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Author(s): Julio A. Scursoni , Ramón Gigón , Andrés N. Martín , Mario Vigna , Eduardo S. Leguizamón , Carolina Istilart , and Ricardo López

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# Changes in Weed Communities of Spring Wheat Crops of Buenos Aires Province of Argentina

Julio A. Scursoni, Ramón Gigón, Andrés N. Martín, Mario Vigna, Eduardo S. Leguizamón, Carolina Istilart, and Ricardo López*

During 2004 to 2008, weed surveys were conducted in 373 wheat fields of two different cropped areas (southwest [SW] and southeast [SE]) of the southern region of Buenos Aires Province of Argentina where different weed communities were expected because of changes in cropping practices over time, including tillage, crop sequence, fertilizers, and herbicides applied. Weed communities differed between regions, with greater numbers of native species for the SW. Weed community diversity was also greater for the SW region, probably due to the more diverse land use that resulted in greater landscape heterogeneity. Rush skeletonweed, sand rocket, yellow starthistle and turnipseed occurred at higher constancy (proportion of fields in which a given species is present) in the SW region, whereas common chickweed, false bishop's weed, corn speedwell, and common lambsquarters were present more frequently in the SE region. Compared with the 1982 survey, constancy of weeds increased, but those species with high constancy in 1982 were also with high constancy in the recent surveys. Diversity (species richness) was greater in conventional than in a no-tillage system. The constancy of Italian ryegrass, sand rocket, and yellow starthistle was lower under no-till than conventional tillage. Surveys allow identification of changes in weed community related to different agricultural systems. Rotation of crops and livestock avoid the homogenization of the environment at the landscape level. Management strategies will be necessary to prevent the increase of weeds populations' size, preserving plant diversity and the properties of the agroecosystem.

**Nomenclature:** Common chickweed, *Stellaria media* (L.) Vill. STEME; common lambsquarters, *Chenopodium album* (L.) CHEAL.; corn speedwell, *Veronica arvensis* L. VERAR; false bishop's weed, *Ammi majus* L. AMIMA; Italian ryegrass, *Lolium multiflorum* Lam. LOLMU; rush skeletonweed, *Chondrilla juncea* L. CHOJU; sand rocket, *Diplotaxis tenuifolia* (L.) DC. DIPTE; yellow starthistle, *Centaurea solstitialis* L. CENSO; turnipweed, *Rapistrum rugosum* (L.) All. RASRU; wheat, *Triticum aestivum* L.

**Key words:** Floristic composition, tillage systems weed shifts, weed survey.

Wheat is the most important winter crop in Argentina, with annual production on about 4.3 million ha. The primary production is located in southern Buenos Aires Province (37.03° to 40.42°S, 57.27°W to 62.24°W), representing 33% of the whole cropped area and wheat production (MDA 2011). The annual crops commonly grown in the region are cereal grain crops such as wheat and barley (*Hordeum vulgare* L.), with a common sequence being barley or wheat (winter-spring crops)/sunflower (*Helianthus annuus* L.) or soybean [*Glycine max* (L.) Merr./corn (*Zea mays* L.) (summer crops). Cropping history differs between areas. The number of years with continuous cropping is higher in the southeast (SE) than in the southwest (SW) and summer crops are also more frequent in the SE. This means that many fields are cropped continuously in the SE but not in the SW, where it is common to have continuous wheat or barley and oat (*Avena sativa* L.), with chemical or mechanical fallow between crops that (on the basis of management level) can affect weed community. In the SW mixed system, livestock-farming is predominant. The agricultural area is about 60% and 30% in the SE and SW, respectively. Date of sowing is between May and July, with P at sowing and N fertilizers at sowing or at tillering. The no-till (NT) system at the time of surveys was more common in the SE than at the SW. Approximately

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* First and third authors: Professor and Graduate Student, Departamento de Producción Vegetal, Facultad de Agronomía, Universidad de Buenos Aires, Av. San Martin 4453 (1417), Buenos Aires, Argentina; second, fourth, and seventh authors: Researcher Agronomists, Estación Experimental Agropecuaria Bordenave, Instituto Nacional de Tecnología Agropecuaria (INTA) CC Nro. 44–8187 Bordenave, Ruta Prov., 76 km, 36.5 (8187), Buenos Aires, Argentina; fifth author: Professor, Cátedra de Malezas, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, Campo Experimental. Villarino, CC 14 (2125) Zavalla, Santa Fe, Argentina; sixth author: Research Agronomist, Estación Experimental Agropecuaria Barrow, (INTA), CC 50 B7500WAA Tres Arroyos Ruta 3 km 487 (7500), Buenos Aires, Argentina. Corresponding author's E-mail: scursoni@agro.uba.ar

30% and almost all the wheat crops were sown in a NT system in the SW and SE, respectively.

Weed communities can vary with cultural practices, such as rotation and crop sequencing, tillage management, and herbicide choice. Weed diversity has been shown to increase under crop rotation compared with monoculture (Stevenson et al. 1997). Diversity of weed communities as measured by richness, evenness (*E*), diversity index (*H*′), and total weed biomass were greater for NT than for conventional tillage (CT) (Legere et al. 2008). In addition, species richness and seed density were greatest in the NT systems (Sosnoskie et al. 2006).

Spraying auxin-type herbicides has been the most common weed control practice used by farmers in the mid-20th century. Reliance on herbicides to control broadleaf weeds can shift the weed flora, particularly to grass weeds (Andreasen et al. 1996). This resulted in the greater use of acetyl-coenzyme A inhibitors that control a broad spectrum of annual and perennial grasses in a range of crops (Cobb and Kirkwood 2000). Sulfonylurea (group 2) herbicides became commonly used in Argentina in the 1980s when they largely replaced auxin herbicides. Metsulfuron-methyl currently is the most commonly applied herbicide to control broadleaf weeds in wheat and barley in Argentina.

Wild oat (*Avena fatua* L.) and Italian ryegrass are the most important grass weeds present in wheat crops of southern Buenos Aires Province (Scursoni et al. 2007), and their control is strongly dependent on herbicides. Fenoxaprop and pinoxaden are the most used and iodosulfuron plus metsulfuron, and pyroxsulam are also recommended to control grass weeds. Despite the frequent application of these herbicides, cases of wild oat and Italian ryegrass resistance to these herbicides in Argentina are scarce, though they have been recently documented (Heap 2012). In contrast, there have been many cases of resistance to acetyl-coenzyme A carboxylase herbicides in countries such as Chile, Australia, Mexico, and the United States (Heap 2012). More crop rotations including wheat or barley with soybean, sunflower, and corn in Argentina could explain this difference in terms of resistance biotypes.

Although weeds have high adaptability, the fitness of weeds in response to different environmental conditions is often very specific (Soriano 1965). Crop sequence, soil characteristics, and herbicide applications act as environmental constraints that filter traits (Booth and Swanton 2002; Storkey 2006; Storkey et al. 2010), leading to new assemblages of weed communities (Mas et al. 2010). An example is the effect of light stimulation on seed germination of Chinese thornapple (*Datura quercifolia* Kunth), in which brief light requirements for germination are satisfied through soil tillage (Scopel et al. 1991, 1994). In contrast, under NT systems the thornapple seed survival is reduced in soil by exposure to predation and environmental extremes; thus, their presence has diminished in NT systems (de la Fuente et al. 2006). In experiments conducted in southern Santa Fe, Argentina, Tuesca et al. (2001) recorded major changes in the spectrum of weeds present under different tillage systems. In a NT corn and soybean rotation, the presence of large crabgrass [*Digitaria sanguinalis* (L.) Scop.] increased significantly compared with CT. On the other hand, the density of annual broadleaf weeds such as common lambsquarters and Chinese thornapple were greater in CT.

Surveys of weed communities in agroecosystems of southern Buenos Aires Province, ‘‘Pampa Austral’’ (Chaneton 2006), are scarce compared with those for the rolling Pampas. Catullo et al. (1983) carried out a weed survey in SE Buenos Aires Province with the aim of identifying the most important weeds in spring wheat and sunflower crops. This survey was carried out before weed control and covered 114 wheat fields in an estimated area of 1,200,000 ha. At the survey time, crops were between Z21 and Z31 (Zadoks et al. 1974). The regional presence of each different weed species was characterized by its constancy (proportion of fields in which a given species is present) (de La Fuente et al. 2006) At the time of the survey, most dicotyledonous weeds in spring wheat were controlled with 2,4-D mixed with dicamba or picloram. Now, sulfonylureas are the most important herbicides applied on that area. In addition, during the last 20 yr NT has replaced the CT (mouldboard plow–chisel plow), the use of fertilizer increased significantly, and soybean was included in crop rotations in the area.

Weed surveys are necessary to identify current weed problems in an area, highlight changes occurring in weed flora, and develop weed research programs for species identified as being important (Webster and MacDonald 2001). Therefore, objectives of this work were: (1) to study the weed community composition of wheat crops in two different ecological areas (southeastern and southwestern Buenos Aires Province), (2) to quantify the evolution of the weed community of southeastern Buenos Aires Province since the early 1980s, and (3) to study the relationship between weed community composition and tillage system (CTl and NT) in southwestern Buenos Aires Province.

Table 1. Average temperatures (C) and rainfall (mm) at the SE and SW regions of Buenos Aires Province. (Means of 30 yr, 1960 to 1990.)

| | SE | SW |
|---|---|---|
| Annual average temperature | 15 | 14.8 |
| Annual average maximum temperature | 20.5 | 21.5 |
| Annual average minimum temperature | 8.5 | 7.7 |
| Annual average temperature 2004 | No data | 13.5 |
| Annual average temperature 2005 | No data | 14.8 |
| Annual average temperature 2006 | No data | 14.1 |
| Annual average temperature 2007 | No data | 14.6 |
| Annual average temperature 2008 | 14.4 | 15.1 |
| Annual average rainfall | 810 | 612 |
| Annual rainfall 2004 | 750 | 853 |
| Annual rainfall 2005 | 686 | 475 |
| Annual rainfall 2006 | 662 | 591 |
| Annual rainfall 2007 | 627 | 706 |
| Annual rainfall 2008 | 540 | 473 |

## Materials and Methods

**Site Description.** The surveys were conducted over 5 yr (2004 to 2008), 3 yr in the SE and 2 yr in the SW portions of the province in 1,400,000 wheat crops. The prevailing soil type at the eastern limit of this region is Typic Argiudol with a petrocalcic layer. Sand content of soils increases toward the west, accompanying a gradient in rainfall that decreases in the same direction. Soil types at the SW are Typic Haplustols, Udic Paleustols, and Aridic Haplustols. The climate is temperate with colder winters at the SW and higher rainfall in the SE (Table 1).

**Sampling Procedures.** The surveys were carried out in two subsets of random fields each year within two areas (SW or SE) of Buenos Aires Province. In total, 197 fields were sampled within the SE and 176 within the SW area. In the SW 70 fields surveyed were under NT and 96 under CT, whereas most of fields were under NT in the SE area. Surveys were made before herbicides were sprayed (August to September each year) and the crop plants were between Z14 and Z23 growth stage (Zadoks et al. 1974). Within a selected field, the presence of each weed species was recorded as a trained observer walked along a W pattern across the field. Average area of the surveyed fields was 70 ha, and margins and depressions in fields were excluded. Species were classified according to life cycle: annual, biennial, perennial; morphotype: dicotyledonous, monocotyledonous; and origin: native, exotic, cosmopolitan. Regional constancy of each weed was calculated as the proportion of fields in which a particular species was present (Equation 1).

In the SE 20 or 30 1-m$^2$ quadrats were sampled for the uniformity of species in each field. Quadrat number depended on field size. Uniformity indicates the percentage of sampled quadrats with a species present. Uniformity (Equation 2) (Van Acker et al. 2000) in all fields was assessed for each weed species and was obtained by dividing the number of quadrats in which the species was present by the total number of quadrats assessed. In the SW, the presence of each species in each field was evaluated visually and uniformity was classified into three categories: low, medium, and high. The observers stop at every 50 paces and record the species in a given area, usually 1 m$^2$.

$$\text{Constancy}(C_i) = (\text{number of fields with species } i \,/\, \text{total fields surveyed}) \times 100 \quad [1]$$

$$\text{Field uniformity } (\%) = (\text{number of quadrats with } i \text{ species}/\text{total number of quadrats}) \times 100 \quad [2]$$

The weed communities were described in terms of floristic and functional structure. Alpha or local diversity, also called species richness, is the average number of species occurring in each field. Gamma or regional diversity is the total number of species occurring in each year (de la Fuente et al. 2006). Beta diversity (Equation 3) is the rate of change of species richness.

$$\text{Beta diversity} = ([\text{gamma diversity}/\text{average alpha diversity}] - 1) \quad [3]$$

**Data Analysis.** Differences in the weed communities between areas were investigated by using multiple responses permutations (MRPP) (Zimmerman et al. 1985) by testing the null hypothesis that two or more a priori-defined groups of species do not differ in their composition. A principal components analysis (PCA) also was performed by using those species having a constancy $>$ 5% with the software PCORD 4.0 (McCune and Mefford 1999) using correlation matrix in the calculation of Euclidean distances between species. The binomial confidence intervals were calculated for alpha diversity and constancy of each species (Leemis and Trivedi 1996).

To study the changes in weed communities from the early 1980s, results from the southeastern surveys in 2004 and 2005 were compared with those observed in the same area in 1982 by Catullo

Table 2. Richness and constancy of each functional plant type in southeastern and southwestern Buenos Aires provincial regions.

| | Southeast (SE) | | | Southwest (SW) | | |
|---|---|---|---|---|---|---|
| | Alpha diversity[a] | Species richness[b] (gamma diversity) | Constancy[c] | Alpha diversity | Species richness (gamma diversity) | Constancy |
| | | | % | | | % |
| Total | 9.4 (8.8–9.9)* | 70 | | 5.3 (4.8–5.8) | 85 | |
| Natives | 0.5 (0.3–0.6) | 7 | 43 | 0.6 (0.6–0.7) | 22 | 45 |
| Exotics and cosmopolitans | 8.8 (8.5–9.5) | 63 | 100 | 4.7 (4.2–5) | 63 | 98 |
| Annuals and biennials | 8.4 (7.9–8.8) | 53 | 100 | 4.2 (3.9–4.7) | 54 | 97 |
| Perennials | 1 (0.9–1.2) | 17 | 66 | 1.1 (0.8–1.2) | 31 | 56 |
| Monocotyledons | 1 (1–1.3) | 10 | 72 | 1.3 (1.2–1.4) | 13 | 82 |
| Dicotyledons | 8 (7.7–8.7) | 60 | 99 | 4 (3.5–4.5) | 72 | 86 |

[a] Alpha diversity is the average number of species occurring in each field.
[b] Species richness (gamma diversity) is the total number of species occurring in each region.
[c] Constancy is the proportion of fields with presence of each functional plant type.
* Values in parentheses are the lower and upper limits of the confidence interval at 95%.

et al. (1983). The 3 yr during which surveys were conducted had similar rainfall patterns (i.e., within 1 standard deviation for a 28-yr data series). Weed communities were compared in the same states (Necochea, Tres Arroyos, San Cayetano) that were surveyed in all 3 yr. For comparisons among species constancy, the binomial confidence intervals were calculated.

Weed community compositions in CT and NT sowing systems in the SW were compared using MRPP and regional constancies of different weed species. For constancy of each species, the binomial confidence intervals were calculated. The statistical significance was evaluated by Pearson chi-square test for each weed. This method tests whether the differences in the distribution of the presence–absence for each weed is attributable to tillage systems.

## Results and Discussion

**Southeast and Southwest.** Total recorded species numbered 70 in the SE and 85 in the SW. However, alpha diversity was higher ($P < 0.05$) in the SE than in the SW, and thus, beta diversity was higher in the SW than in the SE (Table 2). Although there were no differences between areas in the amount of exotic species recorded, there were more native species in the SW than in the SE, probably associated with lower agricultural activity. The average number of exotic species in each field was higher at the SE than the SW. As indicated by the species richness, there were more dicotyledonous and perennial species in the SW than in the SE (Table 2). More crop production in the SE triggers a certain number of paths of succession in weed communities. The community structure diverged markedly between cropping areas and native grasslands. Greater dominance of the culture, the less richness and evenness (relative abundance of the species) of weeds, and mainly different species composition enriched with exotic species are characteristics of cropped fields (Martinez Ghersa et al. 2000).

Regarding all the surveyed fields during 2004 to 2008, 114 species were recorded, and these belonged to 20 botanical families, with Asteraceae and Poaceae being the most abundant (31 and 20 species, respectively). The floristic composition was significantly different ($P < 0.001$) between areas according to MRPP analysis. Association between weeds and regions (SE and SW fields) depicted by PCA shows on axis 1 the weeds with more constancy on the different areas (Figure 1). Rush skeletonweed , sand rocket, yellow starthistle, and turnipweed were species related to the SW with low rainfall and sandy soils. In contrast, common chickweed, false bishop's weed, corn speedwell, and common lambsquarters were representative of the SE (Figure 1, Table 3). Scursoni (1995) also registered different weed community composition between humid and semiarid areas of barley crops. Common chickweed was the most constant weed in the humid area (SE), but it decreases in the semiarid areas in the SW of Buenos Aires Province. Yellow starthistle was important in semiarid areas, but it was not observed in humid areas. This weed is well adapted to sandy soils with low water content (Hanf 1983). Another specific weed of the SW was rush skeleton, distributed across a wide range of soil types, but is generally most abundant on sandy soils, with deep profiles that favor root development. Areas of suitable sandy soil and the type of cultivation (wheat/fallow) are most associated with dense stands of rush skeletonweed that occur in

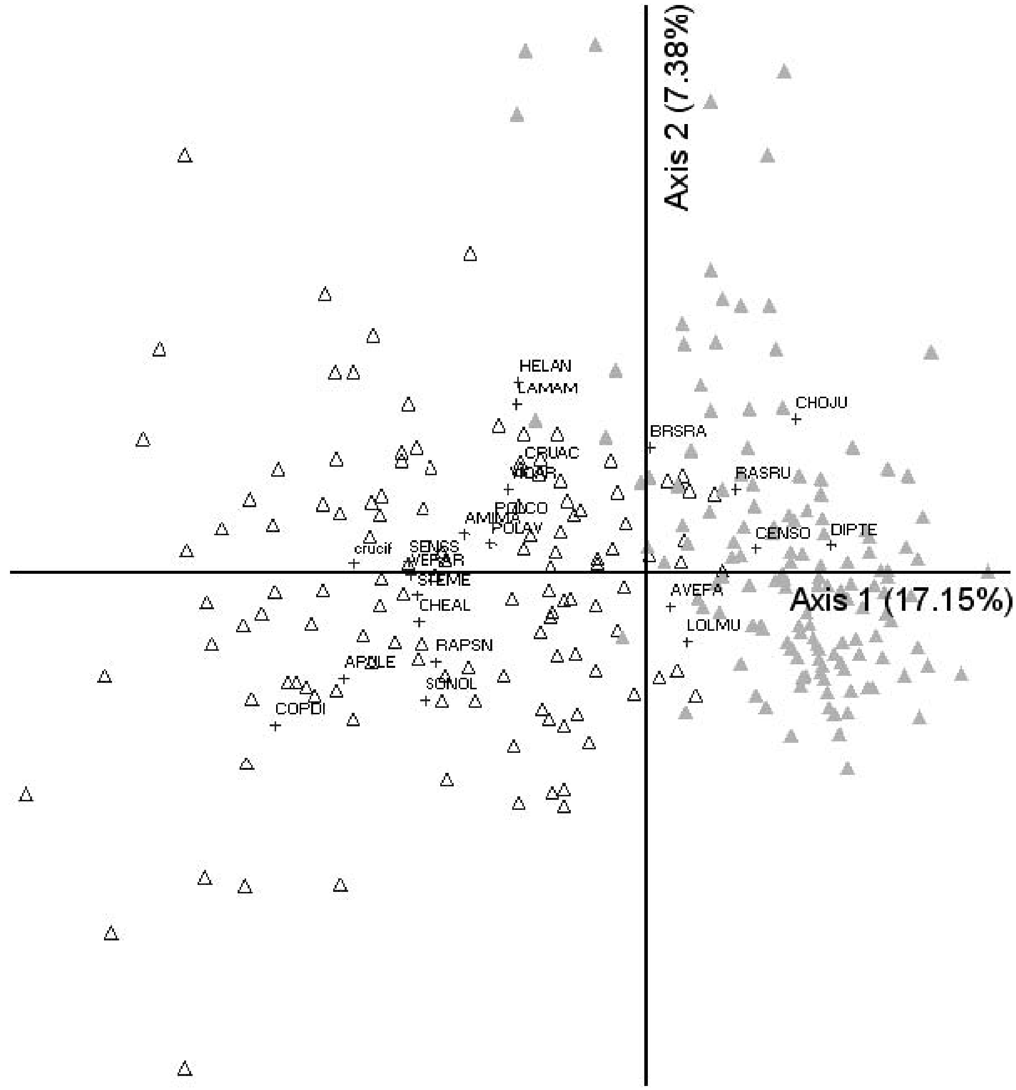


Figure 1. Principal component analysis plot showing the asociation betwen weeds and regions (southeastern fields Δ; southwestern fields ▲). HELAN (sunflower), LAMAM (henbit), CRUAC (welted thistle), VIOAR (European field pansy), POLCO (wild buckwheat), AMIMA (false bishop's weed), POLAV (prostrate knotweed), SENSS (*Senecio* sp.*)* VERAR (corn speedwell), STEME (common chickweed), RAPSN (radish), APULE (marsh parsley), CHEAL (common lambsquarters *)*, SONOL (annual sowthistle), COPDI (swinecress), CHOJU (rush skeleton weed), BRSRA (wild turnip), RASRU (turnipweed), CENSO (yellow starthistle), DIPTE (sand rocket), AVEFA (wild oat), LOLMU (Italian ryegrass).

Australia over a wide range of climatic conditions, although semiarid and Mediterranean-type climates appear to provide the optimum conditions (Wapshere et al. 1976). Similarly, sand rocket is often associated with waste land and poorer pastures in South Australia, found commonly in well-drained sandy soils often with high calcium content (DAFWA 2012).

New agricultural technologies such as NT and Roundup Ready crops reduced differences among crop fields, and thus, homogenized the environment at regional–landscape levels. Habitat heterogeneity is associated with biodiversity at landscape level (de la Fuente et al. 2006). Beta diversity is the rate of change of species richness across the region and it was higher in the SW, suggesting a more heterogeneous landscape than in the SE. Greater heterogeneity of the agricultural landscape in the SW could have contributed to its higher weed diversity than the SE (Gabriel et al 2005). Additionally, the higher number of native species in the SW than in the SE could be indicative of lower agricultural intensity. Livestock activity is a more important component of the farming systems in the SW than in the SE, as it has more fields with pastures or natural vegetation for cattle grazing (Cruzate et al. 2008).

The weed communities were characterized by the more constant weeds (Table 3). In the SE, prostrate knotweed (*Polygonum aviculare* L.), common chickweed, wild oat, wild buckwheat (*Polygonum convol-*

Table 3. Weed community composition and functional groups in southeastern and southwestern Buenos Aires Province regarding species with constancy higher than 10% in one region.

| Common name | EPPO[a] code | SE | | SW | | Mo | Or | LC |
|---|---|---|---|---|---|---|---|---|
| | | Const.[b] | CI[c] | Const. | CI | | | |
| | | % | | | | | | |
| Prostrate knotweed | POLAV | 85 | 79.2–89 | 31 | 25.4–38.5 | D | E | A |
| Common chickweed | STEME | 77 | 70–81.5 | 3 | 1.7–8.3 | D | E | A |
| Wild oat | AVEFA | 56 | 49–62.3 | 63 | 55.8–69.4 | M | E | A |
| Wild buckwheat | POLCO | 54 | 47.5–60.8 | 22 | 16.8–28.6 | D | E | A |
| False bishop's weed | AMIMA | 52 | 45–58.4 | 14 | 10.5–20.7 | D | E | A |
| Corn speedwell[d] | VERAR | 42 | 35.8–49 | | | D | E | A |
| Common lambsquarters | CHEAL | 41 | 34.3–47.5 | 7 | 5.0–13.1 | D | E | A |
| Brassicaceae[e] | crucif | 40 | 32.9–46 | | | D | | |
| Italian ryegrass | LOLMU | 38 | 31.5–44.5 | 39 | 32.7–46.5 | M | E | A |
| Sunflower | HELAN | 36 | 30.1–42.9 | 11 | 8.1–17.6 | D | E | A |
| European field pansy | VIOAR | 36 | 30.1–42.9 | 10 | 6.8–15.7 | D | E | A/B |
| Radish | RAPSN | 32 | 26.8–39.4 | 4 | 2.5–9.4 | D | E | A/B |
| Annual sowthistle | SONOL | 31 | 25.8–38.3 | 3 | 2.1–8.8 | D | E | A |
| Welted thistle | CRUAC | 24 | 19.4–31 | 9 | 6.3–15 | D | E | A |
| Lesser swinecress[d] | COPDI | 23 | 18.1–29.4 | | | D | N | A/B |
| Marsh parsley | APULE | 22 | 17.6–28.9 | 0.6 | 0.4–18.3 | D | N | A |
| Groundsel[d] | SENSS | 18 | 14.1–24.6 | | | D | | |
| Henbit deadnettle. | LAMAM | 17 | 12.8–23 | 7 | 4.6–12.5 | D | E | A |
| Wild turnip | BRSRA | 16 | 12.3–22.4 | 8.5 | 5.9–14.4 | D | E | A |
| Thistle[d] | CRUSS | 14 | 10.2–19.7 | | | D | E | A |
| Yellow starthistle | CENSO | 12 | 8.9–18 | 26 | 20.8–33.3 | D | E | A |
| Common catchfly | SILGA | 12 | 8.9–18 | 1 | 0.4–18.3 | D | E | A/B |
| German chamomile[d] | MATCH | 12 | 8.9–18 | | | D | E | A |
| Scarlet pimpernel | ANGAR | 11 | 7.7–16.3 | 4 | 2.5–9.4 | D | E | A |
| Bull thistle | CIRVU | 10 | 7.3–15.8 | 5 | 3.3–10.6 | D | E | B |
| Fineleaf fumitory[d] | FUMPA | 10 | 6.9–15.2 | | | D | E | A |
| *Polygonum* L. sp.[d] | POLSS | 10 | 6.9–15.2 | | | D | E | A |
| Turnipweed | RASRU | 9 | 6.0–14.1 | 16 | 11.9–22.5 | D | E | A |
| Sand rocket | DIPTE | 4 | 2.6–9 | 26 | 20.8–33.3 | D | E | A |
| Rush skeletonweed | CHOJU | 1 | 0.6–7.8 | 23 | 17.7–29.7 | D | E | P |
| Drug fumitory | FUMOF | 1 | 0.6–7.8 | 11 | 7.7–16.9 | D | E | A |
| Field gromwell[d] | LITAR | | | 12 | 9.1 | D | E | A |
| Woodsorrel[d] | OXASS | | | 10 | 7.2 | D | N | |
| Foxtail[d] | SETSS | | | 10 | 7.2 | M | N | P |
| Blanketflower[d] | GAIME | | | 10 | 6.8 | D | N | P |

[a] Abbreviations: EPPO, European Plant Protection Organization; CI, confidence interval; Mo, morphotype (D, dicotyledons; M, monocotyledons); Or, origin (N, native; E, exotic; C, cosmopolitan); LC, life cycle (A, annual; A/B, annual or biennial; B, biennial; P, perennial.

[b] Constancy is the proportion of fields with presence of each species.

[c] CI limits estimated by exact method.

[d] Species present only in one survey.

[e] Brassicaceae are other species out of *Brassica campestris* L., *Raphanus sativus* L., and *Rapistrum rugosum* (L.) All.

*vulus* L.), and false bishop's weed were present in more than 50% of the fields. Interestingly, wild oat had a regional constancy higher than 50% in both areas and was the only weed with constancy higher than 50% in the SW. In addition, wild oat and Italian ryegrass were recorded as co-occurring in almost 30% of the fields. Regarding the uniformity in each field, common chickweed, wild oat, and prostrate knotweed co-occurred with greater than 30% of uniformity.

Annual ryegrass, prostrate knotweed, yellow starthistle, sand rocket, rush skeletonweed, and wild buckwheat were important weeds in the SW (Table 3). These weeds showed moderate to high levels of uniformity (data not shown). Interestingly, species such as sunflower, false bishop's weed, plumeless thistle (*Carduus acanthoides* L.), and corn speedwell were prevalent in areas where there are more summer crops (soybean, sunflower, and corn). Additionally, yellow starthistle, sand rocket, and blanketflower (*Gaillardia* sp.) were associated and co-occurred with one another in many fields.

The low variance (24%) being captured by the first two axes (Figure 1) suggests that factors other than regional differences would explain differences in weed communities. Floral composition is influenced by agronomic management practices applied in each area. In the SE there are crop sequences alternating grass (wheat, barley, oat, corn) and broadleaf crops (sunflower, soybean) with higher use of inputs such as fertilizers and herbicides. In the SW, the cropped area is mostly cereal crops and fallow and in terms of amount of area is much lower than at the SE, which is over 60% of the whole area. Field experiments carried out by Doucet et al. (1999) showed that weed management accounted for 37.9% and 38.4% of the variance in total weed density and species richness, respectively. In addition, Mas et al. (2010) surveyed fields within a gradient of the most frequent cropping histories and found that 32.6% of the variance in the species data was related to crop yield, number of years under NT agriculture, and the previous crop. It is likely that the inclusion of livestock in the agricultural system contributes to diversity of the weed flora, which may function to sustain wildlife and protect against physical and chemical degradation of soils (Altieri 1999).

**Weed Community Changes from 1982.** The surveys were conducted before in-season herbicide application, thereby excluding this factor on the flora. The total number of weed species present in the SE region (gamma diversity) has increased since the survey of 1982. There were 33 species recorded in 1982 (Catullo et al. 1983), which increased to 53 species in 2004/2005 (Table 4). This increase is similar to that registered by Ghersa et al. (1998), who described an increase of approximately 30 weed species during 30 yr (1930 to 1960) in the northern area of Buenos Aires Province, a period characterized by increased land use for agriculture and large gains in crop productivity. Exotic (nonnative) species increased from 31 in 1982 to 47 species in 2004/2005, whereas native species increased from two to four. Likewise, the number of annual species increased from 21 in 1982 to 34 in 2004/2005, and dicots from 29 to 44. Monocots also increased from four to nine species, as did perennial species. Twenty-nine species recorded in the recent survey were not present in 1982. However, nine species recorded in 1982 were not found in the recent surveys. In addition, some dicots present in both surveys such as common chickweed, false bishop's weed, prostrate knotweed, and radish (*Raphanus sativus* L.) were the species with the greatest constancy increases from 1982. Among grass weeds, the constancy of wild oat increased from 39% in 1982 to 65% in 2004/2005, whereas Italian ryegrass remained at about 40% (Table 4). In the same way, Suarez et al. (2000) studied the shifts of species groups in crop–weed communities of the Pampas during 1926 to 1999 and registered a persistent group of species in the crop fields characterized by exotic annual dicotyledonous species.

Increases in both the number and constancy of species occurred at the regional scale and also at individual states such as Necochea (Figure 2). Here, the recent survey showed that nine new weed species with constancy higher than 5% appeared and only three species with constancy higher than 5% were lost.

The more relevant changes in crop systems during last years were the adoption of NT sowing system and the increase of the soybean area. Weeds such as dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers) and annual sowthistle (*Sonchus oleraceus* L.) are associated with NT. Dandelion was prevalent in the NT rotation. The success of dandelion in these treatments was attributed to reduced soil disturbance compounded by the effects of a forage production year and inappropriate weed management (Legere and Samson 2004). Dandelion and sowthsitle are small-seeded species that failed to emerge from deeper depths under either tillage system and showed higher total seedling recruitment under the NT system (Chauhan et al. 2006a; Ghersa and Martinez Ghersa 2000). In addition, wind dispersal favors the establishment on NT systems (Chauhan et al. 2006a). European field pansy (*Viola arvensis* Murr.) has small seeds, but is recognized as moderately tolerant to glyphosate. Glyphosate is normally applied at least four times each year in a soybean continuous crop or even in corn–soybean rotation in Argentina. This could explain the increase of this weed in NT systems. In addition, the amount of N and P fertilizers applied on wheat and barley have increased significantly during last years (FAO 2004). Weed species such as lesser swinecress [*Coronopus dydimus* (L.) Sm] may respond favorably to these nutrients (Hanf 1983). The relevance of johnsongrass [*Sorghum halepense* (L.) Pers.], a herbaceaous, rhizomatous perennial, decreased in the last 20 yr. Tillage promotes vegetative reproduction by fragmenting and spreading rhizomes. Vitta et al. (2004) also registered a

Table 4. Weed shifts in southeastern Buenos Aires Province weed community composition from 1982 to 2004/2005. Species with constancy higher than 10% in 1 yr are listed.

| Common name | EPPO[a] code | 1982 | | 2004/2005 | | Mo | Or | LC |
|---|---|---|---|---|---|---|---|---|
| | | Const.[b] | CI[c] | Const. | CI | | | |
| | | % | | | | | | |
| Prostrate knotweed | POLAV | 59.6 | 46.2–70.7 | 90.8 | 78.2–94.3 | D | E | A |
| Common chickweed | STEME | 15.4 | 9.7–29.9 | 87.7 | 75.2–92.2 | D | E | A |
| Wild oat | AVEFA | 38.5 | 27.7–52 | 64.6 | 52.4–74 | M | E | A |
| False bishop's weed | AMIMA | 25.0 | 16.8–39.3 | 64.6 | 52.4–74 | D | E | A |
| Wild buckwheat | POLCO | 71.2 | 57.0–80.2 | 61.5 | 49.4–71.4 | D | E | A |
| Radish | RAPSN | 25.0 | 16.8–39.3 | 47.7 | 36.7–59.1 | D | E | A/B |
| Cruciferae[d] | | | | 46.2 | 35.3–57.7 | D | | |
| Common lambsquarters | CHEAL | 28.8 | 19.8–43 | 41.5 | 31.2–53.5 | D | E | A |
| Italian ryegrass | LOLMU | 40.4 | 29.3–53.8 | 40.0 | 29.9–52 | M | E | A |
| Annual sowthistle[e] | SONOL | | | 40.0 | 29.9–52 | D | E | A |
| Corn speedwell[e] | VERAR | | | 40.0 | 29.9–52 | D | E | A |
| Lesser swinecress[e] | COPDI | | | 32.3 | 23.4–44.7 | D | N | A/B |
| Sunflower | HELAN | 17.3 | 11.1–31.8 | 29.2 | 20.8–41.7 | D | E | A |
| *Senecio* L. sp. | SENSS | 3.8 | 2.3–24.6 | 27.7 | 19.6–40.2 | D | E | |
| Welted thistle[e] | CRUAC | | | 23.1 | 15.9–35.6 | D | E | A |
| Common catchfly[e] | SILGA | 19.2 | 12.5–33.7 | 16.9 | 11.1–29.4 | D | E | A/B |
| German chamomile | MATCH | 15.9 | 9.7–29.9 | 16.9 | 11.1–29.4 | D | E | A |
| Marsh parsley[e] | APULE | | | 16.9 | 11.1–29.4 | D | N | A |
| *Carduus* L. sp.[e] | CRUSS | | | 16.9 | 11.1–29.4 | D | E | A |
| Yellow starthistle | CENSO | 19.2 | 12.5–33.7 | 15.4 | 10.0–27.8 | D | E | A |
| Common dandelion[e] | TAROF | | | 13.8 | 8.9–26.3 | D | E | P |
| European field pansy[e] | VIOAR | | | 13.8 | 8.9–26.3 | D | E | A/B |
| Bull thistle[e] | CIRVU | 21.2 | 13.9–35.5 | 10.8 | 6.7–23.2 | D | E | B |
| Turnipweed | RASRU | 51.9 | 39.3–64.1 | 7.7 | 4.6–20.5 | D | E | A |
| Wild turnip[e] | BRSRA | 19.2 | 12.5–33.7 | 7.7 | 4.6–20.5 | D | E | A |
| Annual wallrocket[e] | DIPMU | 15.9 | 9.7–29.9 | | | D | E | A/B |
| Drug fumitory[e] | FUMOF | 19.2 | 12.5–33.7 | | | D | E | A |
| Stinking chamomile[e] | ANTCO | 13.5 | 8.3–28.1 | | | D | E | A |

[a] Abbreviations: EPPO, European Plant Protection Organization; CI, confidence interval; Mo, morphotype (D, dicotyledons; M, monocotyledons); Or, origin (N, native; E, exotic; C, cosmopolitan); LC, life cycle (A, annual; A/B, annual or biennial; B, biennial; P, perennial.

[b] Constancy is the proportion of fields with presence of each species.

[c] CI limits estimated by exact method.

[d] Cruciferae species correspond to Brassicaceae species that are not *Brassica campestris* L., *Raphanus sativus* L., and *Rapistrum rugosum* (L.) All.

[e] Species present only in one survey.

decrease in importance of johnsongrass in NT soybean crops.

In the last 20 yr, crop management practices have triggered many changes in weed communities in this region. In recent decades weed communities have undergone structural transformations on the basis of the changes in agricultural management (Ghersa and León 1999). There has been an expansion in the southeastern Buenos Aires Province during the last 30 yr in cropped land area and the frequency in which farms are annually in crop production (Figure 3). These changes also included a decrease in livestock activity since 1982, resulting in less land for grazing, greater grazing pressure on the pastures, and shorter times for pastures in rotations. In addition, the increased agricultural intensity of the area also resulted in greater input levels, such as fertilizers and agrochemicals.

**Tillage System.** MRPP analyses indicated that community composition differed significantly between tillage systems ($P < 0.05$). Species richness (gamma diversity) was 77 species in CT systems and 64 species in NT systems. Alpha diversity was 5.5 in CT systems and 4.7 in NT systems ($P > 0.05$). Italian ryegrass showed decreased constancy in NT compared with CT systems ($P < 0.05$; Table 5, Figure 4). Chauhan et al. (2006b) also observed greater recruitment of a related ryegrass species, rigid ryegrass (*Lolium rigidum* Gaudin), under minimum till than under NT scenarios. Mechanical disturbance is the primary way that weed seeds

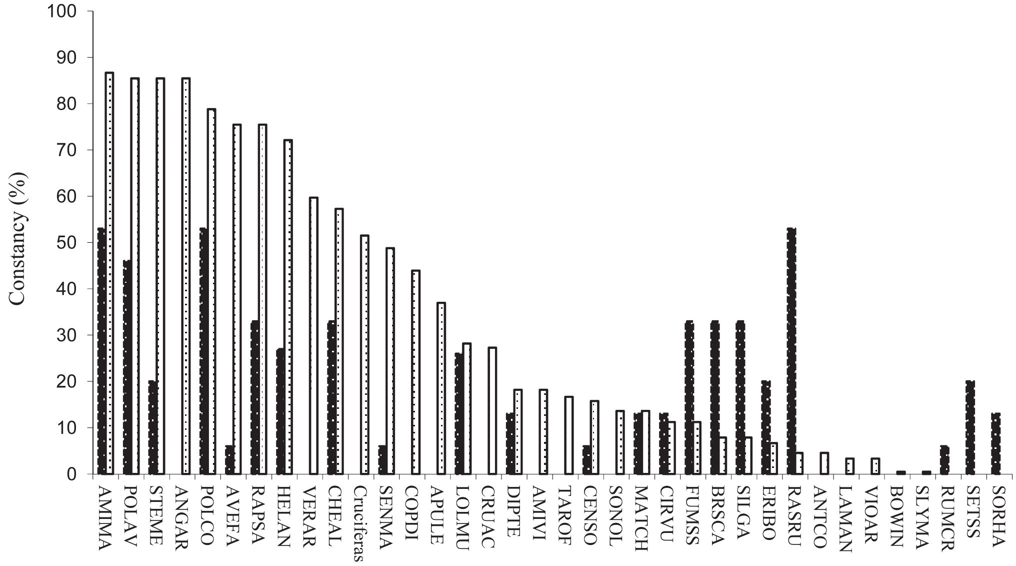


Figure 2. Constancy (%) of weeds recorded in weed surveys at Necochea (southeastern Buenos Aires Province). Black bars 1982 and white bars 2004/2005.

become incorporated into the soil (Yenish et al. 1992). Lower seedling establishment of ryegrass under NT could be due to more rapid desiccation of seeds on the soil surface or to greater herbivory predation activity of insects on or near the soil surface (Mohler and Galford 1997). Overwinter predation could be important in NT systems where, because of the lack of soil disturbance, a larger proportion of seeds will remain on the soil surface and thus be available to vertebrate predators, and for larger weed seed species, because these seeds are more slowly incorporated in the soil matrix (Westerman et al. 2009). Moreover, Spafford et al. (2006) registered higher postharvest herbivory rate in Italian ryegrass seeds relative to wild oat. This herbivore preference for seeds of annual ryegrass could be related to different sizes of these seeds. Similarly, yellow starthistle was more prevalent in CT than in NT, reflecting its adaptation to highly disturbed environments. Disturbance increased yellow starthistle abundance and performance far more in nonnative ranges than in the native range, a scenario that has been previously observed with other species (Hierro et al. 2006). The severity of infestation across all species was greater in CT than in NT systems. In contrast, Sosnoskie et al. (2006) in a 35-yr-old study found that mean seed density declined as soil disturbance increased. In this study, variations in total weed density and biomass were due more to tillage than to nutrients. Legere et al. (2008) in a 12-yr study suggested that the greater weed density and biomass recorded in NT com-

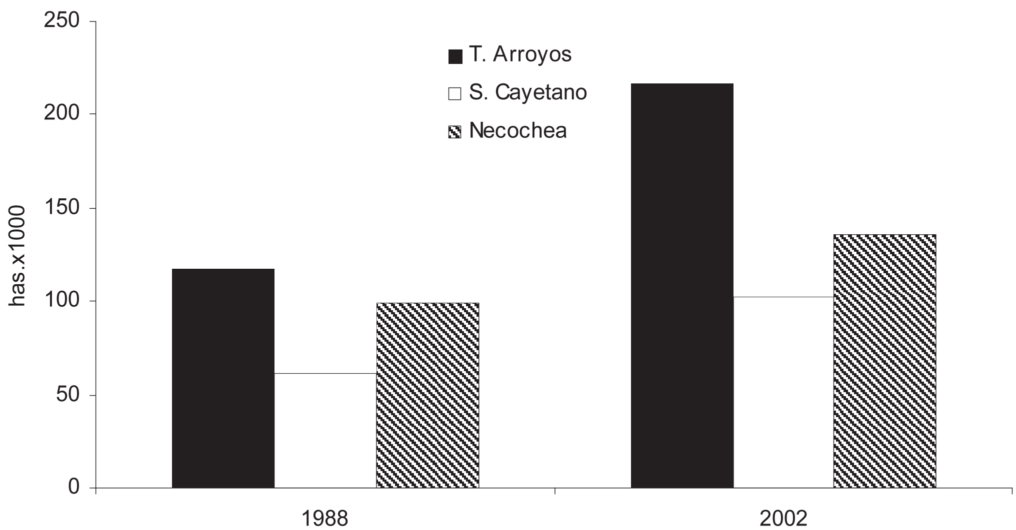


Figure 3. Wheat area (hectares) in three states of southeastern Buenos Aires Province in 1988 and 2002.

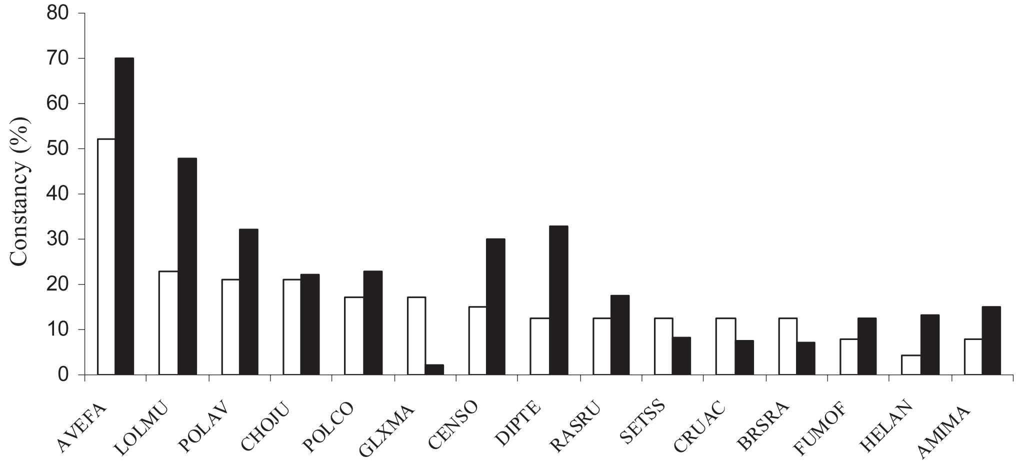


Figure 4. Constancy (%) of 15 weeds recorded in weed surveys on fields in different tillage systems in southwestern Buenos Aires Province. White bars no-till and black bars conventional tillage.

Table 5. Constancy of weeds higher than 4% in wheat fields in different tillage systems in southwestern Buenos Aires Province.

| Common name | EPPO[a] code | NT[b] | CI[c] | CS[b] | CI | Statistics* |
|---|---|---|---|---|---|---|
| | | % | | | | |
| Wild oat | AVEFA | 52.1 | 39–65 | 69.2 | 60–76 | NS |
| Italian ryegrass | LOLMU | 22.9 | 15–38 | 47.5 | 39–56 | * |
| Prostrate knotweed | POLAV | 20.8 | 13–36 | 32.5 | 25.5–41 | NS |
| Rush skeleton weed | CHOJU | 20.8 | 13.5–36.0 | 21.7 | 16–30 | NS |
| Wild buckwheat | POLCO | 16.7 | 10–32 | 23.3 | 17.5–32 | NS |
| Soybean | GLXMA | 16.7 | 10–32 | 1.7 | 1–12 | * |
| Yellow starthistle | CENSO | 14.6 | 9–30 | 30 | 23–39 | * |
| Sand rocket | DIPTE | 12.5 | 8–28 | 33.3 | 26–42 | * |
| Turnipweed | RASRU | 12.5 | 8–28 | 17.5 | 12–25 | NS |
| Foxtail | SETSS | 12.5 | 8–28 | 8.3 | 5–16 | NS |
| Welted thistle | CRUAC | 12.5 | 8–28 | 7.5 | 5–15 | **NS** |
| Field mustard | BRSRA | 12.5 | 8–28 | 6.7 | 4–14 | NS |
| Little bur-clover | MEDMI | 12.5 | 8–28 | 5 | 3–13 | NS |
| Corn gromwel | LITAR | 10.4 | 6–26 | 14.2 | 10–22 | NS |
| Woodsorrel | OXASS | 10.4 | 6–26 | 10 | 7–18 | NS |
| Birdeye speedwell | VERPE | 10.4 | 6–26 | 6.7 | 4–14 | NS |
| Common lambsquarters | CHEAL | 10.4 | 6–26 | 6.7 | 4–14 | NS |
| Henbit deadnettle | LAMAM | 10.4 | 6–26 | 5 | 3–13 | NS |
| False bishop's weed | AMIMA | 8.3 | 5–25 | 15 | 11–23 | NS |
| Drug fumitory | FUMOF | 8.3 | 5–25 | 12.5 | 10–21 | NS |
| European field pansy | VIOAR | 8.3 | 5–25 | 10 | 7–18 | NS |
| Hoary bowlesia | BOWIN | 8.3 | 5–25 | 6.7 | 4–14 | NS |
| Bull thistle | CIRVU | 8.3 | 5–25 | 3.3 | 2–11 | NS |
| Bermudagrass | CYNDA | 8.3 | 5–25 | 3.3 | 2–11 | NS |
| Alfalfa | MEDSA | 6.3 | 4–24 | 2.5 | 1.5–11 | NS |
| Prickly lettuce | LACSE | 6.3 | 4–24 | 0.8 | 0.6–25 | NS |
| Cereal rye | SECCE | 6.3 | 4–24 | 0.8 | 0.6–25 | NS |
| Sunflower | HELAN | 4.2 | 2.5–26 | 13.3 | 9–21.5 | NS |
| Nodding plumeless thistle | CRUNU | 4.2 | 2.5–26 | 9.2 | 6–17 | NS |
| Stinking chamomile | ANTCO | 4.2 | 2.5–26 | 7.5 | 5–15 | NS |

[a] Abbreviations; EPPO, European Plant Protection Organization; NT, no-tillage system; CI, confidence interval; CS, conventional sowing system.

[b] Constancy is the proportion of fields with presence of each species.

[c] CI limits estimated by exact method.

* Statistical significance ($P < 0.05$) evaluated by Pearson chi-square test for each weed.

pared with CT may have been due to reduced crop competitiveness or to herbicides being less efficacious in NT than in CT. However, it is important to take into account that those were long-term studies larger than the time with NT systems in the surveyed fields.

Conducting periodic surveys allows identification of changes in weed flora associated with management practices, identifying potential production problems and thus, design management strategies to prevent the increase of population size. For this purpose it should be necessary to study the ecophysiological and demographic properties that regulate weed populations and quantify the impact of weeds on crops, and the ecological value of weeds. Thus, knowledge should be integrated to predict the impact of different agronomic practices on the community and design strategies with selective impact on the different species of the weed community.

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