Ber.Geobot.Inst.ETH, Stiftung Rübel, Zürich *55* (1989), 39-50

Local and regional variability in granitic grasslands in the mountains of central Argentina

Variabilidad local y regional en pastizales de ambientes graniticos en las montañas de Argentina central

by

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1. INTRODUCTION

Aspects of scale have major and obvious consequences in ecological investigations, both on assessing results as well as on drawing generalizations and variation patterns in natural systems (WHITE and GLENN-LEWIN 1984, WIENS et al. 1986). Thus, it is useful to identify different spatial scales when studying the structure of grasslands. From this point of view, local changes may be depicted by continuous trends such as geomorphology, moisture, salinity or land use gradients (WHITTAKER 1970). In other instances, the analysis is simplified by applying discontinuous variation criteria, usually related to discrete environmental

features like lithologic or edaphic irregularities (MENGHI et al. 1989).
In the Córdoba Mountains (Central Argentina), the granitic substrate shows a complex fracture and diaclase system with rock outcrops, deep and shallow soils. Thereby, in this type of landscapes, the influence of the underlying bedrock could be a major source of local variation.
It has often been suggested that different lithological substrates (MENGHI et al. 1989) as well as altitude, a complex environmental factor which interacts with climatic, edaphic and topographical features (WHITTAKER and NIERING 1975), are variables with possible effects on regional variability in mountain areas. LEVASSOR et al. (1980) pointed out that even small altitudinal differences include significant changes in mediterranean pastures composition. Since the lithological substrate in the area (granite) is relatively uniform, the altitudinal range (over 1000 m a.s.l.) leads to consider altitude as an important source of regional changes.
The present study focuses on structural aspects related to geomorphological variation and regional changes associated to altitude in granitic grasslands. We postulate that edaphic discontinuities due to granite morphological features might condition the occurrence of locally defined zones in grassland vegetation. A similar discrete pattern would be observed all over the granitic region whereas floristic changes are likely to occur as a response to altitudinal rainfall or cold.

Acknowledgements

The present work was supported by the National Council of Scientific Research (CONICET), the Council of Scientific Research of Córdoba Provice (CONICOR), and National University of Córdoba. We thank Prof. Diana Abal Solis for the drawings and the personnel of the Botanical Museum of the University of Córdoba for their help in plant determinations.

2. MATERIAL AND METHODS

2.1. Study area

The Córdoba mountains have an area of some 35'000 km^2 between 29°S and 33°30'S, raising from 500 up to 3000 m a.s.l. Major plant formations are distributed along different altitudinal belts with *Lithraea ternifolia* and *Schinopsis haenkeana* forests at lower levels and perennial tussock grasses at higher altitudes (montane grassland belt, LUTI et al. 1979). CABIDO (1985) and CABIDO and

ACOSTA (1986) partially describe the plant communities of this belt and MENGHI et al. (1989) analyse structural and floristic patterns of grassland in different lithological substrates. In granitic landscapes natural grasslands develop from approximately 1400 m upwards. At present, they are grazed mostly by cattle and sheep; burning is the traditional practice of management.
Macroclimate in the region is typically temperate and wet. The average yearly temperature is 8°C at 2000 m and rainfall ranges between 800 and 1200 mm. Soils are generally residual derived from granite alteration and alternate with 30-60% rock outcrops.

2.2. Sampling design and data processing

A stratified sampling was carried out considering slopes as reference units. Discontinuities within the slopes were appreciated through the physiognomy of the grassland. Local erosion processes (rexistasis) near the rock outcrops as well as intact soils with tall grasslands and turfs outside the influence of the outcrops, were observed (Fig. 1). A 3x3 m sample plot was established in each situation

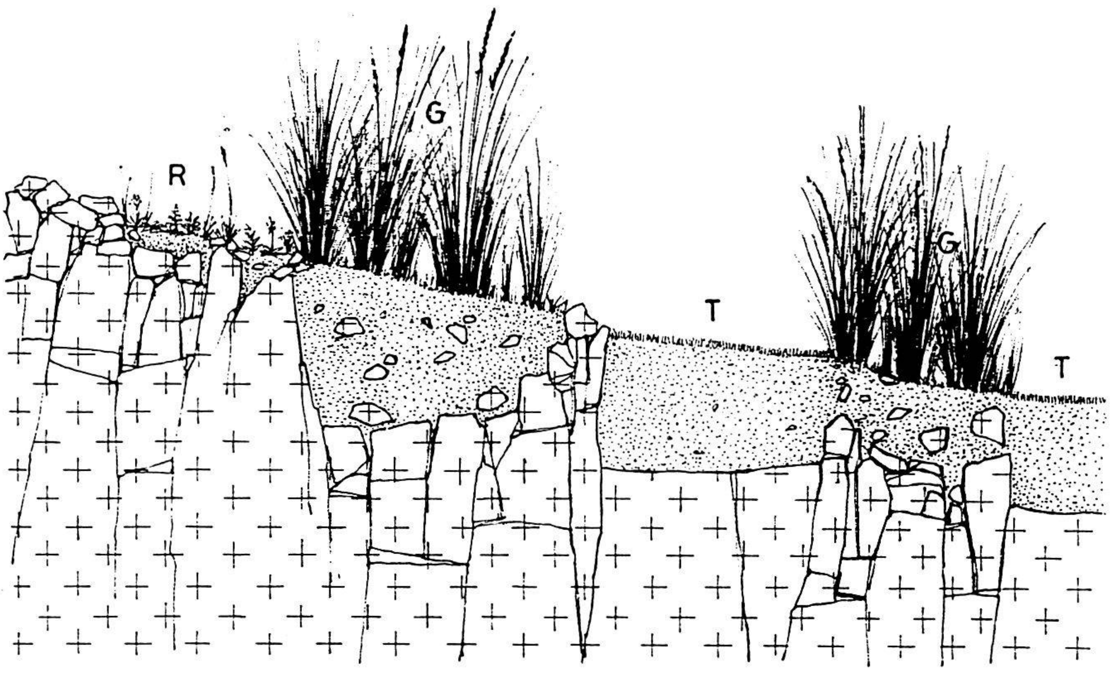

Fig. 1. Diagrammatic representation of the different situations found in granitic grasslands.
Diagrama de las diferentes situaciones halladas en pastizales graníticos.
R = Rexistasis - *rexistasias*, T = turfs - *céspedes*, G = tall grasslands - *pajonales*

(rexistasis, tall grasslands and turfs). Each situation was sampled twice, both on the upper and the lower part of the slopes. Within each plot, the presence of species was recorded in eight 20x20 cm squares randomly located.
In order to consider altitudinal trends, three levels (1400, 1800 and 2100 m a.s.l.) were sampled, with three slopes per level. The complete list of species recorded is shown in the appendix.
All the slopes were N facing with an inclination ranging from 10 to 20%; also a moderate grazing intensity and the lack of fire for several years were taken into account.
Detrended correspondence analysis (DCA) was used (Hill 1979, Hill and Gauch 1980) to analyse the major floristic trends for each altitude and for the whole set of data (frequency of species per plot).

3. RESULTS AND DISCUSSION

Local variability of each level (1400, 1800 and 2100 m) and of the global data were assessed. Figure 2 represents the results of the ordination of plots belonging to each level according to the first two axes of DCA. The main associated species have been included. In all the cases, axis I clearly differentiates groups of sampling plots corresponding to turfs, tall grasslands and rexistasis.
Turfs are found in relatively plain and deficiently drained sites with subsuperficial run-off. In some cases, hydromorphic soils with high organic matter content in the upper histic horizon have been observed (Cabido et al. 1987). Whereas tall grasslands generally develop on relatively well-drained and deep soils, rexistasis occur on shallow, sandy or stony soils where the rock is close to the surface. Besides, it may be pointed out that the local variability in rexistasis is less striking than on well-preserved soils whose heterogeneity is shown along axis II. Even though in some cases it is possible to distinguish between sample plots from upper and lower slope positions, evidences account for only a minor influence of the topographic gradient in grassland structure.
In assessing the effects of altitude, Figure 3 shows the result of the detrended correspondence analysis performed on the frequency data of the species in all plots. The main variation trend discriminates plots sampled on rexistasic zones, tall grasslands and turfs (local variability). The second axis, differentiates the three levels according to an altitudinal trend (regional variability). In this case, it is notable that eroded sites show a lower variation range along both axes which leads us to infer minor altitudinal changes.

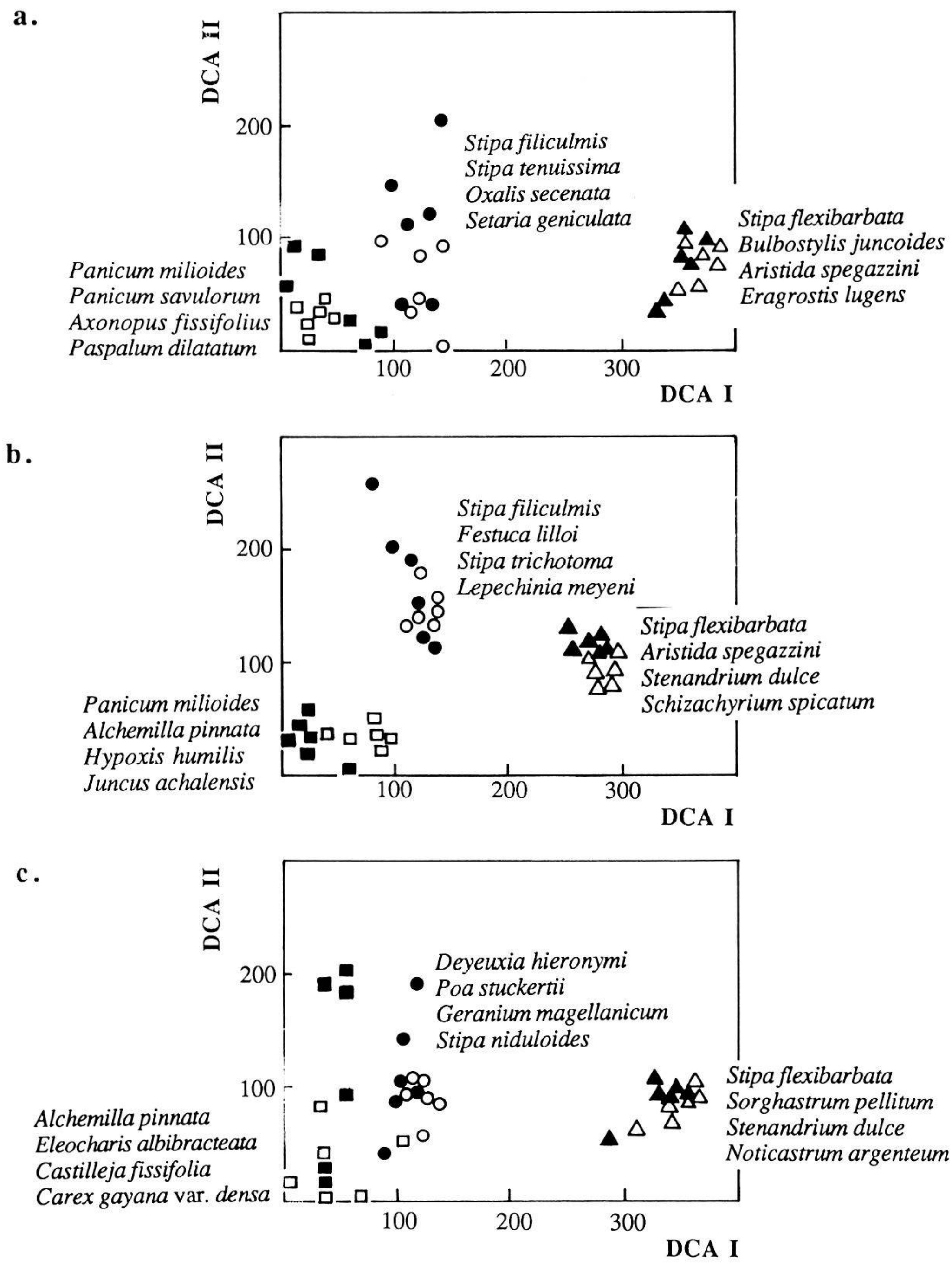

Fig. 2. Detrended correspondence analysis ordination of plots with major associated species.
Ordenación de las parcelas (análisis de correspondencias "libre de tendencias") con las principales especies asociadas.
Granitic grasslands at - *pastizales graníticos a* 1400 m a.s.l. (a), 1800 m a.s.l. (b), 2100 m a.s.l. (c)
Squares = turfs, circles = tall grasslands, triangles = rexistasis.
Open symbols = upper sector on slopes, solid symbols = lower sectors.
Cuadrados = céspedes, círculos = pajonales, triángulos = rexistasias.
Símbolos blancos = sector alto de la ladera, símbolos negros = sector bajo de la ladera

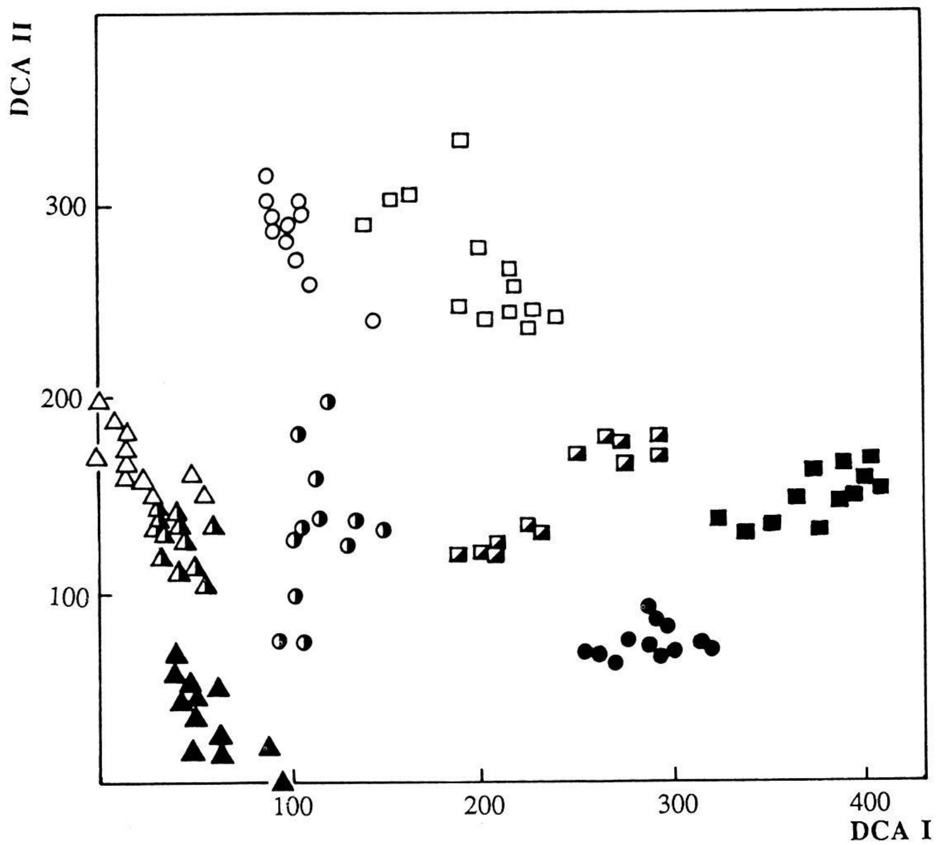

Fig. 3. Detrended correspondence analysis ordination of all plots in granitic grasslands, Córdoba Mountains.
Análisis de correspondencias "libre de tendencias" de todas las parcelas censadas en pastizales de ambientes graníticos de las Sierras Córdoba.
Squares = turfs, circles = tall grasslands, triangles = rexistasis.
Open symbols = plots at 1400 m a.s.l., half solid symbols = plots at 1800 m a.s.l., solid symbols = plots at 2100 m a.s.l.
Cuadrados = céspedes, círculos = pajonales, triángulos = rexistasias.
Símbolos blancos = parcelas a 1400 m de altitud, símbolos negros = a 2100 m de altitud

As regards floristic trends, Table 1 shows species associated to altitudinal levels obtained through the ordination analysis.

Big tussock grasses mainly develop in tall grasslands forming a "matrix" with few "interstices". *Stipa filiculmis* is found at lower and intermediate levels (1400 and 1800 m), in the latter together with *Festuca lilloi*. *Deyeuxia hieronymi* and *Poa stuckertii* especially occur at higher altitudes (2100 m). It should be mentioned that dominant species from each extreme level studied appear in the intermediate, but not in the opposite extreme level.

Turfs comprise mostly tussock grasses and sedges, forming a dense cover usually not taller than 15 cm. At 1400 m *Panicum milioides, Axonopus fissifolius* and *Paspalum dilatatum* prevail. At higher levels *Alchemilla pinnata*, an andean stolonipherous, dominates with *Panicum milioides* at 1800 m and *Eleocharis albibracteata* at 2100 m. Several species of the genus *Carex*, *Juncus* and *Cyperus* are found, probably as a consequence of the more favourable moist conditions of higher altitude. Just like in tall grasslands, species mentioned for one extreme do not appear in the other but are often found in the intermediate level.

Table 1. Granitic grasslands in Córdoba Mountains. Principal associated species in each altitude.
Pastizales de ambientes graníticos de las Sierras de Córdoba. Principales especies asociadas a cada nivel altitudinal.

1400 m a.s.l.	1800 m a.sl.	2100 m a.s.l
Panicum savulorum *Schizachyrium imberbe* *Axonopus fissifolius* *Eragrostis bahiensis* *Paspalum dilatatum* *Paspalum notattum* *Micrichloa indica*		
Stipa filiculmis *Panicum milioides* *Hypoxis humilis* *Stipa trichotoma* *Chloris retusa* *Cuphea glutinosa*		
	Festuca lilloi *Alchemilla pinnata* *Stipa niduloides* *Grindelia globulariaefolia* *Hieracium giganteum* var. *setulosum* *Juncus achalensis*	
		Deyeuxia hieronymi *Poa stuckertii* *Geranium magellanicum* *Geranium patagonicum* *Conyza burkartii* *Agrostis breviculmis* *Gentianella achalensis*

In rexistasic plots, species with storage organs and small grasses occur. Typical rexistasic species appear in all three levels, mainly *Stipa flexibarbata*, *Sorghastrum pellitum*, *Stenandrium dulce* and *Noticastrum marginatum*, which support the idea of higher floristic homogeinity mentioned before.

4. CONCLUSIONS

Local variability of grasslands growing on granitic environments may be described in terms of discrete units associated to local edaphic discontinuities inherent to granitic substrate. A mosaic of well-preserved soil zones (tall grasslands and turfs) alternating with locally eroded zones (rexistasis) is detected. The variability due to topographic gradient along the slopes is less evident, since in general upper and lower plots are not clearly differentiated. The organization pattern reported is similarly found in the three altitudinal levels, nevertheless, some floristic variation trends are found. Well-preserved soil zones exhibit conspicuous floristic discontinuities between extreme levels (1400 and 2100 m) while the intermediate level (1800 m) shows intermingling floristic composition. At lower levels, tall grasslands and turfs are rich in tropical and subtropical elements such as *Paspalum dilatatum*, *P. notatum*, *P. plicatulum*, *Axonopus fissifolius* and *Panicum miliodes* (CABRERA 1970). It is likely that tropical and subtropical species are absent or poorly represented at higher altitudes because of the decrease in mean and absolute temperatures as well as the consequent increase in the number of days with frost. Andean and andean-patagonian species like *Deyeuxia hieronymi*, *Alchemilla pinnata*, *Geranium magellanicum*, *G. patagonicum* and *Muhlenbergia peruviana* (CABRERA 1970, LUTI et al. 1979) are conspicuous at the upper level and probably have an opposite altitudinal response than tropical elements. In other words, the regional source of variation considered (altitude) is more evident in tall grasslands and turfs than in rexistasis. Regarding the particularly stressing edaphic conditions in rexistasis, it is possible that generalist species development is favoured with the consequent less altitudinal differentiation.

SUMMARY

The variability of granitic grasslands in the mountains of Córdoba (Central Argentina) is analysed considering two sources of variation: local changes related to lithology, geomorphology and regional changes due to altitude. Stratified sampling of three different levels (1400, 1800 and 2100 m a.s.l.) is carried out with DCA data processing as ordination technique.
Grassland structure is described in terms of discrete units associated to local edaphic discontinuities. A mosaic of well-preserved soil zones (tall grasslands and turfs) alternating with locally erdoded zones (rexistasis) is detected. Although floristic variation trends are observed, the discrete structural pattern is found at the different altitudes considered. At lower levels tall grasslands and turfs are rich in tropical elements whereas andean and andean-patagonian species are conspicuous above 2000 m a.s.l. The rexistasis zones are internally homogeneous and regional variability within them is less evident when compared with the other units.

RESUMEN

Se analiza la variabilidad de pastizales naturales de ambientes graníticos de las Sierras de Córdoba (Argentina Central), considerando dos fuentes de variación una local, relacionada con el sustrato litológico, y otra regional, referida a tendencias altitudinales. Se realiza un muestreo estratificado en 3 niveles (1400, 1300 y 2100 m), con procesamiento de los datos según técnicas multivariantes de ordenación (DCA).
Los pastizales sobre granito pueden describirse mediante pautas de organización discretas que se asocian a la variabilidad geomorfológico-edáfica del sustrato. Se diferencian situaciones con suelos conservados (pajonales y céspedes) que alternan con otras con suelos donde se observa une ruptura del equilibrio bio-geo-edáfico (rexistasias). Este modelo de organización se manifiesta en los diferentes niveles considerados, si bien se observan algunas tendencias florísticas relacionadas con la altitud. En el nivel inferior se destaca la presencia de elementos de regiones tropicales y cálidas en céspedes y pajonales, mientras que en niveles superiores se asocian elementos andinos y andino-patagónicos. Las rexistasias, en cambio, presentan una composición florística más uniforme, con diferencias altitudinales menos evidentes.

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APPENDIX

List of species

Ophioglossaceae
Ophioglossum crotalophoroides var. *nanum* Osten
Schizaeaceae
Anemia tomentosa (Sav.) Swartz
Selaginellaceae
Selaginella peruviana (Milde) Hieron.
Acanthaceae
Stenandrium dulce (Cav.) Nees
Amaranthaceae
Alternanthera pumila Stutzer
Gomphrena perennis L.
Pfaffia gnaphaloides (Vahl) Mart.
Apiaceae
Apium leptophyllum (Pers.) Muell.
Bowlesia lobata R. et P.
Daucus pusillus Michx.
Eryngium agavifolium Griseb.
Eryngium horridum Malme
Eryngium nudicaule Lam.
Asteraceae
Baccharis articulata (Lam.) Pers.
Bidens triplinervia var. *macrantha* (Wed.) Sherff
Carduus thoermeri Weinn
Cirsium vulgare (Sav.) Ten.
Conyza bonariensis (L.) Cronquist
Conyza burkartii Zardini
Cotula mexicana (DC.) Cabr.
Chaptalia integerrima (Vell.) Burkart

Chaptalia runcinata
Chevreulia sarmentosa (Pers.) Blake
Facelis retusa (Lam.) Sch.Bip.
Gamochaeta americana (Mill.) Wedd.
Gamochaeta calviceps (Fern.) Cabr.
Gamochaeta filaginea (DC.) Cabr.
Gamochaeta spicata (Lam.) Cabr.
Gnaphalium gaudichaudianum DC.
Hieracium giganteum var. *setulosum* Sleu.
Hypochoeris argentina Cabr.
Hypochoeris caespitosa Cabr.
Lucilia acutifolia (Poir.) Cass.
Noticastrum argenteum Cabr.
Noticastrum marginatum (H.B.K.) Cuatrecasas
Spilanthes decumbens (SM.) A.H.Moore
Stevia achalensis Hieron.
Stevia satureiifolia (Lam.) Sch.
Tagetes argentina Cabr.
Taraxacum officinale Web.
Brassicaceae
Lepidium bonariense L.
Lesquerella mendocina (Phil.) Kurtz
Rorippa bonariensis (Poir.) Mackloskie
Cactaceae
Gymnocalycium sp.
Campanulaceae
Wahlenbergia linarioides (Lam.) DC.
Caryophyllaceae
Cardionema ramosissimum (Weinm.) Nelson
Cerastium arvense L.
Paronychia chilensis DC.
Silene argentina (Pax) Bocquet
Spergula ramosa ssp. *rossbachiae* Pedersen
Convolvulaceae
Dichondra repens var. *repens* Forst.
Evolvulus sericeus Swartz
Ipomoea minuta Fries
Crassulaceae
Crassula connata (R. et P.) Berg.
Euphorbiaceae
Croton argentinus Muell. Arg.
Euphorbia portulacoides (L.) Spreng.
Euphorbia serpens H.B.K.
Tragia geraniifolia Klotzsch
Fabaceae
Adesmia incana Vog.
Astragalus parodii Johnston
Trifolium amabile H.B.K.
Gentianaceae
Gentiana achalensis Hieron.
Gentiana prostrata Haenke
Geraniaceae
Erodium cicutarium (L.) L'Her.
Geranium melanopotamicum Speg.
Geranium patagonicum Hook. f.
Lamiaceae
Lepechinia meyeni (Walp.) Epling
Lobeliaceae
Pratia hederacea (Cham.) Don
Lythraceae
Cuphea glutinosa Cham. et Schl.
Malvaceae
Sida prostrata Cav.
Onagraceae
Oenothera indecora Camb.
Oxalidaceae
Oxalis chrysantha Prog.
Oxalis sexenata Sav.
Plantaginaceae
Plantago argentina Pilger
Plantago australis Lam.
Plantago brasiliensis var. *cordobensis* Pilger
Plantago myosurus Lam.
Plantago paralias Dec.
Polygonaceae
Rumex acetosella L.
Rosaceae
Alchemilla pinnata R. et P.
Margyricarpus pinnatus (Lam.) O.K.
Rubiaceae
Borreria verticillata (L.) Mey.
Mitracarpus cuspidatus DC.
Relbunium richardianum (Gill. ex Hook. et Arn.) Hicken
Scrophulariaceae
Castilleja fissifolia L.f.
Scroparia grisebachii Fritsch
Solanaceae
Nierembergia hippomanica Miers
Solanum incisum Griseb.
Turneraceae
Turnera sidoides L.
Verbenaceae
Glandularia dissecta (Willd.) Schnack et Covas
Glandularia peruviana (L.) Small
Violaceae
Hybanthus serratus (Phil.) Hass
Amaryllidaceae
Zephyranthes longistyla Pax.

Cyperaceae
Bulbostylis juncoides (Vahl) Kth.
Bulbostylis tenuispicata (Bechl.) Barros
Carex boliviensis Heurck et Mull.
Carex fuscula var. *distenta* (Boeck.) Kth.
Carex gayana var. *densa* Kth.
Cyperus reflexus Vahl
Eleocharis albibracteata Ness v. Esenbeck et Meyen
Eleocharis dombeyana Kth.
Hypoxidaceae
Hypoxis humilis Kth.
Iridaceae
Sisyrinchium chilense Hook.
Sisyrinchium ungiculatum Griseb.
Sisyrinchium palmifolium L.
Sisyrinchium valdivianum Phil.
Juncaceae
Juncus achalensis Barros
Juncus stipulatus Nees et Meyen
Juncus uruguensis Griseb.
Liliaceae
Nothoscordum inodorum (Ait.) Nicholson
Poaceae
Agrostis breviculmis Hitchcock
Agrostis montevidensis Spreng. ex Nees
Andropogon ternatus Nees
Aristida achalensis Mez
Aristida spegazzini Arech.
Axonopus fissifolius (Raddi) Kuhlm.
Bothriochloa barbinodis (Lag.) Henr.
Bothriochloa laguroides (DC.) Pilger
Bothriochloa saccharoides (Sw.) Rydberg
Bouteolua curtipendula (Michx.) Torr.
Briza paleapilifera Parodi
Briza subaristata Lam.
Bromus auleticus Trin. et Nees
Bromus brevis Nees
Bromus unioloides H.B.K.
Cynodon hirsutus Stent
Chloris retusa Lagasca
Danthonia cirrata Hack. et Arech.
Deyeuxia hieronymi (Hack.) Turpe
Digitaria californica (Benth.) Henrard
Elyonurus muticus (Spreng.) Kunt.
Eragrostis bahiensis Schrader
Eragrostis lugens (Spreng.) Kunt.
Eragrostis polytricha Nees
Festuca circinata Griseb.
Festuca hieronymi Hack.
Festuca lilloi Hack.
Gymnopogon grandiflorus Roseng. Arre. et Izag.
Microchloa indica (L. f.) O.K.
Muhlenbergia peruviana (Beauv.) Steud.
Panicum milioides Nees
Panicum savulorum Lam.
Paspalum dilatatum Poir.
Paspalum notatum Flueg.
Paspalum plicatulum Michx.
Paspalum quadrifarium Lam.
Piptochaetium montevidense (Spreng.) Parodi
Poa annua L.
Poa hubbardiana Parodi
Poa ligularis Nees
Poa scaberula Hook.
Poa stuckertii (Hack.) Parodi
Schizachyrium imberbe (Hackel) Camus
Schizachyrium microstachyum (Desv.) Roseng.
Schizachyrium spicatum (Spreng.) Herter
Setaria geniculata (Lam.) Beauv.
Sorghastrum pellitum (Hack.) Parodi
Sporobolus indicus (L.) Brown
Stipa amethystina Steudel
Stipa filiculmis Delile
Stipa flexibarbata Mez
Stipa neesia Trin. er Rupr.
Stipa nidulans Mez
Stipa niduloides Caro
Stipa tenuissima Trin.