Table 2) including *D. sanguinalis*, *A. hybridus* and *Chenopodium album*. These species have been indicated as highly competitive (Guglielmini et al., 2017) causing great crop yield losses. Moreover, herbicide resistant biotypes of some of these species have already been recognized under field conditions in the region (REM AAPRESID, http://www.aapresid.org.ar/rem/). Our results call the attention that rotation intensification should not be considered individually as an easy solution but a weed management alternative to temporarily reduce herbicide use and to diversify weed control methods. As already occurred with soybean in the simple low ISI predominant cropping system, if farmers tend to rely in easy solutions to weed problems, it seems that few more competitive and adapted weed populations may be selected in intensified fields.

CALM affected the frequency of some weed species and weed community composition was also slightly modulated by YCA. On one hand, as YCA increases, soil resources are depleted in the grain extensive low input flat Pampa agriculture. On the other hand, as CALM is low (L), fallow periods are long and more soil and light resources are available for some weed populations to grow. Therefore crop rotation length and crop sequence may differently release resources and affect establishment, growth and/or dispersion of weed populations (Soriano et al., 1971; Ghersa and León, 1999). This is particularly true in weed communities mainly composed by therophyte species (Fig. 1, Table 3), whose life form implies that they must rely exclusively on seed production and plant establishment for its persistence (Benvenuti, 2007).

Overall weed frequency, as estimator of weed abundance (Magurran, 1988), was not significantly affected by intensification in the studied fields (Table 3) but, as previously mentioned, floristic richness was significantly reduced by ISI (Table 2 and 3). It is recognized that weed control is a particularly conflicting environmental issue since weeds can cause yield loss but support farmland biodiversity (Bretagnolle and Gaba, 2015; Petit et al., 2016). This study mitigates the conflict since it showed that intensified rotations may cause the reduction of species richness while maintaining weed frequency and some community functions (i.e. life forms, growth habit). Therefore, intensification may be seen as a useful tool in sustainable agriculture by integrating weed management and functional landscape biodiversity.

5. Conclusions

Average intensified sequence index (ISI) is less than 1.1 in the overall Pampa region (Andrade and Satorre, 2015) and at present, weed control is kept at the expense of herbicide inputs and raising costs which are forcing farmers to look to more integrated weed management strategies. In order to deal with specific weed problems which are usually aggressive herbicide tolerant or resistant weeds, intensified rotations are promoted. From our results, crop sequence intensification itself modified weed community, reduced weed species richness and changed the frequency of some weed populations within the agricultural fields of the Flat Pampa in Northwest of Buenos Aires. Thus, crop sequence intensification may be considered a useful tool in weed management, as a part of an integrated solution. However, it also appear that it should not be considered a simple, isolated permanent tool since weed species were differently affected and new harmful weed problems may be promoted. Finally, more research on individual processes of some target weed species need to be explored if we aim to predict weed dynamics and use intensified rotations as effective parts of integrated weed management systems aiming to efficiently neutralize the growth and persistence of weeds.

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