A REVIEW ON INVASIVE PLANTS IN RANGELANDS OF ARGENTINA

CARLOS A. BUSSO, DIEGO J. BENTIVEGNA and OSVALDO A. FERNÁNDEZ

SUMMARY

In Argentina, information on invasive plants is restricted to croplands, while no information is available on rangelands. Our objectives were to 1) identify and describe various characteristics of the most important non-native species that have become invasive and widespread in major rangeland territories of Argentina; 2) summarize the biological information about some naturalized, non-native species with potential to transform natural plant communities, and 3) discuss strategies for plant invasion management and biodiversity conservation in local rangeland ecosystems. The invasive species most represented at local, regional or state scale studies were Acroptilon repens*,* Centaurea solstitialis*,* Eleagnus angustifolia*,* Medicago minima*,* Chondrilla juncea*,* Dipsacus sativus *and* Sorghum halepense*. Successful invasion and naturalization rates have been the result of several combined ecological traits: 1) capacity to produce allelophatic compounds, 2) deep rooting, 3) high module density, 4) rapid vegetative spread aboveground, 5) various traits that make species highly competitive, 6) tolerance to shading and water stress, 7) ability to take advantage of disturbances, 8) high seed production, germination and dispersal, and 9) high viability of residual seed banks. The determination of the abundance of invasive species at country scale, and their ecological and economical damage, are objectives of future research. This information will be a critical tool to make decisions on the need to control invasive species. Ecological studies providing understanding of the strategies which make an invader species a successful competitor are critical, and should be the first step to establish policies for control of invasive species and use of rangelands.*

Scientific and societal awareness of the problems linked with the invasion of non-native plant species into the Argentine rangelands has increased lately due to their eventual economical and ecological harm on native ecosystems (Klich, 2005; Bezic, 2010). The recognition of the problems related to plant invasions into local rangelands has grown considerably because of the negative effects of some non-native species have became too evident to be ignored (Vigna and López, 2008; Bezic, 2010). Another point is that the number of alien species introduced into novel locations appears to be growing (Cipriotti *et al*., 2010). This question is critical in a country where about two thirds of its 2.8×10^{6}km^2, extending from 22º to 55ºS, are associated with arid and semi-arid rangeland ecosystems (Fernández and Busso, 1999). Rangeland vegetation provides the forage for livestock production in a country whose major economical activities are the production of grains and meat (www.surdelsur.com/economía/indexing/es.html).

As in many other parts of the world, anthropogenic perturbations are considered the main cause assisting plant invasions on the Argentine rangelands (Cipriotti *et al*., 2006, 2010). In the long term, these disturbances are associated with changes in 1) community structure, 2) soil resource availability, and 3) the creation of open areas accessible for to the establishment of non-native species (Vilá, 1998; Castro Díezo *et*

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Carlos A. Busso. Agronomical Engineer and M.Sc., Universidad Nacional del Sur (UNSur), Argentina. Ph.D. in Range Ecology, Utah State University, USA. Professor, UNSur, and Research Scientist, Centro de Recursos Naturales Renovables de la Zona Semiárida (CERZOS)-CONICET, Argentina. Address: Departamento de Agronomía, CERZOS, UNSur. Altos del Palihue, 8000 - Bahía Blanca, Argentina. e-mail: cebusso@criba.edu.ar

Diego J. Bentivegna. Agronomical Engineer and M.Sc., UNSur; Argentina. Ph.D. in Plant Insect and Microbiology Science, University of Missouri, USA. Researcher, CONICET, Argentina. e-mail: dbentive@criba.edu.ar

Osvaldo A. Fernández. Agronomical Engineer, UNSur, Argentina. M.Sc. in Plant Physiology, University of Toronto, Canada. Ph.D. in Range Ecology, Utah State University, USA. Professor, UNSur, Argentina. Researcher, CONICET, Argentina. e-mail: ofernan@criba.edu.ar

al., 2004). Disturbing factors have included timber extraction, uncontrolled fuel wood harvesting, plowing of non-arable lands and the development of a livestock grazing industry based on the over-utilization of natural ecosystem vegetation (Fernández and Busso, 1999). The massive addition of new, non-native herbivores with their own foraging behavior was critical in a region where large herbivores were very scarce from the end of the Pleistocene to the European colonization (Webb, 1978). Herbivory is considered as one of the main causes in disturbing arid and semi-arid ecosystems of the country (Fernández and Busso, 1999). Major environmental impacts as a result of rangeland livestock mismanagement have included shifts in species composition, changes in community structure and soil erosion (Fernández *et al*., 2009). Even further, Hierro *et al.* (2005, 2006) have shown that the effects of disturbances on the abundance, size and fecundity of exotic, invader weeds have been greater at the place of exotic weed introduction than at that of origin.

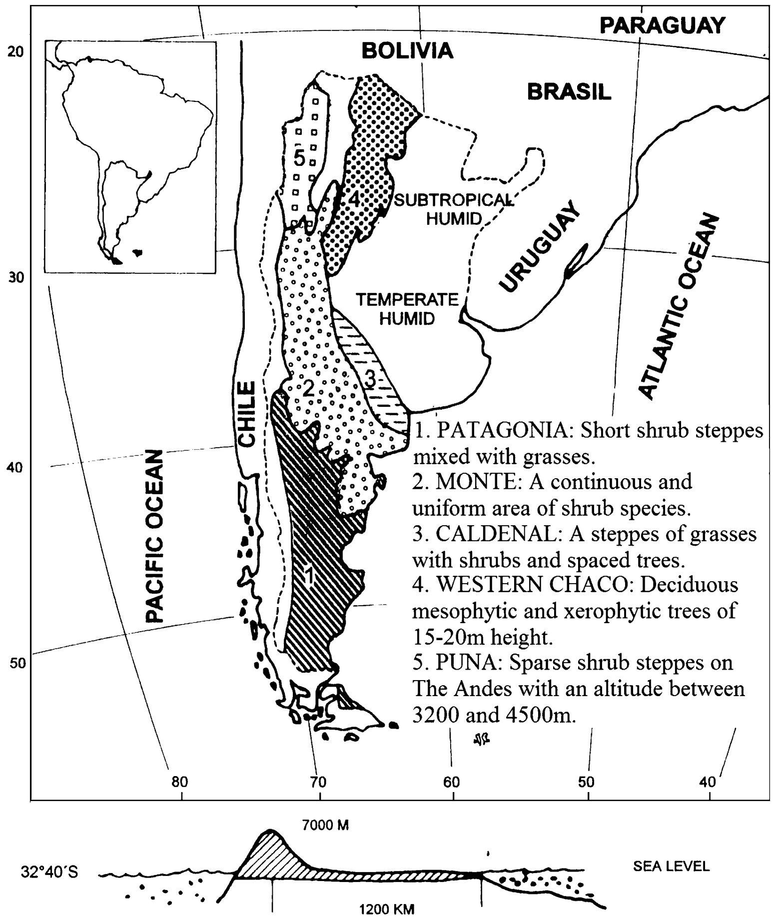

Figure 1. Major arid and semiarid rangelands of Argentina. Adapted from Cabrera (1976) and Fernández and Busso (1999).

Most of the invasive plants in Argentina (39%) came exclusively from Europe (Table I). However, the precise information about their date and pathway of entry or location of release is known only for very few species. Despite the awareness that they often cause substantial ecological and economical problems, we are short of experimental information about the reasons of their success as colonizers, or their environmental and economic impacts on native ecosystems. Increased understanding of invasions, in turn, has the potential to provide unique insights into fundamental ecological theory, including that on 1) top-down *vs* bottom-up control of communities, 2) disturbances as drivers of invasions, and 3) the role of soil microbes in regulating plant populations and interactions among species. This information is critical for developing management practices that allow avoidance of establishment or reductions in abundance of invasive plant species.

Clements *et al.* (2004) indicated that the ecological theory on invader species is highly applicable to weeds that affect agricultural as well as rangeland ecosystems. A perennial plant species can be considered as invader if it proliferates effectively, and grows vigorously, within a wide environmental tolerance but it is also difficult to control (Bezic, 2010). In the whole world, various exotic species threaten the integrity of rangelands and agricultural systems [e.g., North America: Di Tomaso, 2000; Argentina: Zalba *et al*., 2008; other countries in Central America (e.g., Nicaragua: http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=&rn=Nicaragua&hci=-1&ei=-1&lang=EN/species/search.asp?.Nicaragua) and South America (e.g., Colombia: http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=&rn=Colombia&hci=-1&ei=-1&lang=EN/species/search.asp?.Colombia); Europe (http://www.europe-aliens.org/); Asia (http://en.wikipedia.org/wiki/List_of_invasive_species_in_Asia); Australia (http://en.wikipedia.org/wiki/List_of_invasive_species_in_Australia); and Africa (http://en.wikipedia.org/wiki/List_of_invasive_species_in_Africa)]. The majority of invader species do not behave as dominant competitors in their native habitats but they have the capacity to competitively replace the existing communities in the new habitats (Callaway and Aschehoung, 2000). Plant invasions would be favored in habitats which are compatible with the requirements of the new species (Rejmanek *et al*., 2005) or where disturbances have occurred that allow proliferation of the invader species (Mashhadi and Radosevich, 2004).

The objectives of this work were to 1) identify and describe various characteristics of the most important non-native species that have become invasive and widespread in the major rangeland territories of Argentina; 2) summarize the biological information about some naturalized, non-native species with the potential of transforming natural plant communities; and 3) discuss strategies for plant invasion management and biodiversity conservation in rangeland ecosystems of the country.

Area Description and History

There are pronounced ecological differences in environmental factors within regions in Argentina which make them unique in several ways. These regions vary from the hot and high mountain deserts in the north to the cool sub-antartic districts in Patagonia (Figure 1). A detailed work on the climate, soils, vegetation and land use of the arid and semi-arid Argentine rangelands has been published (Fernández and Busso, 1999).

The first introduction of exotic plant species into Argentina occurred during the colonization of South America by the Spanish (http://www.banrepcultural.org/blaavirtual/historia/puti/puti1.htm; Guadagnin *et al*., 2009; Fonseca *et al.* (in press)). They brought these plant species mainly for food purposes. However, long distances and slow or dangerous ground transportation led to little movement inside the country in that period, thus avoiding seed dispersal. A second phase of human-mediated transport, which is still ongoing, occurred during the late 19th and early 20th centuries (http://www.enjoy-patagonia.org/related-articles/cientific-oxotic-species.php; Guadagnin *et al*., 2009; Fonseca *et al*. (in press)). This was associated with the heavy immigration of European people, and the land occupation and settlement of the colonizing ranchers in the interior of the country. The movement of men and their materials has resulted in a flood of alien species into new regions, both by accidental as well as by deliberate introduction of species considered of interest to humans.

Creation of a Plant Invasion Database in Argentina

Strategies to deal with plant invasions in the country were determined in the first National Meeting about Biological Invasion and Biodiversity Conservation, during July 1998, in Bahía Blanca, Argentina. At the beginning of 2002, Argentina developed a survey system to save and organize information about biological invasions through a project of the Inter-American Biodiversity Information Network (IABIN). Researchers, managers of protected areas, the government and other people contribute to generate a database (Invasive Plant Database, 2009). This database allowed tabulation and access to updated information of invasive plants and provides vital information about the biology, management, propagation and other characteristics of the species included in it.

National regulations include the Biological Diversity Law (http://www2.medioambiente.gov.ar/sian/pan/Leyes-decretos/Ley24375.htm). It avoids introduction and fosters inspection of any potential invasive species. In addition, it contains guidelines for 1) eliminating plants that could limit biodiversity, and 2) preserving the renewable natural resources. Recently, the Government established the Secretary of Environment and Sustainable Development to achieve and protect biodiversity. Argentina federal authorities, together with those of all states in the country, regulate the introduction of alien species.

The current Invasive Plant Database of Argentina comprises 219 invasive plant species (Invasive Plant Database, 2009; http://inbiar.org.ar/? p=NTkwc3A4ZTQyPWAhJUJZE0N-RAFVXBxUaHEolb21ofj9m). In addition, a list of 100 aggressive invasive species has been reported by Delucchi (2009). Only 51 of these plant species will be considered in this work as exotic invaders which have become naturalized and expanded into the extensive rangeland territories of the country. Their names, origin, growth habit, way of reproduction, dispersal and details of the phytogeographical territories (Figure 1) are presented in Table I. These species are distributed in 14 families. The families that showed the greatest number of species were: Asteraceae (18 species), Fabaceae (6) and Poaceae (6). There were a 76.5, 15.7 and 7.8% of herbaceous, shrubby and tree species, respectively. More than 54% of the species were perennials, and 37.2% were annuals. A little over 39% of the species came exclusively from Europe while 60.8% had various origins (Table I).

Major Naturalized, Non-Native Plant Species in Argentine Rangelands

Many exotic non-native plant species have become rangeland weeds in various provinces of Argentina (Table I). Even more, some of them have been declared national plagues. The seven most abundant plant species with these characteristics in rangelands of Argentina (Burkart, 1957; Cipprioti *et al*., 2006, 2007; Vigna and López, 2008) are indicated below.

Acroptilon repens (L.) DC. (= *Rhaponticum repens* (L.) Hidalgo= *Centaurea repens*), of the Asteraceae family, is a perennial invasive weed in rangelands and irrigation agricultural sites (Table I; Ibarra and La Porte, 1944; López-Alvarado *et al*., 2011). Bezic *et al*. (2008) and Bezic (2010) emphasized the importance of achieving a scientific basis and criteria to develop a weed management program for controlling the *A. repens* invasion in the Lower Valley of Río Negro and arid rangelands of southwestern Buenos Aires Province. Dispersal of *A. repens* aggregated in patches can be constrained when competition from range, native perennial grasses is high (Bezic, 2010). Plants of this species, for example, produce allelopathic compounds that have excluded various native species in other regions (Fletcher and Renney, 1963; Jakupovic *et al*., 1986). The work of Jakupovic *et al*. (1986) focused on the perspective of biological invasions, and on the prevailing theory that habitat and plant attributes would be the major determinants of the invasion process. *A. repens* is a broadleaf herbaceous species that reproduces from seed and gemmiferous root sprouting. Its gemmiferous roots can grow deep, although most of them grow shallow and produce new shoots during spring (Fryer and Makepeace, 1977; Bezic *et al*., 2005). These erect, branched shoots can be 30-90cm tall (Whitson, 1987; Panter, 1991). Vertical roots of *A. repens* can reach from 1.8-2.4 to 7m during the first or second year of establishment, respectively (Whitson, 1987; Dall and Zimdahl, 1988). Patches of shallower roots (30cm depth) can give rise to ramets at a density of 65 to 300/m^2 (Bezic *et al.,* 2005). Lineal growth of this species can reach 6m annually in the absence of factors that promote dispersal of its vegetative, belowground structures (Watson, 1980). It means that 20 years would be necessary for obtaining a complete 1ha colonization with plants of *A. repens*. Despite the vegetative (root) propagation of *A. repens*, it can be controlled effectively if an intensive tillage is applied adequately (Fryer and Makeplace, 1977). Also, the timing of active growth and the stage of the belowground reserves can determine the best time for grazing and the applications of systemic herbicides (Bezic, 2010). On undisturbed sites and in the absence of competition, gemmiferous roots of *A. repens* can have a radial increment of 12m^2 within the patch in a two-year-period (Watson, 1980). Weed sprouting responds to thermal time above 10°C, and occurs in one inundating event where the weed density (100 to 300 ramets/m^2) remains constant until the end of the season; however, there are small simultaneous recruitment and mortality events that occur during the entire growing season (Bezic, 2010). This author also suggested that the high competitive capacity of *A. repens* might be the result that two thirds of its clonal population biomass corresponded to underground components, which in turn represent the bud bank.

Changes in the bud bank represent the most appropriate criterion to measure the level of control. The aboveground biomass of *A. repens* has a high phenotypic plasticity to shade, and a high degree of tolerance to low irradiance (Bezic, 2010). A significant effect on aboveground biomass accumulation, without changes in belowground accumulation, was achieved only with shading levels >80% (Bezic, 2010). Glyphosate applied in doses ranging from 1.92 to 3.84kg ai/ha provided a belowground biomass control >95% after two years of treatment (Bezic, 2010). However, tillage (typical of intensive agricultural systems) enables partitioning of sprouting roots, and might explain the high weed densities found in agricultural sites (Bezic, 2010). Also, *A. repens* can produce allelochemicals that might exclude native species in the rangelands of Argentina (Gajardo *et al*., 2004).

TABLE I
INVASIVE SPECIES IN RANGELANDS OF ARGENTINA

Family	Species	Origin	Growth	Reproduct.	Main dispersal way	Location	Ref.
Apiaceae	*Conium maculatum* (L.)	Europe–Western Asia	P	Seed	Water-Wind	P-M	1, 2
	Foeniculum vulgare (Mill.)	Europe	P	Seed	Water-Birds-Animals	P-M-WC	3
Asteraceae	*Acroptilon repens* (L.) Dc.	Europe-Asia	P	Seed-Veg	Human activities	P	4, 5
	Anthemis cotula L.	Europe	A	Seed	Wind	AC	6
	Baccharis sp.	America Center	P	Seed-Veg	Wind	P-C-M-P-WC	7
	Carduus acanthoides L.	Europe	A-B	Seed	Wind	M-WC-PU	8
	Carthamus lanatus L.	Europe	A	Seed	Water-Adhesion-Wind-Contaminant of grain and wool	P-M-C	A
	Centaurea solstitialis (L.)	Europe- Asia	A-B	Seed	Wind-Animal	P-C-M-WC	9, 10
	Chondrilla juncea (L)	Europe- Asia	P	Seed-Veg	Wind	C-M	11
	Cichorium intybus L.	Mediterranean	P	Seed	Wind	P-M-C	1, 8
	Cirsium vulgare (Savi) Ten.	Europe	A	Seed	Wind	AC	1, 8
	Crepis setosa (Hallier f)	Europe	A	Seed	Wind	P-C	B
	Cynara cardunculus L.	Spain-North Africa	P	Seed	Wind	M-C	12
	Hieracium pilosella	Europe-Asia	P	Seed-Veg	Wind	P	13
	Leucanthemum vulgare Lam.	Europe- Asia	P	Seed-Veg	Water-Animal-Agricultural products-Vehicles	P-C-M	C
	Matricaria recutita L.	Europe- North Asia	A	Seed	Animal	M-P	D
	Picris echioides L.	Mediterranean	A-P	Seed	Wind-Adhesion	P-M	14
	Silybum marianum L. Gaertn.	Mediterranean	A	Seed	Wind	P-M-C-PU	1, 8
	Sonchus asper (L.) Hill	Europe	A	Seed	Wind	AC	1
	Taraxacum officinale (G. Webber)	Europe	P	Seed	Wind	AC	1,8
Brassicaceae	*Diplotaxis tenuifolia* (L.) Dc.	Europe	P	Seed	Water-Animals-Vehicles-Clothes	P-M-C-WC	E; 15, 16
	Raphanus sativus (L.)	Europe	A	Seed	Wind-Water-Machinery	AC	8
	Rapistrum rugosum (L.)	Mediterranean	A-B	Seed	Contaminated commercial seeds	AC	F
Caryophyllaceae	*Cerastium glomeratum* (Thuill)	Europe	A	Seed	Wind	P-M-C	G
	Stellaria media (L.) Cirillo	Europe	A	Seed	Foot traffic-Tools-Rain-Birds-Machinery	AC	H
Dipsacaceae	*Dipsacus fullonum* (L.) Honck.	Europe-Asia	B	Seed	Water-Animal-Human-Vehicles	P-M-C	17
Eleagnaceae	*Elaeagnus angustifolia*	Asia	P	Seed-Veg	Water-Animal	M	18
Fabaceae	*Cytisus scoparius* (L.)	Europe-Mediterranean British islands	P	Seed	Self	P	19
	Lupinus polyphyllus (Lindl.)	North America	P	Seed	Vehicles-Human activities-Soil transport	P	20
	Medicago minima (L.) Grufberg	Europe	A	Seed	Animal	M-C-WC-P	21, 16
	Trifolium repens (L.)	Europe	P	Seed	Animal	AC	I
	Prosopis glandulosa Torr.	North Mexico-South USA	P	Seed	Animal	WC	22
	Ulex europaeus (L.)	Europe	B-P	Seed-Veg	Ejection from pod contaminated soil	AC	23
Oleaceae	*Fraxinus pennsylvanica* (Marshall)	North America-Eurasia	P	Seed	Wind-Water	M-C	24
	Ligustrum lucidum (W. T. Aiton)	Asia	P	Seed	Birds	M-C-WC-P	25
	Ligustrum sinense (Lour)	China	P	Seed	Birds	M-WC	26, 27
Pinaceae	*Pinus* sp.	North America	P	Seed	Wind	P-M-C	28
Plantaginaceae	*Plantago lanceolata* (L.)	Europe - Asia	P	Seed	Animal-Human	P-M-C	29
	Plantago major (L.)	Europe - Asia	P	Seed	Animal-Birds-Contaminant of seeds	P-M-C	29, 30
Poaceae	*Avena barbata* Pott	Eurasia	A	Seed	Human	P-C-M	J
	Cynodon dactylon (L. Pers.)	Consmopolite	P	Seed-Veg	Water-Tillage	P-M-C	31
	Lolium multiflorum (Lam.)	Mediterranean	A-P	Seed	Irrigation Water-Animal-Tillage	AC	32
	Poa annua (L.)	Europe	A	Seed	Animal-Human-Machi-nery	AC	1
	Polypogon monspeliensis (L.) Desf.	Europe- Ásia-Africa	A	Seed	Animal	AC	33
	Sorghum halepense (L) Pers.	Central África- Europe	P	Seed-Veg	Water-contaminated grain- Machinery	P-M-WC-PU	16, 21, 34

Growth= A: Annual, B: Biennial, P: Perennial; Veg: Vegetative; Location (see Figure 1)= P: Patagonia: C:Caldenal; M: Monte; WC: Western Chaco; PU: Puna; AC: All Country. References= 1: Holm *et al*., 1977; 2: Woodard, 2008; 3: Erskine and Rejmánek, 2005; 4: Bezic, 2010; 5: Fryer and Makepeace, 1977; 6: Kay, 1958; 7: Giuliano, 2001; 8: Whitson *et al*., 1992; 9: Zouhar, 2002; 10: Young *et al*., 2005; 11: Vigna and López, 2008; 12: White and Holt, 2005; 13: Winkler and Stöcklin, 2002; 14: Sorensen, 1985; 15: Marzocca, 1957; 16: Lamberto *et al*., 1997; 17: Bentivegna, 2006; 18: Klich, 2005; 19: Paynter *et al*., 1998; 20: Fremstad, 2010; 21: Cabrera and Zardini, 1978; 22: Villagra *et al*., 2010; 23: Moss, 1959; 24: Zalba and Villamil, 2002; 25: Aragón and Groom, 2003; 26: Tecco *et al*., 2006; 27: Pokswinski, 2008; 28: Sarasola *et al*., 2006; 29: Fernández *et al*., 2007; 30: Panter and Dolman, 2012; 31: Guglielmini and Satorre, 2004; 32: Gundel *et al*., 2006; 33: Ridley, 1930; 34: Leguizamón, 2006; 35: Requesens and Scaramuzzino, 1999; 36: Paruelo *et al*., 2010; 37: Montaldo, 2000; 38: Dewine and Cooper, 2008. A: http://florbase.dec.wa.gov.au/browse/profile/7911. FloraBase. The Western Australia Flora. (Cons. 02/05/2013); B: http://www2.dmu.dk/1_Om_DMU/2_Tvaer-funk/3_fdc_bio/projekter/redlist/gpdata.asp?ID=67&mode=NA. Fagdatacenter for Biodiversitet og Terrestrisk Natur. (Cons. 02/08/2013); C: http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/invasive_ox_eye_daisy. Victorian Resources Online.

(Continues)

Centaurea solstitialis L. (Yellow starthistle) also belongs to the Asteraceae family (Table I). It is an invasive winter annual, native of Western Europe and Eastern Asia. It is considered an important weed in temperate areas of cereal crops in the Argentina (Montoya, 2010); besides, it is also a widespread naturalized representative of the flora in rangelands (Cabrera and Zardini, 1978; Lamberto *et al*., 1997; Hierro *et al*., 2011). Perhaps the most accepted truism in invasion biology is that disturbance promotes invasion of exotic plant species. Reports of Hierro *et al*. (2006) in the native (Eurasia) and non-native (California and central Argentina) ranges of *C. solstitialis*, as one of the most invasive exotic ruderals in these regions, support this perspective. However, they show that disturbances have much stronger effects on *C. solstitialis* abundance and performance abroad than at home. Their results question the assumption that disturbance *per se* is sufficient to explain the remarkable success of invasive plant species under disturbed conditions in their non-native range. However, they were limited in replication and geographical scope. Hierro *et al*. (2006) indicated that the powerful effects of disturbance must act in concert with the release from other controlling factors, enabling some species to attain community dominance only where they occur as exotics.

The exact moment of its introduction into Argentina it is not known. Parodi (1926) cited its presence as the consequence of multiple introductions, favored by contaminated alfalfa seeds as a vehicle. Once established, the species can survive at higher population densities year after year, affecting the development and germination of other species (Callaway *et al*., 2003). Seed production, germination and dispersal are mayor determinants of its invasive potential (Barthell *et al*., 2001). Dimorphism of achenes is a reproductive characteristic; they are clear, with a small pappus in the center of the capitulum, dark and without pappus in the periphery (Lamberto *et al*., 1997). Both types of achenes show the potential to germinate in a wide temperature range (6-30°C); however, the highest germination values occurred at 14°C with 86% germination for the achenes with pappus, and 46% for those without it (Escandón *et al*., 2005). Regardless of the differences in germination at the cited temperatures, a few established plants can ensure species perpetuation in places where it has become naturalized. *C. soltitialis* can be considered an undesirable species under many circumstances; however, it can be beneficial to the honey industry in the SE of La Pampa and SW of Buenos Aires Provinces (Monge, 1992; Valle *et al*., 2001). Honey derived from *C. solstitialis* in Argentina and other parts of the world, is appreciated for its quality (Cheng *et al.,* 1993; Somerville, 2000).

Elaeagnus angustifolia L. (Russian olive, Narrow-leaved oleaster), of the Elaeagnaceae family, is a deciduous tree introduced as ornamental into the Middle Valley of the Rio Negro (39º30'S, 65º30'W; Table I). Today, this species has become naturalized in extensive regions along river margins, threatening the biodiversity in areas previously occupied by rheophytic vegetation. As a result, it is also threatening the livestock industry that uses natural grassland as the main food source for animals. When the first small plant patches appeared in the 1970s, *E. angustifolia* was either ignored or not judged as an invasive damaging species. A detailed study of its ecology, including the invasive potential, was performed by Klich (2005). The rates of invasion and naturalization have been assigned to the combination of several ecological strategies (Klich, 2005): 1) the huge capacity for sexual reproduction, which secures the existence of a persistent seed bank (recently collected seeds showed 75% germination); 2) vegetative expansion that takes place from a gemmiferous, plagiotropic root system (physical fragmentation of the roots is translated into the release of bud dormancy, and new shoots appear over the soil surface); 3) its adaptive capacity is noticeable for achieving several allometric forms, a result of environmental heterogeneity; and 4) a variable root growth architecture that responds to different soil physical situations. When combined, these ecological strategies make this species a successful thriving invader, which will definitively expand.

Medicago minima (L.) Grufberg. This species, which belongs to the Leguminosae family (Table I), is a naturalized exotic annual that deserves major attention. It is native from Europe, and has become naturalized and widely distributed in extensive semi-arid temperate rangelands of Argentina dedicated to livestock production (Cabrera and Zardini, 1978; Cano, 1988; Lamberto *et al*., 1997; Daddario, 2012). Hauman (1925) quotes its presence in 1925. Several biological and ecological studies have been conducted on *M. minima* in populations coming from the Caldenal (38º45´S, 63º45´W; Figure 1); these studies are related to the morphology and phenology, seed dormancy, germi-

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Family	Species	Origin	Growth	Reproduct.	Main dispersal way	Location	Ref.
Primulaceae	*Anagallis arvensis* (L.)	Europe	A-B	Seed	Water-Animal-Vehicles	P-M-WC-PU	35
	Centunculus minimus (L.)	Europe	A	Seed	Water- Contaminated soil	P-M-C-WC-PU	K
Rosaceae	*Malus domestica* (Borkh)	Europe- West Asia	P	Seed-Veg	Animal	P-M	36
	Pyracantha angustifolia (Franch) C.K. Schnied	China	P	Seed	Birds	WC-PU	26
	Rubus ulmifolius (Schott).	Europe	P	Seed	Animal	P-WC-PU	37
Tamaricaceae	*Tamarix ramosissima* Ledeb.	Mediterranean	P	Seed	Water	P-M-C	38

Invasiveness Assessment. Ox-eye daisy (*Leucanthermum vulgare*) in Victoria (Nox). (Cons. 02/05/2013); D: http://www.gardenorganic.org.uk/organicweeds/weed_information/weed.php?id=51. Organic Weed Management. Scented mayweed. (Cons. 02/05/2013); E: http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/invasive_sand_rocket. Victorial Resources Online. Invasiveness Assessment – Sand rocket (*Diplotaxis tenuifolia*) in Victoria (Nox.). (Cons. 02/05/2013); F: http://www.conabio.gob.mx/malezasdemexico/brassicaceae/rapistrum-rugosum/fichas/ficha.htm#5. Biología y Ecología. Brassicaceae= Crusiferae. *Rapistrum rugosum* (L.) All. Rapistro rugoso (sugerido). (Cons. 02/05/2013); G: http://www.gardenorganic.org.uk/organicweeds/weed_information/weed.php?id=134. Organic Weed Management. Sticky mouse-ear. (Cons. 02/05/2013); H: http://www.freshfromflorida.com/pi/weed_of_the_month/1109_Stellaria_media.html. Botany. Weed of the month. (Cons. 02/05/2013); I: http://florabonaerense.blogspot.com.ar/2012/04/trebol_blanco_trifolium.repens.html. (Cons. 02/05/2013); J: www.albufera.com/parque/content/avena-barbata-pott-ex-link-schrader-avena-erizada-cugula. Parc Natural d L'Albufera. Avena barbata Pott. Ex Link in Schrader (avena erizada, cugula). (Cons. 02/05/2013); K: http://www.floraargentina.edu.ar/detalleespecie.asp?forma=&variedad=&subespecie=&especie=minimus&espcod=1644&genero= centunculus& autor=6&deDonde=4. (Cons. 02/05/2013).

nation, seedling establishment and survival, responses to water stress and forage production (Fresnillo *et al*., 1991, 1992, 1995a, b, c; Fresnillo Fedorenko, 2001; Peláez *et al*., 1995). Its persistence in the local flora is ensured by its capacity to 1) colonize open, overgrazed areas, 2) grow in association with perennial grasses, and 3) tolerate severe drought periods (Fresnillo Fedorenko, 2001). In central Argentina, this species was recognized for making a significant contribution to cattle diet during late winter and spring in wet years (Fresnillo *et al*., 1992; Bontti *et al*., 1999).

Chondrilla juncea L. (Rush skeletonweed), of the Asteraceae family, was introduced in the country in the 70s and declared a national plague in 1977 (Vigna and López, 2008; Table I). It is an herbaceous perennial 0.30-0.90m tall with a gemmiferous taproot that can reach at least 2m in depth (Vigna and López, 2008). Mechanical injury can produce new shoots from any part of the root system, ensuring its persistence in colonized areas. It overwinters as a rosette. Mature plants can produce more than 1000 flower heads with the potential to yield 25000 seeds with pappus, which allows them major wind dispersal (Vigna and López, 2008). Rangeland invasions by *C. juncea* might affect cattle industry because it can outcompete native desirable forage species (Vigna and López, 2008). These authors reported that the area invaded with this species can reach ~4×10^6ha. Current management of this invader species has involved control of small infestations and young plants with herbicides, and synchronized grazing times. A promissory, successful biological control agent in the infested area can be achieved with the gall mite *Eriophyes chondrillae*, released in 1989 (Vigna *et al*., 1993).

Dipsacus fullonum (L.) Honck. **(**Indian teasel), a Dipsacaceae, was introduced from Eurasia and naturalized in several localities of Argentina (Burkart, 1957; Lamberto *et al*., 1997; Daddario, 2012; Table I). It is a biennial species that reproduces only by seed. Plant growth habit is like a rosette in the first year. Despite the fact that seed dispersion is mostly around the parent plant, seeds are also dispersed via water, animals, humans and vehicles. Consequently, new patches of this species can be found far away from the original areas (Bentivegna, 2006).

Sorghum halepense (L.) Pers. (Johnson grass) is a perennial invasive alien species of the Poaceae family of worldwide distribution (Table I). It was introduced as a forage species from Central Africa and the Mediterranean region of Europe around 1910, and it was declared a national plague in 1930 (Leguizamón, 2006; De la Fuente and Suárez, 2008). It is a common crop and rangeland weed (Cabrera and Zardini, 1978; Lamberto *et al*., 1997). Invasion of Johnson grass occurs firstly by seeds germination. Thereafter, the most successful genotypes expand by an extensive and vigorous rhizomatous system at a given environment, making this species difficult to get rid off. It shows high fecundity, seed dormancy and a residual seed bank viable for many years (Leguizamón, 1986). A recent problem is the presence of biotypes resistant to Glyphosate, the chemical product most used as a low-cost herbicide for the control of this species (Vila-Aiub *et al*., 2007).

Weed Management Strategies and Biodiversity Conservation in Argentina's Rangeland Ecosystems

Awareness about the problems associated with plant invasions into rangeland areas has greatly increased during the last two decades, because the ecological or economical damage caused by some alien species on the native flora has been too significant to be overlooked (Cipriotti *et al*., 2006, 2007). This has led to a concern for fostering research focused on invaders management. Recognizing the invasion phase of a non-native particular species that is able to establish into a novel ecological habitat is the first step for risk assessment and management of species invasion. Once the non-native species suspected to be harmful invaders have been detected, or have already established incipient populations, there is the urgent need for early warming systems and a precise understanding of invasion vectors. The problem becomes much more difficult when attempting to implement management of well established invasive plant species. In general, they are geographically widespread and their integration with the invaded ecological system is highly successful. Ecological studies are first needed to gain proper understanding of the strategies that turn a species into a successful invader. Thereafter, it could be possible to implement policies for ecological management.

Plant invasions might have a negative impact on ecosystem biodiversity at a local scale. For example, Cipriotti *et al*. (2006, 2007) have reported that *Hieracium pilosella* L. (Asteraceae: Rauber *et al*., 2005) has invaded the southern Patagonian rangelands in Argentina. As a result, this species might form intraspecific patches that can occupy more than one hectare, replacing native flora. This perennial herb, introduced from Eurasia, was first recognized in Tierra del Fuego in 1993 (Livraghi *et al*., 1998), and thereafter it invaded the southern portion of continental Patagonia.

Policies calling for removal of exotic, alien, or introduced species appear to rest on the old notion that changes in the abundance of any species in the plant community mean a threat to the entire community. However, wildland communities receive continuous new arrivals, yet it does not necessarily result in a net loss of species. For example, Johnson and Mayeaux (1992) reported that plant species richness of the California annual grasslands is probably much higher today than it was prior to the arrival of the Europeans. Most communities do not consist of highly co-evolved species pairs, but exhibit some species replacement within groups (Westman, 1990). This does not deny mutualism and the existence of keystone or critical species (those playing a vital role in ecosystem functioning), but acknowledges that not all species play those roles. We do have to differentiate between the exotics to either worry or not about, based on their effects on ecosystem functioning and man welfare (e.g., the beneficial effects of the exotic, naturalized legume *M. minima* in rangelands of central Argentina). We have to be aware, however, that if invasive noxious species cross a threshold level, they can (and often do) dominate the site (see Pyke *et al*., 2002).

Hobbs and Humphries (1995) already recognized that focusing on the characteristics and control measures of individual invading species is inadequate as a management approach to tackle the problem associated with plant invasions to natural ecosystems. They suggested various strategies for the control of invader plant species: 1) many species have a lag phase following introduction before they spread explosively; as a result, plant invasions should be detected and treated early, before explosive spread occurs; 2) the focus should be placed on the invaded ecosystem and its management rather than on the invader; 3) more effective integrated control programs could be reached after identification of the causal factors enhancing ecosystem invasiveness; 4) management priorities for protection and control have to be reached after a value assessment of particular sites and their degree of disturbance; 5) changes in human activities in terms of plant introduction and use, land use, and timing of control measures are needed to appropriately tackle plant invasion problems;

their thoughts should be taken into account if we simultaneously want to conserve ecosystem's biodiversity.

If sustainable development is to be achieved, we need to find ways for natural resources be both used and maintained. Finding balance points would be easier if the role that species play in ecosystem functioning is better understood. If functional groups, guilds, keystone or critical species, and exotics to be worried or not worried about are identified, the overly simplistic, species-only notions of biodiversity will be replaced, and we will gain a larger role in setting policies on use of rangelands.

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UNA REVISIÓN DE LAS PLANTAS INVASORAS EN PASTIZALES ARGENTINOS

Carlos A. Busso, Diego J. Bentivegna y Osvaldo A. Fernández

RESUMEN

En Argentina, la información sobre plantas invasoras está limitada a cultivos y no hay información disponible en pastizales naturales. Nuestros objetivos fueron 1) identificar y describir varias características de las especies no nativas más importantes que se han convertido en invasoras y distribuido en los principales pastizales naturales de Argentina; 2) resumir la información biológica de algunas especies naturalizadas, no nativas, con potencial de transformar comunidades vegetales nativas, y 3) discutir estrategias para el manejo de plantas invasoras y conservación de la biodiversidad en ecosistemas locales de pastizales naturales. Las especies invasoras más representadas en estudios a escala local, regional o provincial fueron Acroptilon repens*,* Centaurea solstitialis*,* Eleagnus angustifolia*,* Medicago minima*,* Chondrilla juncea*,* Dipsacus sativus *y* Sorghum halepense*. La tasa exitosa de invasión y naturalización de especies vegetales resulta de la combinación de varias estrategias ecológicas: 1) producción de compuestos alelopáticos, 2) enraizamiento profundo, 3) alta densidad de módulos, 4) rápida dispersión vegetativa en la parte aérea, 5) varias características que las hacen muy competitivas, 6) tolerancia al sombreado y estrés hídrico, 7) capacidad de aprovechar disturbios, 8) alta producción, germinación y dispersión de semillas, y 9) alta viabilidad de semillas residuales. La abundancia de invasoras a escala de país, y su daño ecológico y económico, son objetivo de futuros estudios. Esta información proveerá una herramienta crítica para tomar decisiones sobre el control de especies invasoras. Estudios ecológicos que permitan comprender las estrategias que hacen a una especie invasora un competidor exitoso debería ser el primer paso para establecer políticas para control de especies invasoras y uso de pastizales naturales.*

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RESUMO

Na Argentina, a informação sobre plantas invasoras está limitada a cultivos e não há informação disponível em pastiçais naturais. Nossos objetivos foram 1) identificar e descrever várias características das espécies não nativas mais importantes que tem se convertido em invasoras e distribuido nos principais pastiçais naturais da Argentina; 2) resumir a informação biológica de algumas espécies naturalizadas, não nativas, com potencial de transformar comunidades vegetais nativas, e 3) discutir estratégias para o manejo de plantas invasoras e conservação da biodiversidade em ecossistemas locais de pastiçais naturais. As espécies invasoras mais representadas em estudos em escala local, regional ou provincial foram Acroptilon repens*,* Centaurea solstitialis*,* Eleagnus angustifolia*,* Medicago minima*,* Chondrilla juncea*,* Dipsacus sativus *e* Sorghum halepense*. A taxa exitosa de invasão e naturalização de espécies vegetales resulta da combinação de várias estratégias ecológicas: 1) produção de compostos alelopáticos, 2) enraizamento profundo, 3) alta densidade de módulos, 4) rápida dispersão vegetativa na parte aérea, 5) várias características as fazem muito competitivas, 6) tolerância em sombreado e estrés hídrico, 7) capacidade de aproveitar distúrbios, 8) alta produção, germinação e dispersão de sementes, e 9) alta viabilidade de sementes residuais. A abundância de invasoras na escala de país, e o dano ecológico e econômico que provocam, são objetivos de futuros estudos. Esta informação proporcionará uma ferramenta crítica para tomar decisões sobre o controle de espécies invasoras. Estudos ecológicos que permitam compreender as estratégias que fazem com que uma espécie invasora seja um competidor exitoso deveria ser o primeiro passo para estabelecer políticas para o controle de espécies invasoras e a utilização de pastiçais naturais.*