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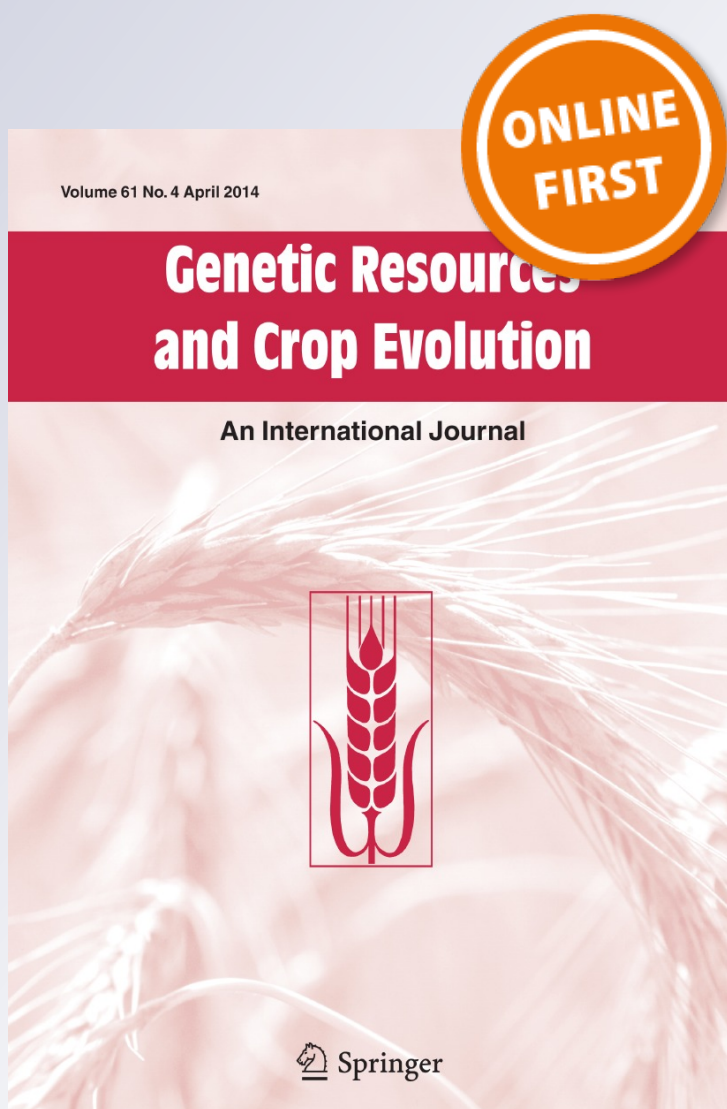
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***In situ* conservation of the wild relative of the common bean (*Phaseolus vulgaris* var. *aborigineus*) at the south of its neotropical distribution: environmental characterization of a population in central Argentina**

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Abstract The common bean (*Phaseolus vulgaris* L.) is a food of worldwide vital importance. Like any crop, the conservation of its wild relatives is essential to maintain the genetic variability needed for plant breeding. *In situ* conservation of such population has the additional benefit of generating new variations through the evolution of its natural environment. In 2004, wild populations of *P. vulgaris* var. *aborigineus* were found in the province of Córdoba (Argentina), being the southernmost specimen of its current distribution. In order to study the state and characterize the environment of such populations, vegetation censuses were conducted along a stretch of the Tanti stream-arroyo Tanti-(Punilla, Córdoba). Results showed that the wild bean has an intermediate to high constancy throughout the watercourse and its presence decreases upstream and away from the stream. Most cover took place in plots with scarce slope, high incidence of light and intense magnitude of floods. Vegetation develops in an environment surrounded by

forests, meadows and intermediate physiognomy. Besides adventitious species, the studied area still has native species of high conservation value. Based on the analysis of this work, and considering the biogeographical significance of this population of wild bean, we conclude that this stretch of the studied stream is a priority area for the *in situ* conservation of *P. vulgaris* var. *aborigineus*.

Keywords Córdoba · Crop improvement · Crop wild relative · *Phaseolus vulgaris* var. *aborigineus* · Tanti

Introduction

The common bean, *Phaseolus vulgaris* L., is one of the leguminous plants of utmost importance for human consumption in the world (Broughton et al. 2003). In addition to the wide use of its unripe green fruits, its seeds are a major source of food in Africa (Jackson et al. 2012) and nearly all America (van Schoonhoven and Voysest 1989).

Commercial crop wild populations are a vital source for plant breeding and, in particular, for the case of *P. vulgaris*, studies show that the main genetic variation of wild populations translates into organisms that morphologically and physiologically better adapt to environment heterogeneity and to different pathogens that cause diseases (García et al. 1997; Singh and Schwartz 2010; Cardozo et al. 2012). The narrow

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genetic basis of commercial variations, caused by production technologies that lead to uniform cultivars, makes them very vulnerable to diseases, plagues and environment adverse conditions (Singh and Schwartz 2010). Protection of these crops through phytochemicals, not only makes production more expensive, but it also pollutes the environment. A more rational, economic and nonpolluting form to increase production is incorporating resistance by using genetic variation in primitive varieties and wild relatives, which tend to disappear in its habitat due to the anthropic impact.

Conservation of ecosystem biodiversity is essential to avoid the loss of the genetic resources that may be useful in the future. According to scientists, a method for biodiversity conservation is to store seeds in genebanks (*ex situ* conservation) or to protect them in wild areas (*in situ* conservation). Currently, the focus is on the *in situ* conservation of crop wild relatives (CWR), since such initiatives allow to keep CWR in their natural environment with their associated species, where these are not only conserved as a useful variation source for the improvement of crops, but these can also continue to evolve and create new varieties, some of which may be used for plant breeding (Hunter and Heywood 2010). A crop wild relative can be defined as a taxon that has an indirect use derived from its relatively close relation to the crop (Maxted et al. 2006). In the case of CWR *P. vulgaris* L. var. *aborigineus* (Burkart) Baudet, it has the closest relationship to the common bean since it belongs to the same species and may be classified in taxonomic group 1b, group with highest protection priority (Maxted et al. 2008).

There are several studies on the origin and domestication of the common bean comparing wild populations with cultivated ones (Berglund-Brücher and Brücher 1976; Chacón et al. 2005), but few investigate the state and causes that affect the wild population conservation (Villalobos et al. 2001). Wild populations of *P. vulgaris* are distributed from Mexico to north and central Argentina (Burkart and Brücher 1953; Debouck et al. 1993). The presence of *P. vulgaris* var. *aborigineus*, in particular, has been reported in Venezuela, Colombia, Ecuador, Peru, Bolivia and Argentina. In Argentina, this variety may be found in the provinces of Salta, Jujuy, Tucumán, Catamarca, San Luis and Córdoba (Berglund-Brücher and Brücher 1976; Drewes

2006). The climate *P. vulgaris* var. *aborigineus* grows in is a mountain mesophytic type with high temperatures during the day and low temperatures during the night. It is found in intermountain valleys, growing besides rivers or other watercourses in altitudes below 3,000 m. It is also associated with thorny shrubs and road slopes which, according to (de Ron et al. 1997), are hostile environments for cattle, animals that can produce a decrease in bean abundance.

While in the provinces of the northwest of Argentina wild bean populations are common and there are many specimens in different herbariums, its presence in the province of Córdoba is questionable and it refers to a specimen collected in 1903. This lead to research trips, in 2003, to central Argentina and resulted in the discovery of wild bean populations in the valley of Punilla (Córdoba), which confirms the current southern limit of distribution of *P. vulgaris* var. *aborigineus* (Drewes 2006). The extinction of these populations would, in consequence, mean the retraction of the distribution of this wild relative of the common bean.

The ecoregion where these populations were found (Dry Chaco or Chaco Seco) are considered high priority by FAO for *in situ* studies of genetic resources conservation (Clausen et al. 2008). Within the known activities for *in situ* conservation of crop wild relatives, ecogeographic surveys are recognized as basic planning tools that provide information for protected area selection and for population management (Meilleur and Hodgkin 2004). Ecological monitoring is one of the main approaches to CWR populations monitoring, since it allows the changes in the community and surrounding environment to be assessed (Maxted et al. 2008).

The aim of this paper was to study the state and characterize the environment of a recently found population of *P. vulgaris* var. *aborigineus* (wild relative of the common bean) located in the southernmost of its distribution: the Tanti stream, valley of Punilla, Province of Córdoba, Argentina.

Methods

Study site

The Tanti stream is located in the valley of Punilla (Fig. 1), Department of Punilla, Province of Córdoba, Argentina (latitude -31.3° ; longitude -64.6°). The

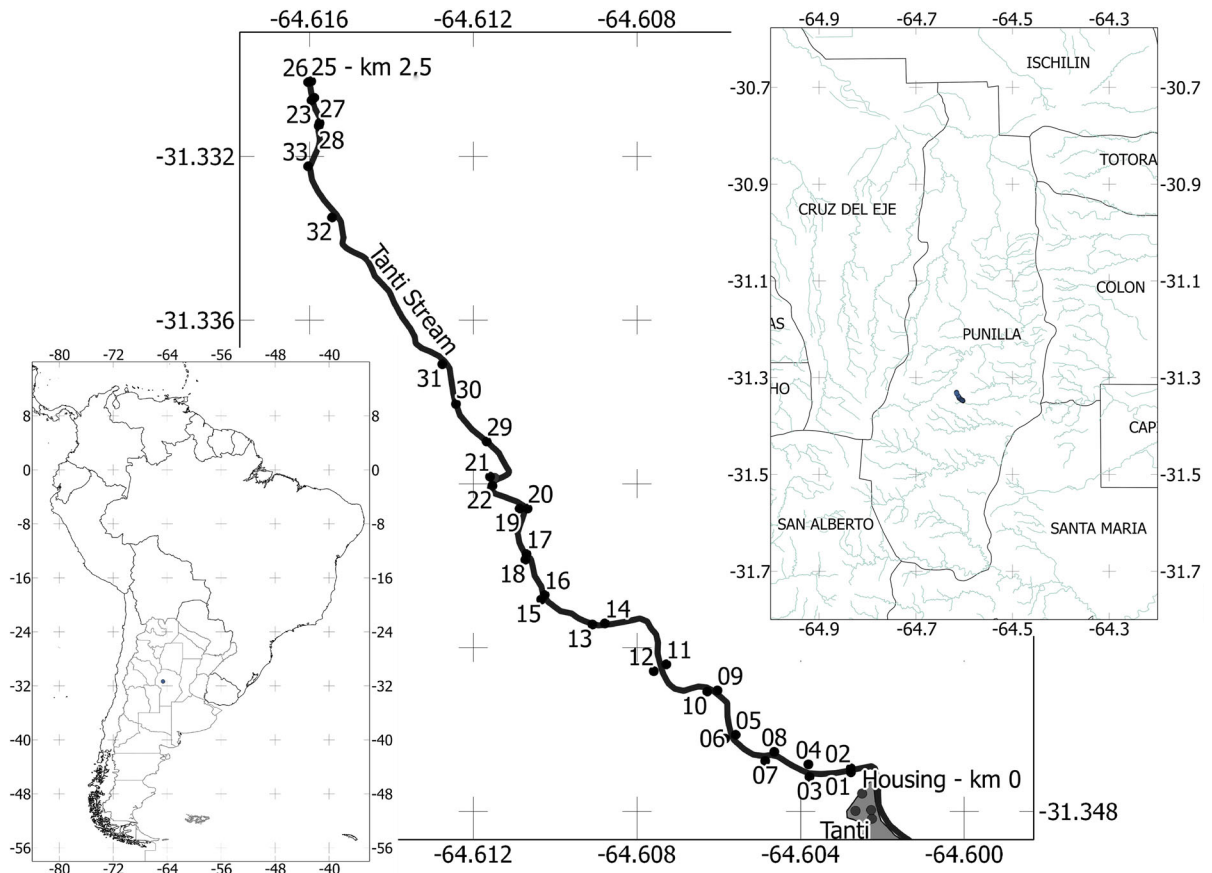


Fig. 1 Censuses location (numbered circles) at the Tanti stream and northwest end of the urban public land where the last housings are marked (circles). The beginning (km 0) and end of the route (km 2.5) are pointed out. Condition of the study

site at the central-north Province of Córdoba; Department limits and hydrographic networks are indicated. Condition of the study site in South America; Argentine national boundaries and provinces are indicated

valley is bordered by Sierras Chicas on the east and by Sierras Grandes on the west. The study site is on the slope of these last mountains which have a geological formation of granite rocks (Capitanelli 1979). There is a temperate climate with normal values of average annual temperatures between 16 and 18 °C and with annual rainfalls of 800 mm (period 1961–1990, National Weather Service).

Original vegetation of the area belongs to Chaqueño Serrano District, Province of Chaco, Chaco Domain (Cabrera 1976). The study site is within the following altitude levels (Luti et al. 1979; Cabido and Zak 1999): (1) Bosque serrano, between 700 and 1,150 m a.s.l., prevailing *Lithrea molleoides* (see authorship of every species in the Appendix Table) with presence of *Zanthoxylum coco* and *Celtis ehrenbergiana*. (2) *Arbustal*, between 1,000 and 1,100 m a.s.l., prevailing

Heterotalamus alienus with presence of *Eupatorium buniifolium*, *Salvia* spp., *Baccharis articulata*, *Eryngium* spp. and *Colletia spinosissima*. Currently, original vegetation shows profound changes, thus registering important set-backs (Gavier and Bucher 2004), invasion of exotic species and development of secondary forests and changes in the use of land for cultural landscapes (Zak and Cabido 2002).

Sampling design

The sampling was taken in the stretch of the Tanti stream that goes from the last housing of the northwest corner of the homonym town (beginning of the route) to its sources (end of the route), along 2.5 km over the watercourse (Fig. 1). With the exception of an unreachable stretch, plots were set systematically at

approximately every 150 m, on both sides of the stream. Thus, a total of 33 plots were delimited by the use of ropes, with a surface of 10×10 m, and they were georeferenced using a “Garmin Etrex-30” GPS.

State of the population and abiotic environment

The presence and cover of *P. vulgaris* var. *aborigineus* was registered in each plot and also whether it grew homogeneously as it distanced from the watercourse in one, two and three-thirds of the plot (0–3.3; 3.4–6.6 and 6.7–10 m as of the watercourse). A measuring tape was used for that purpose. Abiotic variations measured in each plot were the following: traversed distance of the stream, height above sea level, side slope, percentage of incident light, percentage of soil covered by rock and effects of the stream floods. The first two variations were registered through GPS. Traversed distance was used to know the relative position upstream and downstream of each plot and as indirect measure of the pressure exerted by people, who use the edge of the stream for recreational purposes, observing more people at the beginning of the route than at the end. The side slope was measured with “Spectra Precision Laser plane 500C” laser level. Incident light on each plot was estimated as the light percentage that reached the plot without intercepting vegetation, at one meter above the ground. The percentage of plot covered by rock without vegetation was determined using the same scale described below for vegetation. The effects of stream floods (flood magnitude) were determined measuring the maximum height of vegetal remainder (driftwood and rubbish) left by water on standing vegetation.

Biotic environment: the Tanti stream vegetation

In each plot several vegetation species were identified in the field, samples were collected and a herbarium was prepared for subsequent determination at the Systematics of Vascular Plants Laboratory, Faculty of Exact and Natural Sciences, University of Buenos Aires. Cover estimate of found species was made using a modified Braun-Blanquet scale using the next percentage ranges: <1, 1, 1–5, 5–10, 10–25, 25–33, 33–50, 50–75, 75–100 %. The nomenclature, habit and origin used by (Zuloaga et al. 1994; Zuloaga and Morrone 1996, 1999) was applied to the species.

Data analysis

State of population and abiotic environment

The probability of finding *P. vulgaris* var. *aborigineus* accounting the distance of the watercourse was calculated, as the number of censuses in which it appeared in every third of the plot divided the total number of censuses where the wild bean was present. For each plot, the distance at the beginning of the route was calculated over the watercourse with “Google Earth” software. The side slope of every plot was calculated as the inverse sine of the difference between height at the edge of the watercourse and the height at the end of the plot, divided ten meters. Cover of *P. vulgaris* var. *aborigineus* was analyzed based on the abiotic variables with a Canonical Correspondence Analysis, as described below, but using the six variable measures mentioned in “[State of the population and abiotic environment](#)” section.

Each measured abiotic variable was divided into three equal ranges (low, medium and high) and the presence dependency of *P. vulgaris* var. *aborigineus* was compared with each one of those ranges through frequency analysis (Chi square test). The cover of the wild bean was compared similarly, but using the Kruskal–Wallis test; when there was significant cover, ranges were compared in pairs with a Mann–Whitney test (Sheskin 2000). The rejection *alpha* level in ever test was 0.05. Every statistical analysis was carried out with XLSTAT software version 7.5.2.

Biotic environment: The Tanti stream vegetation

Through a classification, different vegetation associations were recognized in relation to the composition and relative abundance of species with the TWINSPAN program. For such classification, species that only appeared on one census were excluded. Groups from the classification were characterized based on the constancy and relative abundance of the main species. For each species, relative constancy was calculated as the number of censuses in which it was present in relation to the total number of censuses. Medium cover was calculated as the sum of covers divided the total censuses. In order to detect the ordering patterns of the censuses and species based on environment variables, the Canonical Correspondence Analysis was used. For such purpose the program CANOCO for

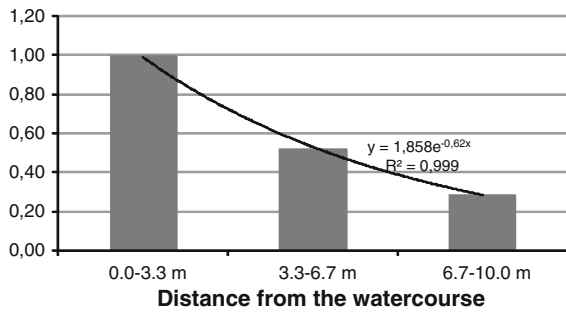


Fig. 2 Probability of finding wild bean based on the distance from the watercourse in the censuses where it was present ($N = 21$)

WINDOWS, version 4.02, was used. The analysis was made by reducing the weight of rare species, focusing the scale of censuses and species symmetrically, selecting the most significant variables ($p < 0.05$) for the arrangement after a Monte Carlo test with 999 non-restricted permutation.

Results and discussion

State of the population and abiotic environment

On general terms, *P. vulgaris* var. *aborigineus* had an intermediate to high constancy (64 %) and low cover (<10 in 91 % of 33 censuses) for the entire stream ($N = 33$), although there was one plot with more than 50 % cover. Whenever it appeared on a census ($N = 21$), probability to find it decreased exponentially accounting the distance of the watercourse (Fig. 2).

The measured abiotic variables of the Tanti stream showed the following behavior (Fig. 3): The traversed distance and the height above the sea level were deeply correlated since, as we moved up the stream, the height increased. Both variables had an inverse relation to the intensity of the flood, since places in which the effects of the flood were greater took place in lower sections of the stream. There was no relationship between the intensity of flooding and the slope, indicating that sites with large magnitude of flooding can be high slope sites and therefore, well drained and not necessarily places where water stagnates. The percentage of exposed rock was deeply correlated with the slope and both variables were

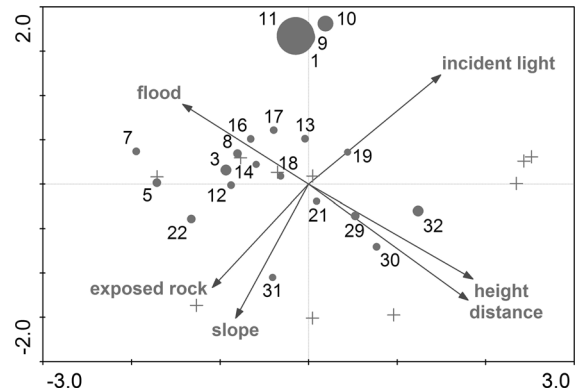


Fig. 3 Arrangement of censuses with (circles) and without (crosses) presence of wild bean, based on the similarity of its floristic composition and the measured abiotic variables (arrows), according to a Canonical Correspondence Analysis. The diameter of the circles is proportional to the cover of *Phaseolus vulgaris* var. *aborigineus*

inversely correlated with the sunlight that reached the first meter of height from the ground.

The proportion of censuses with presence of wild bean was not independent from the traversed distance (Table 1); there was more presence and cover in the stretches closer to the Tanti. This is consistent with a predominantly downstream spread. In addition, these results indicate that places with more presence of beans are in the stretch of greater vulnerability, if we consider the potential negative impact caused by people.

Phaseolus vulgaris var. *aborigineus* grew from 886 to 993 m a.s.l. and its presence and cover were significantly higher in these heights than in 1,000 and 1,060 m a.s.l. (Table 1). The altitudes where it grows were within the cited range for other regions in America (>500 m a.s.l., (Burkart and Brücher 1953; Gepts 1998). The absence in more than 1,000 m a.s.l., rather than being due to the altitudinal limit would be due to the fact that this is a zone of stream source in which there are damp areas and, as described below, there are hardly any wood species that work as support to climb.

There was more presence and cover of wild bean in plots with low ($0-6^\circ$) or intermediate ($6-12^\circ$) slopes. However, we found no significant differences to confirm dependence between the growth of *P. vulgaris* var. *aborigineus* and the plot slope; a variable that would limit the permanence of water by surface runoff (Table 1). We also did not find significant

Table 1 Presence and cover of *Phaseolus vulgaris* var. *aborigineus* in the Tanti stream (Córdoba, Argentina) based on six abiotic environmental variables

	Total no. of censuses	Proportion with presence of wild bean	Cover		
			First quartile	Median	Third quartile
Traversed distance*					
0.0–0.9 km	12	0.75	0.50	3.00	12.50 ^a
1.0–1.9 km	13	0.85	0.01	0.01	1.00 ^b
2.0–2.9 km	8	0.13	0.00	0.00	0.00 ^c
Height*					
880–939 m a.s.l.	17	0.76	0.01	1.00	3.00 ^a
940–999 m a.s.l.	10	0.80	0.01	0.51	3.00 ^a
1,000–1,059 m a.s.l.	6	0.00	0.00	0.00	0.00 ^b
Lateral slope					
0.0–5.9°	12	0.67	0.00	1.00	10.25
6.0–11.9°	14	0.79	0.01	0.51	3.00
12–17.9°	7	0.29	0.00	0.00	1.00
Incident light*					
0–33 %	4	0.00	0.00	0.00	0.00 ^b
34–66 %	13	0.85	0.01	1.00	3.00 ^a
67–100 %	16	0.63	0.00	0.01	5.25 ^a
Exposed rock					
0–24 %	18	0.61	0.00	0.50	3.00
25–49 %	9	0.67	0.00	1.00	5.25
50–75 %	6	0.67	0.00	0.01	1.00
Driftwood and rubbish height*					
0.0–0.8 m	10	0.20	0.00	0.00	0.00 ^b
0.9–1.6 m	13	0.77	0.01	1.00	3.00 ^a
1.7–2.5 m	10	0.90	0.01	2.00	7.50 ^a

For wild bean cover, $a > b > c$ ($p < 0.05$ Mann–Whitney)

* Significant differences in the censuses proportion with wild bean ($p < 0.01$ Chi²) and in the cover ($p < 0.05$ Kruskal–Wallis)

differences between the presence of wild bean and the percentage of exposed rock on the ground (Table 1), although we should emphasize that censuses with more cover belong to zones with low percentage of exposed rock.

Presence and cover of wild bean in places with intermediate to high incident light were significantly higher than shaded plots (<33 % incident light) where there was no *P. vulgaris* var. *aborigineus* (Table 1). Results suggest a preference for sunny places with trees and occasional shrubs where most covers were found, although it is possible to find wild bean growing in not too shaded groves or forests. There was significant presence of wild bean in plots with remainder of driftwood and rubbish in heights above 90 cm, being represented in censuses where driftwood and rubbish were registered above 2 m (Table 1). Thus, results show coexistence of *P. vulgaris* var. *aborigineus* in places where the effects of floods are

intense and where, considering the drag effects of water, the likelihood of wild bean seeds arrive by hydrochory are higher.

Biotic environment: The Tanti stream vegetation

Altitudinal gradient, incident light, traversed distance and side slope were all variables of great importance ($p = 0.001$; 0.002; 0.017 and 0.048 respectively) to explain the obtained vegetation arrangement (Fig. 4).

Vegetation is arranged according to an altitudinal and longitudinal gradient (traversed distance), but there are plots with lesser slope in every height and stretches of the stream where herbaceous vegetation grows (greater incidence of light), and plots with greater slopes where woods grow (less percentage of light). The clearest exponents were the ones furthest from the center of the Figure, but there are cases in between: plots at any height with herbaceous

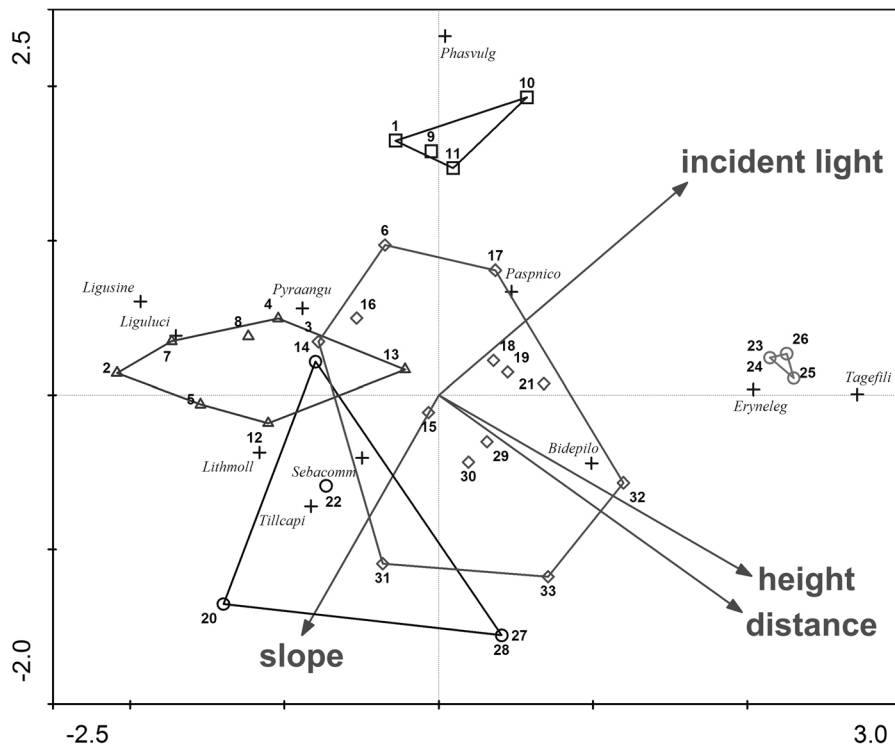


Fig. 4 Canonical correspondence analysis of the Tanti stream vegetation. Censuses (numbers), higher weight species (crosses; see abbreviation in Appendix Table), abiotic variables of great importance for the arrangement (arrows) and censuses groups

(polygons) are indicated according to TWINSpan classification: Group 1 (circles), Group 2 (triangles), Group 3 (rhombus), Group 4 (squares), Group 5 (circles to the right of the figure)

dominance, but with trees, or half meadow and half forest. The analysis of the specific composition made by TWINSpan allowed us to classify the censuses into five groups, described below.

Group 1 (5 censuses: 14, 20, 22, 27, 28) had *Sebastiania commersoniana* (native species of arboreal or shrubby habit), *Cologamia broussonetii* (native subshrub), *Tillandsia capillaris* (native herbaceous epiphytes), *Lithraea molleoides* (native tree), *Verbena litoralis* (native herbaceous) and *Anemia tomentosa* (native fern) as species with greater constancy and cover (Appendix Table). These are sheer woods with a large ($>12^\circ$) and middle ($6\text{--}12^\circ$) slope, shaded or slightly open, with significant cover of exposed rock, in high to medium sections asl. Arboreal life form covers 40 %, shrubby life 10 % and herbaceous life 40 % (Fig. 5). There is little cover of exotic species (<10 %, Fig. 6).

Main species of Group 2 (7 censuses: 2, 4, 5, 7, 8, 12, 13) were *S. commersoniana*, *Ligustrum lucidum* (adventitious tree), *Ligustrum sinense* (adventitious

tree or shrub) and *Pyracantha angustifolia* (adventitious tree or shrub). These are shaded or slightly open forests, with intermediate slopes, in the stretch with lower height and closer to the town. This group had the highest arboreal cover of all, reaching 65 %, and the highest cover of adventitious species (40 %).

Group 3 (13 censuses: 3, 6, 15, 16, 17, 18, 19, 21, 29, 30, 31, 32, 33) has the following species with greater cover and consistency: *S. commersoniana*, *Bidens pilosa* (native herbaceous) and *Paspalum nicorae* (native herbaceous). These are wooded meadows and open forests, in low, intermediate and high altitude stretches, where there is a high percentage of light and a low to high slope. Herbaceous cover is the most significant of all, but there is also considerable arboreal cover (reaches 30 %). Exotic species cover is not very high (close to 10 %).

The most significant species of Group 4 (4 censuses: 1, 9, 10, 11) were *P. vulgaris* var. *aborigineus*, *P. nicorae*, *Lonicera japonica* (adventitious vines) and *Bidens pilosa*. These are meadows with

Fig. 5 Sum of percentage cover of species, according to habit, in different vegetation groups of the Tanti stream. *T* Tree, *S* shrub, *ss* subshrub, *h* herbaceous, *v* vines, *l* liana

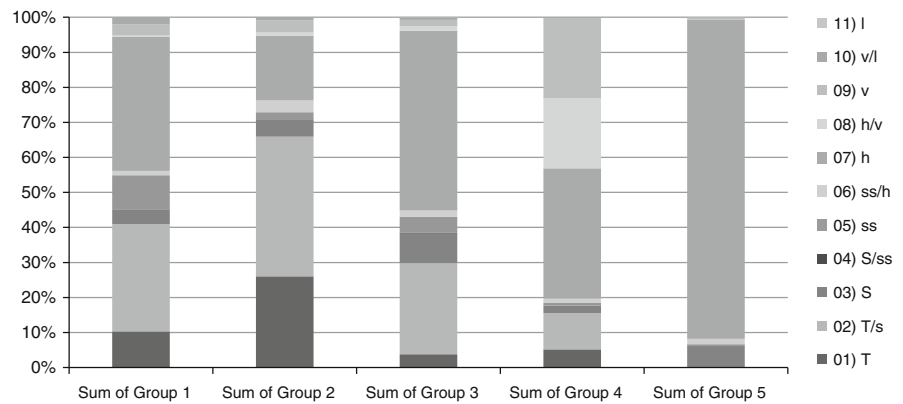
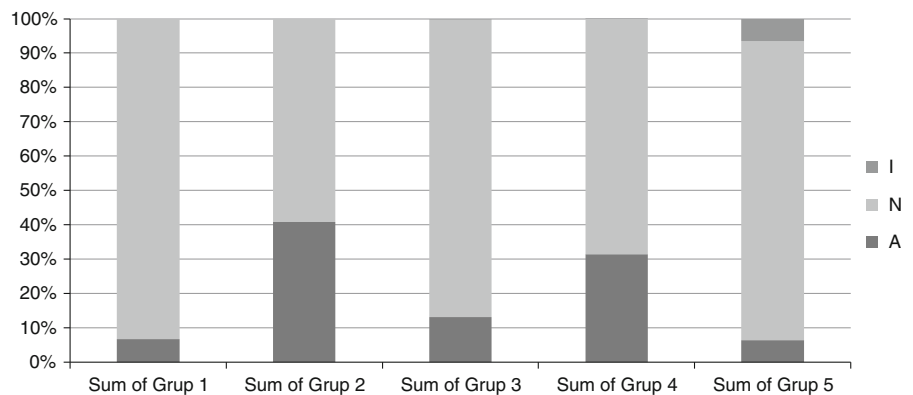


Fig. 6 Sum of percentage cover of species according to its native (N), adventitious (A) or indeterminate (I) origin in different vegetation groups of the Tanti stream



occasional trees or some open groves with high percentage of sunlight, in the first part of the route and low height asl. There were low slopes ($<6^\circ$), with low proportion of exposed rock and high magnitude of floods. There is 80 % cover of both herbaceous and vines and arboreal life form reaches 15 %. There is an important cover of adventitious species (close to 30 %).

The species of main constancy and cover from Group 5 (4 censuses: 23, 24, 25, 26) were the native herbaceous *Eryngium elegans*, *Tagetes filifolia*, *P. nicorae*, *Bidens pilosa* and *Juncus* aff. *dichotomus*. These are damp, sunny and plain meadows ($<6^\circ$ slope) in the stream sources, which is the highest stretch and the one furthest from town. Almost all cover is herbaceous and there are no trees. Exotic species cover was low, although the adventitious shrub *Rubus ulmifolius* was found.

In short, Fig. 7 shows a diagram that sums the vegetation in the studied stretch of the Tanti stream.

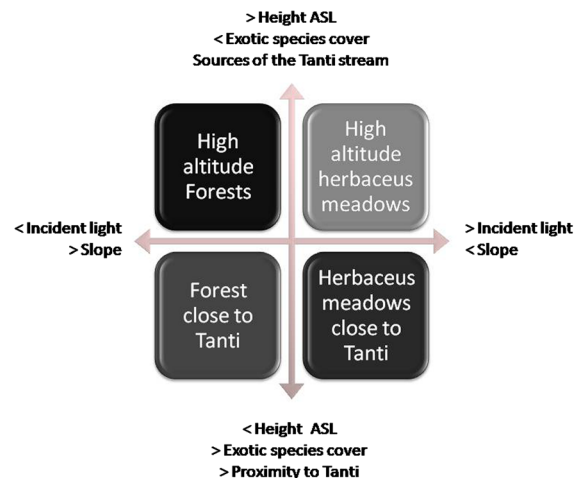


Fig. 7 Diagram that sums the vegetation of the studied stretch of the Tanti stream. The middle depicts situations in between (as the censuses from Group 3). Greatest abundance of *Phaseolus vulgaris* var. *aborigineus* was found in meadows and forests close to Tanti

Conclusion

There is a pressing need to identify priority areas for the conservation and development of *in situ* and *ex situ* conservation strategies, to assure the protection of genetic diversity richness of CWR for the benefit of future generations (Hunter and Heywood 2010). Currently there is a main absence of *P. vulgaris* var. *aborigineus* in Sierras de Córdoba, as could be confirmed by extensive surveys of the area (Giorgis et al. 2011). However, the studied population was a considerably constant element in the Tanti stream, thus showing, in some cases, great cover. The presence of adventitious species would not be incompatible with the presence of this population. Although future studies should analyze the effect of the proximity to cattle and to town on this population. Since its discovery in 2004, its presence was confirmed annually and collections could be deposited in germ plasm banks but it has not yet been studies that quantify the genetic difference between this population and those with Andean distribution in northwestern Argentina. However, unlike the latter populations in which exist hybridization with crops (Hoc et al. 2006), in the region there are not commercial crops or primitive cultivars recorded and it is presumed that the found population is isolated and their gene pool has not received any unwanted gene flow (Drewes 2008). Moreover, the studied stretch of the Tanti stream still has some typical elements of Bosque Serrano (e.g.: *L. molleoides*, *Z. coco*) and great cover of a native pioneer species of interest to its ecological restoration (Valfré-Giorello et al. 2012), which adds to its conservation value. Thus, taking into consideration the uniqueness given by the biogeographical importance of this wild bean population, and what has been analyzed in this paper, we conclude the studied stretch of the Tanti stream is a priority area for the *in situ* conservation of *P. vulgaris* var. *aborigineus* and it is highly recommended to be declared as a protected area.

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Appendix

See Table 2

Table 2 Relative (RC) and average constancy of covers (for censuses with cover greater than zero) of species of every vegetation group of the Tanti stream

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Abutilon pauciflorum</i>	A. St.-Hil.	S	N	0.40	1.55								
<i>Acacia caven</i>	(Molina) Molina	T/S	N	0.20	0.10	0.57	0.33	0.77	0.84	0.75	0.40		
<i>Acalypha communis</i>	Müll. Arg.	ss/h	N	0.60	0.10	0.29	8.80	0.54	0.49			0.50	1.00
<i>Acer aff. negundo</i>	L.	T	A			0.29	0.10						
<i>Achyrocline satureioides</i>	(Lam.) DC.	ss	N	0.20	0.10	0.14	0.10					0.25	1.00
<i>Adiantum radicans</i>	C. Presl	h	N	0.80	2.18	0.29	1.55	0.46	0.10	0.25	0.10		
<i>Aloysia gratissima</i>	(Gillies et Hook. ex Hook.) Tronc.	S	N					0.15	1.00				
<i>Ambrosia tenuifolia</i>	Spreng.	h	N					0.23	0.10				
<i>Anemia tomentosa</i>	(Savigny) Sw.	h	N	1.00	10.00	1.00	4.74	0.85	4.69	0.75	0.70	0.75	0.70
<i>Aristida aff. laevis</i>	(Nees) Kunth	h	N	0.20	1.00	0.14	3.00						
<i>Baccharis articulata</i>	(Lam.) Pers.	S	N			0.14	0.10						
<i>Baccharis cordifolia</i>	DC.	S	N									0.50	0.10

Table 2 continued

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Baccharis salicifolia</i>	(Ruiz et Pav.) Pers.	S	N							0.25	0.10		
<i>Bidens laevis</i>	(L.) Britton, Stern et Poggenb.	h	N	0.20	0.10			0.46	0.55				
<i>Bidens pilosa</i>	L.	h	N	1.00	2.92	0.57	0.55	0.92	19.64	1.00	12.63	1.00	17.38
<i>Bidens subalthernans</i> var. <i>simulans</i>	DC. var. Sherff	h	N			0.14	0.10	0.08	0.10	1.00	0.33		
<i>Blechnum australe</i> subsp. <i>auriculatum</i>	L. subsp. (Cav.) de la Sota	h	N	0.60	6.00	0.57	1.78	0.54	0.61	0.50	2.00		
<i>Boehriochloa barbinodis</i>	(Lag.) Herter	h	N					0.08	1.00				
<i>Bouteloua curtipendula</i> var. <i>caespitosa</i>	(Michx.) Torr. var. Gould et Kapadia	h	N			0.43	1.00	0.08	0.10	0.25	7.50		
<i>Buddleja</i> aff. <i>stachiodes</i>	Cham. et Schtdl.	S/ss	N	0.20	0.10			0.38	0.64				
<i>Canna indica</i>	L.	h	N			0.14	1.00	0.15	0.10	0.25	1.00		
<i>Castilleja lithospermoides</i>	Kunth	h	N									0.25	0.10
<i>Celtis australis</i>	L.	T	A	0.40	0.10	0.14	1.00			0.25	0.10		
<i>Celtis ehrenbergiana</i>	(Klotzsch) Liebm.	T/S	N	0.40	9.25			0.08	1.00				
<i>Cestrum parqui</i>	L'Hér.	S	N			0.14	0.10						
<i>Chenopodium album</i>	L.	h	A					0.08	1.00	0.50	0.10		
<i>Citrus</i> sp.	L.	T	A	0.20	0.10								
<i>Collaea argentina</i>	Griseb.	ss	N	0.20	1.00	0.57	0.55	0.62	2.09	0.75	0.10		
<i>Colletia spinosissima</i>	J.F. Gmel.	S	N	0.80	2.28	1.00	5.67	0.77	5.35	0.75	2.33	0.50	0.55
<i>Cologania outifolia</i>	(Balb.) DC.	ss	N	1.00	15.40	0.86	2.27	1.00	2.70	0.75	0.70	0.25	0.10
<i>Commelina erecta</i>	L.	h	N							0.25	7.50		
<i>Conyza</i> aff. <i>sumatrensis</i> var. <i>leiotheca</i>	(Retz.) E. Walker var. (S.F. Blake) Pruski et G. Sancho	h	N							0.25	0.10		
<i>Cotoneaster</i> sp.		S	A					0.08	29.00				
<i>Croton lanatus</i> var. <i>lorentzii</i>	Lam. var. (Müll. Arg.) P.E. Berry	S	N	0.40	0.55	0.43	0.70	0.46	0.40	0.50	0.10	0.75	0.10
<i>Cuphea glutinosa</i>	Cham. et Schtdl.	ss/h	N					0.15	0.55			0.50	3.00
<i>Cyperus aggregatus</i>	(Willd.) Endl.	h	N	0.20	0.10								
<i>Cyperus entrerianus</i> var. <i>entrerianus</i>	Boeck.	h	N			0.14	0.10	0.23	0.10	0.25	0.10		
<i>Cyperus prolixus</i>	Kunth	h	N			0.29	0.10	0.38	0.28	0.75	1.67	0.75	3.00
<i>Desmodium uncinatum</i>	(Jacq.) DC.	ss/h	N	0.60	1.67	0.57	2.63	1.00	1.10	1.00	1.28	1.00	0.55

Table 2 continued

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Dichondra sericea</i>	Sw.	h	N					0.08	0.10	0.25	0.10	0.25	0.10
<i>Dicliptera squarrosa</i>	Nees	h	N					0.15	0.55				
<i>Eleocharis montana</i>	(Kunth) Roem. et Schult.	h	N					0.08	0.10	0.25	0.10	0.50	2.00
<i>Eleocharis</i> sp.		h	I					0.08	3.00			0.25	41.50
<i>Equisetum giganteum</i>	L.	h	N	0.20	3.00	0.14	3.00	0.15	5.25				
<i>Eragrostis airoides</i>	Nees	h	N			0.29	0.10	0.23	0.70			0.75	1.00
<i>Erechtites hieracifolia</i> var. <i>caicalioides</i>	(L.) Raf. ex DC. var. (Fisch. ex Spreng.) Griseb.	h	A					0.15	0.10			0.25	1.00
<i>Eryngium elegans</i>	Cham. et Schltdl.	h	N	1.00	3.58	0.57	2.00	0.85	4.44	1.00	1.50	1.00	34.50
<i>Eupatorium</i> aff. <i>argentinum</i>	Ariza	ss	N							0.25	1.00		
<i>Eupatorium arnotianum</i>	Griseb.	ss	N	0.80	1.50	0.57	0.33	1.00	1.03	0.50	0.10	1.00	0.55
<i>Eupatorium macrocephalum</i>	Less.	h	N					0.23	0.10				
<i>Eupatorium subhastatum</i>	Hook. et Arn.	ss	N			0.14	1.00	0.08	0.10				
<i>Festuca hieronymi</i>	Hack	h	N					0.08	17.50	0.25	1.00		
<i>Galium latoramosum</i>	Clos	ss/h	N	0.60	0.10	0.57	0.10	0.69	0.50				
<i>Geranium</i> sp.		h	I					0.15	0.10	0.25	0.10		
<i>Gleditsia triacanthos</i>	L.	T	A	0.20	0.10			0.38	0.46	0.25	3.00		
<i>Gomphrena perennis</i>	L.	h	N			0.29	0.10	0.38	0.28	0.25	0.10	0.50	0.10
<i>Habenaria hexaptera</i>	Lindl.	h	N			0.14	0.10						
<i>Heimia salicifolia</i>	(Kunth) Link	S/ss	N	0.20	0.10								
<i>Heterosperma ovatifolium</i>	Cav.	h	N			0.14	1.00						
<i>Heterothalamus alienus</i>	(Spreng.) Kuntze	S	N			0.43	0.73	0.62	1.53	0.50	0.10	0.25	0.10
<i>Hydrocotyle modesta</i>	Lam.	h	N	0.20	0.10			0.23	0.10	0.75	0.70		
<i>Hypericum comatum</i>	Lam.	ss/h	N			0.14	1.00						
<i>Hypochaeris</i> aff. <i>chilensis</i>	(Kunth) Hieron.	h	N							0.25	1.00		
<i>Hyptis mutabilis</i>	(Rich.) Briq.	h	N	0.20	0.10					0.25	29.00		
<i>Ipomoea indica</i>	(Burm. f.) Merr.	v	N			0.29	0.55	0.08	0.10	0.25	1.00		
<i>Iresine diffusa</i>	Humb. et Bonpl. ex Willd.	ss	N	0.20	0.10			0.38	0.46	0.50	0.10	0.25	0.10
<i>Iris pseudacorus</i>	L.	h	A					0.08	0.10				
<i>Janusia guaranitica</i>	(A. St.-Hil.) A. Juss.	v	N					0.08	0.10				
<i>Jarava ichu</i>	Ruiz et Pav.	h	N							0.25	3.00		

Table 2 continued

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Jodina rhombifolia</i>	(Hook. et Arn.) Reisseck	T	N	0.20	0.10								
<i>Juncus</i> aff. <i>dichotomus</i>	Elliot	h	N	0.20	1.00	0.71	0.82	0.38	0.64			0.50	45.75
<i>Kageneckia lanceolata</i>	Ruiz et Pav.	T/S	N							0.25	0.10		
<i>Krapovickasia flavescens</i>	(Cav.) Fryxell	h	N			0.14	1.00						
<i>Ligustrum lucidum</i>	W.T. Aiton	T	A	0.80	2.90	1.00	25.21	0.85	3.74	0.75	2.33		
<i>Ligustrum sinense</i>	Lour.	T/S	A	0.20	3.00	0.86	19.00	0.92	2.41	0.75	5.03		
<i>Lithraea molleoides</i>	(Vell.) Engl.	T	N	0.80	19.15	0.57	16.25	0.77	1.76	0.50	5.25		
<i>Lonicera japonica</i>	Thunb.	v	A	0.20	1.00	0.57	3.13	0.08	3.00	0.50	62.50		
<i>Ludwigia</i> aff. <i>longifolia</i>	(DC.) H. Hara	h	N			0.14	0.10	0.08	0.10	0.25	0.10		
<i>Ludwigia peploides</i>	(Kunth) P.H. Raven	h	N			0.14	0.10						
<i>Malvastrum coromandelianum</i>	(L.) Garcke	ss	N			0.14	0.10						
<i>Mandevilla pentlandiana</i>	(A. DC.) Woodson	v/l	N	1.00	3.50	0.57	2.00	0.85	1.10	0.50	0.55	0.25	0.10
<i>Manihot</i> aff. <i>grahamii</i>	Hook.	T/S	N	0.20	0.10	0.29	2.00	0.23	0.10	0.25	0.10		
<i>Melia azedarach</i>	L.	T	A					0.08	0.10				
<i>Melinis repens</i>	(Willd.) Zizka	h	A					0.08	17.50				
<i>Mikania periplocifolia</i>	Hook. et Arn.	v	N	0.60	7.17	0.29	2.00	0.23	3.17	0.25	0.10		
<i>Morus alba</i>	L.	T	A	0.20	0.10	0.43	1.07	0.23	1.37	0.50	4.25		
<i>Nassella neesiana</i>	(Trin. et Rupr.) Barkworth	h	N							0.25	0.10		
<i>Oenothera</i> aff. <i>affinis</i>	Cambess.	h	N							0.25	0.10		
<i>Ophryosporus</i> aff. <i>charua</i>	(Griseb.) Hieron.	S	N	0.40	3.00	0.14	0.10	0.15	1.55				
<i>Ophryosporus axilliflorus</i>	(Griseb.) Hieron.	S	N			0.14	0.10						
<i>Orthosia virgata</i>	(Poir.) E. Fourn.	v	N			0.14	0.10						
<i>Otholobium higuierilla</i>	(Gillies ex Hook.) J.W. Grimes	ss	N	0.40	0.10	0.14	1.00	0.54	1.70	0.50	0.55		
<i>Paspalum malacophyllum</i>	Trin.	h	N			0.14	29.00						
<i>Paspalum nicorae</i>	Parodi	h	N	0.80	1.50	0.71	2.12	0.92	16.38	1.00	17.13	1.00	19.38
<i>Paspalum urvillei</i>	Steud.	h	N							0.25	1.00		
<i>Passiflora caerulea</i>	L.	l	N					0.08	0.10				
<i>Pavonia aurigloba</i>	Krapov. et Cristóbal	S	N	0.20	0.10	0.57	0.55	0.69	0.62	0.50	0.55	0.50	0.55
<i>Phaseolus vulgaris</i> var. <i>aborigineus</i>	L. var. (Burkart) Baudet	h/v	N	0.40	1.55	0.71	1.80	0.77	2.14	1.00	28.00		
<i>Phyllanthus niruri</i>	L.	h	N							0.50	0.10		

Table 2 continued

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Piptochaetium montevidense</i>	(Spreng.) Parodi	h	N	0.20	0.10			0.69	12.73			0.75	2.33
<i>Pleopeltis tweediana</i>	(Hook.) A.R. Sm.	h	N	0.20	1.00			0.23	0.40				
<i>Pluchea sagittalis</i>	(Lam.) Cabrera	h	N									0.25	0.10
<i>Polygonum acuminatum</i>	Kunth	h	N	0.20	0.10			0.38	1.04	0.50	0.10	0.25	0.10
<i>Polygonum hidropiperoides</i>	Michx.	h	N	1.00	0.46			0.23	0.10	0.75	0.40	0.25	0.10
<i>Polygonum punctatum</i>	Elliott	h	N					0.08	0.10				
<i>Portieria microphylla</i>	(Baill.) Descote, ÓDonnell et Lourteig	S	N	0.40	1.00	0.14	0.10	0.08	0.10				
<i>Porophyllum ruderale</i>	(Jacq.) Cass.	h	N					0.08	0.10				
<i>Prunella vulgaris</i>	L.	h	A	0.60	1.07			0.15	0.55	0.50	1.00	0.25	0.10
<i>Pterocaulon alopecuroides</i>	(Lam.) DC.	h	N			0.14	0.10						
<i>Pyracantha angustifolia</i>	(Franch.) C.K. Schneid.	T/S	A	0.40	12.50	0.86	13.58	0.31	14.78	0.50	5.25		
<i>Rhynchosia edulis</i>	Griseb.	v	N	0.60	1.67	0.86	2.75	0.85	1.73	0.50	1.00	0.50	2.00
<i>Richardia brasiliensis</i>	Gomes	h	N			0.14	0.10	0.15	4.25				
<i>Robinia pseudoacacia</i>	L.	T	A			0.14	7.50						
<i>Rosa rubiginosa</i>	L.	S	A			0.14	0.10	0.15	0.55	0.25	0.10		
<i>Rubus ulmifolius</i>	Schott	S	A	0.60	4.50	0.57	0.33	0.62	4.45	0.25	3.00	0.50	18.25
<i>Rumex crispus</i>	L.	h	A									0.25	0.10
<i>Ruprechtia apetala</i>	Wedd.	T/S	N					0.08	0.10				
<i>Schinus fasciculata</i>	(Griseb.) I.M. Johnston.	T/S	N			0.14	0.10						
<i>Schizachyrium</i> aff. <i>tenerum</i>	Nees	h	N			0.29	4.25						
<i>Schizachyrium microstachyum</i> var. <i>microstachyum</i>	(Desv. ex Ham.) Roseng., B.R. Arrill. et Izag.	h	N	0.20	0.10			0.08	1.00	0.25	0.10	0.50	0.55
<i>Schizachyrium salzmanii</i>	(Trin. ex Steud.) Nash	h	N									0.25	1.00
<i>Sclkuhria pinnata</i>	(Lam.) Kuntze ex Thell.	h	N					0.08	0.10				
<i>Sebastiania commersoniana</i>	(Baill.) L.B. Sm. et Downs	T/S	N	1.00	43.20	1.00	26.86	1.00	26.69	1.00	7.75		
<i>Setaria</i> aff. <i>oblongata</i>	(Griseb.) Parodi	h	N	0.20	29.00								
<i>Setaria</i> aff. <i>parviflora</i>	(Poir.) Kerguelen	h	N			0.29	1.00	0.62	1.05	0.25	0.10	1.00	4.13
<i>Setaria lachnea</i>	(Nees) Kunth	h	N							0.50	1.00		
<i>Sida</i> aff. <i>rhombifolia</i>	L.	ss/h	N	0.60	1.67	0.57	1.00	0.69	0.71	0.50	0.55		
<i>Solanum sisymbriifolium</i>	Lam.	h	N							0.25	0.10		

Table 2 continued

Species	Species authorities	Habit	Origin	Group 1 (N = 5)		Group 2 (N = 7)		Group 3 (N = 13)		Group 4 (N = 4)		Group 5 (N = 4)	
				RC	Average	RC	Average	RC	Average	RC	Average	RC	Average
<i>Solidago chilensis</i> var. <i>chilensis</i>	Meyen	h	N									0.25	3.00
<i>Symphoricarichum graminifolium</i>	(Spreng.) G.L. Nesom	h	N			0.14	0.10	0.31	0.10	0.25	0.10		
<i>Tagetes filifolia</i>	Lag.	h	N	0.20	0.10	0.14	1.00	0.31	10.68			1.00	26.38
<i>Thalictrum decipiens</i>	Boivin	ss	N	0.20	0.10	0.14	0.10			0.25	0.10		
<i>Thelypteris argentinia</i>	(Hieron.) Abbiatti	h	N	0.40	5.25			0.31	2.90	0.25	1.00		
<i>Tillandsia capillaris</i>	Ruiz et Pav.	h	N	0.80	23.63	0.86	5.83	0.69	6.50	0.25	1.00		
<i>Trifolium repens</i>	L.	h	A	0.20	0.10			0.08	1.00	0.25	1.00	0.50	1.55
<i>Verbascum virgatum</i>	Stokes	h	A							0.25	0.10		
<i>Verbena hispida</i>	Ruiz et Pav.	h	N	0.20	0.10			0.08	0.10				
<i>Verbena litoralis</i>	Kunth	h	N	0.80	16.63	0.86	3.78	0.77	1.82	0.75	2.33		
<i>Xanthium canavillesii</i>	Schouw	h	A							0.25	0.10		
<i>Zanthoxylum coco</i>	Gillies ex Hook. f. et Arn.	T	N	0.20	0.10	0.14	1.00						
<i>Zinnia peruviana</i>	(L.) L.	h	N			0.14	0.10	0.31	0.55	0.50	0.10	0.75	3.53

Abbreviations used in this paper are the concatenation of the first four letters of the genus and the first four letters of the specific epithet. The habit (*T* Tree, *S* shrub, *ss* subshrub, *h* herbaceous, *v* vines, *l* liana) and origin (*N* Native, *A* Adventitious, *I* Indeterminate) of species are also pointed

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