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Alternatives for the development of new industrial crops for Patagonia

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Abstract. *The search for potential arid-adapted crops has yielded several species that produce industrial raw materials and can be cultivated in warm arid lands. However, there are few species adapted to cold arid environments like Patagonia. The objectives of this paper are to propose criteria for the search and development of new industrial crops for Patagonia, to analyze those species that have been suggested as potential crops, and to propose other candidates based on these criteria. We discuss the potential of the few species cited as potential crops for Patagonia:* Colliguaya integerrima *(Euphorbiaceae) and* Lesquerella mendocina *(Brassicaceae) as seed-oil sources;* Grindelia chiloensis *(Asteraceae),* Colliguaya integerrima, Larrea *sp. (Zygophyllaceae), and* Mulinum spinosum *(Umbelliferae) as politerpene sources, and* Prosopis *and* Cercicium *sp. as gum sources. We include a description of prospective families for oils, gums and terpenes.*

Introduction

There are several socio-economical and ecological reasons that justify the search and development of new crops in traditional, mesic, agricultural areas (Knowles et al. 1984). Some of these reasons may also apply in areas with severe ecological restrictions for traditional crop production, but these areas have also special requirements for the selection of new alternative crops.

Hot arid lands need supplemental irrigation for adequate crop production. Lack of water or high water cost set a demand for crops with a high rate of production per unit of applied water (i.e., high water use efficient crops, WUE). Semi-arid lands may have adequate rainfall supplies for growing certain crops at some times of the year, but their water supply for a particular year is uncertain. Crops adapted to these environments and the related agricultural practices need to minimize the risks posed by uncertainty.

In arid and semi-arid environments, the classic approach for improving productivity has been to breed for more WUE and/or more plastic varieties from the available genetic pool of traditional crops. An alternative approach is the search and domestication of plant species native to the arid lands and capable of yielding products with industrial, medicinal, or food/feed uses. This process has already yielded several crops for hot arid environments. However, there are no new adapted crops for cold-arid environments. In particular, in environments like the extra-andean Patagonia, precipitation below 300 mm, strong winds that cause high evaporation rates, low mean annual temperature, and extreme winter temperature create severe restrictions to plant growth and result in short growing seasons. These conditions determine low potential productivity and no chances for cultivating traditional crops.

The objectives of this paper are to propose criteria for the development of new crops for Patagonia, to analyze those species that have been suggested as potential industrial crops, and to suggest other candidates based on these criteria.

The basic assumption in the selection of new crops suited for arid lands is that arid-adapted species have an intrinsically high WUE. This has proven to be a misconception; most C_3 desert plant species have low WUE (McGinnies and Arnold 1939) since their adaptations to conserve water result in a reduced ability for CO_2 uptake. Furthermore, only a few C_4 and CAM plant species (which do have higher WUE) yield attractive industrial products.

Nevertheless, the search has yielded some commercial crops like jojoba and others that are close to commercialization (*Hesperaloe funifera,* for fibers; *Lesquerella fendleri,* for seed-oils; *Parthenium argentatum,* for rubber, among others), all suited for hot deserts. A common characteristic of these new crop species is that they produce unique products with well defined (although small) markets. In all cases, successful candidates are those in which the screening and selection was done using a product/market driven process, while the species selection was secondary.

Not all stories in new crop development have been successful. The literature is filled with unrealized potential new crops that were selected with the criterion that a desert-adapted plant species can be turned into a crop if it is able to yield a product which could replace available raw materials currently harvested from conventional established crops. Another common approach has been the multiple product in which conspicuous, usually weedy (invasive and toxic to domestic animals) plant species were analyzed for a series of primary and secondary metabolites that could potentially be used by the industry. Examples of this approach are *Chrysothamnus nauseosus* (Webber et al. 1985), *Euphorbia lathyris* (Calvin 1983), and several other arid-land species (Angulo Sánchez and Jasso de Rodríguez 1996). The serious fault of this scheme is that most of the target compounds can only be extracted and purified in the laboratory because industrial-scale extractions are either not available or extremely costly. Plants producing these basic metabolites are found in many environments and are not exclusive of arid lands. Thus, even if extraction were feasible, those plants producing more biomass at lower costs would be favoured. Biomass production in mesic areas carries quite lower production costs than those incurred in arid environments, so candidate species would be grown in those areas.

Criteria for selecting candidate species

The only comprehensive analysis for the selection of new crop species for arid lands is probably that of McLaughlin (1985) who proposed four criteria for a candidate species: a) it must have low water requirements, b) it should be tolerant to water stress, c) it should produce high-value botanochemicals, and d) it should not be able to grow in more mesic areas (with intrinsically lower production costs).

These criteria suit new crops for hot arid and semi-arid lands, although need to be reformulated if they are to be applied in the selection of crops for temperate deserts like Patagonia. First, we need to consider that there are severe restrictions in the length of the growing-season in the region and thus, on potential productivity. Thus, we propose a fifth criterion: to compensate for this restriction, production of harvestable material should be stimulated by the environmental conditions. Examples of this are the stimulation of terpene production in aromatics by low temperature and moderate water or nutrient stress, or the accumulation of gamma linolenic acid in *Oenothera* seed-oils when grown at low temperature during seed filling. The relationship between biomass production and product accumulation creates a production window mostly regulated by temperature and water and nutrient availability, in which the reduction in biomass production can be over-compensated by the increase in the product content of the biomass, resulting in higher product yields.

A second comment about many potential areas in Patagonia is that water may be relatively easier to obtain than in other arid lands. This reduces the importance of costs, and makes McLaughlin's first criterion less relevant for Patagonia. The issue of water cost and availability is not independent of the target environment for cultivation. In this sense, a distinction needs to be made between irrigated valleys and non irrigated lands.

River Valleys

Several rivers originate in the Andes and end their way in the Atlantic ocean (Colorado, Negro, Chubut, Deseado, Chico and Santa Cruz, Coyle, Gallegos, etc.). These river valleys have been in part cultivated with traditional crops like wheat, potato, fruit orchards, alfalfa and other pastures, and in the better soils, vegetable crops. In some cases, cultivation has extended for more than 100 years. Water is distributed through vast nets of canals and crops are irrigated by furrow or flood irrigation. Water rights belong to the state which may trust the distribution control to cooperative-owned irrigation companies. Water costs depend on the particular valley but is relatively inexpensive (i.e., $25/Ha/year for the lower Chubut Valley), mostly because there is more water available than can be used with the available systematized land (Ferrari Bono 1990). Both the inefficiency of the distribution through unlined canals and excess irrigation on heavy, clay soils have lifted the water table and increased salt contents, in some cases to levels that preclude further cultivation.

Competition with products coming from outside the region has halted local productions and industry; (i.e., dairy industry in the 80's). Both the public and private sectors are searching for new technologically and economically feasible alternatives. In recent years the production of berries and the ensilage for feeding sheep for milking have been tested. The production of essential oils is also been considered as an alternative for these areas and there is a clear need for other alternatives (J. Salomone, pers. com.). In this sense, there is a need for the search and development of new crops, and the approach would be to substitute for crops with better prices and markets than the available ones, and to use traditional irrigated-cropping systems. Still, to be successful, these crops must be able to compete with similar products grown elsewhere. Our view is that for this to happen, the new crops need to comply with our additional criterion: product yield must be stimulated by the particular environmental conditions and harvest indexes must be higher than in better environments. Also, there may be possibilities on saline lands, although restrictions to productivity are so severe in these environments that even euhalophytes (i.e., *Salicornia* spp for seed oils; Glenn et al. 1991) may not be able to produce enough harvestable materials to make them economically attractive.

Non-irrigated lands

Non-irrigated lands in Patagonia are characterized by low and erratic net primary productivity (Sala et al. 1989, Soriano and Paruelo 1990). This low productivity conditions the harvest of natural stands for the recovery of natural products. The major barrier towards utilization of this land is the low harvest index per unit area due to: a) low net primary productivity; b) low plant density; c) low concentration of the harvestable products in the plants -i.e., low harvest index; and d) the inverse relationship between conditions that promote biomass production and the accumulation of carbon based secondary metabolites (Herms and Mattson 1992). In this sense, there are several options to promote new crops for these areas:

1) To evaluate and collect high-price products like medicinals. A problem that prospective medicinal compounds have to face is that once the process of discovery and isolation of the active compounds is concluded the pharmaceutical industry quickly develops synthetic or hemisynthetic compounds with lower production costs since their concentration in the plant tends to be too low for direct economic utilization (Cragg et al. 1995). A multinational project looking for bioactive compounds is current underway in Patagonia (B. Timmermmann, pers. com).

2) To collect those products which harvest index is stimulated by environmental variables (our first new criteria; i.e., resins in *Grindelia chiloensis*).

3) To increase the density of the candidate species through management of the native stands or the establishment of stands through seeding or transplanting of improved genotypes of the target species. For instance, the productivity of *Grindelia chiloensis* (with above ground biomass resin contents close to 23 %) was between 3 and 60 g of resin/m^2 (Ravetta et al. 1996b). The highest value was found in a dense, low-diversity stand (2.8 *Grindelia* shrubs/m^2), a value probably similar to the potential productivity of an artificially-established stand. This alternative requires knowledge not only on aspects related to the harvestable products but also on population dynamics of each

Table 1. Plant sources of seed oils, terpenes and phenolics, and gums cited in the literature and prospective families in which to search for these products.

Product		Species	Prospective families
Seed oils	oleic, linoleic, linolenic acids	*Colliguaya integerrima* *Prosopis* sp., *Prosopidastrum globosum*, *Rosa rubiginosa*	
	specialty	*Lesquerella mendocina*	Brassicaceae, Chenopodiaceae, Asteraceae Euphorbiaceae, Fabaceae, Onagraceae
Terpenes, phenolic resins		*Colliguaya integerrima* *Grindelia chiloensis*, *Mulinum spinosum*, *Larrea* sp.	Asteraceae, Euphorbiaceae
Gums		*Prosopis* sp. *Cercidium praecox*	Fabaceae

particular candidate. In any case, the limit to maximum potential primary productivity is set by the environment, mostly by water availability (Paruelo et al. 1998).

4) To concentrate resources in patches through water harvesting methods. This is probably the most disturbing of the options, but may have low-impact alternatives like the use of road-sides and other disturbed areas that collect run-off water. Increased water availability will undoubtedly increase primary productivity but could result in decreased production and accumulation of carbon based secondary metabolites like terpenes, gums and waxes, increasing extraction costs (Benzioni et al. 1989, Meinzer et al. 1990, Ravetta et al. 1996b).

Candidate species

In this section we will analyze suggested candidates in the light of the discussed criteria and will also propose prospective species to be included in future work. The analysis has been organized by product: seed-oils, terpenes (essential oils, resins, polyterpenes, and related compounds), and gums (Table 1).

Seed-oils

Sources of oleic, linoleic, and linolenic acids. The major fatty acids available commercially vary in chain length from 12 to 18 carbon atoms and are either saturated, monounsaturated or diunsaturated. A handful of major crops are the main sources of these fatty acids: sunflower, soybeans, rapeseed, linseed and saflower (linolenic), and palm oil (palmitic). Their mainly use is in the food industry although they are important sources of industrial precursors for soaps, detergents, lubricants and greases, and inks and paints. Except for palm oil (source of palmitic acid, C_{16}), the other four are readily substitutable in their industrial applications and command prices of around 0.40 U$S dollars/kg of oil (Morris and Ahmed 1992, USDA 1997). These are all commodity crops in temperate areas all over the world. They are so successful because they can produce inexpensive oil, mostly due to their high yields of seed, not so much for their seed oil content.

Fatty acids with 18 carbon atoms are the most common ones in seeds that accumulate oil as an energy source for germination. Many warm-desert adapted species have been proposed as potential seed-oil crops for oleic, linoleic and linolenic acids (Berry et al. 1981, Deveaux and Schultz 1985, Glenn et al. 1991, among others) under the criteria of high oil content in the seeds. None of these has become a crop, in spite of their adaptation to arid environments. In a highly substitutable commodity market, the cost, and not the seed oil content or adaptation, should be the prevailing criteria. In fact, soybean has only 18% oil in the seeds, but is the largest crop because its oil is a by-product of the protein in the seeds.

Colliguaya integerrima Gill. et Hook. ex Hook ("Coliguay", "duraznillo"; Euphorbiaceae). This is an evergreen shrub native to Patagonia and Monte regions where it covers extensive areas. Its distribution seems to be associated mostly with fire and overgrazing, related to its vegetative propagation via rhizomes (Ravetta et al. 1988). Riganti et al. (1947) and Malec et al. (1986) evaluated this species' seed-oil and residual meal. The oil is composed mainly of linoleic and linolenid acids and is considered a drying-oil that could be used in varnishes and paints and other applications similar to those of linseed-oil. The residual meal is high in protein with a fairly good proportion of lysine, although it may contain certain toxic compounds. In an evaluation of natural stands, maximum seed production (51 kg/ha) and seed-oil content (37%) were considered too low to justify its utilization (Ravetta et al. 1988).

Prosopis L. and *Prosopidastrum* Burkart ("algarrobo"; Mimosaceae). The genus *Prosopis* is widely distributed throughout the Monte, Chaco, Espinal, and the northern areas of Patagonia. Several species contain between 3 % and 14 % oil in the seeds with major components of palmitic, oleic and linoleic acids. In *Prosopidastrum globosum* 70% of the seed-oil fatty acids are linoleic acid with a total oil content of about 5 % (Madriñan Polo et al. 1976).

Rosa rubiginosa L. ("Rosa mosqueta"; Rosaceae). This European species is naturalized and has now a wide range of distribution within Patagonia. It is mainly found in the Payunia district, in disturbed areas in the ecotone between the forest and the steppe, and in many of the river valleys. Although its fruits are mainly used for the preparation of jams, the seed-oils are extracted and sold for cosmetic purposes in Argentina and Chile. Seeds contain around 8 % of a drying oil composed mostly of linoleic and linolenic acids (Malec et al. 1993) with significant amounts of tocopherol (Peredi et al. 1996).

Sources of other fatty acids. In the late 1950's, the USDA initiated a program on new crops for the production of industrial raw materials. From this program and through the years a number of new fatty acids were discovered. Many promising species were evaluated for agronomic potential in screening programs, and the survey resulted in a series of new prospective oilseed crops that are now at various stages of development (Earle et al. 1962, Kleinman et al. 1965, Kleinman and Spencer 1982). Most of them are targeted to replace or complement traditional crop production in mesic areas. Even more, for those crops targeted for arid lands (i.e., *Vernonia galamensis, Lesquerella fendleri*) projected areas are shifting to more traditional crop areas since they do produce a crop in humid environments and no comparative advantage has been found when cultivated in arid lands (Puppala et al. 1997).

In this sense the search for potential oil-seed crops for arid lands in general, and particularly for Patagonia, faces the challenge of finding oils in which the targeted fatty acid accumulation is stimulated by the target environment. In Patagonia, lower temperatures and high solar radiation during seed filling and maturation may compose a unique environmental pattern that should be differentially exploited. To do so, it is critical to determine the effect of these variables on fatty acid synthesis and storage for the potential oils. For example, the effect of temperature on the degree of unsaturation of 18 carbon fatty acids is well established, with low temperatures increasing iodine values (Ivanov 1924); this effect was found in natural populations of *Colliguaya integerrima* (Ravetta et al. 1988).

Lesquerella mendocina Rollins (Brassicaceae). This is another species native to Patagonia and Monte, although only appearing in small, dispersed patches. Several North-American species of this genus accumulate lesquerolic acid (C:20-OH) in its seeds and a member of this group, *L. fendleri*, is in the process of commercialization. *L. mendocina* has a similar seed-oil composition, larger seeds (although notably fewer seeds per capsule), and perennial habit. It is currently being evaluated under cultivation (Ploschuk et al. 1997, Windauer and Ravetta 1997).

Resins, polyterpenes, and related compounds

Colliguaya integerrima. This species has also been evaluated for latex content and composition in a search for rubber and polyterpenes. Hexane extracts (hydrocarbons) were between 0.5 % and 0.8 for leaves and shoots, respectively, probably too low to continue the evaluation of its composition (Ravetta et al. 1988).

Grindelia chiloensis (Cron.) Cabr. ("Botón de oro", "melosa"; Asteraceae). Nineteen species of *Grindelia* have been described for South America (Cabrera 1931, Bártoli and Tortosa 1994). About half of them are native to Patagonia and Monte. Several of these species have been evaluated for diterpene resin content and composition (Timmermann and Ravetta 1990). Diterpene resin acids are produced in trichomes on the surface of the leaves, capitula, and stems and are similar to those found in the North American *G. camporum.* They could potentially be used in various applications in the naval stores industry complementing those produced by pines with current prices of around 0.45 U$S/kg (Hoffmann and McLaughlin 1986, Ravetta et al. 1996a). *Grindelia chiloensis* appears as a good candidate species because some accessions have resin contents up to 30% of dry biomass (Ravetta et al. 1996a). The species compares favorably with *G. camporum* (approximately. 10% resin; McLaughlin and Linker 1987, Ravetta et al. 1996b). In a common garden experiment, tetraploid *G. chiloensis* accessions produced 14% more total resin per plant than *G. camporum.* This highlights the importance of resin content on total resin production (Ravetta et al. 1996b). Resin production appears to be modified by environmental variables like water (Zavala and Ravetta 1997, Zavala et al. 1997) and nitrogen availability (Wassner et al. 1997), radiation (Zavala and Ravetta, unpublished data); the mechanism for these responses may be related to the Carbon-Nutrient Balance hypothesis (Bryant et al. 1983). Current research is actively continuing in aspects of eco-physiology, agronomy and product utilization.

Larrea Cav. ("jarilla"; Zygophyllaceae). There are four species of *Larrea* native to Argentina in the Monte and Patagonia. These species were studied as a source of nordihidroguaiaretic acid (NDGA), an antioxidant used in foods during World War II and extracted from *Larrea tridentata* in the southwestern U.S.A. Resins are phenolics and contents (defined as alcohol extract) for *L. nitida, L. divaricata, L cuneifolia,* and *L ameghinoi* were 38 %, 35 %, 35 %, and 23 %, respectively, and all of them contained about 1 % of essence that was extracted with water vapor distillation (Mizrahi 1967). NDGA constitutes 13.6%, 8.6%, 8.4%, and 3.0% of plant dry weight for *L. nitida, L divaricata, L cuneifolia,* and *L. ameghinoi,* respectively. These values are too low for commercial exploitation of NDGA as antioxidant in industrial and food applications (Timmermann 1977).

Mulinum spinosum (Cav.) Pers. ("neneo"; Umbelliferae). This species accumulates an oleo-gum-resin in stems and roots. The substance exudates after incisions or removal of above ground biomass. It is composed of essential oils, resin, and gum (approx. 13%, 82 %, and 5%, respectively, Chiesa 1960). The resin has similar physico-chemical properties as galbanum, obtained from *Ferula galbaniflua* (Umbelliferae), and used commercially in medicine and cosmetics with world production values around U$S 240,000 (Verlet 1993). A recent interest has developed in the distillation and use of the essential oil present in the mixture (DiLeo Lira et al. 1996). This effort may be sustained also by the wide distribution and high density in Patagonia, although net primary production of this species has been estimated to be between 20 and 30 g m^{-2} yr^{-1} even with the removal of grass competition (Sala et al. 1989). Another five species of *Mulinum* are indigenous to Patagonia but have not been evaluated for oleo-resins.

Gums

Prosopis and *Cercidium.* Gums are obtained from seeds or exudates from trees. The endosperm of *Prosopis* species contains galactomannans that can be separated by an aqueous process, producing gum of 85-95% purity, yield 60% (Saunders et al. 1986). The economic value and utility of *Prosopis* gum should be analogous to guar gum because of the similar quality of purified galactomannan of some species (i.e., *P. velutina* and *P. chilensis*) (Saunders and Becker 1989).

Prosopis trees exude gum, marketed in North-America as “gum-mesquite”, that has been used as substitute for gum arabic. *Prosopis* gum closely resembles the gum from *Acacia senegal* in polysaccharide and amino acid composition and physical properties (Anderson and Farquhar 1982, Anderson et al. 1985). In *Prosopis laevigata*, Espejel (1981) reported an induced production of 32-120 g of gums/tree/year, while in P. *flexuosa up* to 1.660 g has been naturally exudated by a single tree (Vilela and Ravetta unpublished data).

Cercidium praecox (Ruiz et Pavón) Harms (“brea”, “palo verde”) exudes a clear gum whose chemical composition differs significantly from that of the majority of the Fabaceae (Pinto et al. 1993). Brea gum is an acidic polysaccharide consisting mainly of residues of pentose and hexuronic acid (Cerezo et al. 1969). In hot dry areas of Argentina it is collected by Huichi communities in Santiago del Estero (La Nación, 13 de Abril de 1996).

Prospective families for uncommon seed-oils, gums, and terpenes

The flora of Patagonia is largely unexplored for sources of industrial products. There are two ways to undertake the search for new materials: the collection and extraction for each type of compound of all available plant material, or a systematic search in which prospective species are selected by phylogenetic relationships. While the former tends to be used with medicinals, we consider the latter a better approach for industrial raw materials. What follows is a list of some prospective families, based on known species that yield commercially important industrial products:

Brassicaceae. There are 132 species with 47 genera (22 indigenous to the region) in the family, in Patagonia (Correa 1984). Soriano et al. (1994) identified 11 endemic species within the family that should be analyzed for seed-oil content and composition. Within the family, together with the production of hydroxy fatty acids by *Lesquerella* species, the European *Crambe abyssinica* (Capelle 1997, Mastebroek 1996) as well as *Eruca sativa* are alternative sources of erucic acid currently obtained from *Brassica* (Muuse et al. 1992).

Chenopodiaceae. There are 13 genera in Argentina, several of which are present in Patagonia (Correa 1971). Several members of the family, like species of *Salicornia,* are able to produce $C_{,\$}$ fatty acids (oleic, linoleic, and linolenic) under extreme salt concentrations and have been investigated as potential new crops (Glenn et al. 1991, Glenn and Watson 1993).

Asteraceae. There are 197 genera represented in Argentina, 110 of which are found in Patagonia, with several endemic species (Correa 1971, Soriano et al. 1994) The family has several members (exotic to Patagonia) that accumulate C_{18} fatty acids of economic importance like *Helianthus, Carthamus, Madia,* and *Silybum* (although the latter is used for the flavonoids, silimarin accumulates in the pericarp of the fruits). Other species in the family produce uncommon fatty acids like epoxy acids (*Vernonia galamensis,* and *Stokesia laevis*), hydroxy fatty acids (*Dimorphoteca pluvialis*), and fatty acids with three conjugated double bonds (*Calendula officinalis*), among others (Muuse et al. 1992).

Several species in the family are known to produce essential oils (some of which are commercially cultivated or harvested from the wild), epicuticular resins, and other polyterpenes. Some of the genera native to Patagonia that have been found to produce high amounts of dicloromethane extracts (terpenes) are: *Grindelia, Haplopappus, Gutierrezia, Baccharis, Tessaria, Parthenium, Ambrosia,* among others (Ravetta and Soriano unpublished data; Ravetta et al. 1997).

Euphorbiaceae. There are six genera with 14 species represented in Patagonia (Correa 1971). Several uncommon fatty acids are known to accumulate in seeds of members of the family: *Ricinus cominunis is* the only commercial source of hydroxy fatty acids ($C_{,8}$-OH), *Euphorbia lagascae* native to the Mediterranean area is a source of epoxy fatty acids used in several industrial application like plastics and low volatile-organic-compounds paints (Kleinman 1990) and several other species of *Euphorbia* and *Jatropha* produce linoleic and linolenic acid (Mazzani 1963, Martin and Mayeux 1984). Also, *Aleurites fordii* (Tung) is a source of poli-unsaturated fatty acids.

The family is also a source of latex-producing plants that should be investigated as sources of polyterpenes and rubber, as well as sources of epicuticular waxes like *Euphorbia antisyphilitica* the Mexican commercial source of candelilla wax (Hodge and Sineath 1955, Angulo Sánchez and Jasso 1996). The search for politerpenes should also include some potential candidates members in the Asclepiadaceae.

Fabaceae. There are 21 genera with approximately 160 represented in Patagonia (Correa 1984). Together with soybean and lupin (two of the world's most important sources of commercial seed-oils) there are many species in the family that produce C_{18s} fatty acids and would face competition from established sources of these seed-oils. On the other side, desert adapted legumes are important commercial sources of exudates (*Acacia senegal* and others, gum arabic; *Astragalus* sp., gum tragacanth; *Prosopis* and *Cercidium* species, mesquite gum; among others) and seed-gums (*Cyamopsis tetragonoloba*, guar gum). Several genera from Patagonia should be considered for seed-oil, seed-gum and sugar and protein production from the fruits of *Astragalus* (26 species in Patagonia), *Adesmia* (53 species in Patagonia), among others. Also, the production of gum-exudates from *Prosopis* and *Cercidium* needs quantification.

Onagraceae. Eight genera with 25 species are represented in Patagonia (Correa 1988), among which there are eight species of *Oenothera* . *O. biennis* and *O. lamarckiana* are commercial sources of gamma linolenic acid, although *Borago officinalis* (Boraginaceae) is a better source, due to higher oil contents.

Conclusions

Although there are a few available crops for cold arid environments like Patagonia, some efforts have been started to undertake the exploration of the flora of this region in the search of plant species that can supply industrial raw materials. Most of the work done in the past has not been systematic and was not based on clear product/market requirements. Neither were biological criteria used, although there may be enough available information to understand the processes that result in restrictions to plant growth impossed by the environmental conditions of the region. Furthermore, some of these restrictions may stimulate the plant to produce the desired material, increasing its harvest index, and reducing the importance of biomass productivity.

The efforts necessary to obtain new productive alternatives are large and the chances of finding the right combination of plant biological and agronomic traits, product, and price are modest. Clear objectives based on solid criteria and a precise methodology should increase our opportunities in the development of new crops for Patagonia.

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